

IAEA Safety Standards

for protecting people and the environment

Decommissioning of Medical, Industrial and Research Facilities

Specific Safety Guide

No. SSG-49



IAEA

International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

<http://www-ns.iaea.org/standards/>

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

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The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

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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. SSG-49

DECOMMISSIONING OF
MEDICAL, INDUSTRIAL AND
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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2019

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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to "establish or adopt... standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For 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 regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

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

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

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

Safety Fundamentals

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

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

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

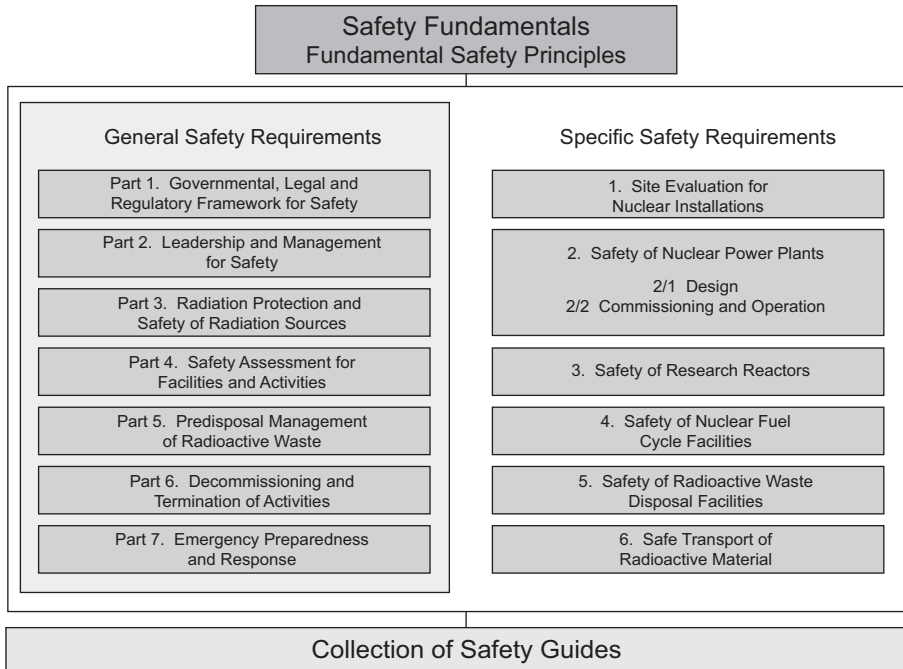


FIG. 1. The long term structure of the IAEA Safety Standards Series.

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 five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on 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

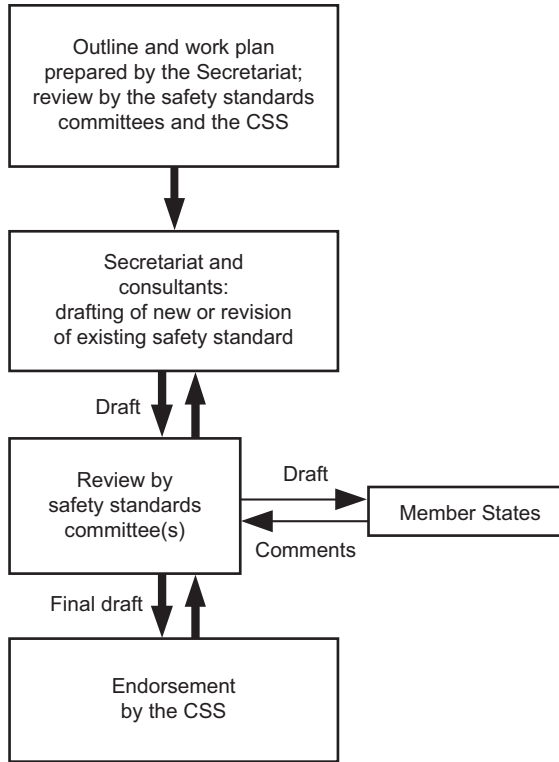


FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

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

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international

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

INTERPRETATION OF THE TEXT

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

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

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

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

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1. INTRODUCTION

BACKGROUND

1.1. For many decades, radioactive material has been in use in medical, industrial and research facilities¹. Facilities using radioactive material and radioactive sources in a variety of applications were constructed and commissioned in many States over the past decades. Many of these facilities are reaching the end of their operational lifetimes and will be facing permanent shutdown². Other facilities might be facing early permanent shutdown owing to bankruptcy or other unanticipated reasons. These facilities will all need to be decommissioned. This Safety Guide recommends a consistent approach to planning and implementing the decommissioning of both new and existing facilities, incorporating experience and lesson learned from previous decommissioning projects.

1.2. As defined in the IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [1], “the term ‘decommissioning’ refers to the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility”. While decommissioning is the last stage in the lifetime of a facility, aspects of decommissioning, such as designing for the minimization of radioactive waste, planning for decommissioning and record keeping, should be considered throughout the lifetime of the facility, beginning with the initial planning and design of the facility.

1.3. Decommissioning actions involve decontamination, dismantling and removal of structures, systems and components (SSCs), including the management of the resulting radioactive waste and radiation protection of workers who are carrying out the decommissioning, as well as radiological surveys to support decommissioning. These actions are carried out to achieve a progressive and systematic reduction of radiological hazards during decommissioning, and are taken on the basis of planning and assessment to ensure safety, to ensure protection of workers and the public and protection of the environment, and to demonstrate that the facility achieves the planned end state.

¹ The term ‘facility’ means buildings and their associated land and equipment, including the surface and subsurface soil, and any surface or subsurface water or aquifers. In this Safety Guide, the term ‘facility’ is used with a limited scope to refer to medical, industrial and research facilities.

² The term ‘permanent shutdown’, as used in this Safety Guide, means that the facility has ceased operations and operation will not be recommenced.

1.4. Decontamination, dismantling and other decommissioning actions may be carried out immediately following permanent shutdown or may be deferred until after a safe enclosure³ period (e.g. to allow for radioactive decay). As a consequence, the time period for the conduct of decommissioning actions typically ranges from a few weeks for simple and small facilities, to years for larger and more complex facilities, especially if there is a safe enclosure period. Decommissioning may include a phased release of parts of the facility from regulatory control during conduct of decommissioning actions. On completion of all planned decommissioning actions and on reaching the planned end state, the authorization for decommissioning can be terminated. The site and remaining structures of the facility, if any, will be available for unrestricted or restricted reuse for other purposes.

1.5. Depending on the national regulatory system, decommissioning of a facility might be subject to the granting of a licence for decommissioning or an authorization to perform decommissioning actions in the framework of a licence granted for the whole lifetime of the facility. In this Safety Guide, the term ‘authorization for decommissioning’ is used to mean whichever of these regulatory concepts is relevant.

1.6. For some small and simple facilities with a very low level of hazard, decommissioning actions may consist of removal and return of all the sources to the supplier, followed by a survey to verify that there are no areas with residual contamination above the approved end state criteria. This may be done in the bounds of the operating licence⁴, if so allowed by national regulations. In such cases, no specific authorization for decommissioning is granted before the conduct of decommissioning actions. After performing decommissioning actions, a final report is produced by the licensee to request termination of the operating licence for the facility (see Section 9 of this Safety Guide).

1.7. The decommissioning of a medical, industrial or research facility is usually conducted as a project. A decommissioning project is a collaborative initiative, involving supporting analyses and studies, which is carefully planned to ensure the safety of the planned actions, and to achieve partial or complete removal of

³ The term ‘safe enclosure’ means the period during the implementation of the deferred dismantling strategy in which the facility is placed and maintained in a safe, long term storage condition until decontamination and dismantling actions are performed.

⁴ In certain States, the term ‘operating licence’ may encompass the licence to conduct decommissioning; in some cases, the operating licence may need only to be amended to cover all regulatory aspects pertaining to decommissioning.

regulatory controls from a facility. A decommissioning project is temporary and is conducted by teams within or across organizations. A decommissioning project usually starts when preparation of the final decommissioning plan is initiated or, in some cases, when an authorization for decommissioning is granted.

1.8. In order to simplify approaches to the decommissioning processes and to provide more illustrative guidance, this Safety Guide categorizes the facilities to be decommissioned into three different types, based on their radiation risk: simple facilities, intermediate facilities and complex facilities. This categorization relates to the application of a graded approach in the decommissioning of different types of medical, industrial and research facility. This Safety Guide addresses implications of this categorization scheme in the regulatory review of decommissioning regarding the type of information and documents to be submitted to the regulatory body (e.g. the decommissioning plan and the safety assessment). Typical examples of the three different categories of facility are provided in Annex I.

1.9. This Safety Guide supersedes Decommissioning of Medical, Industrial and Research Facilities, issued in 1999.⁵ Guidance on the decommissioning of nuclear power plants, research reactors and other fuel cycle facilities can be found in IAEA Safety Standards Series No. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities [2].

1.10. Requirements and guidance on the radiation protection, regulatory control of discharges of radioactive effluents to the environment and associated management of radioactive waste are provided in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [3] and IAEA Safety Standards Series No. GSG-9, Regulatory Control of Radioactive Discharges to the Environment [4].

1.11. Requirements and guidance on radiological criteria for the release of materials, equipment and sites from regulatory control are provided in GSR Part 3 [3]; IAEA Safety Standards Series No. RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance [5]; and IAEA Safety Standards Series No. WS-G-5.1, Release of Sites from Regulatory Control on Termination of Practices [6].

⁵ INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Medical, Industrial and Research Facilities, IAEA Safety Standards Series No. WS-G-2.2, IAEA, Vienna (1999).

1.12. Requirements and guidance on transport of radioactive material and the associated safety and environmental aspects are provided in IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [7] and IAEA Safety Standards Series No. SSG-26, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition) [8].

OBJECTIVE

1.13. The objective of this Safety Guide is to provide guidance for regulatory bodies, licensees, owners, technical support organizations and other interested parties on meeting the requirements on planning for decommissioning, conducting decommissioning actions including characterization surveys, demonstrating completion of decommissioning and terminating the authorization for decommissioning of medical, industrial and research facilities. It aims to assist States in ensuring that decommissioning of these facilities is conducted in a safe and environmentally acceptable manner, in accordance with good international practice.

SCOPE

1.14. This Safety Guide addresses decommissioning considerations and actions for safe decommissioning of medical, industrial and non-reactor research facilities in which radioactive materials and sources are produced, used or stored. This Safety Guide does not address decommissioning of nuclear fuel cycle facilities (uranium conversion plants, uranium enrichment plants, nuclear fuel fabrication plants, research reactors including subcritical and critical assemblies, nuclear power plants, facilities for storage of spent fuel, reprocessing facilities and facilities for predisposal management of radioactive waste) and decommissioning of the surface processing facilities for mining and processing of uranium and thorium ores and other facilities used for industrial activities involving naturally occurring radioactive material. The decommissioning of these types of facility is addressed in SSG-47 [2] and IAEA Safety Standards Series No. WS-G-1.2, Management of Radioactive Waste from the Mining and Milling of Ores [9].

1.15. The scope of this Safety Guide includes the decommissioning of nuclear fuel cycle research and development facilities that conduct laboratory scale experiments and fundamental research studies on specific nuclear materials such as prototype nuclear fuels (before and after irradiation in a reactor) or investigations of nuclear

material or waste arising from new processes. The decommissioning of nuclear fuel cycle research and development facilities conducting activities on processes and equipment envisaged for use on an industrial scale (e.g. pilot plants or demonstration plants) is outside the scope of this Safety Guide. Recommendations and guidance on decommissioning of such facilities are provided in SSG-47 [2].

1.16. Compliance with decommissioning requirements can be achieved through the application of a graded approach, depending on the type and complexity of the facility, its radioactive inventory and the potential hazards associated with decommissioning. For example, the graded approach can be applied to the process of selecting the decommissioning strategy, planning for decommissioning, the conduct of decommissioning actions, and the envisioned end state.

1.17. In cases where only a part of a facility is being decommissioned, this Safety Guide applies only to decommissioning actions associated with the part of the facility being decommissioned. However, the potential safety implications for any continuing operations of the facility need to be addressed.

1.18. This Safety Guide applies to planned, authorized activities. Although some reference is made to remediation in the context of decommissioning of facilities, this Safety Guide does not apply to remediation situations, which are addressed in other IAEA safety standards [3, 10].

1.19. This Safety Guide addresses the radiation risks resulting from actions associated with decommissioning of medical, industrial and research facilities, and from the management of waste and material arising from the decommissioning actions. It is intended primarily for facilities with a normal operational history, followed by a planned permanent shutdown. However, many of the considerations are also applicable to decommissioning after an early, unintended permanent shutdown or an accident that has resulted in damage to the facility or contamination of the facility's premises. In such cases, this Safety Guide may be used as a basis for developing special decommissioning provisions to address the post-accident situation.

1.20. The hazards associated with medical, industrial and research facilities often involve chemical, biological and industrial hazards in addition to the radiological hazards, and consideration should be given to addressing all hazards in an integrated manner, to ensure a high level of safety in relation to both radiological and non-radiological hazards. For example, non-radiological hazards, such as those due to the release of asbestos or polychlorinated biphenyl, might be encountered during decommissioning actions. This Safety Guide does not explicitly address

non-radiological hazards, but these hazards need to be considered in all aspects of decommissioning, including planning for decommissioning, management of decommissioning, financing of decommissioning, conduct of decommissioning actions and completion of decommissioning.

1.21. Normally, the decommissioning of most medical, industrial and research facilities does not involve major security concerns, but for some facilities, security aspects during decommissioning may have to be considered. This Safety Guide does not provide guidance on the security aspects of decommissioning. The IAEA issues Fundamentals and Recommendations on nuclear security in the IAEA Nuclear Security Series [11–13]. Requirements pertaining to interfaces of safety with nuclear security are established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [14]. Aspects relating to accounting for and control of nuclear material might continue to exist during decommissioning of some types of facility, but are outside the scope of this Safety Guide.

STRUCTURE

1.22. Section 2 addresses the issues relating to protection of people and protection of the environment, including the application of a graded approach for the whole decommissioning process and optimization of protection and safety. It also addresses the assessment of safety for decommissioning. Section 3 describes the responsibilities of the major parties involved in decommissioning. Guidance on the management of decommissioning is provided in Section 4, while Section 5 describes the selection of a decommissioning strategy. Section 6 addresses financing of decommissioning. Planning for decommissioning during all stages of the facility's lifetime is addressed in Section 7. Section 7 describes various types of decommissioning plan, which are developed and maintained throughout the facility's lifetime. Section 8 describes the conduct of decommissioning actions, including the management of decommissioning waste, radiation protection and emergency response. Section 9 addresses the completion of decommissioning, including surveys and reporting to support the termination of the authorization for decommissioning.

1.23. Appendix I addresses the development of a safety assessment in support of the decommissioning plan for medical, industrial and research facilities. Appendix II elaborates on the factors to be considered when selecting a decommissioning strategy.

1.24. Annex I defines the three categories of medical, industrial and research facilities and provides examples of facilities in each category. Annex II provides an example of an outline of a final decommissioning plan for medical, industrial and research facilities. Annex III provides an example of the content of the final decommissioning report. Annex IV provides an example of the content of the final radiological survey report. Annex V provides a list of typical supporting documents for the final decommissioning plan. Annex VI provides a list of reference publications that contain additional information on specific organizational, technical, financial and safety issues relating to decommissioning, including considerations for facilities other than medical, industrial and research facilities.

2. PROTECTION OF PEOPLE AND PROTECTION OF THE ENVIRONMENT

Requirement 1 of GSR Part 6 [1]: Optimization of protection and safety in decommissioning

“Exposure during decommissioning shall be considered to be a planned exposure situation and the relevant requirements of the Basic Safety Standards shall be applied accordingly during decommissioning.”

2.1. The principles of radiation protection and safety for radiation sources are provided in GSR Part 3 [3] and IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [15].

2.2. Arrangements for radiation protection during decommissioning should be addressed in the decommissioning plan and should be based on the national requirements for radiation protection. In addition to compliance with dose limits, optimization of protection is required to be implemented (para. 2.1 of GSR Part 6 [1]), with account taken of the specifics of the decommissioning project and with due regard to the relevant dose constraints.

2.3. Although the principles and aims of radiation protection during operation and during decommissioning are fundamentally the same, the methods and procedures for implementing radiation protection might differ owing to differences in the actions to be performed, the physical conditions of the facility, the need for access to highly activated materials or contaminated equipment or areas, and the removal of SSCs. Special situations might need to be considered, which might require the

use of remote technology or specialized equipment and the implementation of temporary measures or use of certain non-routine procedures.

2.4. Proper consideration is required to be given to the protection of workers and the public and protection of the environment against consequences of incidents that might occur during decommissioning (para. 2.2 of GSR Part 6 [1]). A system for protection and safety that is commensurate with the likelihood and the magnitude of potential exposures should be maintained. Where appropriate, this can be a system of multiple, sequential, independent provisions for protection and safety.

2.5. An example where protection of workers should be considered is workers having to work in close proximity to activated components (e.g. in accelerators) being dismantled or decontaminated, which could lead to significant exposure or spread of contamination. Special attention should be paid to preventing and reducing the exposure of workers by implementing specific and appropriate controls for protection of personnel. Engineering controls may also be needed and personal protective equipment may need to be tailored to specific work conditions, for example enhancing the puncture resistance of protective gloves to prevent injuries that might result in an intake of radionuclides.

2.6. Incidents or accidents that might occur during decommissioning could lead to radiological impacts outside the boundaries of the facility undergoing decommissioning. For example, to protect on-site personnel, the public and the environment from exposure due to the spread of radioactive substances, active safety systems such as ventilation systems and fire protection systems might need to be retained for some period during decommissioning. In the case of on-site or off-site contamination, actions might be necessary to remediate the contaminated areas or to confine releases of radioactive substances, such as contaminated water, by applying emergency response actions. Such issues are not addressed in this Safety Guide. Remediation of off-site areas is addressed in IAEA safety standards [3, 10], while emergency preparedness and response is addressed in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [16].

2.7. Remedial actions for the area immediately surrounding a facility might be part of the decommissioning project when the facility has been permanently shut down after an accident. Decommissioning usually does not include remedial actions for large areas outside the facility boundaries defined in the operating licence.

2.8. Records and data of the nature and extent of the emergency arrangements established during normal operation should be considered during planning for decommissioning.

2.9. In addition to protection of workers and the public, licensees are required to consider and plan for protection of the environment during decommissioning (para. 2.3 of GSR Part 6 [1]). Adequate controls should be defined to ensure mitigation of significant impacts on the environment, both on the site and in the surrounding area. For some facilities, an environmental impact assessment⁶ may need to be developed concurrently with the final decommissioning plan, consistent with national requirements. Protection of the environment should be ensured during decommissioning and after its completion if a site is released with restrictions on its future use. Specific measures should be implemented by the licensee, depending on the end state described in the final decommissioning plan. The stringency of measures relating to protection of the environment should be commensurate with the level of hazard. Some of the measures recommended in this Safety Guide might not be necessary for simple facilities with a low level of hazard (see Annex I).

2.10. The licensee should indicate in the environmental impact assessment for decommissioning, which supports the final decommissioning plan, how compliance with applicable requirements for protection of the environment will be ensured, including responsibilities and measures for monitoring, control and surveillance during decommissioning and after its completion, if necessary.

Requirement 2 of GSR Part 6 [1]: Graded approach in decommissioning

“A graded approach shall be applied in all aspects of decommissioning in determining the scope and level of detail for any particular facility, consistent with the magnitude of the possible radiation risks arising from the decommissioning.”

2.11. The range of decommissioning actions for medical, industrial and research facilities is broad, and the scope, extent and level of detail of planning,

⁶ The term ‘environmental impact assessment’ is included in many international instruments and national legislation and regulations. In the context of IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [17], an environmental impact assessment refers to a procedure within a governmental decision making process for identifying, describing and assessing prospectively the effects, and the risk of effects, of a particular proposed activity or facility on aspects of environment significance.

assessment and demonstration of safety and preparation, review and update of safety related documentation should be commensurate with the types and magnitude of hazards, and their potential consequences for workers, the public and the environment. Therefore, a graded approach is required to be applied to planning for decommissioning, conducting decommissioning actions, completing the decommissioning and terminating the authorization, releasing the site for unrestricted or restricted use and to the regulatory oversight of the decommissioning process (Requirement 2 of GSR Part 6 [1]). The graded approach should be applied in a manner that does not compromise safety and ensures compliance with all relevant safety requirements and criteria.

