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Decommissioning of Medical, Industrial and Research Facilities

DRAFT SAFETY GUIDE
DS403 *(Revision of Safety Guide WS-G-2.2)*

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CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. For many decades, radioactive materials have been in use in medical, industrial and research facilities. Many countries have facilities that were constructed and commissioned over the past decades using radioactive materials and sources in a variety of applications. Many of them are reaching the end of their operational lifetimes and will be facing shutdown[1] in the near future. These facilities will need to be decommissioned, after completion of operations.

1.2. Decommissioning refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a facility (except for a disposal facility, which is, by definition, subject to closure and not decommissioning) [1]. These actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. They are carried out to achieve a progressive and systematic reduction in radiological hazards and are taken on the basis of planning and assessment to ensure safety during decommissioning operations. This Safety Guide uses the terms: simple, intermediate and complex[2] based on the radiological hazard level to define the types of medical, industrial and research facilities.

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[1] The term "shutdown" in this Safety Guide means cessation of operations unless otherwise specified.

[2] A simple facility is licensed to possess sealed radioactive source(s), limited quantities of radioactive material in specific physical forms and/or limited number of radionuclides authorized for limited use for specific applications. An intermediate facility is licensed to possess highly radioactivity source(s), a large inventory of radioactive materials in various physical forms, and/or multiple radionuclides authorized for use in specific applications. A complex facility is licensed to possess highly radioactive source(s), (very) high radiation producing machines, large inventories of radionuclide materials in various forms, and/or a multitude of radionuclides, including special nuclear material authorized for use in broad applications.

1.3. The time period for decommissioning activities may typically range from a few months to decades (for example, to allow for radioactive decay), and may include phased release of parts of a site or facility from regulatory control. As a consequence, decommissioning may be carried out immediately following shutdown or deferred until after a safe enclosure period. On completion of decommissioning and on reaching the desired end state, the facilities and sites will be available for unrestricted or restricted use.

1.4. Adequate planning and conduct of decommissioning is required to ensure the protection of workers, the public and the environment. In the past, decommissioning of some facilities was performed in a case by case manner using the same framework of regulations which was applied during the operational period. This proved to be inadequate and subsequently regulatory frameworks for decommissioning were established. With the use of radioactive materials worldwide, experience has shown the importance in considering decommissioning for new facilities at the design stage, developing an initial decommissioning plan and periodically updating the initial decommissioning plan during and at the conclusion of the operational phase. The subsequent objective is to develop a final decommissioning plan prior to the start of decommissioning activities.

1.5. However, some existing facilities do not have decommissioning plans and others have already been shutdown and therefore, need to develop a final decommissioning plan. In order to provide a consistent approach to the decommissioning of both new and existing facilities, as well as to incorporate lessons learned from previous decommissioning efforts, Member States have expressed the desire for decommissioning guidance within the context of an internationally accepted programme of safety publications.

1.6. This guidance is part of a set of publications within the framework of the IAEA Safety Standards Programme, which, amongst other things, addresses decommissioning. This set includes Safety Fundamentals [2], Safety Requirements [1] and other Safety Guides in the IAEA Safety Standards Series.

1.7. This Safety Guide is a revision of the IAEA Safety Guide No. WS-G-2.2 published in 2001 and supersedes it [3]. This document provides guidance on planning, conducting and completing decommissioning of medical, industrial and research facilities and provides recommendations to assist in fulfilling the basic safety requirements for decommissioning. It includes guidance on the relevant safety and regulatory aspects, application of the graded approach, selection of the appropriate decommissioning strategy, key considerations in

facilitating decommissioning during design, construction and operation, development and review of decommissioning plans, main aspects of radiation protection for decommissioning, safety assessment, funding, decommissioning management, transition from operation to decommissioning, and completion of decommissioning.

1.8. This Safety Guide complements the concurrent revision of the Safety Guides that are concerned with the decommissioning of nuclear power plants and research reactors [4] and fuel cycle facility [5]. These Safety Guides are also being revised and combined into one document on the basis of recently published Safety Fundamentals, Safety Requirements and their supporting Safety Guides, as well as the experience of Member States, and outcomes of the international conferences and initiatives.