2.12. The application of a graded approach should support effective and optimized use of resources. In the context of medical, industrial and research facilities, in a graded approach, the type of information and the level of detail in the decommissioning plans and supporting documents, including the safety assessments and actions necessary to comply with the safety requirements, should be commensurate with the factors listed below:

- The size and type of the facility, including its complexity and its operational history;
- The physical state of the facility, specifically the integrity of the SSCs and, in particular, the extent to which ageing or abandoned buildings or other structures may have been compromised owing to, for example, a long period of poor maintenance;
- The radiological inventory (e.g. the activity of sealed sources and unsealed sources and contamination), the biological inventory and the chemical inventory and the hazards associated with the decommissioning of the facility;
- The stage in the lifetime of the facility (siting, design, construction, commissioning, operation, shutdown or decommissioning), for example the preparation of an initial decommissioning plan at the design stage and preparation of a final decommissioning plan prior to conduct of decommissioning actions;
- The scope of the project (e.g. for a part of a facility, a whole facility, a single facility at a multifacility site or an entire multifacility site); and the extent to which the proposed decommissioning actions could adversely affect ongoing activities elsewhere at the facility or at nearby facilities;
- Uncertainty of the information (e.g. information on the quality and extent of the characterization of the facility) and the reliability and availability of relevant supporting information (e.g. drawings and records of modifications) to be used as input data for planning;

- The complexity and risks associated with the planned decommissioning actions;
- The end state of the decommissioning of the facility (e.g. unrestricted or restricted use, total removal of all structures or reuse of some structures or parts of the facility);
- The extent and level of radiological contamination as well as accessibility to conduct cleanup or remediation.

2.13. Successful decommissioning depends on adequate and organized planning and the systematic conduct of the decommissioning actions in accordance with the authorization issued. The application of a graded approach has an impact throughout the decommissioning project, specifically in the following areas:

- Documentation (the scope of the final decommissioning plan, its content and the level of detail necessary might differ depending on the complexity and hazard potential of the facility and should be consistent with national regulations);
- Identification of the SSCs (SSCs already present in the facility and new SSCs) that are needed for the safe decommissioning of the facility, and specification of the associated control requirements;
- The authorization process;
- Control of decommissioning actions;
- The monitoring programme;
- Management of the decommissioning project (e.g. the organizational structure);
- Staffing and training;
- Regulatory oversight;
- The involvement of interested parties.

2.14. Some decommissioning actions can be limited in scope and the hazard from radioactive material might consequently be small. The actual approach to decommissioning should be determined with account taken of the hazards involved, as inappropriate or unduly restrictive safety measures might be a barrier to the good management of safety and could increase costs to no benefit.

Requirement 3 of GSR Part 6 [1]: Assessment of safety for decommissioning

“Safety shall be assessed for all facilities for which decommissioning is planned and for all facilities undergoing decommissioning.”

2.15. Decommissioning of facilities is associated with numerous radiological and non-radiological hazards. In addition to existing radiological hazards associated with a permanently shutdown facility, decommissioning actions might create new hazards that need to be considered, for example through the use of cutting tools or the generation of airborne contamination and secondary radioactive waste⁷. Therefore, through planning for decommissioning, those hazards should be adequately assessed and managed.

2.16. Decommissioning of facilities often involves the removal, at an early stage, of significant quantities of radioactive material, including radioactive sources and waste from operation. After this step, the remaining total contamination and activation of the facility should be taken into account in the safety assessment.

2.17. A safety assessment is required to be performed (para. 2.6 of GSR Part 6 [1]) to support development of the final decommissioning plan (see Fig. 1 in Section 7) and to support the conduct of associated specific decommissioning actions by demonstrating that the safety and the protection of workers and the public are optimized and that exposures do not exceed the relevant limits and constraints.

2.18. The safety assessment should be conducted to define the protective measures necessary to ensure the protection of workers, the public and the environment. Such protective measures should be determined on the basis of an optimization approach to radiation protection, with due regard to industrial safety, in accordance with the requirements established in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [18] and the guidance provided in IAEA Safety Standards Series No. WS-G-5.2, Safety Assessment for the Decommissioning of Facilities Using Radioactive Material [19]. In the case of medical facilities where there is regular access by the public, the exposure of the public during decommissioning should be assessed, optimized and controlled.

⁷ Secondary radioactive waste is a by-product of the processing of primary radioactive waste.

2.19. The licensee is required to control the work of any subcontractors (para. 4.3 of GSR Part 6 [1]) involved in development of the safety assessment. The results of the safety assessment or part of the safety assessment developed by subcontractors, depending on their relevant knowledge and experience in specific decommissioning techniques, should be reviewed, made subject to approval or acceptance, and implemented by the licensee, in accordance with the integrated management system. The results of the safety assessment should also be reviewed and made subject to approval by the regulatory body to ensure overall safety during decommissioning.

2.20. The results of the safety assessments will determine which safety functions and related SSCs used in the operational stage will no longer be needed after operation has permanently ceased. However, some of the safety functions will continue to be required during decommissioning, and decommissioning can also give rise to the identification of new safety functions and to a need for the commissioning of associated SSCs. The safety assessment should demonstrate consistency among the safety measures during the entire process of decommissioning, and it should be updated when necessary to reflect the ongoing changes in the status of the facility as decommissioning actions progress.

2.21. The safety assessment should enable demonstration of compliance with regulatory safety criteria and demonstration of optimization of protection. The results of the safety assessment should lead to the definition of decommissioning limits and conditions, which consist of a set of rules that establish parameter limits, the functional capability and the performance levels of the equipment and the personnel for the safe decommissioning of a facility. The decommissioning limits and conditions should be reflected in the authorization for decommissioning and in the decommissioning procedures. The results of the safety assessment should also be used to inform the radiation protection programme. The safety assessment should be used to help ensure that interested parties are confident in the safety of decommissioning.

2.22. The safety assessment should demonstrate that interdependences between planned decommissioning actions are taken into account, and that any negative impacts of one action on another, as well as the possible generation of additional hazards, are properly taken into account.

2.23. For the majority of medical, industrial and research facilities, an extensive environmental impact assessment is not required for decommissioning. However, an environmental analysis could be included as part of the decommissioning plan. For complex facilities, a summary and the conclusion of the environmental

impact assessment of the decommissioning actions should be included in the decommissioning plan.

2.24. Appendix I provides additional guidance on preparation of the safety assessment for decommissioning of medical, industrial and research facilities.

3. RESPONSIBILITIES ASSOCIATED WITH DECOMMISSIONING

3.1. The decommissioning process for facilities involves several organizations, the key organizations being the government, the regulatory body and the licensee. This section addresses the responsibilities of the government, the regulatory body and the licensee in the planning, conduct and completion of decommissioning of facilities.

Requirement 4 of GSR Part 6 [1]: Responsibilities of the government for decommissioning

“The government shall establish and maintain a governmental, legal and regulatory framework within which all aspects of decommissioning, including management of the resulting radioactive waste, can be planned and carried out safely. This framework shall include a clear allocation of responsibilities, provision of independent regulatory functions, and requirements in respect of financial assurance for decommissioning.”

3.2. In preparing and implementing the national policy for decommissioning, which may be part of the national policy for management of radioactive waste, the government should establish the overall objectives of decommissioning. The policy should be developed by the government in cooperation with relevant organizations, including licensees, and with an involvement of the public and other interested parties. Where a national policy and strategy for decommissioning of medical, industrial and research facilities has not yet been developed or is at an early stage of development, the regulatory body should advise the government on the requirements for, and the effectiveness of, the national policy for decommissioning and radioactive waste management and should provide assistance in its update and improvement.

3.3. A framework for regulating decommissioning is required to be established in national legislation (Requirement 4 of GSR Part 6 [1]). The enabling legislation should be consistent with the relevant national policies, and should be straightforward, feasible and flexible, so that the need for its subsequent amendment is minimized. This is important because amending legislation is usually a slow and resource intensive process.

3.4. Although it is preferable that regulatory responsibilities for decommissioning are held by a single regulatory body, in some States such responsibilities are divided among several bodies already having specific responsibilities for protection and safety. It should be ensured that the regulation of all aspects of radiation safety, transport safety, waste safety, industrial safety and environmental safety is covered adequately and that the responsibilities of the governmental bodies involved are clearly specified and allocated. The legislation should establish clear lines of authority and responsibility, so as to avoid gaps or overlaps between different regulatory bodies having responsibilities for decommissioning.

3.5. One of the main responsibilities of the government is to ensure that mechanisms for providing adequate financial resources are put in place, so that an appropriate level of funding is available to decommission facilities in a safe and timely manner.

3.6. If decommissioning has to be performed in a situation for which the government has not established a legal and regulatory framework, for example to address safety issues relating to deteriorating structures, the decommissioning should be planned and managed on a case by case basis in consultation with the relevant authority or authorities having responsibility for radiation, transport, waste, industrial and environmental safety. In such cases, the licensee should consult the regulatory body with regard to development and implementation of a decommissioning plan.

Requirement 5 of GSR Part 6 [1]: Responsibilities of the regulatory body for decommissioning

“The regulatory body shall regulate all aspects of decommissioning throughout all stages of the facility’s lifetime, from initial planning for decommissioning during the siting and design of the facility, to the completion of decommissioning actions and the termination of authorization for decommissioning. The regulatory body shall establish the safety requirements for decommissioning, including requirements

for management of the resulting radioactive waste, and shall adopt associated regulations and guides. The regulatory body shall also take actions to ensure that the regulatory requirements are met.”

3.7. When developing regulations, the regulatory body should identify clearly the facilities and activities to which regulatory requirements are to be applied. The regulatory body is required to establish safety criteria and regulations for all aspects of decommissioning, including for management of the associated radioactive waste (Requirement 5 of GSR Part 6 [1]). The regulatory body is required to oversee the implementation of the requirements (para. 3.3 of GSR Part 6 [1]) and should control compliance by the licensee with the requirements for planning for decommissioning, conduct of decommissioning actions and completion of decommissioning, including termination of the authorization for decommissioning.

3.8. The regulatory body should follow consistent procedures for establishing, revising and revoking regulations and guidance. Interested parties should be involved in the process.

3.9. Experience in implementing the regulations should be examined by the regulatory body and any problems or difficulties that might arise should be duly considered. The status of applicable requirements should also be examined taking into consideration the state of the art of science and technology (e.g. new safety related developments and lessons learned from decommissioning projects in the State and in other States).

3.10. In order to facilitate the regulatory review process, the regulatory body should provide guidance for the licensee on the typical content of decommissioning plans and supporting documentation, as well as the necessary analysis that would support the process of assessing safety and regulatory compliance. Details of the guidance should consider the graded approach concept (e.g. less detail for simple facilities with low level hazards). In particular, the regulatory review of the safety related documentation for decommissioning should focus on determining whether the selection of decommissioning strategy, the final decommissioning plan, the proposed decommissioning actions, the environmental impact assessment⁸ and the safety assessment for decommissioning comply with the regulatory requirements.

⁸ The review of the environmental impact assessment might be the responsibility of a national authority other than the regulatory body.

3.11. The regulatory body should develop a process for consideration of applications for an authorization for decommissioning, including the process for review of the application. This process should identify milestones and decision points and should specify the period of time for the regulatory review. The process might include performing an acceptance review of the application for decommissioning prior to performing the review of the final decommissioning plan and its supporting documents in accordance with national requirements. Interested parties are required to be given an opportunity to comment on the final decommissioning plan and safety related supporting documents before the authorization is granted, in accordance with national regulations (para. 3.3 of GSR Part 6 [1]).

3.12. The regulatory body should require notification by the licensee of any significant changes to the planned actions described in the final decommissioning plan that might have implications for the safety of decommissioning or for the end state of the facility. Such changes should be subject to an assessment by the licensee, with account taken of the nature and potential magnitude of the associated risks. The regulatory body should review this assessment and should consider amending or renewing the authorization for decommissioning, as appropriate.

3.13. The regulatory body is required to establish a regulatory provision for the termination of an authorization (para. 3.3 of GSR Part 6 [1]), which would support a decision for release of a site (entire site or parts of the site) for unrestricted or restricted use. For cases for which unrestricted use of a site is unachievable, the regulatory body is required to consider whether the site conditions and any proposed institutional controls, as well as proposed provisions for on-site and off-site radiological and environmental monitoring, are acceptable (para. 9.3 of the GSR Part 6).

3.14. In order for decommissioning to be performed in a safe and efficient manner, the regulatory body is required to establish requirements for a mechanism to ensure that adequate resources will be available when necessary for safe decommissioning⁹ (para. 3.3 of GSR Part 6 [1]). The amount of funds necessary and the timeline for the expenditure of the funds should be consistent with the cost estimate for decommissioning of the facility.

⁹ The definition of the funding mechanism might be the responsibility of other governmental organizations.

3.15. On-site inspection is one of the elements of the regulatory regime and the regulatory body should allocate adequate resources to this task. The regulatory body should develop an inspection programme, based on a graded approach, which should include the following key elements: a system of prioritizing inspections; on-site visits of inspectors; review of safety assessments made by the licensee; investigation and follow-up of events; and submission of information on compliance with safety criteria by the licensee. The inspection programme should include industrial safety elements as well, if this is not regulated separately.

3.16. The regulatory body is required to perform inspections during decommissioning (para. 3.3 of GSR Part 6 [1]) using established inspection procedures. The regulatory body should inspect key decommissioning actions, such as decontamination, dismantling, management of decommissioning waste; application of radiation protection measures; and monitoring performed to confirm compliance with the authorization. Inspections should verify compliance with the safety objectives and criteria defined in the final decommissioning plan, compliance with the results and conclusions of the safety assessment, and compliance with the limits and conditions of the authorization for decommissioning.

3.17. The regulatory body is required to take enforcement actions (para. 3.3 of GSR Part 6 [1]) in case of non-compliance with the national legal and regulatory framework, or with the authorization or licence conditions and safety requirements. The regulatory body should ensure that the existing enforcement policy, addressing radiation protection and safety and protection of the environment, covers aspects of decommissioning. The regulatory body should develop and use procedures for determining and exercising enforcement actions.

3.18. The regulatory body should maintain communication with the licensee to determine the future decommissioning timelines and schedules, as well as changes in schedules. Knowledge of the timelines of the licensee and changes to schedules will allow the regulatory body to plan its activities and to ensure it has appropriate staffing levels and experience to avoid regulatory related delays in decommissioning.

3.19. The regulatory body should inform the public and interested parties about the key decisions with regard to decommissioning of facilities for the purpose of transparency and in order to address public concerns relating to the safety of decommissioning. Information should be provided to interested parties as soon as such information becomes available [20]. In addition, the regulatory body is required to give interested parties an opportunity to provide input into

the decommissioning process (para. 3.3 of GSR Part 6 [1], see IAEA Safety Standards Series No. GSG-6, Communication and Consultation with Interested Parties by the Regulatory Body [21]).

3.20. As stated in para. 3.3. of GSR Part 6 [1], the regulatory body is required to establish requirements for ensuring that records important for the planning and implementation of decommissioning actions are collected and retained by the licensee throughout all stages of the facility's lifetime. Certain records developed during the decommissioning project will be important for legal purposes after the authorization for decommissioning has been terminated. Such records should be identified and preserved, and the responsibility for their retention should be assigned clearly.

3.21. A strong safety culture is an important part of a decommissioning project since actions that might not be routine are being performed and specialist personnel might be used to perform some of these actions. One of the purposes of the regulatory body's management system is to foster and support a strong safety culture in the regulatory body through the development and reinforcement of leadership, as well as good attitudes and behaviour in relation to safety on the part of individuals and teams [14, 22]. The regulatory body should cooperate with the licensee in order to maintain a strong safety culture throughout the decommissioning project [1]. Requirements on safety culture are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [23].

Requirement 6 of GSR Part 6 [1]: Responsibilities of the licensee for decommissioning

“The licensee shall plan for decommissioning and shall conduct the decommissioning actions in compliance with the authorization for decommissioning and with requirements derived from the national legal and regulatory framework. The licensee shall be responsible for all aspects of safety, radiation protection and protection of the environment during decommissioning.”

3.22. Prior to permanent shutdown of a facility, the licensee should discuss with the regulatory body and should reach agreement on the timing of decommissioning, the proposed decommissioning actions, applicable regulations and guidance and other requirements of the regulatory body. During the lifetime of the facility, the licensee is required to select a strategy for decommissioning (para. 3.4 of

GSR Part 6 [1]) that is consistent with national policies, to prepare and submit for regulatory review an initial decommissioning plan and its updates, and to ensure that adequate financial resources will be in place for the decommissioning project. The licensee is required to submit a final decommissioning plan and supporting documents for review and approval by the regulatory body (para. 3.4 of GSR Part 6 [1]), in accordance with national regulations, in its application for an authorization to conduct decommissioning. It has been demonstrated that early dialogue between the regulatory body and the licensee improves the planning and implementation of decommissioning, and can facilitate the process of obtaining regulatory approval.

3.23. In preparing for decommissioning, the licensee might perform activities such as the removal of sealed radioactive sources, waste from operation and historical waste stored on the site during operation. Such activities should be carried out in accordance with the current operating licence of the facility to ensure that the facility is maintained in a safe configuration during the transition from operation to decommissioning, until the final decommissioning plan is approved for implementation and the authorization for decommissioning is granted.

3.24. The licensee is responsible for ensuring that trained and qualified workers are available for safely conducting decommissioning actions, for the overall safety performance, for demonstrating that the end state of decommissioning complies with the end state criteria defined in the final decommissioning plan and for retaining decommissioning records, as required. The availability of qualified experts in radiation protection is essential for ensuring safety in decommissioning.

3.25. The licensee is required to estimate the cost of decommissioning actions and provide financial assurances and resources to cover the costs associated with safe decommissioning (para. 3.4 of GSR Part 6 [1]), including management of the resulting radioactive waste.

3.26. More details on how the licensee should fulfil its responsibilities for decommissioning are provided in Sections 4–9 of this Safety Guide.

4. MANAGEMENT OF DECOMMISSIONING

Requirement 7 of GSR Part 6 [1]: Integrated management system for decommissioning

“The licensee shall ensure that its integrated management system covers all aspects of decommissioning.”

4.1. The licensee should establish, implement, assess and continually improve an integrated management system for decommissioning. The management system is required to cover all aspects of the decommissioning (Requirement 7 of GSR Part 6 [1]) and should be commensurate with the size, complexity and nature of the decommissioning project, in accordance with a graded approach. The licensee should implement an appropriate integrated management system before the commencement of decommissioning actions and the management system should extend to all phases of the decommissioning project.

4.2. The integrated management system provides a single common framework in which decommissioning is undertaken. This framework should include planning for decommissioning, conduct of decommissioning actions and completion of decommissioning, including management of decommissioning records. General requirements and guidance on the management system are provided in other IAEA safety standards [23–25]. A description of or reference to the management system, including a definition of its scope and intent, should be included in the final decommissioning plan.

4.3. The integrated management system should provide for a graded approach to the application of the requirements, considering the magnitude of risk and commensurate with the complexity of the task to be performed (e.g. by specifying the type and level of detail of the required decommissioning documents, the plans and procedures for performing decommissioning tasks, the oversight activities and the training necessary for personnel to ensure that the task will be performed safely).

4.4. The organizational structure that is to be adopted for decommissioning should define the roles, responsibilities, authorities and key personnel of the licensee, including contractors if applicable. The organizational structure to be employed for decommissioning should be described in the decommissioning plan. In the description of the organizational structure, there should be a clear delineation of authorities and responsibilities among the various units. This is particularly

important when subcontractors are used for dedicated decommissioning actions. Mechanisms for controlling subcontractors appropriately should be established in written procedures; however, the prime responsibility for safety remains with the licensee.

4.5. Where appropriate, a ‘work breakdown structure’ should be established for the overall management of the decommissioning project. A high level work breakdown structure, describing decommissioning actions, should be included in the final decommissioning plan. A detailed work breakdown structure should describe the project in terms of work packages and individual tasks, including interdependences between tasks.

4.6. The licensee should develop a safety policy applicable to decommissioning that promotes a strong safety culture and sets out the responsibility of all individuals to identify and to bring any safety concerns to the attention of management of the decommissioning project.

4.7. The licensee should ensure that the safety policy applies to all individuals and includes the authority to stop unsatisfactory work, the responsibility to report safety concerns and the requirements for maintaining a safe working environment. Safety should be the highest priority for everyone involved in the decommissioning process.

4.8. The licensee should foster a safety culture in order to discourage complacency at every level [1]. This is particularly important in decommissioning, where the facility’s configuration is undergoing continuous change. Managers should foster an attitude of willingness to learn in relation to safety matters and should promote an open exchange of information upwards, downwards and horizontally within the organization.

4.9. The licensee should apply appropriate levels of control, supervision and training for individuals in all organizations involved in the decommissioning project in order to ensure a high level of safety performance is maintained, particularly when high hazard tasks are to be performed or when a large number of contractors are engaged. However, the overall responsibility for safety remains with the licensee.

4.10. In accordance with an evaluation of the skills and knowledge necessary to decommission a facility, a team composed of decommissioning specialists and appropriate site personnel should be formed to manage the decommissioning project. Specialized expertise may be necessary in areas such as:

- Radiological characterization;
- Technologies and procedures for decontamination, dismantling and demolition;
- Robotics and remote handling of sources;
- Waste processing (i.e. pretreatment, treatment and conditioning of waste);
- Site cleanup;
- Radiation protection and health physics.