OBJECTIVES

1.9. The objective of this Safety Guide is to provide guidance to regulatory bodies, operating organizations, technical support organizations and other interested parties on planning, conduct and completion of the decommissioning of medical, industrial and research facilities. It also aims to assist Member States in ensuring that the decommissioning of all of these facilities is conducted in a safe and environmentally acceptable manner in accordance with good international practice.

SCOPE

1.10. This Safety Guide addresses related considerations and activities for the decommissioning of medical, industrial and research facilities from design until completion of decommissioning. It applies to facilities where there has been no prior planning for decommissioning, as well as to facilities with plans in preparation or ready for implementation. On the basis of general considerations regarding safety, radiation protection, protection of human health and the environment and regulatory aspects, this document provides guidance on the selection of a decommissioning strategy, development of initial and final decommissioning plans and implementation of decommissioning management principles. Several key decommissioning tasks are also discussed.

The range of medical, industrial and research facilities where radioactive materials and sources are produced, received, used and stored includes:

(a) Medical facilities with radiography and radiotherapy units and those using radioisotopes for diagnosis and treatment;

(b) Industrial facilities, such as those producing and using radioisotopes, using irradiation and radiography devices, using sealed sources for calibration or in detectors and gauges, or manufacturing products incorporating radioactive materials, e.g., luminous signs and dials, smoke detectors, lightning conductors and ionizing filaments;

(c) Research facilities, such as particle accelerators, and facilities undertaking spent fuel research on behalf of the nuclear fuel industry, pharmaceutics and medicine; and

(d) Teaching and research laboratories in universities and schools.

1.11. These facilities have a wide range of activities and hazards associated with their operations. The level of details for meeting decommissioning requirements varies depending on the type and complexity of the facility, radioactive inventory, and the potential hazards during decommissioning but the approach to decommissioning remains the same. This variety of factors results in different decommissioning strategies, use of technology and end state. A graded approach should be applied in the planning, conduct and regulation of the decommissioning.

1.12. This Safety Guide mainly addresses the radiological hazards resulting from the activities associated with the decommissioning of medical, industrial and research facilities and the management of material and waste arising from the decommissioning operations, after a planned shutdown. Many of the provisions are also applicable to decommissioning after an abnormal event or an unanticipated shutdown that has resulted in serious facility damage or contamination. In these cases, this Safety Guide may be used as a basis for developing special decommissioning provisions.

1.13. It is important to recognize that the hazards associated with these facilities, often involve chemical, biological, and industrial, as well as radiological hazards, and consideration needs to be given to achieving a balanced approach in addressing all hazards. For example, non-radiological hazards, such as those due to potential fire sources or those resulting from the release of asbestos, can also arise during decommissioning activities. This Safety Guide does not explicitly address non-radiological hazards, but they should be given due consideration during the planning, conduct and completion of decommissioning and in the supporting assessments.

1.14. In the event that a part of the facility is being decommissioned, this Safety Guide only applies to the decommissioning activities. However, the potential safety implications with respect to the interaction between any decommissioning work and any continuing facility operations should be addressed on a case-by-case basis.

1.15. This Safety Guide is not applicable to fuel cycle facilities, nuclear power plants and research reactors. Guidance for decommissioning of nuclear power plants and research reactors and decommissioning of fuel cycle facilities is provided in other IAEA publications [4][5]. The management of mining and milling residues, such as tailings and waste rock, is outside the scope of this publication and are considered in other IAEA publications [6][7]. While this Safety Guide covers facilities associated with processing and interim storage of radioactive waste, the disposal of associated radioactive waste and closure of waste disposal facilities are not addressed in this Safety Guide but are considered in other IAEA publications [8][9]. The document applies to planned authorized practices. Although some reference is made to remediation in the context of the facility decommissioning, this document does not apply to remediation situations as these are considered in other IAEA Safety Standards [10][11].

STRUCTURE

1.16. The structure of this Safety Guide is similar to the structure of the Safety Requirements [1]. Section 2 briefly addresses the issues related to protection of human health and environment including the application and consequences of a graded approach for the whole decommissioning process and radiation protection. Section 3 describes the responsibilities of the major parties associated with decommissioning. The factors influencing the selection of the decommissioning strategy is discussed in Section 4. The planning of decommissioning at the design, construction, operation, transition from operation to decommissioning and decommissioning of the facility lifecycle are reviewed in Section 5. Sections 6 and 7 describe the funding and the management of decommissioning, respectively. Section 8 describes the conduct of decommissioning. Section 9 discusses the completion of decommissioning including surveys to support the termination of decommissioning activities.

1.17. Appendix I details the application of the graded approach to simple, intermediate and complex facilities. Appendix II provides the general content of a decommissioning plan for a simple facility and Appendix III is for a complex facility. Appendix IV provides an example of the contents of a final radiological survey report. Appendix V provides the contents of the

final decommissioning reporting documents. Annex I is a table showing the grouping of radiological facility types relative to the level of hazard. Annex II provides a suggested approach for countries without a strategy or regulatory framework for decommissioning.

2. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

2.1. During decommissioning, the workers, the public and the environment should be properly protected from radiological and non-radiological hazards. The national exposure limits for workers and the public, and the environmental discharge limits should be adhered to. A radiation protection programme should ensure that radiation protection of workers and the public is optimized during decommissioning. Optimization should be implemented, taking into account the specifics of the decommissioning project ([1], para 2.2).

2.2. Although the principles and aims of radiation protection during operations and during decommissioning are fundamentally the same, the methods and procedures for implementing the radiation protection may differ. During decommissioning, special situations may need to be considered, which may require the use of specialized equipment and the implementation of certain non-routine procedures.

2.3. Consideration must be given to the radiation protection of both workers and the public, not only during the course of decommissioning but also when a site is for restricted release [1].

2.4. Consideration must be given during decommissioning for protection against, and the mitigation of, potential exposures from incidents or accidents. Other IAEA Safety Standards give guidance for such situations ([1], para 2.3) and [10].

2.5. The operating organization of a facility that is undergoing decommissioning must manage and control activities to mitigate any impact on the environment of the site and the surrounding area. These arrangements should be maintained during decommissioning and beyond, if a facility is released with restrictions on its future use. The end state conditions must be met before a site or facility is released with no restrictions.

2.6. Decommissioning tasks have the potential to create hazards. Therefore, an important objective of decommissioning planning is to adequately assess and manage the safety aspects of decommissioning operations.

2.7. A safety assessment should be conducted to define protective measures, utilising an optimization approach for radiological protection with due regard for radiological safety. There are many safety functions and related structures, systems and components (SSCs), e.g., ventilation or drainage, that have to be addressed to ensure the safety of facilities during the operational phase. Many of these SSCs are no longer needed after operations has ceased. However, some of the SSCs will continue to be required during decommissioning, and decommissioning can also give rise to the identification of the requirements for new safety functions and SSCs. These should be considered to ensure overall safety during decommissioning [12].

2.8. Decommissioning can be facilitated by planning and preparatory work undertaken during the entire lifetime of the facility. These actions are intended to minimize the eventual human health and environmental impacts which can occur during the active and passive processes undertaken during decommissioning (see Section 5). Experience has shown that, provided that these actions are properly planned and implemented, decommissioning of facilities and management of the resulting radioactive materials can be accomplished without undue risk to or radiological impacts on workers, the public or the environment.

2.9. Both the operating organization and the regulatory body must foster and maintain a safety culture ([1], para 2.4). Appropriate training on health, safety and environmental matters should be provided to individuals engaged in decommissioning activities.

2.10. During decommissioning, radioactive and non-radioactive effluents may be discharged to the environment. These discharges should be controlled in compliance with appropriate national regulations. Guidance on the regulatory control of discharges of radioactive effluents to the environment and waste management is provided in other IAEA Safety Standard Series publications [13][14][15].