4.11. As appropriate, key personnel from the operational stage of the facility should be retained to help in conducting the decommissioning actions. They should have the necessary background knowledge of the facility, including knowledge of the facility's design and modifications made, its operating history and incidents relevant to decommissioning that may have occurred during its lifetime.

4.12. Decommissioning might involve actions that pose hazards that were not faced during operation of the facility. The licensee should develop and implement a robust decommissioning training programme for personnel, irrespective of whether former operations personnel are involved or the activities are performed by contractors. The training can be in the form of oral briefings, practical exercises, training lectures or comprehensive training courses.

4.13. Specialized training might be necessary for some decommissioning actions, and this may involve the use of mock-ups, models and computer-based simulations to ensure that the actions can be carried out safely and to incorporate lessons learned into the work procedures. Additional refresher training might be necessary for decommissioning actions that are conducted infrequently. The training programme for decommissioning should be addressed in the decommissioning plan (see Annex II).

4.14. In some cases, contractors may be used to perform all or some aspects of decommissioning (e.g. its planning, conduct or completion of actions). This is likely to be the case if decommissioning takes place after a long period of safe enclosure, or when specialized decommissioning skills or expertise are necessary, such as the use of specific decontamination processes or the application of specific dismantling or demolition tools. All personnel involved in decommissioning actions, both the personnel of the licensee and personnel of any contractors, should be made familiar with the procedures for safe and effective conduct of their duties, in accordance with their specific roles. All project personnel who will perform decommissioning tasks should receive basic training in radiation protection and safety and should be able to demonstrate their knowledge.

Additionally, depending on the actions to be performed, certain personnel should receive specific training in:

- The design and layout of the facility;
- Technical characteristics of the facility and its operational history;
- Planned decommissioning actions and associated procedures;
- The use of personal protective equipment;
- Industrial safety aspects, including hazards present, and the resulting risks and their control;
- Radiation protection;
- Practices and procedures for the management of radioactive material and radioactive waste;
- Emergency preparedness and response.

4.15. Training requirements should be identified, documented and communicated to all personnel, including those of contractors and subcontractors, and, before a specific decommissioning procedure is applied, it should be demonstrated that the relevant personnel are adequately trained.

4.16. Different approaches can be used when decommissioning a complex facility. One approach is to progress from low hazard areas to higher hazard areas of the facility. Such an approach permits the gradual development and improvement of decommissioning skills and experience, while reducing potential risk to decommissioning workers. Another possible approach is to remove the most highly radioactive material first to create a better working environment for subsequent phases of the decommissioning project.

4.17. All decommissioning actions should be carried out in accordance with approved work procedures, which should be developed by taking into account the output of the safety assessment (the limits and conditions for safe decommissioning). The procedures should define how the decommissioning actions are to be carried out and, where appropriate, should identify steps to be taken in the event of an abnormal occurrence. The procedures should be established and controlled in accordance with the provisions of the integrated management system.

4.18. Decommissioning workers can initiate and should participate in the process of developing work procedures. The knowledge and experience of personnel involved in decommissioning should be utilized in the drafting of work procedures, and experience coming from the testing of a technique or tool in a radiologically

clean environment and from previous decommissioning actions or projects should be incorporated into the work procedures.

4.19. Each work procedure should be sufficiently detailed, such that a qualified individual is able to perform the required actions. Consideration should be given to the layout of the area concerned, the general design of the facility, staffing requirements and decommissioning experience at the facility concerned. Procedures should be developed in accordance with established requirements and recommendations relating to the management system.

4.20. To ensure consistency in format and content, work procedures should be prepared in accordance with the administrative procedure that governs the development, review and control of such documents, including a provision for periodic review. A mechanism should be established to verify that any work procedure has been approved (e.g. by means of signatures) and that it is current (e.g. through a list of the most recent dates of revision).

4.21. Depending on the State, the approval process for work procedures may be different; however, the approval process should be commensurate with the risk posed by the actions described in the procedure. Persons with appropriate competence and experience should be designated to prepare and verify procedures. In order to develop safe, reliable and effective work procedures, human factors should be taken into account.

4.22. Administrative procedures used in the operational stage of the facility might be relevant for decommissioning. However, these procedures should be reviewed and modified as necessary to ensure that they are appropriate for the decommissioning actions that will be undertaken. All procedures, as well as their revisions and changes, should be subject to approval by the licensee, to ensure that the decommissioning actions will be performed safely and that the work is integrated into the overall decommissioning work plan and schedule.

4.23. Experience from decommissioning projects has indicated that a lack of attention to documentation and record keeping could result in safety problems and in an ineffective use of resources, resulting in higher costs. Records are essential for the preparation of decommissioning plans. Records from all stages of the lifetime of the facility, including its siting, design, construction, commissioning, operation and decommissioning that are of importance for the planning and conduct of decommissioning should be identified, preserved and made available when necessary. The process of development of the initial decommissioning plan, updating the decommissioning plan and preparing the final decommissioning

plan should use pertinent records to ensure safety and to enhance efficiency in the decommissioning of the facility. These records should include:

- (a) Records of the history of the facility, including:
 - Design specifications and information from siting and construction, including as-built drawings, photographs, diagrams of piping (including drainage systems) and cable penetrations, and other details helpful for decommissioning purposes;
 - Relevant environmental and radiological data from the stages before operation of the facility and from the operational stage;
 - Accountancy records of sealed and unsealed sources;
 - Use of chemicals and their inventories;
 - Incidents leading to spillage or inadvertent release of radioactive material, including information about actions, corrective measures and close out of such events;
 - Radiation survey data and contamination survey data (radionuclide inventory and its distribution throughout the facility, particularly for areas of the facility that are rarely accessed or especially difficult to access);
 - Releases and leaks that could have affected surface water, groundwater, soil and sediment;
 - The location of sources;
 - Waste storage locations.

- (b) Records of modifications to the facility and experience from maintenance works, including:
 - Updated as-built drawings, videos and photographs, including details of the materials used;
 - As-built drawings and background samples for added buildings;
 - Special repair or maintenance actions and techniques (e.g. effective temporary shielding arrangements or techniques for the removal of large components);
 - Details of the design, the composition of added materials, and the history and location of all temporary experiments and devices.

4.24. During the facility's operation, records should be retained as appropriate to meet the needs of future decommissioning and as dictated by national requirements.

4.25. In the case of deferred dismantling, where long periods of storage of records are anticipated prior to final dismantling, records should be periodically checked to confirm that they are being preserved in a safe and retrievable media and format. Records may be in the form of facility logbooks, video footage and photographs to aid future decommissioning of the facility and future training. Preferably, more than one copy of key records should be kept in different locations.

4.26. Periodic briefings adapted to the complexity of the decommissioning actions should be performed as they are an integral part of the control of decommissioning actions. They give an opportunity for the management to check the workers' understanding of the scope of actions to be undertaken and their understanding of related decommissioning limits and conditions (the set of rules and parameters for safe decommissioning). The periodic review of decommissioning actions helps in identifying critical steps and facilitates learning from relevant experience gained through the conduct of similar actions in other projects or facilities.

4.27. If the licensee changes after permanent shutdown of the facility or during decommissioning, the new licensee responsible for decommissioning should have qualified managers and technical expertise to manage the decommissioning project and should have sufficient financial resources to carry out safe decommissioning of the facility. Procedures should be put in place to enable such transfer of responsibilities for decommissioning and to ensure it is a controlled process in which the licensee maintains responsibility for safety and for compliance with the licence conditions.

4.28. For more complex facilities, the configuration management process should be capable of managing a high rate of changes to the facility and its records, including drawings. The objective of the configuration management process is to keep records and procedures consistent with the current physical status of the facility at any time.

4.29. On the completion of decommissioning actions, the final decommissioning report is prepared, which should document the end state of decommissioning of the facility and should provide reference to the decommissioning records, typically including the results of radiological surveys, inventories of radioactive waste and non-radioactive waste (types and volumes of waste generated), destinations of waste removed from the facility, results of effluent and environmental monitoring, and records of personnel monitoring. More details on the final decommissioning report are provided in Section 9 of this Safety Guide and in Annex III.

4.30. Requirements pertaining to nuclear security concerns will be reduced as decommissioning progresses and radioactive material is removed from the facility. Since contractors might be assigned major dismantling tasks, site access and security might still remain an important issue. In the case of deferred dismantling, nuclear security requirements will remain in effect through the entire safe enclosure period. In cases when security still presents a concern during decommissioning, safety measures and nuclear security measures should be applied in an integrated manner so that nuclear security measures do not compromise safety and safety measures do not compromise nuclear security.

5. DECOMMISSIONING STRATEGY

Requirement 8 of GSR Part 6 [1]: Selecting a decommissioning strategy

“The licensee shall select a decommissioning strategy that will form the basis for the planning for decommissioning. The strategy shall be consistent with the national policy on the management of radioactive waste.”

5.1. The overall purpose of a decommissioning strategy is to serve as a basis for the decommissioning plan, and, in turn, to facilitate achieving the end state of the decommissioning project.

5.2. In principle, two possible decommissioning strategies are applicable: immediate dismantling and deferred dismantling. These strategies are defined in GSR Part 6 [1]. Immediate dismantling and deferred dismantling are generic terms, and do not necessarily mean that the decommissioning should include dismantling of structures, as this is not essential for all medical, industrial and research facilities. No action (leaving the facility as it is after operation, and waiting for decay of the radioactive inventory) is not an acceptable decommissioning strategy. Experiences worldwide show that most medical, industrial and research facilities can be decommissioned applying an immediate dismantling strategy. In some cases, however, a strategy involving deferral of parts of the dismantling actions might be more appropriate, taking into account specific considerations. In most of these cases, the deferral period is much shorter than in the case of large nuclear facilities [2], when the safe enclosure period might take several decades.

5.3. The selection of a decommissioning strategy follows a progressive process. A ‘preferred decommissioning strategy’ should be proposed in the initial decommissioning plan. It should be reviewed and updated during the lifetime of the facility and, as appropriate, confirmed by the licensee when the decision is taken to permanently shut down the facility. Immediate dismantling is the preferred strategy, as it avoids transferring the burden of decommissioning to future generations. The immediate dismantling strategy means that decommissioning actions start soon after the permanent shutdown of the facility, and there is no delay of decommissioning for many years. In this context, release from regulatory control without restrictions should be the preferred end state and ultimate objective of decommissioning, especially when a disposal facility is available for the radioactive waste. If a disposal facility is not available, arrangements for removal of the radioactive waste arising from decommissioning and for its storage in a licensed facility should be put in place so that immediate dismantling and release without restriction are still possible.

5.4. A justification for the selection of a particular strategy should be provided to demonstrate the advantages of the selection made and the reasons for its choice, especially if deferred dismantling is selected, as it implies to some extent a transfer of responsibilities for decommissioning to future generations. Any strategy that involves waiting periods should be justified in terms of safety, management of decommissioning waste and radiation protection issues. In the deferred dismantling option for medical, industrial and research facilities, the deferral period will normally be relatively short (i.e. on the order of a few months to years).

5.5. In accordance with the selected strategy, the final decommissioning plan should describe the timing and sequencing of decommissioning actions, and should describe how safety and protection of workers and the public and protection of the environment will be optimized.

5.6. The main factors influencing the selection of the decommissioning strategy include:

- The national policy and the regulatory framework;
- The type of facility and interdependences with other facilities or infrastructure located at the same site;
- Proposed reuse of the facility or site and the desired end state;
- The physical status (e.g. ageing components and structures) and the radiological status of the facility (as derived from characterization data);
- Safety aspects;

- The availability of expertise (knowledge, skills and experience), technologies and infrastructure (tools, equipment, supporting facilities and services);
- The environmental impact of the facility and of its decommissioning;
- The availability of financial resources for decommissioning;
- Societal and economic factors and the socioeconomic impact of decommissioning;
- The availability of infrastructure for radioactive waste management, including facilities for pretreatment, treatment, conditioning and storage, as well as existing or anticipated waste disposal options.

5.7. This list contains many issues that have a greater or lesser significance, depending on the specific circumstances for decommissioning in the State. More detailed considerations relating to the above factors are provided in Appendix II. For the facilities in the scope of this Safety Guide, consideration of the above factors should generally lead to selection of a strategy of immediate dismantling. However, in some cases (e.g. the decommissioning of complex radioisotope manufacturing facilities) deferred dismantling may be considered.

5.8. The decommissioning of most medical, industrial and research facilities can usually be accomplished with proven decontamination and dismantling technologies, applying the immediate dismantling strategy and allowing prompt release of the site from regulatory control.

5.9. When a deferred dismantling strategy for medical, industrial and research facilities has been justified, there are two approaches applicable. In the first approach, measures to control access to the contaminated areas are put in place until such time that the decay of radionuclides results in the activity reaching a level at which the facility can be released from regulatory control. Owing to the decay of radionuclides, this strategy will usually not require any dismantling operations or will involve only dismantling of non-contaminated systems, structures and components, enabling elimination of radiological risks during dismantling. For the second approach, often called phased decommissioning, there are periods of deferral between active decommissioning phases. This phased conduct of decommissioning actions allows time for:

- The allocation of necessary resources;
- The resolution of technical issues;
- The decay of short lived radionuclides to reduce occupational exposure or to reach release levels for buildings or clearance levels for materials (e.g. to permit the sale of recycled copper piping from a cyclotron);
- The development of adequate waste management capacity.

5.10. If the deferred dismantling strategy has been selected, it should be clearly demonstrated in the decommissioning plan that such a strategy will be implemented safely and that only a minimum of active safety components or systems will be necessary during the period of safe enclosure (i.e. reliance will be placed on passive safety components and systems). The ageing and potential deterioration of any safety related equipment and system should also be considered.

5.11. As described in Section 6 of this Safety Guide, the financial arrangements for decommissioning should be established early in the lifetime of the facility to enable safe decommissioning in a timely and efficient manner. A lack of financial provisions should not be a driving factor in the selection of a decommissioning strategy.

5.12. The licensee should check at regular intervals whether the decommissioning strategy is still appropriate. Updates of the final decommissioning plan and supporting safety documentation during the conduct of decommissioning should reflect the progress of the work, the continuous removal of material and the waste generated, and the evolution of the physical and radiological status of the facility, in order to demonstrate that a safe configuration is maintained at all times and that the decommissioning project is still aligned with the selected decommissioning strategy.

5.13. For a multifacility site, a strategy for decommissioning of the site as a whole should be developed in order to identify and evaluate the interdependences between facilities on the site, both those in operation and those permanently shut down. This site strategy for decommissioning should be used as a basis for the selection of individual decommissioning strategies for individual facilities on the site, and for development of the facilities' decommissioning plans. Each individual decommissioning strategy should be consistent with the site strategy for decommissioning, and should properly accommodate interfaces between the facilities. These interdependences should be detailed in the individual final decommissioning plans for each facility.

5.14. The site strategy for decommissioning, reflected in the individual decommissioning plans for each facility on the site, should identify opportunities for synergies between individual decommissioning projects, in order to optimize resources, efforts and skills, as well as to make use of supporting facilities in an optimal manner. Site considerations that impact the selection of an individual decommissioning strategy and the development of the decommissioning plan for a facility located on a multifacility site include the following:

- A general approach to decommission first those facilities having the highest priority in terms of safety, waste management and radiation protection, prior to those facilities with lower priority issues, with consideration given to ageing and obsolescence of SSCs.
- A decision to decommissioning the least contaminated or activated facilities and buildings first prior to the more contaminated facilities and buildings, to allow benefit to be gained from experience and radioactive decay.
- The optimization of decommissioning actions across the site and their sequencing by using pooled resources and skills as appropriate to avoid underutilization of workers.
- Coordination of the use of specialized contractors and subcontractors as appropriate, with account taken of the availability of the best qualified personnel, equipment and infrastructure at a given time, in accordance with the decommissioning schedule for each individual facility.
- Establishment of common facilities providing support for the predisposal management of radioactive waste (i.e. its processing, storage and removal from the site) and coordination of the use of such common facilities for different decommissioning projects on the site. This might require a revision of facilities' boundaries to allow the allocation of buildings, equipment and infrastructure to the waste management tasks.
- The optimization of discharges of gaseous and liquid effluents from individual operating facilities and facilities undergoing decommissioning in accordance with the authorization for discharges granted by the regulatory body for the entire site.
- The need to use a consistent approach for final remedial actions and to apply consistent criteria across the entire site for release of the site from regulatory control, irrespective of whether the release from regulatory control is done in parts after completion of each individual decommissioning project, or at once after completion of the last decommissioning project on the site.

5.15. Unforeseen permanent shutdown could occur during operation of a facility for financial, technical or political reasons. In such cases, the decision to permanently shut down the facility might not have been anticipated by the licensee. Consequently, a review of the preferred decommissioning strategy might be necessary on the basis of the situation that initiated the unforeseen shutdown, in order to evaluate whether a revision of the decommissioning strategy is necessary.

5.16. The decommissioning strategy should include provisions to ensure that if shutdown occurs before a final decommissioning plan is prepared, adequate arrangements are provided to ensure the safety of the facility until a satisfactory decommissioning plan can be prepared and implemented.

5.17. Unforeseen permanent shutdown of a facility might also be the result of an accident. In this case, the first objective is to bring the facility into a safe state before the decommissioning strategy is reviewed and any final decommissioning plan is reviewed or implemented. The recovery actions undertaken are precursors to decommissioning actions, and the consequences of the recovery actions should be addressed in the final decommissioning plan.

5.18. Once a safe state has been achieved after an accident at a facility, a comprehensive survey of the physical and radiological conditions of the facility should be performed to determine whether the selected decommissioning strategy is still feasible. In developing the final decommissioning plan after an accident, special attention should be given to the physical and radiological conditions of the facility, considering that it might be impossible to repair damaged SSCs, even if an acceptable safe state has been reached.

5.19. Incidents or accidents might lead to a spread of contamination outside the buildings of the facility, implying the need to conduct remediation actions on the site where the facility is located. Such on-site actions are usually considered a part of the overall decommissioning of the facility, and in most cases are implemented as the last phase of the decommissioning project. The extent of the on-site contamination might necessitate a change in the previously selected strategy and the end state criteria, as well as the establishment of long term institutional controls or a remediation plan for the site. Off-site contamination as a consequence of an accident is addressed in IAEA Safety Standards Series WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents [10].

6. FINANCING OF DECOMMISSIONING

Requirement 9 of GSR Part 6 [1]: Financing of decommissioning

“Responsibilities in respect of financial provisions for decommissioning shall be set out in national legislation. These provisions shall include establishing a mechanism to provide adequate financial resources and to ensure that they are available when necessary for ensuring safe decommissioning.”

6.1. Financial resources for decommissioning should be consistent with the chosen decommissioning strategy and with the decommissioning actions

described in the decommissioning plan. Financial assurance for decommissioning should be included as part of the application for authorization, and should be in place prior to initiation of construction or operation of the facility. The costs associated with decommissioning include costs for the following:

- (a) Decommissioning planning, including initial decommissioning planning prior to the start of operation of the facility, preparation of the final decommissioning plan during the transition from operation to decommissioning, and the detailed planning necessary for the conduct of decommissioning actions;
- (b) Pre-decommissioning actions (e.g. radiological characterization), application for and approval of the authorization for decommissioning and post-operational decontamination of the facility's systems;
- (c) Decommissioning actions, as described in the decommissioning plan, such as decontamination, dismantling of SSCs, demolition of buildings and structures, steps in the management of decommissioning waste that are defined as part of the decommissioning project, refurbishment of existing systems necessary to support decommissioning, and replacement or commissioning of new systems necessary for decommissioning;
- (d) Actions after termination of the authorization for decommissioning (e.g. monitoring in case of release of the facility with restrictions), preparation of the final decommissioning documentation and archival storage of decommissioning records, ongoing handling and processing of waste after completion of decommissioning and storage of waste and its subsequent disposal.

6.2. The financial resources necessary for decommissioning are determined on the basis of a cost estimate. The cost estimate for decommissioning is one of the key supporting documents to the decommissioning plan and should be prepared by the licensee or by a specialized contractor. The first cost estimate should be prepared in support of the initial decommissioning plan, and it should be revised and updated together with the revisions and updates of the decommissioning plan.

6.3. The cost estimate for decommissioning should cover all actions required to plan and perform the decommissioning. There will be additional costs for other actions, which might be included as part of the decommissioning project, but these are normally financed with funds used for operation of the facility, depending on the national legal framework. Such additional costs typically include costs associated with the management of waste from operation and costs for some pre-decommissioning actions.

6.4. The decommissioning cost estimate should distinguish between operating expenses and decommissioning expenses.

6.5. The latest available versions of the decommissioning plan and its supporting documents should be used as a basis for preparation of the cost estimate. The level of detail of the data needed and used for the cost estimate, and the accuracy of the estimate, will vary depending on the stage in the lifetime of the facility and depending on the level of detail provided in each revision of the decommissioning plan.