2.11. Radioactive waste management is further discussed in Sections 5 and 8. Guidance on radiological criteria for the removal of regulatory control from materials, equipment and sites is provided in other IAEA Standards Series publications [16][17].

2.12. Guidance on the transport of radioactive material is provided in other IAEA Safety Standards Series publications [18] and the associated environmental and safety aspects are also addressed.

GRADED APPROACH TO DECOMMISSIONING SAFETY

2.13. The range of decommissioning activities for medical, industrial and research facilities is broad, and the scope, extent and level of detail of planning, safety assessment and demonstration, preparation, review and update of safety related documentation should be commensurate with the types of and magnitude of hazards, and their potential consequences to workers, the public and environment. Therefore, a graded approach is to be applied to the planning, conduct and completion of decommissioning, and release of the site for unrestricted or restricted use ([1], para. 5.3).

2.14. A graded approach is a process by which the level of analysis, documentation and actions necessary to comply with the safety requirements are commensurate with the factors below.

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

2.16. The application of the graded approach in the context of medical, industrial and research facilities should take into account the factors, such as:

(a) Size and type of the facility (including its complexity and consideration of historical burial of waste from past practices);

(b) Physical state of the facility, specifically the integrity of the SSCs. In particular, the extent to which ageing or abandonment may have compromised building structures or SSCs, for example, due to a long period of poor maintenance;

(c) Radiological (source term), biological and chemical inventories and hazards associated with the decommissioning of the facility;

(d) Lifecycle stage of the facility (design, construction, commissioning, operation, shutdown or decommissioning), such as the preparation of an initial decommissioning plan at a design stage or a preparation of a final decommissioning plan prior to planned shutdown;

(e) Scope of the assessment (e.g., for a part of a facility, a single facility at a multi-facility site or an entire site); Extent to which the proposed decommissioning operations could

adversely affect ongoing operations with safety significance elsewhere at the facility or at nearby facilities;

(f) Uncertainty of information (e.g., 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 the safety assessment;

(g) Complexity of the decommissioning tasks; and

(h) Final end state of the decommissioning of the facility (e.g., unrestricted or restricted use).

CONSEQUENCES OF THE GRADED APPROACH

2.17. Successful decommissioning depends on adequate and organized planning and systematic implementation of the decommissioning activities in accordance with the licence conditions. Grading has an impact throughout the decommissioning project, specifically in the following areas (see Appendix I):

(a) Documentation, e.g., the scope of the decommissioning plan, its content and the degree of detail necessary (including the safety assessment) may vary depending on the complexity and hazard potential of the facility, and the actions necessary to meet national regulations;

(b) Identification of SSCs and control requirements;

(c) Control of decommissioning work activities;

(d) Authorization process;

(e) Review of activities completed;

(f) Project management (e.g., organizational structure) - the management of the decommissioning project should be tailored to the project's complexity and size and to the potential hazards associated with it ([1], para 7.8). Specific guidance for facilities decommissioning is presented in Section 7;

(g) Staffing and training; and

(h) Oversight, i.e., surveillance, inspection and control.

RADIATION PROTECTION

2.18. The principles of radiation protection and safety for practices are provided in the IAEA Safety Standards Series publications and radiation protection system established by International Commission on Radiological Protection ([13], paras 2.20, 2.23 and 2.24)[19]. A radiation protection plan should be included as part of the decommissioning plan and should be based on the national requirements for radiological protection.

2.19. During decommissioning activities, the principal focus of radiation protection is the protection of workers against normal and potential occupational radiation exposure. Consideration must be given to the protection of workers undertaking interventions in the event of an emergency. Radiation protection of worker and the members of the public exposed as a result of decommissioning activities must be optimized with due regard to the relevant dose constraints.