6.6. With regard to the accuracy and associated uncertainties of the decommissioning cost estimate, there are typically three types of cost estimate made during the lifetime of the facility:

- An order of magnitude cost estimate — this type of cost estimate can be utilized prior to receiving the operating licence and is based on the initial decommissioning plan;
- A budgetary estimate — this type of cost estimate is based on the data provided in revisions of the decommissioning plans;
- A definitive estimate — this type of cost estimate can be utilized after the completion of detailed planning of the decommissioning actions, and is based on the data provided in the final decommissioning plan and in the associated working level documentation (procedures), using the results of the detailed characterization survey of the facility.

6.7. Responsibility for preparation of the cost estimate and its updates resides with the licensee, but the work might be done by a contractor. For facilities with higher decommissioning costs or with elaborate and complex cost calculations, an entity independent of the licensee should be involved in the review of the cost estimate, in accordance with the national regulatory framework.

6.8. Cost estimates and financial provisions should be reviewed periodically and should be adjusted as necessary. Factors to be considered include the following:

- Inflation;
- Updates of the decommissioning plan or revisions of the final decommissioning plan;
- Other factors, such as technological advances or waste management costs;
- Regulatory changes, especially in the case of deferred dismantling, where the decommissioning process might take years owing to the safe enclosure period.

6.9. The financial systems adopted by the licensee should be sufficiently robust to provide for decommissioning needs in the event of a premature shutdown of the facility. Mechanisms of providing financial assurance might include insurance, trust funds, surety-bonds, prepayments or other financial guarantees, for example internal or external funds. A combination of these methods may be acceptable to the regulatory body. Some facilities (such as university laboratories) might be government owned, and thus the State budget covers the costs for decommissioning. In any case, financial provisions should be in place prior to approval of the issue of a licence, a licence renewal or a licence extension for the operation of the facility.

6.10. The mechanism by which financial assurance is guaranteed should be robust, so that it will withstand changes in government (for government owned and financed facilities), changes in ownership of a private company (especially following sale of the company to a party that is resident outside the State), changes within financial institutions (where financial assurance is guaranteed, for example, by a bond secured by a financial institution), or bankruptcy of the licensee.

6.11. The decommissioning fund should be properly managed and maintained, and it should be protected so that it is used for decommissioning related activities only, in a manner prescribed by national regulations. A small part of the decommissioning fund may be used for preparatory activities during the transition from operation to decommissioning, subject to approval by the regulatory body, but the main part of the fund should be available only after an authorization for decommissioning is granted.

6.12. Where cost estimates are based on the return of sealed radioactive sources to the manufacturer, periodic checks should be made with the manufacturer to ensure that the agreement is still valid if no other system of guarantee is in place in the State. If there are changes in the source return agreement or shipment arrangements, any impact on costs owing to transport and security requirements, packaging costs or conditioning, storage or disposal costs should be reflected in the updated cost estimates and the financial assurance. If a source purchasing agreement includes pre-paid return of the source, this typically covers only the cost of return transport of the source and might not include costs incurred for removal of the source from the facility. Such costs should be included as part of the decommissioning cost estimate.

6.13. In the case of decommissioning after an accident, after completion of the recovery actions, when the facility is brought to a safe state, a revised cost estimate

should be made on the basis of a reassessment of the selected decommissioning strategy and in accordance with the final decommissioning plan.

6.14. If the end state of a decommissioning project is release of the facility or site from regulatory control with restrictions, the financial provisions should include costs associated with the long term monitoring and surveillance, and implementation of the defined restrictions, to ensure that all the necessary controls remain effective and long term safety will be maintained for the entire period of time for which these controls are necessary.

7. PLANNING OF DECOMMISSIONING DURING THE LIFETIME OF THE FACILITY

Requirement 10 of GSR Part 6 [1]: Planning for decommissioning

“The licensee shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the facility, in accordance with the requirements of the regulatory body, in order to show that decommissioning can be accomplished safely to meet the defined end state.”

7.1. Decommissioning planning throughout the lifetime of a facility is important to facilitate the conduct of decommissioning, to optimize protection of decommissioning workers, the public and the environment, to minimize radioactive waste generation and to estimate the decommissioning costs. Planning for decommissioning should be graded to reflect the complexity of the facility involved. While the general approach described in this Safety Guide can be applied to all facilities, detailed planning should be tailored to the facility concerned.

7.2. Decommissioning planning comprises three phases and each of these phases has a decommissioning plan or plans associated with it: an initial decommissioning plan, updated plans and a final decommissioning plan. For a given facility, the degree of detail in the decommissioning plan will increase significantly from the initial decommissioning plan to the final decommissioning plan. The decommissioning plan is required to be prepared on the basis of the selected decommissioning strategy and to be submitted to the regulatory body for approval (Requirement 10 of GSR Part 6 [1]), in accordance with the national regulatory framework.

7.3. Decommissioning should be facilitated by planning and preparatory work undertaken throughout the entire lifetime of the facility. Figure 1 illustrates the relation between the lifetime of the facility and the evolution of the decommissioning plan. The decommissioning plan is required to be periodically reviewed and updated (para. 7.5 of GSR Part 6 [1]). Aspects of the decommissioning plan to be considered during the lifetime of the facility, as well as aspects relating to unforeseen shutdown, are described in later parts of this section.

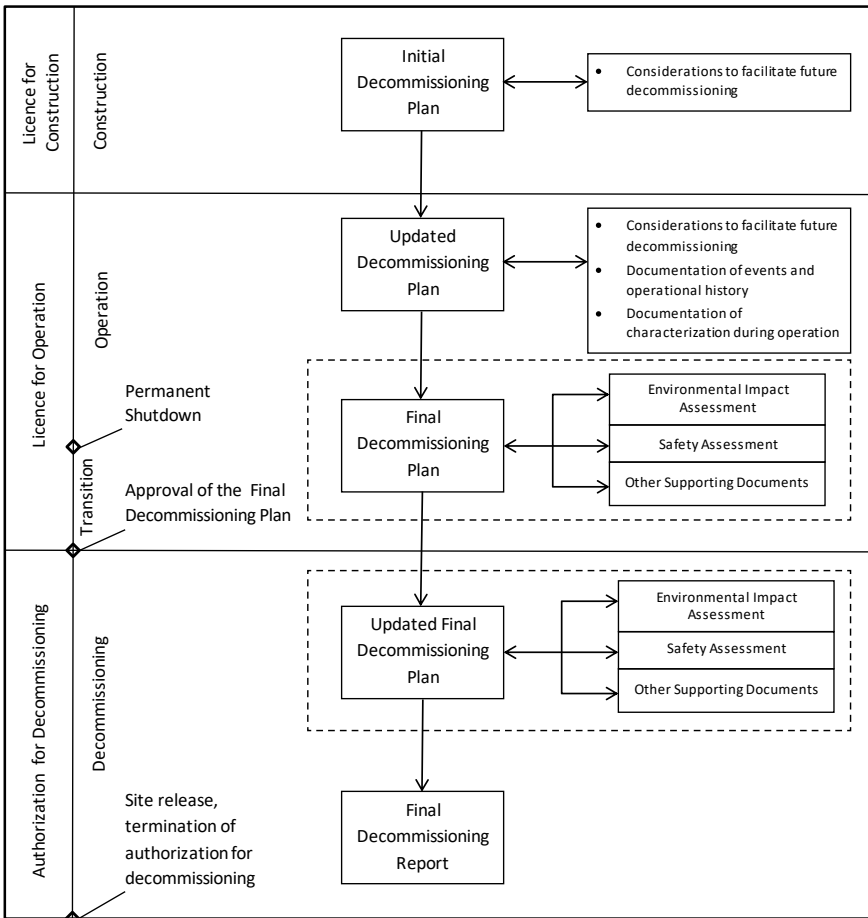


FIG. 1. An example of the evolution of the decommissioning plan during the lifetime of a complex facility.

7.4. Many medical, industrial and research facilities have been operating for many years and decommissioning might not have been considered at the design, construction and operation stages. For such facilities, planning for decommissioning is required to start as early as possible once the deficiency has been recognized (para. 7.6 of GSR Part 6 [1]). Furthermore, in addition to planning for decommissioning of such facilities, possible modifications to buildings and systems during the remaining operating lifetime should be used to incorporate features that will facilitate decommissioning, enhance radiation protection of workers and the public, and minimize environmental impacts, for example the use of components made of materials resistant to activation, the introduction of purification systems to reduce the spread of contamination and the creation of access points for easier decontamination of hot cells. In addition, there might be situations in which individual parts of a facility's premises need to be removed long before the whole facility is permanently shutdown. Each one of these incremental actions should be planned and recorded accordingly, with account taken of possible implications for the facility's decommissioning.

CONSIDERATIONS DURING DESIGN AND CONSTRUCTION

7.5. When designing new facilities, the applicant should take decommissioning considerations into account prior to application to the regulatory body for a licence for construction.

7.6. Relevant features and aspects that should be considered during the design and construction stages of a facility to facilitate decommissioning, and which might also enhance the safe operation and maintenance of the facility, include the following:

- (a) Minimization of the number and size of contaminated areas to facilitate decontamination during decommissioning;
- (b) Facilitation of access to SSCs, including compartmentalization of processes (e.g. through incorporation of hatches and large doors);
- (c) Minimization of underground piping and of embedded pipes in the building structures (e.g. through the use of pipe trenches and pipe sleeves);
- (d) Use of modular construction in order to facilitate the dismantling of equipment and SSCs (e.g. biological shielding);
- (e) Separation and isolation of non-radioactive and radioactive components and systems, such as separation of electrical and mechanical components;
- (f) Facilitation of the removal and/or decontamination of material or equipment, including by means of built-in decontamination mechanisms,

such as protective coverings and liners in process cells and areas where liquids might be present;

- (g) Use of materials that are resistant to activation, that are resistant to degradation by chemicals and that have sufficient wear resistance to minimize the spread of activated corrosion products;
- (h) Design of the facility to avoid undesired accumulations of chemicals or radioactive material, and utilization of processes for minimizing and/or reducing the volume of waste generated;
- (i) Use of smooth, seamless and non-absorbent work surfaces and flooring, and/or removable or strippable coatings in areas likely to become contaminated;
- (j) Provision of proper ventilation and drainage systems to prevent or control the spread of contamination during operation and decommissioning;
- (k) Consideration of lessons learned from previous decommissioning projects or actions;
- (l) Enabling of remote decontamination, maintenance and monitoring, where necessary;
- (m) Enabling of waste from operation or temporarily stored waste to be easily retrieved;
- (n) Minimization of the use of hazardous substances that could result in mixed hazardous and radioactive waste.

7.7. The documentation necessary for an application for an authorization for decommissioning will depend on the complexity of the medical, industrial or research facility and the tasks planned to be performed during decommissioning. For example, a simple facility usually has a brief decommissioning plan prepared in-house by the licensee, typically does not require an extensive environmental impact assessment, and involves limited decontamination and no demolition. On the other hand, an intermediate facility usually has a lengthier decommissioning plan prepared in-house by the licensee or with the assistance of external experts, typically does not require an extensive environmental impact assessment, has project management performed in-house or by an external expert, and involves some dismantling and demolition. A complex facility has a lengthy decommissioning plan, typically requires an extensive environmental impact assessment, often employs an external project manager and involves decontamination, demolition and possibly remediation performed by professional subcontractors.

7.8. During construction or at the latest before the commencement of initial operation of the facility, samples of radiologically clean (non-activated and non-contaminated) construction materials (e.g. concrete and steel) should be

collected and kept to enable determination of relevant background levels of radiation (e.g. from naturally occurring radionuclides in construction materials) and for chemical analyses in support of activation studies.

7.9. A baseline radiological site survey is required to be planned and performed (para. 7.2 of GSR Part 6 [1]) for the proposed site of the planned facility and its surrounding area to establish background concentration levels of radionuclides of natural and artificial origin for use in assessing the future impact of the facility. The licensee should identify the key radionuclides and the media (e.g. soil or surface water and groundwater) to be sampled and measured, so the results can be used for:

- (a) Future evaluation of the impact of the facility on the site and the surrounding area from its operation;
- (b) Determining the acceptability of proposed decommissioning options (as reflected in the decommissioning strategy and the initial decommissioning plan);
- (c) Establishing end state criteria and demonstrating compliance with the proposed end state.

7.10. The background data should be updated prior to the commissioning of any new facility or the construction of additional buildings and structures on an existing site, including an evaluation of naturally occurring radionuclides in building materials. Such data may be useful in supporting any later claim that operation of the facility did not have an adverse radiological impact on the building and the environment, and thus maintain the possibility of terminating the authorization for decommissioning in the future without the need to demolish buildings or structures.

INITIAL DECOMMISSIONING PLAN

7.11. The early development of an initial decommissioning plan will ensure that decommissioning is considered in the design of the facility. The initial decommissioning plan will be limited in detail, because it will be based on experience from previous projects and assumptions, and will need to be validated at a later time (see paras 7.12–7.20). The initial decommissioning plan is required to be submitted by the licensee to the regulatory body in support of the licence application or authorization for commissioning and/or operating the facility (para. 7.4 of GSR Part 6 [1]). The initial decommissioning plan:

- (a) Should preferably be based on the immediate dismantling strategy; however, deferred dismantling of individual facilities may be considered, such as in the case of a multifacility site;
- (b) Should include a generic feasibility study of decommissioning, based on the selected decommissioning strategy, which should consider design provisions and operating experience for facilitating decommissioning, including the proposed end state (preferably release from regulatory control without restrictions), related key decommissioning actions and basic safety issues;
- (c) Should include the approach for management of radioactive waste from decommissioning, and should provide initial identification of waste classes and an initial estimate of waste quantities;
- (d) Should provide a basis for a preliminary cost estimate of the decommissioning project and should specify the means of ensuring financial provisions for the decommissioning.

UPDATING OF THE DECOMMISSIONING PLAN

7.12. During operation, the decommissioning plan is required to be reviewed and updated periodically (para. 7.5 of GSR Part 6 [1]), typically every five years or as prescribed by the regulatory body in accordance with the national regulatory framework. Reasons that might necessitate updating of the decommissioning plan include:

- (a) Design or process modifications;
- (b) Changes in financial conditions, funding assurance or funding requirements;
- (c) Changes to relevant regulatory or safety requirements and criteria (e.g. radiation protection standards);
- (d) A change of the selected decommissioning strategy and/or the planned end state;
- (e) Commissioning of a radioactive waste disposal facility and the availability of waste acceptance requirements or criteria for disposal;
- (f) Feedback from operating and decommissioning experience, and technological developments;
- (g) Extension of the facility's operating period;
- (h) Incidents, events or situations with relevant consequences for decommissioning, such as changes in the estimation of the radiological inventory.

7.13. Updates of the decommissioning plan should become more comprehensive based on actual operating experience, data and technology developments as the facility approaches the end of its operating life.

7.14. A waste management plan should be part of the initial decommissioning plan and should include information about the waste management approach to be applied. This approach might be the same as the waste management approach used during operation of the facility, but its applicability to decommissioning should be reviewed (see the descriptions in paras 8.48–8.69).

7.15. In updating the decommissioning plan, attention should be paid to the information relevant to decommissioning that is available in the established records retention system (see para. 4.23).

7.16. During the operation of the facility, waste from operation should be properly managed and removed from the premises of the facility to dedicated facilities for further processing, storage and/or disposal, to the extent practicable, to simplify the transition to decommissioning.

7.17. The transition from operation to decommissioning starts after permanent shutdown of the facility. The transition period should be as short as practicable. The end of the transition period is defined by the date on which the authorization for decommissioning is granted or by the date of approval of the final decommissioning plan.

7.18. During the transition period, the facility is subject to the operating licence. All applicable operating requirements on the facility remain in place, unless the regulatory body has agreed to reductions of the requirements on the basis of a reduction of the hazards, for example through the removal of radioactive waste or high activity sources from the facility or the permanent absence of prompt radiation from accelerators or X ray devices.

7.19. Some activities preparatory to decommissioning might be carried out after permanent shutdown of the facility under the operating licence, such as management of waste from operation and residual materials (including drainage of systems and removal of combustible materials to reduce the fire loads), characterization of the facility, removal of sources, modification of the facility and preparation of systems to support decommissioning, and post-operational decontamination of systems.

7.20. The existing facilities and equipment identified for decommissioning should be reassessed upon each update of the decommissioning plan as to their viability to support the conduct of the proposed decommissioning actions and the achievement of the planned end state.

THE FINAL DECOMMISSIONING PLAN

Requirement 11 of GSR Part 6 [1]: Final decommissioning plan

“Prior to the conduct of decommissioning actions, a final decommissioning plan³ shall be prepared and shall be submitted to the regulatory body for approval.”

³The final decommissioning plan is that version of the decommissioning plan submitted for approval to the regulatory body prior to implementation of the plan. During implementation of this final plan, revisions or amendments may subsequently be needed as the activity progresses.”

7.21. When the licensee notifies the regulatory body that it plans to cease operation of the facility, it should initiate studies to support development of the final decommissioning plan. These studies should identify the systems, equipment and infrastructure from the operational stage that will need to be maintained for use during decommissioning, and the new systems, equipment and infrastructure that will need to be installed to support decommissioning.

7.22. For the decommissioning of a complex facility, the final decommissioning plan should be supported by additional documents (such as a waste management plan, a safety assessment and an emergency plan). For simple facilities, the final decommissioning plan could be a stand-alone document that incorporates most of the supporting information. An emergency plan is usually requested as a separate document even for a simple facility [16]. A graded approach is required to be applied to the development of the final decommissioning plan (Requirement 2 of GSR Part 6 [1]), such that the type of information and the level of detail in the final decommissioning plan are commensurate with the type and status of the facility and the hazards associated with the decommissioning of the facility.

7.23. For most medical, industrial and research facilities, a relatively simple final decommissioning plan with a logical and adequate demonstration of safety will be sufficient. The final decommissioning plan and supporting documents should cover the following: the selected decommissioning strategy; the schedule, type and sequence of decommissioning actions; the waste management strategy

applied, including clearance; the proposed end state and how the licensee will demonstrate that the end state has been achieved; the storage, processing and disposal of the waste from decommissioning; the time frame for decommissioning; and financing for decommissioning. An example of the typical content of a final decommissioning plan is given in Annex II. The final decommissioning plan should be based on either immediate dismantling after shutdown of the facility or deferred dismantling after an appropriate period to allow for the decay of short lived radionuclides.

7.24. The final decommissioning plan should state the methodology and criteria that the licensee will use to demonstrate that the proposed end state has been achieved. For most medical, industrial and research facilities, the proposed end state should be release of the facility or site for unrestricted use.

7.25. A safety assessment is a key supporting document to the final decommissioning plan. The licensee is required to prepare this document (paras 2.6 and 2.7 of GSR Part 6 [1]) and submit it for review to the regulatory body, in accordance with the national regulatory framework. The scope of the safety assessment, its content and the degree of detail may differ, depending on the complexity and hazard potential of the facility.

7.26. Before submission of the final decommissioning plan and the safety assessment¹⁰ to the regulatory body, these and other selected supporting documents should be subjected to an internal review performed by the licensee. The purpose of this review is to provide confidence that the proposed tasks are feasible and that suitable and sufficient safety controls have been identified.

7.27. Early in the planning stage for decommissioning, characterization surveys should be performed by the licensee to determine the inventories and locations of radioactive material (e.g. sealed radioactive sources, radioactive liquids and irradiated and contaminated structures and components) at the facility. The characterization surveys should include a comprehensive sampling and measurement campaign, and should also include a review of records from the operational stage of the facility, providing information relevant to characterization of radioactive inventory of the facility. The results of the characterization surveys should be summarized in a characterization report, which should include

¹⁰ A safety assessment is typically a stand-alone supporting document to the final decommissioning plan. It is summarized and referenced in the final decommissioning plan. However, for simple facilities, the safety assessment may be included as one chapter of the final decommissioning plan.

information on any remaining radioactive material, radioactive waste from operation, and chemicals and hazardous materials at the facility.

7.28. For medical, research and some industrial facilities, the hazards associated with non-radiological materials (e.g. biological or chemical contaminants) might greatly outweigh any radiological hazards. Due consideration should be given to the determination of the inventory of non-radiological hazardous materials prior to establishing the most appropriate decontamination and dismantling methods.

7.29. Characterization surveys are required to be performed by the licensee to support the development of the final decommissioning plan (para. 7.13 of GSR Part 6 [1]). Outcomes of the characterization surveys should be expressed in terms of activation and contamination maps of the SSCs, rooms, buildings and land areas around the facility, as applicable. The characterization surveys should also be used to identify non-radiological hazards. The information collected should be used as a basis for detailed planning of the decommissioning actions, including the determination of the physical boundaries and possible interactions of proposed decommissioning tasks with the surrounding area or with other activities ongoing at the site. The facility might be part of a larger facility (e.g. a hospital, university or research establishment), and in this case, the physical boundaries for the decommissioning actions should be clearly specified.

7.30. The extent of the characterization surveys should depend on the type of facility being decommissioned. If, for example, the facility contains sealed radioactive sources, it should be determined whether any sources have leaked. For facilities that use unsealed radioactive sources, a more comprehensive survey may be necessary to identify and locate any contaminated areas. Care should be taken that all contaminated areas are identified, especially in any concealed systems such as embedded pipes, liquid handling systems and ventilation systems.

7.31. In planning and implementing characterization surveys, existing records, operating experience, reports of incidents, as-built drawings (including drawings reflecting any modifications of the facility) and past radiation survey data should be used.

7.32. Material samples should be taken, as appropriate, during the characterization process. Selective sampling should be performed (e.g. in the case of particle accelerators), to verify any calculations used in estimating the activation of components or the migration of radionuclides. Samples should be taken to estimate the extent of the migration of radionuclides into structural materials such as concrete.

7.33. Some of the results and maps might be available from surveys that were performed during the operational stage of the facility. However, such maps should be updated to take into account radioactive decay, the ingrowth of progeny products and the migration of radionuclides. Such maps should show the results of any special surveys conducted to determine the penetration depth of contamination in concrete structures, soil and sediments and the extent of such contamination. For completeness, contamination in shielded or self-shielded components, such as inside pipes and other equipment, should be determined to the extent possible.

7.34. Radiological characterization data should include a description of the site area (e.g. the premises of the facility, the surrounding environment, groundwater and surface water, soil, and sediments), contamination levels, dose rate levels, and chemical and physical forms of materials. Characterization surveys should also identify adjacent uncontaminated areas. During planning of decommissioning actions, special attention should be given to preventing cross-contamination of such areas. Radiological characterization of the facility should comprehensively describe contamination levels and activation levels.

7.35. The results of the characterization survey should be used as the basis for and the justification of the selected decommissioning strategy and specific decommissioning tasks. An accurate characterization survey of a facility will provide the input for development of the final decommissioning plan and related safety assessment. A characterization report should be prepared that documents the information and data obtained during the characterization process. The characterization report should be made available for audits or inspections.

7.36. The characterization report should be summarized or referenced in the decommissioning plan and reviewed and made subject to approval by the regulatory body.

7.37. If radioactive material or waste from operation remains at the facility (including in subsurface soils and groundwater), such radioactive material is required to be included in the characterization survey (para. 7.13 of GSR Part 6 [1]). Special attention should be given to the inventory of disused radioactive sources and the storage of packages with unknown and uncharacterized radioactive material. Existing storage areas for liquid radioactive waste are also of importance for decommissioning, as the removal and processing of this type of waste may necessitate consideration of the physical and chemical status, as well as the design life, of the associated storage tanks. Additional characterization of

the site to evaluate potential leakage of radionuclides from liquid waste storage areas should be considered.

7.38. If existing waste processing systems cannot cope with the waste generated during decommissioning in the volumes or types of waste expected, the construction of new facilities or the use of existing facilities for storage of waste should be considered. Such considerations should take place in the framework of updating the initial decommissioning plan. Consideration should be given to minimizing the cross-contamination of waste and other material, and the generation of secondary waste, which may require additional storage or processing capacities on the site. A separate authorization by the regulatory body for such activities may be required.

7.39. Generally, a deferred dismantling strategy will involve early dismantling and decontamination to a limited extent in order to reduce the scope of the area to be enclosed and preserved, then a passive period of safe enclosure, and in the end final dismantling of the facility. Although the concept of safe enclosure is applicable to medical, industrial and research facilities, in most cases it does not mean exactly the same as for large nuclear facilities. It does not always involve extensive preparatory actions with the establishment of additional barriers followed by decades of isolation, but rather is a kind of temporary closure with surveillance for some months or years in order to benefit from the decay of radionuclides, which might allow radioactivity to reach a level at which the site can be released from regulatory control.

7.40. Planning for safe enclosure should identify the area to be preserved until final dismantling by defining the boundaries of the buildings, premises and equipment concerned. The plan should describe the physical and the radiological status to be reached before commencing the period of safe enclosure, and the safety systems that need to remain in operation to ensure safe preservation. Preference should be given to the use of passive systems to ensure safety during the safe enclosure period.

7.41. Preparatory actions for safe enclosure should be supported by characterization surveys and by a safety assessment to demonstrate that the work to be done (e.g. removal of waste, removal from service and/or dismantling of unnecessary SSCs and decontamination) can be performed safely. The deferral period (safe enclosure period) should be supported by a safety assessment to demonstrate that the barriers of the safe enclosure area can withstand internal and external events that might occur during the period of safe enclosure.

7.42. A surveillance and maintenance plan for the safe enclosure period should be based on the outcomes of the safety assessment. It should consider ageing and obsolescence aspects of the SSCs. In case of medical, industrial and research facilities, the duration of the period of safe enclosure is usually significantly shorter than for large nuclear facilities, so the ageing of the SSCs is less problematic. The safety assessment for the deferred dismantling strategy should be the basis for establishing the safety parameters (e.g. temperature, humidity, confinement and level of discharges to the environment) that should be maintained by the means described in the surveillance and maintenance plan. Corrosion and brittle fracture of materials, as well as ageing and obsolescence of materials (spare parts) are less important for medical, industrial and research facilities owing to the relatively short safe enclosure period. During the safe enclosure period, the licensee should review the safety of the facility as a whole to demonstrate compliance with its expected conditions.

7.43. Near the end of the safe enclosure period, the final decommissioning plan should be updated. In some cases, this update should consider additional preparatory actions that will be necessary to re-open the facility in order to conduct dismantling actions.

7.44. In some decommissioning projects, it might be advantageous to remove large components (e.g. accelerator components) as a whole from the facility's building and to move these components to another area on the site, or to ship such components to another facility away from the site for further segmentation, treatment and conditioning. In such cases, this should be reflected in the decommissioning plan and the relevant safety issues should be addressed (e.g. transport safety).

7.45. General experience has shown that it is possible to utilize off the shelf dismantling techniques that are commercially available. In most cases, time does not need to be dedicated to research studies for the development of new tools and techniques.

7.46. The introduction of new techniques might require specific analysis to assess the suitability and the safety of the new technique or equipment and to implement adequate controls, and also might require additional training of personnel. Such training should start during planning for the use of the new technique to provide feedback to the planning process. It should be used to confirm basic assumptions and inputs to the safety assessment and cost estimate, to identify related components and equipment important to safety and to develop working procedures and administrative and engineering controls.

7.47. If deferred dismantling has been selected as a decommissioning strategy, the licensee is required to demonstrate in the final decommissioning plan and supporting documents that such an option will be implemented safely (para. 7.14 of GSR Part 6 [1]). The availability of adequate financial resources to ensure that the facility is maintained in a safe condition during the deferral period and for subsequent decontamination and/or dismantling is required to be demonstrated (para. 7.14 of GSR Part 6 [1]).

7.48. As the decommissioning project is undertaken, modifications to the decommissioning actions might be made based on new data, unexpected events, feedback from experience and other factors. The final decommissioning plan and the related supporting documentation should be updated during implementation of the project as the decommissioning actions progress. These updates might require further approval by the regulatory body. The final decommissioning plan may describe a change control process through which minor changes to actions described in the final decommissioning plan are permitted without the need to seek approval by the regulatory body. The environmental impact assessment should be updated when a previously unconsidered potential environmental impact is identified.

PUBLIC INVOLVEMENT

7.49. In accordance with national requirements and with a graded approach commensurate with the potential risk and hazards, interested parties should be involved in the authorization process for decommissioning, as well as in the process for termination of an authorization for decommissioning, and are required to be given an opportunity to provide comments before decisions are taken by the regulatory body and prior to the granting or termination of an authorization for decommissioning (para. 7.16 and para. 9.6 of GSR Part 6 [1]).

UNANTICIPATED PERMANENT SHUTDOWN

7.50. The unanticipated shutdown or abandoning of a facility is not a common occurrence for larger nuclear facilities, but is more common for smaller privately owned medical, industrial and research facilities. Such situations might raise security issues relating to, for example, abandoned radioactive material (especially sealed sources) left behind at the facility's premises [13].

7.51. A cessation of operations at a facility and an unanticipated shutdown might occur suddenly during operation, owing to political, economic, or societal demands, or owing to an incident, when the final decommissioning plan and its supporting documents are not yet available. In such cases, the final decommissioning plan and supporting documents are required to be prepared as soon as possible (para. 7.7 of GSR Part 6 [1]). Adequate arrangements are required to be made to bring the facility to a safe configuration before an approved decommissioning plan is implemented (para. 7.7 of GSR Part 6 [1]).

7.52. The selection of the decommissioning strategy is required to be reviewed taking into consideration the cause and consequences of the event that resulted in premature permanent shutdown, especially the effect of the event on the condition of the facility. If any actions are required to place a facility into a safe condition as a result of the unanticipated permanent shutdown, such actions should preferably be taken under the operating licence or under an amended operating licence that covers these actions.

7.53. In case of an unanticipated shutdown owing to an accident, the facility should be brought to a safe condition by applying emergency operating procedures and recovery (stabilization) actions. Information should be collected as soon as possible about the physical and radiological status of the facility and the final decommissioning plan should be developed, which should take into account the damage caused by the accident. The final decommissioning plan may need to be updated during the conduct of decommissioning as new information becomes available.

7.54. Planning for the decommissioning of a facility damaged by an accident should involve an extensive update of the characterization surveys carried out previously and should take into account the relevant data and information recorded during emergency response. If accessibility to parts of the facility has deteriorated as a result of the accident, increased use of remote handling equipment for decommissioning might be foreseen. Special attention should be paid to emergency provisions that might have been implemented to mitigate the consequences of the accident and that require removal in the course of the decommissioning.

7.55. The decommissioning process for a facility damaged by an accident should follow the same principles and main steps as for decommissioning of a facility with a normal operating history, and should be consistent and coordinated with the overall strategy including off-site remediation. Technical challenges are likely to be larger, owing to higher dose rates and contamination levels, higher

uncertainties of information about the physical and radiological status of the facility and possible new categories of waste. Decommissioning of such a facility should be planned and should be considered as an authorized activity that should, in principle, comply with the same set of safety criteria as decommissioning after normal operation and planned shutdown.

8. CONDUCT OF DECOMMISSIONING ACTIONS

Requirement 12 of GSR Part 6 [1]: Conduct of decommissioning actions

“The licensee shall implement the final decommissioning plan, including management of radioactive waste, in compliance with national regulations.”

8.1. Conduct of decommissioning involves implementation of the decommissioning strategy and related actions, as described in the final decommissioning plan. It should be approached in a manner that is graded to the complexity and hazards associated with the particular site involved.

8.2. Design considerations (see para. 7.6) can significantly facilitate the decommissioning process. Proper control of operations is also important so that spills, accidents and other events that could lead to significant contamination are minimized.

8.3. Decommissioning, whether based on an immediate dismantling strategy or a deferred dismantling strategy, should commence soon after permanent shutdown. Any transition period between permanent shutdown and approval of the final decommissioning plan should be as short as possible, and should be managed under the operating licence. Some preparatory actions for decommissioning may begin in the transition period. Decommissioning actions should commence after the approval of the final decommissioning plan and issue of an authorization for decommissioning by the regulatory body, and should continue in phases or as a single project until an approved decommissioning end state is reached.

8.4. The approach to implementing the decommissioning strategy is generally consistent across the range of medical, industrial and research facilities, and should include the following:

- (a) Application of a graded approach to the safety requirements for decommissioning;
- (b) Completion and submission of any further applications for authorization and obtaining of approvals from the regulatory body;
- (c) Communication as appropriate with interested parties, both internal and external to the facility or the site, regular consultation with the regulatory body, and the establishment of clear lines of communication;
- (d) Implementation of radiation protection measures;
- (e) Assignment of roles and responsibilities and ensuring that they are clearly understood by all persons involved in the decommissioning project;
- (f) Where relevant, engagement of a suitably experienced project manager or contractors to conduct specific decommissioning tasks;
- (g) Performance of required mock-up trials or provision of additional training for specific staff groups relevant to their assigned decommissioning tasks (see Section 7);
- (h) Ensuring that all workers have a clear understanding of the work tasks to be carried out and are aware of the sequence in which the actions are to be performed and completed;
- (i) Dissemination of the outcome of the safety assessment and ensuring the availability of any required safety equipment;
- (j) Provision of training and competent staff on the correct use of safety equipment;
- (k) Securing the availability of any equipment to be hired for key tasks during the project (e.g. lifting equipment) and ensuring in advance that the written specifications for the hired equipment correspond to the actual item as supplied;
- (l) Implementation of the necessary physical protection, fire protection and emergency preparedness measures, ensuring all workers are familiar with them and ensuring that a mechanism is in place to update workers on any changes, as and when necessary;
- (m) Agreement on and securing the routes for movement of materials, waste, containers and packages, and equipment into and out of the parts of the facility being decommissioned;
- (n) Compliance with clearance levels approved by the regulatory body, agreement on measurement methodology with the regulatory body and ensuring that workers involved have the necessary competence to comply with what has been agreed;
- (o) Implementation of a suitable management system throughout the duration of the decommissioning project;
- (p) Update of the cost estimate for decommissioning, securing of funds and agreement on the timing for their release.

8.5. At the beginning of decommissioning, all readily removable radioactive materials and radiation sources should be removed for reuse, recycling, processing, storage in an approved location or disposal in accordance with regulatory requirements. Where possible, disused sealed radioactive sources should be returned to the original manufacturer or supplier.

8.6. The removal of radiation sources will normally result in a significant reduction of the radiation hazards. In the case of facilities using mainly sealed radioactive sources, this is relatively easy to accomplish. However, where radiation sources are present in the form of activated materials, liquids or contaminated surfaces, the method of removal may require more comprehensive planning. The planning should also consider the means of transport and the destination of the removed sources.

8.7. Decommissioning of a facility might be aided in certain instances by partial or total decontamination of the components, equipment and structures to be dismantled. Decontamination may be applied to internal or external surfaces and covers a broad range of actions directed at the removal or reduction of radioactive contamination in or on SSCs. The process of decontamination associated with the decommissioning actions can be conducted before, during or after dismantling.

8.8. The overall approach to decontamination should be optimized, with account taken of the benefits that result from reduced public exposures, the additional exposures of workers engaged in decontamination, the costs of the decontamination including treatment of the waste generated, and the costs saved by avoiding waste disposal costs.

8.9. Before any decontamination technique is selected, an evaluation of its effectiveness should be performed. This evaluation should address:

- Estimated occupational exposures;
- Consideration of the possible generation of radioactive aerosols;
- Target decontamination levels;
- Consideration of the likelihood that available techniques will achieve the target decontamination level for particular components;
- An ability to demonstrate by measurement that the target decontamination level has been reached;
- The availability of facilities required for decontamination and their eventual decommissioning;
- The cost of the technique compared with the expected benefits;
- The size and geometry of SSCs;

- The type and characteristics of the contamination;
- An estimate of the volume, nature, category and activity of any liquid or solid waste;
- Consideration of the compatibility of these wastes with existing treatment, conditioning, storage and disposal systems and discharge limits;
- Any possible deleterious effect of decontamination on the integrity of equipment and systems;
- Any possible on-site and off-site consequences as a result of decontamination actions;
- Non-radiological hazards (e.g. the toxicity of solvents used).

8.10. Preliminary decontamination of process equipment should be carried out as early as possible. This reduces the radiation risks posed, because a significant amount of contamination or radioactive material might remain in the process equipment after permanent shutdown of the facility. If preliminary decontamination is carried out successfully, and the hazard (such as high dose rates) is removed or reduced, then the safety assessment for the decommissioning actions can be updated accordingly. This allows more flexibility in how the decommissioning of the facility will be undertaken (e.g. it allows a reduction in the amount of liquid to be used for decontamination), it permits removal of the SSCs that were used in operation and are associated with the hazard, or it minimizes the potential for cross-contamination of redundant equipment. Decontamination can lead to a minimization of the volume of radioactive waste.

8.11. As the decommissioning actions progress, new hazards might emerge. New hazards might arise during mechanical cutting of metal pipes, where sharp edges are generated, and additional control measures might need to be adopted, such as the application of protective coverings. Decommissioning workers should highlight any such new hazard at daily briefings and feedback sessions. New hazards should be addressed properly to maintain overall safety of the decommissioning actions undertaken.

8.12. Consideration should be given to the early removal, confinement or immobilization of any remaining loose contamination, where practicable, as this reduces the challenge posed to the ventilation system (the possibility of its contamination) and the exposure of workers undertaking the decommissioning actions. Records of such activities should be kept, including the level of residual contamination.

8.13. Modifications of the existing infrastructure of the facility may be necessary to facilitate immediate dismantling or, in some cases, to prepare the facility for

a period of safe enclosure, and such modifications should be identified early in the planning process. For immediate dismantling, the main modifications may involve:

- Modification or substitution of SSCs that are important for ensuring safety during decommissioning, such as ventilation systems and confinement systems;
- Isolation and removal of SSCs that are not needed for decommissioning;
- Establishment of new access routes and transport routes for personnel, equipment and waste to and from the facility;
- Installation of additional equipment, such as remotely operated equipment for size reduction and waste handling equipment;
- Establishment of an interim waste storage area on the site.

8.14. For deferred dismantling, the main modifications to the facility may involve:

- Establishment of physical protection measures;
- Removal of driving forces and channels for the spread of radioactive material (i.e. drainage systems);
- Establishment of barriers to isolate the safe enclosure area;
- Isolation and removal of SSCs that are not necessary;
- Establishment of alternative SSCs (preferably passive SSCs);
- Creation of storage areas for equipment, materials and waste.

8.15. If decontamination and dismantling actions are deferred in part or as a whole, the licensee is required to ensure the safety of the facility through an approved monitoring, surveillance and maintenance programme (para. 8.2 of GSR Part 6 [1]). In the review of the systems required to support the deferred dismantling strategy, the SSCs that are not required should be identified, so that the surveillance and maintenance carried out on these systems can be reduced or terminated.

8.16. Dismantling has the potential for creating new hazards, and therefore necessary steps should be taken to ensure safety during dismantling. To ensure safe dismantling, provision should be made for:

- Decontamination and handling of material;
- Facilitation of access to radioactive sources or other radioactive material for further management;
- Segregation of contaminated equipment, structures and materials from those that are not contaminated or do not pose a non-radiological hazard, in

order to reduce radiation risks to workers in subsequent handling and also to reduce the quantity of waste requiring final disposal.

8.17. In selecting the dismantling approach, consideration should be given to:

- The simplicity and reliability of the techniques and equipment;
- Optimization of protection and safety;
- Minimization of the generation of liquid and solid waste;
- The use of proven technology wherever practicable;
- Minimization of possible adverse effects on adjacent and interconnected systems, structures, areas and operations (e.g. control of the spread of contamination).

8.18. There are many techniques and methods available for dismantling. It is preferable to select proven techniques that are commercially available and technically mature. The available techniques to be deployed to carry out the decommissioning actions should be evaluated to confirm their feasibility and suitability in accordance with the final decommissioning plan. The following factors might influence the choice of the dismantling techniques to be deployed:

- The potential impact on workers and the environment; for example, preference should be given to techniques that do not generate high levels of airborne radioactivity;
- A cost-benefit analysis comparing the radiological benefits and waste management benefits of the dismantling techniques with the expected overall costs;
- The availability of suitable waste containers, routes and facilities for waste storage and disposal;
- The types and physical properties (e.g. the size, shape and accessibility) of the equipment and structures to be dismantled;
- The maturity of the technology that will be deployed for the dismantling actions and the time frame for development of new technologies;
- The reliability of the dismantling equipment and tools, and simplicity of their operation, decontamination and maintenance;
- The impact on adjacent systems and structures and on other work in progress within the facility;
- Time and schedule constraints, such as the availability of waste processing facilities;
- Requirements for special resources and training, such as resources for and training on the use of remotely operated equipment;
- The generation of secondary radioactive waste;

- The potential impact on workers and the environment arising from the presence of hazardous non-radioactive contaminants.

8.19. Those SSCs to which little attention has been given, or to which access has been limited during the operational stage of the facility, might have suffered degradation. Such SSCs should be given special consideration when decommissioning techniques are considered. Examples of such SSCs might include storage tanks for liquid radioactive waste and remote handling systems.

8.20. Removal from service of SSCs is a key issue during decommissioning, and a decision making process addressing the removal of SSCs from service should be carefully developed and implemented by the licensee. A good practice is to establish a list of SSCs important to safety during decommissioning. The list should be developed and updated during the ongoing decommissioning actions. This information can be used to update the facility's inspection and surveillance and maintenance programmes. The SSCs from the operational stage of the facility may be required to facilitate decommissioning, but the condition of these SSCs should be evaluated in accordance with the safety assessment for decommissioning. The evaluation should take the following into account:

- The condition of the SSCs;
- The extent of inspection, monitoring and maintenance of the SSCs during operation;
- The requirement for the SSCs to perform safety functions during decommissioning;
- The expected duration of the decommissioning actions.