2.20. The operating organization should establish an organization for radiation protection that functions independently in matters affecting the health and radiation safety of workers and the public. Appropriate procedures should be formulated and implemented. These procedures for decommissioning may be the same as those already established during operation and maintenance of the facility. Additional emphasis should be placed on mitigating the following hazards:

(a) Closer proximity of radiation sources to personnel (due to the removal of shielding or interlocks to gain access to sources), and hence the greater potential for radiation exposure;

(b) Greater potential for the creation of airborne radionuclides, due to removal of containment or barriers during dismantling; and

(c) Introduction of new techniques necessitating specific controls and adequate training of personnel.

2.21. During decommissioning, the following issues should be considered:

(a) Ensuring radiation protection of workers and the public is optimized;

(b) Having the appropriate number of skilled radiation protection personnel to assist in ensuring the safe conduct of the decommissioning tasks;

(c) Ensuring that the decommissioning personnel have the appropriate skills, qualifications and training with respect to radiation protection techniques and requirements;

(d) Using protective equipment for shielding to limit internal/external exposure and doses (e.g., lead blankets, tents, local ventilation and filtering systems);

(e) Applying good housekeeping practices to reduce doses and to prevent the spread of contamination;

(f) Dismantling of never accessed areas with highly contaminated equipment and pipes should be considered by remote control and techniques to minimize workforce internal/external exposure;

(g) Zoning of the occupational activities as a function of the levels of radiation and contamination, as well as appropriate rezoning as decommissioning work proceeds and according to the radiological hazards involved; and

(h) Documenting all radiation protection measures and survey results.

2.22. The operating organization should review the classification of radiation areas implemented during operation and determine its relevance during decommissioning activities by taking into consideration the magnitude of the expected normal exposures, the likelihood and magnitude of potential exposures, and the nature and extent of the required protection and safety procedures during decommissioning activities.

2.23. The operating organization should consider the end state of the facility and associated site. Consideration should be given to the protection of both workers and the public from exposure, not only during decommissioning but also as a result of any subsequent occupancy or use of the decommissioned site.

2.24. Radiation protection is discussed in more details in other IAEA Safety Standards Series publications [20].

ENVIRONMENTAL PROTECTION

2.25. An operating organization must consider environmental protection to enable efficient management of decommissioning and define the controls to ensure any impact to the environment, both onsite and the surrounding area, is mitigated. Environmental protection should be maintained during the entire decommissioning process and beyond, if a facility is released with restrictions on future use. In the decommissioning process, an environmental impact assessment is developed concurrently with the decommissioning plan (see Section 5).

2.26. Environmental monitoring should be conducted throughout decommissioning. All potential radioactive releases should be prevented or be controlled at source. Where releases are expected and authorized, the releases through identified release points should be monitored. Off-site monitoring may be conducted to demonstrate the adequacy of the control over releases of radioactive materials to the environment.

3. RESPONSIBILITIES ASSOCIATED WITH DECOMMISSIONING

3.1. Radioactive materials and sources that are produced, received, used and stored during decommissioning should be managed within a national statutory and legal framework. The government, regulatory body, and operating organization have specific responsibilities during decommissioning [1]. Decommissioning activities could involve many different organizations, including contractors and subcontractors, and it is important to define clearly the responsibilities between the different organizations.

GOVERNMENT

3.2. The government is responsible for establishing a legal, statutory and organizational framework, supported where necessary by appropriate guidance, for decommissioning so that workers, the public and the environment are protected during decommissioning and after the release of sites from regulatory control and during restricted release. The government should define the policy for decommissioning including credible and acceptable general regulations for the conduct of decommissioning consistent with the selected strategy, institutional control and radioactive waste management arrangements and the legal, technical and financial responsibilities of involved organizations and should ensure that the appropriate scientific and technical expertise exist. Additional guidance on the role of the government can be found in other IAEA Safety Standards Series publications [21]. In many countries, one of the main

responsibilities of the government is to ensure a mechanism for providing adequate financial resources is put in place, so that an appropriate level of funding should be available to decommission the facility in a safe and timely manner. Funding is discussed further in Section 6.