8.21. Aspects that should be periodically considered and assessed during the conduct of decommissioning actions include:

- The existing structures of the facility;
- The confinement capability of the existing infrastructure of the facility, including tanks, vessels, piping and ventilation ducting;
- The adequacy and integrity of the facility's existing infrastructure required for decommissioning, including electrical distribution systems and security systems;
- The availability and adequacy of the support systems for the existing SSCs, including alarm systems and ventilation systems;
- Interfaces with other facilities with regard to processes and infrastructure, in the case of a multifacility site.

8.22. Decommissioning actions might involve the deliberate removal of SSCs that had fulfilled specific safety functions during operation of the facility (e.g. shielding, ventilation and liquid collection). Such actions should be recorded and aligned with the ongoing decommissioning phases, work packages and tasks identified in the final decommissioning plan.

8.23. During decommissioning, radioactive and non-radioactive effluents will be generated. The discharge of radioactive effluents requires authorization from the regulatory body and control in compliance with appropriate national regulations. In general, the expected discharges of effluents during decommissioning will be less than during operation of the facility, but might be in a different form and with a different radionuclide composition. It is typical for effluent discharges to vary through the different phases of decommissioning. For example, as decommissioning leads to a progressive reduction of radiological hazards, the radioactive discharges might decrease.

8.24. In some instances, decommissioning actions might result in elevated discharges for a limited period of time. Hence, the authorization for discharges in decommissioning should be revised as appropriate [4]. Guidance for the development and implementation of an environmental monitoring programme can be found in IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection [26].

8.25. Depending on the end state of the decommissioning project, demolition of the remaining structures of the former facility might be required. In many cases, the decommissioning actions are aimed at ensuring that the demolition of building structures does not involve exposure to radiation. Where building structures to be demolished are contaminated, radiation protection considerations should be addressed. In such cases, specific techniques such as water spraying and the use of local confinement systems should be applied in order to reduce the exposure of decommissioning workers and the impact on the environment. Care should be exercised during demolition to ensure that contaminated material is segregated from non-contaminated material and from non-radiological hazardous materials.

8.26. During decommissioning, records should be maintained of key decommissioning actions. Such records include accurate and complete information concerning the quantities and types of radionuclides remaining at the facility, their locations and distributions, and the volume of radioactive waste generated. Such records should be used to demonstrate that all radioactive material that was present at the beginning of decommissioning has been properly accounted for and that its final disposition (e.g. restricted reuse or disposal) has

been identified and confirmed. Documentation should also take into account materials, structures and land that has been removed from regulatory control.

REGULATORY OVERSIGHT DURING CONDUCT OF DECOMMISSIONING ACTIONS

8.27. Regulatory oversight of decommissioning actions is required to be performed by the regulatory body during the conduct of decommissioning (para. 8.5 of GSR Part 6 [1]) and should follow a graded approach. The frequency and scope of inspections should be commensurate with the nature and extent of decommissioning actions and the associated hazards and risks, and can be significantly reduced in periods of safe enclosure. Guidance relevant to regulatory oversight is provided in IAEA Safety Standards Series No. GSG-13, Functions and Processes of the Regulatory Body for Safety [27].

8.28. Depending on the nature and extent of the decommissioning actions to be performed, regulatory oversight should focus on the actions having a significant impact on safety or on the milestones in the decommissioning project, such as:

- Removal from service of SSCs important to safety or commissioning of new SSCs;
- Actions associated with a high risk;
- The transition between phases of the decommissioning project, especially when an end state of one phase is decisive for the start of the actions of the next phase;
- Commissioning and operation of supporting facilities for the management of radioactive waste;
- Removal of radioactive waste from the site;
- Release of land and buildings from regulatory control.

8.29. In addition to the inspection of decommissioning actions listed above, the regulatory oversight should also cover aspects such as staffing and organizational issues, the use of contractors, safety culture, occupational exposure and public exposure, potential environmental contamination and related risks, contamination control, flow control for radioactive material, industrial safety, and the radiological condition of areas that might not be easily accessible at a later time during decommissioning.

8.30. An internal process should be put in place in the licensee's organization for minor modifications of decontamination and dismantling techniques that do not

have a significant impact on safety. This process should be subject to approval by the regulatory body, so that there is a clear understanding of which changes are subject to approval by the regulatory body and which can be approved internally by those parts of the licensee's organization responsible for safety. This process should be subject to oversight by the regulatory body during its implementation, in accordance with national requirements.

8.31. If a deferred dismantling strategy is chosen, the frequency and scope of inspections may be reduced during a period of safe enclosure. Inspections during the period of safe enclosure should focus on surveillance and preservation of the facility (e.g. preventing degradation that might result in a loss of control of material and the spread of contamination), adequacy of record keeping, site monitoring and surveillance, industrial safety, staffing and organizational issues, the use of contractors, safety culture and radiation protection.

8.32. In some cases, regulatory oversight might continue after the completion of decommissioning and termination of the authorization for decommissioning, for example in the case of restricted release of the site.

RADIATION PROTECTION

8.33. As decommissioning proceeds, the radiation protection programme should be periodically reviewed and revised, as necessary.

8.34. An appropriate radiation monitoring system commensurate with the complexity of the facility and the radiological hazards should be put in place. Monitoring of workers engaged in works involving radioactivity should be performed during decommissioning actions.

8.35. Those individuals charged with the responsibility for radiation protection should be provided with the resources, competence and independence necessary to implement an adequate radiation protection programme.

8.36. Arrangements should be made for the zoning of areas in accordance with radiation levels and contamination levels as a means of controlling radiation exposure and reducing the spread of contamination.

8.37. Equipment necessary for radiation protection in relation to decommissioning includes:

- Equipment for radiation shielding, prevention of contamination of personnel and minimization of the intake of radioactive materials (e.g. by means of local ventilation systems and filtration systems);
- Personal dosimeters to record radiation doses received by workers;
- Monitoring equipment for external dose rates and surface contamination survey meters for use in workplaces, and for checking components and materials during decontamination, dismantling and handling;
- Monitoring equipment for airborne radioactive substances in the workplace.

8.38. All the equipment used for radiological monitoring and measurements should be properly calibrated.

8.39. Records should be kept of occupational exposures and of the radiation protection measures adopted and radiation surveys conducted.

8.40. Radiation and contamination monitoring of workers, components, waste and materials should also be performed for handling, packaging and transport operations. The spread of loose contamination to personnel and non-contaminated areas should be prevented.

8.41. If the facility being decommissioned is within a larger facility, it may be necessary to specify controls and monitoring for personnel and areas in the surrounding facility to control the spread of contamination.

8.42. Where the staff of the licensee do not have the necessary expertise in radiation protection, the licensee may consider using contractors. However, the prime responsibility for safety remains with the licensee.

8.43. The requirements for on-site and off-site monitoring should be specified in the decommissioning plan. On-site monitoring should be planned for specific decommissioning actions. All potential release points should be monitored. Off-site monitoring may be necessary to demonstrate the adequacy of the control over the release of radioactive material to the environment. The off-site monitoring programme that exists for the operational stage may require modification, depending on the conditions existing in decommissioning.

EMERGENCY PREPAREDNESS AND RESPONSE

Requirement 13 of GSR Part 6 [1]: Emergency response arrangements for decommissioning

“Emergency response arrangements for decommissioning, commensurate with the hazards, shall be established and maintained and events significant to safety shall be reported to the regulatory body in a timely manner.”

8.44. GSR Part 7 [16] requires that complete emergency arrangements are put in place for the on-site areas for any regulated facility or activity that could necessitate emergency response actions before commencement of operation of the facility or commencement of the activity and that the licensee prepare an emergency plan and submit this plan to the regulatory body for approval. In addition, GSR Part 7 [16] requires the regulatory body to ensure that the licensee performs appropriate reviews and, as necessary, revises the emergency arrangements prior to any changes in the facility or activity that affect the existing hazard assessment, and when new information becomes available that provides insights into the adequacy of the existing arrangements. Thus, before the commencement of the decommissioning actions and periodically thereafter, the hazard assessment in relation to the facility or activity should be reviewed and existing emergency arrangements including the emergency plan should be revised accordingly in line with GSR Part 7 [16].

8.45. In the hazard assessment referred to in para. 8.44, a range of postulated events should be identified in relation to decommissioning actions including those of very low probability. Examples of such events could be a loss of confinement function or a dropped waste package, either within the facility or on transfer to a storage facility or disposal site.

8.46. The licensee is required to ensure that adequate resources, including personnel, equipment, means for communication, logistical support and emergency response facilities, are available and that procedures, tools, coordination and organization are in place to effectively respond to a nuclear or radiological emergency [16] in accordance with the approved emergency plan. Personnel are required to be qualified, trained in emergency procedures and fit for duty, procedures are required to be periodically reviewed and updated and exercise programmes are required to be developed and implemented [16].

8.47. The emergency plan and related procedures, tools and other arrangements should cover on-site emergency arrangements and, where necessary, arrangements to obtain off-site assistance, including the timely notification of appropriate off-site authorities and communication with the public in line with GSR Part 7 [16]. Guidance for emergency preparedness and response is provided in IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [28]; IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [29]; and IAEA Safety Standards Series No. GSG-11, Arrangements for the Termination of a Nuclear or Radiological Emergency [30].

RADIOACTIVE WASTE MANAGEMENT

Requirement 14 of GSR Part 6 [1]: Radioactive waste management in decommissioning

“Radioactive waste shall be managed for all waste streams in decommissioning.”

8.48. Decommissioning invariably involves the generation of large amounts of material and waste in forms that might be different from the material and waste categories routinely handled during the operational stage of the facility. A waste management plan that covers all the anticipated decommissioning waste streams and waste categories should be developed. The waste management plan should define the manner in which radioactive waste will be removed from the facility and the means for segregating radioactive waste from non-radioactive and hazardous waste.

8.49. In managing the radioactive waste from decommissioning, several factors should be considered. These include:

- The origin, amount, category and nature of waste that is generated in decommissioning (relatively large quantities of radioactive waste might be generated in a short time);
- The possibility for removal of waste from regulatory control (clearance);
- The possibilities for the reuse or recycling of material, equipment and premises;
- The generation of secondary waste and its minimization to the extent applicable;
- The presence of known non-radioactive hazardous materials (e.g. asbestos);

- The availability of recycling or waste treatment plants, and storage and disposal facilities;
- Any special requirements for the packaging and transport of radioactive waste (e.g. for activated material);
- Traceability of the origin and nature of the waste arising from decommissioning;
- The potential impact of waste on workers, the public and the environment.

8.50. Waste generated in decommissioning should be segregated into different categories (radioactive waste and non-radioactive waste, hazardous waste and non-hazardous waste) in accordance with accepted procedures and criteria. Specific plans for the clearance, reuse, recycling, storage or disposal of the waste should be developed. Such plans should aim to minimize the volume of waste to be disposed of as radioactive waste, facilitate future downstream processing of the waste and reduce overall costs of the management of decommissioning waste. The proper determination and documentation of the characteristics of the waste form, waste containers and/or waste packages should be ensured to provide the data necessary for future management of the waste (e.g. for its disposal).

8.51. Waste from decommissioning should be disposed of in the appropriate waste disposal facilities, subject to their availability. Decommissioning of complex facilities may require dedicated radioactive waste management facilities and arrangements for processing, storage and transport of decommissioning waste. These facilities should be planned as part of the decommissioning plan and should be commissioned under the authorization for decommissioning or under separate authorizations issued by the regulatory body.

8.52. While the bulk of the radioactive waste from medical, industrial and research facilities will be low level radioactive waste, a small percentage might consist of disused sealed radioactive sources with very high contact dose rates, requiring shielded packages for safe storage.

8.53. Consideration should be given to minimizing cross-contamination of waste and materials and minimizing the generation of secondary waste. The different categories of waste should be managed in accordance with their characteristics and toxicity (radiological and non-radiological).

8.54. The waste management plan for decommissioning should address waste minimization. Significant reductions in the volume of radioactive waste can be achieved through a decontamination programme, controlled dismantling techniques, contamination control, segregation of waste, effective processing

and, in some cases, administrative controls. Reuse and recycling strategies have the potential of further reducing the amount of waste to be managed. Similarly, the removal of low activity material from regulatory control (clearance) for management as ordinary waste or for reuse and recycling can substantially reduce the amount of material that has to be considered as radioactive waste.

8.55. Records should be maintained of the removal of material from regulatory control as well as of the reuse or recycling of materials. Such records should be retained until decommissioning is complete, or alternatively for a period of time after decommissioning as agreed with the regulatory body. Records should be provided to the regulatory body, if required.

8.56. The radiation exposure of workers and the public might differ depending on the waste minimization strategy. An integrated approach should be used to balance waste minimization goals with the objective of keeping radiation exposures as low as reasonably achievable, societal and economic factors being taken into account.

8.57. If radioactive waste from operation is present in the facility after its permanent shutdown, such waste is required to be removed prior to the conduct of decommissioning actions (para. 8.10 of GSR Part 6 [1]) and to be transported to an authorized facility in accordance with the requirements of SSR-6 (Rev. 1) [7]. In case such removal is not possible during the period of transition between permanent shutdown and the granting of the authorization for decommissioning, the approved final decommissioning plan should address the removal of this waste as part of decommissioning (during the initial phases of immediate dismantling or during the preparatory phase for safe enclosure).

8.58. In general, an update of the existing waste management plan for the operational stage of the facility should be performed, with consideration given to the additional materials and new waste categories associated with the decommissioning. The waste management plan should anticipate periods in which the processing of relative high volumes of waste will be necessary and should propose means of minimizing any impacts of such waste processing on the decommissioning actions or on the operations of other facilities at a multifacility site. The licensee should ensure that the waste management plan for decommissioning is maintained and implemented.

8.59. Decisions on the processing of radioactive waste generated in decommissioning should take into account the interdependences among all steps in waste management, and should consider existing or planned options for waste disposal.

8.60. Verification of the waste characteristics and waste packages should be based on procedures that may include direct measurements on the material, laboratory measurements of representative samples, the use of properly derived radionuclide vectors (e.g. scaling factors and correlations between difficult to measure radionuclides and reference nuclides) and adequate identification of the waste origin.

8.61. Transport of radioactive waste from the facility to the processing, storage or disposal facilities should be conducted in accordance with national transport regulations. The requirements for the transport of radioactive material are established in SSR-6 (Rev. 1) [7] and the associated guidance is provided in SSG-26 [8]. Precautions should be taken to prevent the external contamination of disposal containers, which could spread contaminants during transport.

8.62. The licensee should ensure that each waste package generated in decommissioning is provided with a durable label bearing an identification number and relevant information, and that proper records of each waste package and all the unpackaged waste are kept as part of the integrated management system. All records should be securely stored on a specific database, easily accessible and capable of being retrieved over an extended period of time after completion of decommissioning. Information should include the following at a minimum for each individual waste package:

- The origin of the waste (including the material, item or components that the waste package contains);
- The identification number of the package;
- The type of waste package;
- The volume or mass of the package;
- The radioactive inventory (total activity, nuclide composition or spectrum and activities of reference nuclides, and the date of measurement);
- Results of the measurement of surface contamination and the date of measurement;
- The maximum dose rate at contact and at a distance of 1 m from the external surface of the package (to derive the transport index) and the date of measurement;
- Corresponding classification of the radioactive waste [31].

8.63. Management of radioactive waste from operation, disused sealed radioactive sources and process materials should take place under the operating licence during the transition from operation to decommissioning. This will ensure that any delays in the removal of waste from operation and a costly extended shutdown mode of

the facility at the end of its operation are avoided, and the facility is efficiently brought to a condition in which decommissioning can begin.

8.64. The removal of disused sealed radioactive sources and waste from operation before implementation of any decommissioning actions might be difficult when the related waste management facilities are not available or when these actions are foreseen as part of the decommissioning programme. In such cases, the removal of the remaining disused sealed radioactive sources, radioactive waste and material should be addressed in the final decommissioning plan and associated waste management plan. Advance planning for decommissioning during operation of the facility should help to identify any milestones and tasks that have to be completed to facilitate decommissioning, including timely arrangements for the management of radioactive waste from both operation and decommissioning.

8.65. In cases where no suitable waste disposal facilities are available, consideration should be given during the preparation of the decommissioning plan to dismantling the facility and storing the generated radioactive waste in an appropriate storage facility.

8.66. A large part of the waste and other materials arising from decommissioning might be sufficiently low in activity concentration, and so can be wholly or partly removed from regulatory control. Some waste might be suitable for disposal in normal landfill sites while some materials, such as steel and concrete, might be suitable for recycling or reuse. The removal of material and waste from regulatory control should be done in accordance with the criteria established by the national regulatory body. Guidance on the criteria for removal of material from regulatory control and on the management of all the regulatory processes of removal of controls is provided in RS-G-1.7 [5], WS-G-5.1 [6] and GSG-13 [27].

8.67. Discharges to the environment need to be appropriately monitored and authorized [4]. During decommissioning, radioactive and non-radioactive effluents might be generated. The discharge of effluents requires authorization of the regulatory body and control of compliance with appropriate national regulations. In general, the expected discharges of effluents during decommissioning will be less than during operation of the facility, but might be different in form and in radionuclide composition.

8.68. The authorization for discharges will generally require source and environmental monitoring to be performed. For some medical, industrial and research facilities, there will be no need for off-site radiological monitoring,

and in many States, there is no regulatory requirement during normal operation to carry out off-site radiological monitoring. However, on-site monitoring is routinely performed during operation as part of the identification and management of radiological hazards. The programme of on-site monitoring should be reviewed prior to the commencement of decommissioning and should be modified during the conduct of decommissioning to reflect the changes occurring as decommissioning progresses.

8.69. Requirements on the management of radioactive waste are established in IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [32] and requirements on the disposal of radioactive waste are established in IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [33].

9. COMPLETION OF DECOMMISSIONING ACTIONS AND TERMINATION OF AUTHORIZATION FOR DECOMMISSIONING

Requirement 15 of GSR Part 6 [1]: Completion of decommissioning actions and termination of the authorization for decommissioning

“On the completion of decommissioning actions, the licensee shall demonstrate that the end state criteria as specified in the final decommissioning plan and any additional regulatory requirements have been met. The regulatory body shall verify compliance with the end state criteria and shall decide on termination of the authorization for decommissioning.”

9.1. When decommissioning actions are completed, a final radiological survey of the facility is required to be performed (para. 3.4 of GSR Part 6) to demonstrate that the decommissioning objectives, as described in the final decommissioning plan and in the authorization for decommissioning, have been fulfilled, and that the residual radioactivity meets the regulatory criteria for restricted or unrestricted release from regulatory control. A report of the final radiological survey should form part of the basis for the application for release of the facility or site from regulatory control. The results of the final radiological survey should be included in the final decommissioning report. An example of the suggested

structure and content of the final radiological survey report for a complex facility or an intermediate facility is provided in Annex IV.

9.2. The final radiological survey should be performed in accordance with the final survey plan, which is part of the final decommissioning plan (as described in Annex II). Any changes to the design and implementation of the final survey plan should be discussed with the regulatory body during the planning period for the survey, and should be submitted to the regulatory body for review and approval before the final radiological survey is conducted. The final radiological survey may be carried out in phases, as portions of decommissioning work are completed, to enable parts of the facility or the site to be released from regulatory control. If the final radiological survey is to be completed in phases, the licensee should put procedures in place to ensure that the surveyed areas are not impacted by ongoing decommissioning actions at other parts of the site.

9.3. The end state criteria for release of the facility from regulatory control, established by the regulatory body, should be convertible into measurable quantities that can readily be compared with the results of the field measurements. Sampling methods should be implemented as defined and should be justified in the final survey plan. The radionuclides present will influence the survey and sample methods adopted. The final survey plan and procedures should provide sufficient data and detail to produce a report of the final radiological survey. The final radiological survey report, as a part of the final decommissioning report, should be submitted to the regulatory body for review and approval, in accordance with national requirements. The results of the survey will be the major portion of the final decommissioning report.

9.4. The final decommissioning report should summarize the final status of the facility. The final physical and radiological status of the remaining structures, if any, of the facility and/or of the site at the time of release from regulatory control or at the time of its conversion to another use should be described. A summary of, or reference to, the results of the radiological survey report should be provided. Furthermore, the final decommissioning report should provide information on any remaining restrictions on the site, if they exist. A review of the environmental impact assessment may be necessary depending on the final radiological status of the facility, as required by national regulations. The final decommissioning report should summarize the actions performed in decommissioning, and should also provide additional information on the decommissioning project, as appropriate.

9.5. After the completion of decommissioning actions, the final decommissioning report should be submitted by the licensee in a timely manner to the regulatory

body. Additionally, the licensee may prepare more specific documentation of the decommissioning project, for example details about methods and tools applied for conducting decommissioning actions and a summary of lessons from the decommissioning project that could be utilized in similar decommissioning projects in the future.

9.6. The regulatory body should ensure that relevant plans, records and reports (addressing decontamination, demolition and dismantling actions, as well as remediation of surface water, groundwater, soil and sediment remediation, and the final radiological survey) are prepared by the licensee, and are retained for an appropriate time frame.

9.7. The results of the regulatory body's review of the final decommissioning report should be made available by the regulatory body in a timely manner to allow further decommissioning actions to be performed, if deemed necessary by the regulatory body, in the event that non-compliance with the end state criteria is identified.

9.8. The regulatory body should perform inspections during the conduct of the final radiological survey to verify that the survey procedures are being properly implemented and are in compliance with requirements. The regulatory body should perform independent confirmatory radiological surveys and sampling to ensure compliance with the end state criteria for the site or with the implementation of restrictions at the site. Such independent surveys should be conducted by experts with special training in this field. If the regulatory body has no such experts of its own, such surveys should be conducted by an accredited organization and under the responsibility of the regulatory body.

9.9. The regulatory body is required to verify or validate that the site meets the end state criteria [1, 6]. In the event that the site or remaining structures of the former facility do not comply with the initially approved end state criteria for release from regulatory control, a reassessment of the situation should be performed by the licensee and presented to the regulatory body for review and approval.

9.10. When deviations from the end state criteria are considered unacceptable or are not properly justified, the regulatory body may require the licensee to resume decommissioning actions to reach the end state as foreseen in the final decommissioning plan.

9.11. If the approved end state, as set out in the final decommissioning plan, cannot be achieved, deviations from that end state should be clearly identified, their consequences should be assessed, and a new end state should be described and submitted to the regulatory body for approval. Such deviations should be addressed in the final decommissioning report. Sometimes an update of the final decommissioning plan may also be necessary if additional decommissioning actions are needed to achieve the new end state.

9.12. In case unrestricted release of an entire site is not feasible, partial or restricted release from regulatory control may be sought in order to achieve termination of the authorization for decommissioning for some or all the facilities on a multifacility site. In such cases, restrictions on access to or use of the facilities will be necessary to ensure protection of people and the environment. If restrictions are necessary for access to or for the use of the remaining parts of the facility or site, the regulatory body should ensure that an appropriate mechanism is put in place to demonstrate compliance with these restrictions.

9.13. For sites released from regulatory control with restrictions, appropriate arrangements for continuous control should be put in place to ensure protection of people and the environment. The restrictions should be documented and established as part of the institutional controls, so that future uses of the site are not contrary to the restrictions. An example of such documentation is a land deed restriction. Responsibility for implementing and maintaining these controls should be clearly assigned to an organization or institution. The implementation of controls is required to comply with regulatory requirements, and monitoring and surveillance for compliance is required to be put in place, as approved by the regulatory body (para. 9.3 of GSR Part 6 [1]).

9.14. If specific restrictions are to be imposed upon future owners or users of the decommissioned facility and its site, these restrictions should be legally established and should be enforceable.

9.15. A long term surveillance and maintenance plan for an area released with restrictions should be prepared by the licensee and submitted for approval by the regulatory body. Interested parties should be informed of any site restrictions and of the results of monitoring and surveillance. Legal and financial arrangements should be made for the implementation of the long term surveillance and maintenance plan.

9.16. The regulatory body should conduct periodic inspections to ensure compliance with the long term monitoring and surveillance requirements and

to ensure that maintenance is being performed to meet site restrictions and institutional control requirements.

9.17. If the decommissioning waste needs to be stored on the site for a long period of time after the completion of decommissioning, an application for the construction of a new storage facility for radioactive waste should be prepared by the licensee and submitted to the regulatory body for review, approval and authorization. Requirements and guidance on the storage of radioactive waste are provided in GSR Part 5 [32]; IAEA Safety Standards Series No. SSG-45, Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education [34]; and IAEA Safety Standards Series No. WS-G-6.1, Storage of Radioactive Waste [35]. A decommissioning plan should be prepared for the waste storage facility established on the site.

9.18. It is permissible to progressively release buildings and land areas from regulatory control. In the event that such an approach is envisaged, a discussion between the licensee and the regulatory body should be initiated as soon as possible.

9.19. If a partial site release and reduction of the licensed part of the site is the objective, this should be reflected in the final decommissioning plan, in the final survey plan and in the procedures to demonstrate compliance with the national requirements for site release. The request for release from regulatory control of a particular part of the facility or part of its site should take into account the radiological end state criteria for the final release of the entire site and its future use. For example, release of part of the site should not be based on end state criteria for an industrial reuse (a brownfield scenario) if the licensee's plans for the entire site are to reuse it without restrictions (a greenfield scenario) after completion of decommissioning on the entire site.

9.20. Comments from interested parties (e.g. the public) are required to be solicited and addressed before the authorization for decommissioning is terminated (para. 9.6 of GSR Part 6 [1]). Appropriate consideration should be given to the communication with the public, especially if the end state is release from regulatory control with restrictions.

9.21. Prior to terminating the authorization for decommissioning, the regulatory body should communicate relevant issues to, and reach its decision in agreement with, other relevant competent authorities that have authority or responsibilities for other issues or aspects relating to the site.

9.22. When the end state criteria for release of the site have been met in accordance with the defined decommissioning end state, the regulatory body should formally notify the licensee, other relevant competent authorities and interested parties of the decision to release the site from regulatory control. Once the criteria for unrestricted release of all or some of the facility areas have been met, signs and labels indicating the presence of radioactivity should be removed. In the event of a decision to release the site with restrictions, the notification should specify the restrictions, the associated measures to be applied and the time frames for the application of these measures, as well as the entities responsible for the implementation, monitoring and regulatory control of the restrictions.

9.23. The regulatory body should specify a period for which the documents associated with decommissioning are to be maintained and retained. The documents retained should be consistent with national requirements.

9.24. An adequate records management system should be applied to the records relating to release of the site after the completion of decommissioning. It should cover some records produced before the termination of the authorization for decommissioning, such as the description of the nature and level of residual radioactivity, and should also cover the decisions relating to the release of the site made prior to and after decommissioning of the site, and their rationale, and information that verifies that the end state criteria for the site have been met. Record keeping is particularly important where restrictions are imposed on the future use of the site.

9.25. The nature and extent of the decommissioning records to be preserved after termination of the authorization for decommissioning should be determined taking into consideration a possible transfer of ownership of the site after its final release from regulatory control. Provisions for the long term management of the knowledge base of the former facility should be put in place. Any caretaker responsibility, including keeping relevant records for potential litigation or for other purposes, is then likely to be transferred to other institutions, as required by national laws and regulations.

9.26. Typically, the national regulatory body or another national authority will take over from the licensee in keeping the records. The duration of records control is usually determined by national regulations for records of occupational exposures and for potential future liabilities. Other records might need to be kept for institutional purposes or for other reasons.

9.27. Records might be required to identify and justify actions that were taken in the event that a later review of the end state of the facility or of the decommissioning project takes place because of, among other things, new regulatory requirements (e.g. on clearance levels) or the development of more advanced, higher resolution detection equipment. The past decommissioning actions might be in conflict with such new developments and the information will provide the history of and a justification for these past actions.

9.28. Appropriate records should be retained on completion of decommissioning in accordance with appropriate protocols and procedures (e.g. use of electronic media or retention of multiple hard copies). Such records should be held and maintained for purposes such as confirming that decommissioning has been completed in accordance with the approved plan; recording the disposition of waste, material and premises; and responding to possible liability claims. The following list includes examples of the kinds of records that should be retained, commensurate with the complexity of the facility being decommissioned and the associated hazard potential:

- The decommissioning plan and its subsequent amendments;
- The facility characterization report;
- The final decommissioning report;
- Quality management records, including relevant completed work packages and work plans;
- Engineering drawings, photographs and videos produced during and on completion of decommissioning;
- Manufacturing records and as-built records of construction, including engineering drawings for any installation or construction work done to assist with, or as part of, decommissioning;
- Records of personnel doses;
- Radiological survey records;
- Records of radioactive waste sent for disposal (e.g. the exact contents and serial numbers of waste containers);
- Details of significant abnormal events during decommissioning and the actions taken.

Appendix I

CONSIDERATIONS FOR SAFETY ASSESSMENT FOR DECOMMISSIONING OF MEDICAL, INDUSTRIAL AND RESEARCH FACILITIES

I.1. The aim of the safety assessment for decommissioning is to determine the safety functions necessary in decommissioning and the related SSCs that will deliver these safety functions, as well as the administrative procedures important to safety, in accordance with a graded approach. The SSCs important to safety provide the means for the safe conduct of decommissioning actions, for prevention of the occurrence of initiating events leading to abnormal events, for the control and limitation of accidents and the mitigation of potential consequences. In addition, the requirements for maintenance or replacement of systems for mechanical handling, ventilation, power supply and waste handling should be considered in the safety assessment as part of the engineering assessment.

I.2. The safety assessment should employ a systematic methodology to demonstrate compliance with safety requirements and criteria for decommissioning, including a methodology for the release of material, buildings and sites from regulatory control [1, 5, 6, 17, 18].

I.3. The safety assessment should be commensurate with the complexity and potential hazard of the facility and, in the case of deferred dismantling, should take into account the safety of the facility in the period leading up to final dismantling.

I.4. Analyses of accident scenarios should be performed and protective measures for preventing accidents or minimizing the likelihood of their occurrence and for mitigating their potential consequences should be proposed. The protective measures might require changes to the existing safety systems that were used during the operational stage. The acceptability of such changes should be clearly justified in the safety assessment. Protective measures could be either engineered features or procedural (administrative) measures.

I.5. Postulated initiating events that could lead to elevated radiation levels or to a release of radioactive material or hazardous chemical substances should be identified. The resulting set of identified postulated initiating events should be confirmed to be comprehensive and should be defined in such a manner that the postulated initiating events cover credible failures of the SSCs of the facility,

as well as human errors that could occur during decommissioning actions. The set of postulated initiating events should include both internal events and external events.

I.6. Human factors are an important aspect of the safety of facilities, as the state of the facility changes frequently with decommissioning actions. The safety assessment should consider the potential for human error in accordance with the complexity and hazard potential of the facility concerned (e.g. the presence of large amounts of equipment, tanks, pipes and valves with unexpected remaining radioactive material and contaminated liquid).

I.7. Depending on the complexity of the facility, the hazards and the risks involved, an assessment of the likelihood and consequences of external events should be performed, with account taken of the decommissioning strategy and the site characteristics (e.g. seismic hazards, flooding, extreme temperatures, influence from or dependence on any neighboring facilities) and the likelihood and consequences of potential initiating events (e.g. human error, fire, flood, dropped loads, collapse or failure of buildings or structures, and releases of non-radioactive hazardous chemicals). This is particularly relevant for facilities associated with a high level of hazard and for which decommissioning actions will continue for a long time. A systematic safety approach should be implemented in order to minimize human error (e.g. built-in controls and procedural and engineered protective measures to avoid the risk of contamination).

I.8. The implementation of the results of the safety assessment should lead to the definition of decommissioning limits and conditions, which are the set of rules that establish parameter limits, functional capability and performance levels for the equipment and the personnel necessary for safe decommissioning of a facility. The decommissioning limits and conditions should also define the required intervals for periodic testing and inspection of SSCs important to safety.

I.9. Dismantling might involve the deliberate destruction and removal of engineered SSCs that had fulfilled specified safety functions during operation of the facility (e.g. confinement, shielding, ventilation and cooling). If these safety functions are still required, they should be provided by suitable alternative means or SSCs (e.g. tents, temporary systems or structures, fire protection systems, electrical systems and administrative procedures) for as long as it is required on the basis of the safety assessment. The appropriateness of the alternative means of fulfilling these safety functions should be demonstrated. Procedures for changing the means by which safety functions are provided during decommissioning should be justified and demonstrated in advance before their implementation.

I.10. The safety assessment should address the main safety issues and objectives of the final decommissioning plan. In accordance with the result of the safety assessment that is developed for the entire decommissioning project and covering all phases of decommissioning, the licensee should develop detailed safety assessments for each phase, where relevant, to demonstrate safety of the actions foreseen for a given phase.

I.11. A given phase of decommissioning can be subdivided into discrete work packages or tasks for which specific safety assessments can be performed. Such detailed safety assessments for the first phase of decommissioning should be performed during the transition period, while detailed safety assessments for the other phases may be performed later, but prior to the beginning of each phase.

I.12. In all phases of decommissioning of a facility, the workers, the public and the environment are required to be properly protected from hazards resulting from the decommissioning actions for both normal situations and abnormal situations (para. 2.2 of GSR Part 6 [1]). Safety assessments are required to contain an analysis of radiological hazards associated with decommissioning actions and are required to demonstrate compliance with the regulatory requirements and criteria [18]. Non-radiological hazards should also be evaluated. In decommissioning, a number of conventional occupational health hazards will play a larger role than during operation of a facility, for instance in connection with the dismantling and demolition of large components and structures. The risk arising from these hazards will need to be addressed, but is outside the scope of this Safety Guide.

I.13. The licensee should consider the following when assessing the radiological hazards and non-radiological hazards associated with the decommissioning of a facility:

- The presence and nature of all types of contamination;
- Hazards associated with the possible in-growth of radionuclides (such as ^{241}Am);
- The potential for criticality hazards associated with the possible accumulation of fissile material in the process equipment during operation or during decommissioning actions (such as decontamination);
- The complexity of strategies for waste management owing to the diversity of waste streams;
- For multifacility sites, hazards associated with facilities that are not under decommissioning;
- Inaccessible areas and buried pipes;

- Separation and concentration of material stored in tanks;
- Hazardous chemicals located in SSCs and in buildings, soil, sediment, surface water and groundwater;
- Changes in chemical and physical forms of materials;
- Non-radiological hazards, such as fire or explosion, associated with decommissioning actions.

I.14. In the planning stage for decommissioning, the degree and extent of contamination in a facility should be clearly determined, characterized, evaluated and classified. Surveys should be conducted to determine the inventories and locations of radioactive material and other hazardous materials. An accurate characterization of the facility will provide the input for the decommissioning safety assessment.

I.15. Prior to decommissioning, safety issues such as radiation exposure (e.g. external exposure due to direct irradiation and internal exposure due to inhalation, ingestion or cuts and abrasions), potential criticality and loss of confinement leading to an uncontrolled release of radionuclides should be considered in the safety assessment. An update of the safety assessment may become necessary during actual decommissioning work.

I.16. For facilities that were shut down a long time before the start of decontamination or dismantling, a survey of equipment and buildings should be made to assess hazards associated with the deterioration of SSCs. In addition, consideration should be given to the materials of the physical barriers and process equipment for which mechanical properties might have changed during operation, owing to factors such as fatigue (e.g. from cyclic mechanical or thermal loading), stress corrosion, erosion, chemical corrosion or irradiation. In implementing decontamination actions, consideration should be given to the risk associated with the ageing of physical barriers and process equipment.

I.17. If suitable temporary protective measures (e.g. mobile tents and administrative procedures) are necessary when dismantling process equipment and physical barriers, the nature and number of the temporary protective measures and the requirements on their performance should be commensurate with the potential contamination hazards. Special attention should be paid to specific aspects, such as the potential for dispersion of residual alpha emitters, if applicable. In many situations, mobile tents might become the first confinement barrier during decommissioning. The design of this first confinement barrier should be described in the safety assessment (e.g. static confinement, ventilation, filtration systems, fire and mechanical resistance) and its use should be justified.

The associated SSCs should be defined within the safety assessment and should be taken into account in the decommissioning limits and conditions.

I.18. The licensee should determine design considerations for fire safety on the basis of a fire safety analysis. Special attention should be given to the use of thermal cutting techniques (e.g. plasma cutting) and non-thermal cutting techniques (e.g. grinders and saws) and the associated risk of outbreak of fire during dismantling especially when mobile confinement tents and personal protective equipment are used.

I.19. During decommissioning, additional consideration should be given to the following:

- (a) The closer proximity of radiation sources to personnel (owing to the removal of shielding or interlocks to gain access to sources), and hence the greater potential for radiation exposure;
- (b) The greater potential for the creation of airborne radionuclides, owing to the removal of containment or barriers during dismantling.

I.20. The safety assessment for decommissioning might identify a number of potentially significant non-radiological hazards, which might have radiological consequences during the decommissioning of the facility. These non-radiological hazards might not normally have been encountered in the operational stage. These hazards might include the lifting and handling of heavy loads, drop of loads, fire or explosion, collapse of structures and the generation of hazardous materials during the actions for decontamination and dismantling. The non-radiological hazards should be managed in accordance with national regulations, and, in addition, a strong safety culture will help to ensure that such hazards are identified and adequately controlled.

Appendix II

FACTORS INFLUENCING THE SELECTION OF A DECOMMISSIONING STRATEGY

II.1. The following are factors that should be considered when selecting a decommissioning strategy for a medical, industrial or research facility.

NATIONAL POLICIES AND REGULATORY FRAMEWORK

II.2. The national policies on decommissioning and management of radioactive waste might influence the choice of possible decommissioning strategies or combinations of options. For example, some basic decommissioning strategies might be excluded for political or other non-technical reasons. Such policy requirements might be established for particular facility types, and might not apply for all the different types of facility present in the State.

TYPE OF FACILITY AND INTERDEPENDENCES WITH OTHER FACILITIES OR INFRASTRUCTURE LOCATED AT THE SAME SITE

II.3. There might be different considerations relating to the selection of a decommissioning strategy for a facility depending on its type, size and complexity; the activities performed during operation of the facility; the residual inventory of radionuclides; and the location of the facility and its relations and interdependences with other facilities on the same site. The type of the facility to be decommissioned, its past functions and the extent of remediation needed (e.g. soil, sediment, surface water and groundwater) might have a major impact on the selection of the decommissioning strategy.

II.4. The decommissioning strategy for a particular facility should also take into account the characteristics of the site on which the facility is located. The capabilities of the other facilities (if existing on the site, either in operation or in shutdown mode) may be used, as well as the experience of the site's personnel. Such considerations might affect the options available for selection of a strategy.

II.5. The diversity of types of facility makes radiological characterization of the facility a critical step in the process of selecting a decommissioning strategy

because the characterization results are used when defining the scope of the proposed project.

II.6. The location of the facility might pose unique challenges to decommissioning. For example, a facility might be surrounded by many other facilities on the same site or a research laboratory could be located in an operating medical facility, or in a university.

PROPOSED REUSE AND DESIRED END STATE

II.7. There might be a request for reuse of part of the site or the entire site, or for reuse of existing building structures after the completion of decommissioning. The time frame for such reuse of the site, either restricted or unrestricted, is an important consideration in the selection of a decommissioning strategy. If the site is needed for the siting and construction of new facilities in the near future, such a request will lead to a preference for selection of an immediate dismantling strategy.

II.8. There might be other reasons that simplify the selection of a decommissioning strategy for a facility or eliminate some strategies from consideration. For example, public opinion and expectations that a facility has to be decommissioned within a short period of time, and the site released from regulatory control, might also give priority to an immediate dismantling strategy.

PHYSICAL AND RADIOLOGICAL STATUS OF THE FACILITY

II.9. The physical and the radiological status of the facility at the end of its operational stage is an important factor to be considered in selection of the decommissioning strategy.

II.10. The extent of contamination will depend greatly on past operating practices and on the age and type of the facility. The age and type of the facility will have influenced the types of material used in construction, which in turn results in different levels and types of contamination and naturally occurring radionuclides in the construction materials.

II.11. An assessment should be carried out of the integrity and conditions of the buildings and SSCs at the end of the operation time. Facilities that have poor

integrity and deteriorated conditions should be given priority for immediate dismantling.

II.12. Depending on the activation and contamination levels within a facility and the related composition of radionuclides, the selection of the decommissioning strategy might have an impact on the radiation exposure of workers, the public and the environment. High radiation levels might make deferred dismantling a more appropriate strategy because radioactive decay might allow radiation levels to decrease over time. However, for medical, industrial and research facilities, this deferral period would usually be on the order of a few years at most. When no benefit from radioactive decay is expected, immediate dismantling is the preferred strategy.

SAFETY ASPECTS

II.13. The licensee should periodically review the decommissioning strategy, considering the results of the periodic safety reviews performed during operation of the facility. The results of conformity checks and reassessments should be addressed and analysed to confirm whether the preferred decommissioning strategy is still applicable. When the decision to permanently shut down a facility is a consequence of such a periodic safety review, the identified weaknesses of the safety demonstration should be considered carefully in terms of the selected decommissioning strategy.

II.14. The technical feasibility of the dismantling actions should be assessed in order to ensure that the preferred decommissioning strategy can be implemented safely, considering modifications to the facility and changes to the design that might have been undertaken during operation.

AVAILABILITY OF EXPERTISE, TECHNOLOGIES AND INFRASTRUCTURE

II.15. The availability and utilization of institutional knowledge should be considered in choosing a decommissioning strategy (e.g. documentation of the operational history and/or the retention and utilization of key personnel familiar with site specific conditions). This documentation and expertise could decrease the potential for events such as industrial accidents or undue exposures and might help to reduce problems associated with loss of corporate memory. The

availability of staff with operational knowledge might be an argument in favour of immediate dismantling.

II.16. The availability of existing systems and infrastructure (e.g. air supplies, ventilation systems and overhead cranes) and considerations on their ageing might make immediate dismantling advantageous, in order to avoid maintenance or recertification of the systems at a later time.

ENVIRONMENTAL AND SOCIOECONOMIC IMPACT

II.17. When the impact on the local economy is an important issue, immediate dismantling might be the preferred strategy because this might reduce the immediate negative societal effect by continuing to provide employment for the local workforce.

II.18. The environment around the facility might have changed since the building was constructed. An example might be the rising of water levels, which could make deferred dismantling unfeasible.

II.19. The location of the facility might influence the selected decommissioning strategy. If the facility is located adjacent to public dwellings and other buildings, immediate dismantling might be the preferred option. Such public buildings might have been built in close proximity to the facility after it was constructed.

AVAILABILITY OF INFRASTRUCTURE FOR RADIOACTIVE WASTE MANAGEMENT

II.20. Aspects of waste generation and waste management can have an impact on the selection of a decommissioning strategy. Some important aspects are:

- The national waste management policy (e.g. a policy in which clearance is the preferred approach);
- The types, categories and amount of waste (including historical waste and remaining waste from operation);
- The availability of waste processing facilities or infrastructure for all types of radioactive waste;
- Arrangements for the transport of radioactive waste;
- The availability of capacity for storage of waste;
- The availability of disposal options.

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Annex I

CATEGORIES OF FACILITY

I-1. In this Safety Guide, three different categories of facility are considered for the purposes explained in para. 1.8, based on the associated radiation risk:

- A simple facility is a facility: (a) that has sealed radioactive sources that can be removed with relative ease; (b) that may have a relatively small localized area or areas of contamination that can be addressed through simple decontamination methods and techniques; and (c) for which the risk to the public and the environment due to decommissioning activities is relatively low.
- An intermediate facility is a facility that may have sealed radioactive sources that can be removed with relative ease, but usually has a contaminated area or areas of differing sizes in different locations of the facility, including contaminated structures, systems and components (SSCs). The risk to the public for intermediate facilities ranges from low to medium.
- A complex facility is a facility similar to an intermediate facility; however, it usually has high activity radioactive sources and/or contamination requiring special methods or techniques and equipment to address source removal and/or decontamination. Furthermore, decommissioning of a complex facility usually involves a need for remediation of the area immediately surrounding the building. In addition, a complex facility may require special considerations for waste handling, storage and disposal.

I-2. Table I-1 provides typical examples of the three different categories of medical, industrial and academic and research facilities.

TABLE I-1. EXAMPLES OF DIFFERENT TYPES OF FACILITY IN LOW, INTERMEDIATE AND HIGH HAZARD CATEGORIES

	Simple (low hazard)	Intermediate (intermediate hazard)	Complex (high hazard)
Medical facility	<ul style="list-style-type: none"> — Radioimmuno assay laboratory — Radiotracer laboratory — Linear accelerator — Nuclear medicine clinic with diagnostic use of radiopharmacy — Remote after-loading unit 	<ul style="list-style-type: none"> — Blood irradiator — Facility in which a gamma knife is used — Nuclear medicine department with therapeutic use of radiopharmacy — Radiotherapy department 	<ul style="list-style-type: none"> — Large hospital with cancer unit and a cyclotron
Industrial facility	<ul style="list-style-type: none"> — Radiotracer unit — Facility associated with sealed sources used in crop harvesting — Facility containing portable instruments (e.g. moisture density gauges or chemical detectors) — Fixed gauges (e.g. for level, thickness or flow measurements) — Industrial radiography facility — Facility associated with sealed sources used in well logging — Radiochemistry laboratory — Facility for irradiation of gem stones — Facility for manufacture of lightning conductors — Irradiator with low activity source 	<ul style="list-style-type: none"> — Radioactive waste treatment facility for low level waste — Manufacturing and maintenance facilities for luminescent control panels for airplanes 	<ul style="list-style-type: none"> — Medical isotope production facility — Industrial irradiator with a high activity source — Radiochemical manufacturing and research and development facility (with hot cells) — Source manufacturing facility including source encapsulation in hot cells and recycling — A large facility with many diverse uses of sealed and unsealed sources

TABLE I-1. EXAMPLES OF DIFFERENT TYPES OF FACILITY IN LOW, INTERMEDIATE AND HIGH HAZARD CATEGORIES (cont.)

	Simple (low hazard)	Intermediate (intermediate hazard)	Complex (high hazard)
Academic and research facility	<ul style="list-style-type: none"> — Chemistry or physics laboratory — Cell labelling unit — Facility associated with small scale agricultural field trials 	<ul style="list-style-type: none"> — Animal research facility — Laboratory with glove boxes — Particle accelerator facility with research and development laboratories — Research laboratory with hot cells 	<ul style="list-style-type: none"> — Nuclear research and development facility (with glove boxes and hot cells)

Annex II

SUGGESTED STRUCTURE AND CONTENT OF A FINAL DECOMMISSIONING PLAN AND SUPPORTING DOCUMENTS

II-1. The final decommissioning plan is the key document in the entire decommissioning process. It contains the information on which the regulatory body will base its decision regarding the safety of the decommissioning project as proposed by the licensee. There is a range of documentation supporting the final decommissioning plan that will be referenced and/or summarized in the final decommissioning plan. This is particularly likely to be the case for the decommissioning of intermediate and complex facilities (see Annex I). For simple facilities, such supporting documents can be integrated into the final decommissioning plan itself. See also Ref. [II-1].

II-2. This annex provides an example outline of the possible content of a final decommissioning plan for a facility. In accordance with a graded approach, the level of detail will depend on the complexity of the decommissioning actions.

II-3. The content of the final decommissioning plan is specified by the regulatory body.

0. SUMMARY

1. INTRODUCTION

- 1.1. Scope and context of the decommissioning project
- 1.2. General information on the licensee and existing licences

2. DESCRIPTION OF THE SITE AND FACILITY

- 2.1. Site location and site description
- 2.2. Description of the facility, including related structures, systems and components
- 2.3. New systems or systems that are to be modified
- 2.4. Operational history of the facility, including modifications and events

- 2.5. Radiological characterization of the facility, including surface and subsurface soils and water
- 2.6. Storage facilities, and means for removal, transport and storage of large components
- 2.7. Interdependences with other facilities on the site (in the case of a multifacility site)

3. DECOMMISSIONING STRATEGY

- 3.1. Objectives
- 3.2. Description of the overall decommissioning strategy for the site (in the case of a multifacility site)
- 3.3. The selected decommissioning strategy, including the end state
- 3.4. Justification of the selected decommissioning strategy

4. INTEGRATED MANAGEMENT SYSTEM FOR DECOMMISSIONING

- 4.1. The safety policy, including the policy for safety culture
- 4.2. The organizational structure, including responsibilities and authorities
- 4.3. Staffing and qualification, including training
- 4.4. Engagement of interested parties, including interfaces with the regulatory body
- 4.5. Decommissioning and radioactive waste management procedures
- 4.6. Document and records management
- 4.7. The approach to project management, including the involvement of contractors and subcontractors

5. CONDUCT OF DECOMMISSIONING ACTIONS

- 5.1. The work breakdown structure, including related tasks, resources and schedule of work
- 5.2. Contaminated structures, systems and equipment
- 5.3. Decontamination and dismantling methods and techniques including demolition techniques
- 5.4. Surveillance and maintenance

6. WASTE MANAGEMENT AND MATERIAL MANAGEMENT
 - 6.1. Identification of radioactive waste and radioactive material
 - 6.2. Waste classification and waste streams, waste acceptance criteria and criteria for clearance from regulatory control
 - 6.3. Predisposal management of solid and liquid radioactive waste, including waste from supporting facilities
 - 6.4. Management of waste containing both radionuclides and other hazardous material
 - 6.5. Storage and disposal of radioactive waste
 - 6.6. Clearance actions, including records and procedures

7. FINANCIAL RESOURCES
 - 7.1. Availability of financial resources, including cost estimates
 - 7.2. Allocation of financial resources
 - 7.3. Review and update of financial resources

8. RADIATION PROTECTION [II-2]
 - 8.1. Radiation protection principles and objectives
 - 8.2. The radiation protection programme
 - 8.3. Monitoring, control and surveillance during decommissioning

9. SAFETY ASSESSMENT [II-3]
 - 9.1. Safety assessment framework, including safety requirements and safety criteria
 - 9.2. Methodology for the safety assessment
 - 9.3. Identification of hazards and initiating events and identification of scenarios for analysis for normal and abnormal situations
 - 9.4. Results of the safety assessment
 - 9.5. Implementation of safety assessment, including limits and conditions for decommissioning actions
 - 9.6. Surveillance and maintenance of safety measures

10. ENVIRONMENTAL IMPACT ASSESSMENT

- 10.1. Identification of the discharges in the environment during decommissioning actions
- 10.2. Identification of sources of radiation causing direct exposure of the public and environment
- 10.3. Radiological impact assessment for the public and the environment for decommissioning actions
- 10.4. Non-radiological impact assessment
- 10.5. Measures for protection and control
- 10.6. Involvement of interested parties

11. EMERGENCY ARRANGEMENTS [II-4]

- 11.1. Basis for emergency planning, including possible emergency situations and potential consequences
- 11.2. Organization and responsibilities
- 11.3. Plans and procedures for emergency response
- 11.4. Arrangements for emergency preparedness

12. PHYSICAL PROTECTION AND ARRANGEMENTS FOR ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIAL¹

- 12.1. Legal and regulatory policy and framework
- 12.2. Organization and responsibilities
- 12.3. Physical protection programme and measures
- 12.4. Programme and measures for accounting for and control of nuclear material

13. FINAL RADIOLOGICAL SURVEY

- 13.1. Objectives of the final radiological survey
- 13.2. Methodology for conducting the final radiological survey

¹ Public information on arrangements for physical protection and for accounting for and control of nuclear material that is included in the decommissioning plan does not contain sensitive security information. The section on accounting for and control of nuclear material is usually not applicable to most medical, industrial and research facilities.

- 13.3. Map or drawing of the area to be surveyed
- 13.4. Definition of sampling parameters and background or baseline levels of radiation
- 13.5. Types of equipment, instruments, techniques and procedures
- 13.6. Methodology for evaluating the results of the final radiological survey
- 13.7. Records that will be maintained
- 13.8. Guidelines governing the release of records

REFERENCES TO ANNEX II

- [II-1] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, Safety Reports Series No. 45, IAEA, Vienna (2005).
- [II-2] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, IAEA, Vienna (2018).
- [II-3] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series WS-G-5.2, IAEA, Vienna (2008).
- [II-4] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency, EPR-METHOD 2003, IAEA, Vienna (2003).

Annex III

SUGGESTED STRUCTURE AND CONTENT OF THE FINAL DECOMMISSIONING REPORT

III-1. The final decommissioning report is prepared by the licensee as a basis for the regulatory decision to terminate the authorization for decommissioning. This report:

- (a) Summarizes the final decommissioning plan, its updates and any related authorizations;
- (b) Includes the final radiological survey report(s);
- (c) Describes residual restrictions, if any, after completion of decommissioning, for the site itself and relating to the remaining facilities on the site and describes the necessary controls and plans for their removal in the future;
- (d) Provides information on radiation exposures of workers;
- (e) Provides information on radioactive discharges to the environment;
- (f) Provides information on the management of radioactive waste and radioactive material;
- (g) Provides detail on abnormal occurrences and incidents during decommissioning.

III-2. The licensee might include additional information in the final decommissioning report for its own use. In order to improve the conduct of decommissioning projects in the future, within the final decommissioning report the licensee may summarize and share experiences and lessons from the project, or may provide details about methods and tools applied in conducting decommissioning actions.

Annex IV

SUGGESTED STRUCTURE AND CONTENT OF THE FINAL RADIOLOGICAL SURVEY REPORT

IV–1. The report of the final radiological survey presents the final conditions of the facility and the site at the conclusion of the physical decommissioning actions. The final radiological survey report is usually part of the final decommissioning report.

IV–2. The final radiological survey report includes the following information:

- (a) Conduct of the final radiological survey and the survey results:
 - (i) A summary of the survey, including changes from the final radiological survey plan and comparison with the initial (baseline) radiological survey;
 - (ii) The sampling performed (e.g. maps indicating sampling and measurements points, type and number of measurements, and analyses performed);
 - (iii) Measured data and analytical results;
 - (iv) Evaluation of data, comparison with established guidelines, and reporting in accordance with the national regulatory framework;
 - (v) Quality management aspects relating to the final radiological survey.

- (b) Summary and conclusion:
 - (i) A concise description of the final radiological situation at the facility, including any areas that were not surveyed;
 - (ii) Identification of all site areas and structures, systems and components that can be released for unrestricted use;
 - (iii) Description of any institutional controls that will be required for any areas that have not been released, including overview drawings and maps.

Annex V

EXAMPLES OF DECOMMISSIONING RELATED DOCUMENTS

V-1. In practice, the final decommissioning plan, as described in Annex II, is supported by a set of documents (depending on national regulatory requirements) explaining aspects of the decommissioning plan. A typical example is the safety assessment report, which for decommissioning of facilities is usually a stand-alone document, providing more detail on the safety aspects of decommissioning than presented in chapter 9 of the final decommissioning plan (in accordance with the content presented in Annex II).

V-2. The supporting documents may provide information on the following:

- Historical site assessment;
- Characterization survey report;
- Safety assessment report;
- Decommissioning limits and conditions;
- Environmental impact assessment;
- Radiation protection programme;
- Industrial health and safety plan;
- Waste management plan;
- Quality management plan (as part of the integrated management system);
- Emergency plan;
- Security plan and plan for accounting for and control of nuclear material;
- Funding provisions and cost estimate;
- Public relations plan.

Annex VI

RELEVANT LITERATURE

This annex provides a list of reference publications that contain additional information on specific organizational, financial, technical and safety issues relating to decommissioning. The reference publications are grouped in accordance with the main topic discussed.

CONTENT OF THE DECOMMISSIONING PLAN

INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, Safety Reports Series No. 45, IAEA, Vienna (2005).

OECD NUCLEAR ENERGY AGENCY, Achieving the Goals of the Decommissioning Safety Case, NEA No. 5417, OECD, Paris (2005).

INTERNATIONAL ATOMIC ENERGY AGENCY, Planning, Management and Organizational Aspects of the Decommissioning of Nuclear Facilities, IAEA-TECDOC-1702, IAEA, Vienna (2013).

TRANSITION FROM OPERATION TO DECOMMISSIONING

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities, Safety Reports Series No. 36, IAEA, Vienna (2004).

INTERNATIONAL ATOMIC ENERGY AGENCY, Transition from Operation to Decommissioning of Nuclear Installations, Technical Reports Series No. 420, IAEA, Vienna (2004).

DECOMMISSIONING STRATEGIES

INTERNATIONAL ATOMIC ENERGY AGENCY, Safe Enclosure of Nuclear Facilities During Deferred Dismantling, Safety Reports Series No. 26, IAEA, Vienna (2002).

INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning Strategies for Facilities Using Radioactive Material, Safety Reports Series No. 50, IAEA, Vienna (2007).

INTERNATIONAL ATOMIC ENERGY AGENCY, Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities, IAEA Nuclear Energy Series No. NW-G-2.1, IAEA, Vienna (2011).

INTERNATIONAL ATOMIC ENERGY AGENCY, Selection of Decommissioning Strategies: Issues and Factors, IAEA-TECDOC-1478, IAEA, Vienna (2005).

RADIOLOGICAL CHARACTERIZATION

INTERNATIONAL ATOMIC ENERGY AGENCY, Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes, Technical Reports Series No. 389, IAEA, Vienna (1998).

OECD NUCLEAR ENERGY AGENCY, Radiological Characterisation for Decommissioning of Nuclear Installations, NEA/RWM/WPDD (2013)², OECD, Paris (2013).

SAFETY ASSESSMENT

INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Decommissioning, Safety Reports Series No. 77, IAEA, Vienna (2013).

DECOMMISSIONING TECHNOLOGIES

INTERNATIONAL ATOMIC ENERGY AGENCY, State of the Art Technology for Decontamination and Dismantling of Nuclear Facilities, Technical Reports Series No. 395, IAEA, Vienna (1999).

OECD NUCLEAR ENERGY AGENCY, R&D and Innovation Needs for Decommissioning Nuclear Facilities, NEA No. 7191, OECD, Paris (2014).

MANAGEMENT OF MATERIAL AND WASTE FROM DECOMMISSIONING

INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, Safety Reports Series No. 44, IAEA, Vienna (2005).

INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Exemption and Clearance Levels, Safety Reports Series No. 67, IAEA, Vienna (2012).

INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring for Compliance with Remediation Criteria for Sites, Safety Reports Series No. 72, IAEA, Vienna (2012).

INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities, Technical Reports Series No. 441, IAEA, Vienna (2006).

INTERNATIONAL ATOMIC ENERGY AGENCY, Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities, Technical Reports Series No. 462, IAEA, Vienna (2008).

RECORDS MANAGEMENT

INTERNATIONAL ATOMIC ENERGY AGENCY, Record Keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience, Technical Reports Series No. 411, IAEA, Vienna (2002).

INTERNATIONAL ATOMIC ENERGY AGENCY, Long Term Preservation of Information for Decommissioning Projects, Technical Reports Series No. 467, IAEA, Vienna (2008).

TRAINING

INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Facilities: Training and Human Resource Considerations, IAEA Nuclear Energy Series No. NG-T-2.3, IAEA, Vienna (2008).

INVOLVEMENT OF INTERESTED PARTIES

INTERNATIONAL ATOMIC ENERGY AGENCY, An Overview of Stakeholder Involvement in Decommissioning, IAEA Nuclear Energy Series No. NW-T-2.5, IAEA, Vienna (2009).

INTERNATIONAL ATOMIC ENERGY AGENCY, Managing the Socioeconomic Impact of the Decommissioning of Nuclear Facilities, Technical Reports Series No. 464, IAEA, Vienna (2008).

DECOMMISSIONING COSTING

OECD NUCLEAR ENERGY AGENCY, EUROPEAN COMMISSION, INTERNATIONAL ATOMIC ENERGY AGENCY, International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, NEA No. 7088, OECD, Paris (2012).

INTERNATIONAL ATOMIC ENERGY AGENCY, Cost Estimation for Research Reactor Decommissioning, IAEA Nuclear Energy Series No. NW-T-2.4, IAEA, Vienna (2013).

INTERNATIONAL ATOMIC ENERGY AGENCY, Financial Aspects of Decommissioning, IAEA-TECDOC-1476, IAEA, Vienna (2005).

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**FUNDAMENTAL SAFETY PRINCIPLES****IAEA Safety Standards Series No. SF-1**

STI/PUB/1273 (21 pp.; 2006)

ISBN 92-0-110706-4

Price: €25.00

**GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK
FOR SAFETY****IAEA Safety Standards Series No. GSR Part 1 (Rev. 1)**

STI/PUB/1713 (42 pp.; 2016)

ISBN 978-92-0-108815-4

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STI/PUB/1750 (26 pp.; 2016)

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**RADIATION PROTECTION AND SAFETY OF RADIATION SOURCES:
INTERNATIONAL BASIC SAFETY STANDARDS****IAEA Safety Standards Series No. GSR Part 3**

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STI/PUB/1714 (38 pp.; 2016)

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PREDISPOSAL MANAGEMENT OF RADIOACTIVE WASTE**IAEA Safety Standards Series No. GSR Part 5**

STI/PUB/1368 (38 pp.; 2009)

ISBN 978-92-0-111508-9

Price: €45.00

DECOMMISSIONING OF FACILITIES**IAEA Safety Standards Series No. GSR Part 6**

STI/PUB/1652 (23 pp.; 2014)

ISBN 978-92-0-102614-9

Price: €25.00

**PREPAREDNESS AND RESPONSE FOR A NUCLEAR OR
RADIOLOGICAL EMERGENCY****IAEA Safety Standards Series No. GSR Part 7**

STI/PUB/1708 (102 pp.; 2015)

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Price: €45.00

**REGULATIONS FOR THE SAFE TRANSPORT OF RADIOACTIVE
MATERIAL, 2018 EDITION****IAEA Safety Standards Series No. SSR-6 (Rev. 1)**

STI/PUB/1798 (165 pp.; 2018)

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Yukiya Amano
Director General

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