3.3. The framework should be such that there are no unresolved jurisdictional issues associated with the decommissioning. It is recognized that one government entity may have responsibility for the radiological and another entity may have responsibility for non-radiological hazards. Where different governmental bodies regulate and administer these aspects, their authorities and responsibilities should be clearly delineated to eliminate duplication or conflict. The need and timing for involving other governmental bodies should be considered within the national regulatory framework.

3.4. The framework associated with the decommissioning activities should also include consideration of:

(a) Principles, objectives and guidelines for decommissioning;

(b) Decommissioning licensing structure;

(c) Adequate resources to complete the decommissioning;

(d) Development, review and approval of the decommissioning plans and conduct of decommissioning;

(e) Management of decommissioning radioactive waste, including disposal; and

(f) Determination of end points for completion of the decommissioning including boundary conditions.

3.5. Where national policy and strategy for decommissioning of simple facilities is absent or in its infancy 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 updating and improvement. Further information is provided in Annex 2.

REGULATORY BODY

3.6. The regulatory body is responsible for establishing the safety criteria, requirements and guidelines related to decommissioning, including the management of the resulting radioactive waste, and for carrying out activities to ensure that the requirements are met. The regulatory body regulates decommissioning from initial planning to completion of decommissioning and the release of the site for restricted or unrestricted use. The regulatory body is also responsible for establishing the radiological criteria for the removal of materials, buildings and sites from regulatory control, and to ensure that adequate systems are in place for properly managing the removal of controls and the release criteria (unrestricted release and restricted release).

3.7. The regulatory body should conduct the regulatory review of a final decommissioning plan and supporting documents to assist the regulator's decision-making on the safety of decommissioning activities. The regulatory body could provide guidance to the operating organization on the documentation and analysis that would support the operating organization in assessing safety issues and facilitate the regulatory process for conducting the regulatory review. In particular, the regulatory review could focus on determining whether the selection of decommissioning strategy, final decommissioning plan, the proposed decommissioning activities, environmental impact and safety assessments related to the decommissioning comply with regulatory policy and safety requirements. The regulatory body could provide a written decision on the decommissioning plan and supporting documentation. Consistent with the national framework, the regulatory body may decide to issue, amend, or deny the authorization for decommissioning based on safety grounds.

3.8. The regulatory body should provide operating organizations with guidance on the implementation of the regulations, on the procedures that the operating organization is expected to follow in terms of license applications and on the time scales likely to be required for consideration of a license application. While the regulatory arrangements should be comprehensive, they should also be commensurate with the scale and potential hazard of the facilities under regulatory control.

3.9. As during operation of the facility, the regulatory body should perform onsite inspections during decommissioning, until the termination of the license. These inspections should mainly address topics in relation to decommissioning activities, e.g., dismantling, waste management, radiation protection, and surveillance to confirm compliance with the

safety objectives and criteria defined in the final decommissioning plan and the operating limits and conditions defined in the detailed safety assessment. The regulatory body should especially ensure key decommissioning tasks are inspected, especially where it involves surveying of an area that may be inaccessible in the future (e.g., subsurface areas), and that there has been no significant deviation without prior approval from the final decommissioning plan.

3.10. The regulatory body should ensure that there is a regulatory provision for the termination of a license, which would sustain the decision for release of a site for unrestricted or restricted use. For cases where unrestricted use of a site is unachievable, the regulatory body should consider whether to accept the site conditions and any proposed institutional controls, as well as onsite and offsite radiological and environmental monitoring. This regulatory framework should also provide the basis for establishing any restrictions that may be placed upon the use of or access to the site before, during and, if necessary, after decommissioning which would be included in the final decommissioning plan [17]. The regulatory body should use appropriate regulatory and statutory mechanisms (e.g., dose limits, discharge limits, clearance levels, etc.) as the basis for its control ([1], paras 3.5 and 3.6).

3.11. Decommissioning can be accomplished under a single overall license or separate licenses as defined in the national regulation. The single license can contain several hold points that require individual authorization by the regulatory body. A facility's license should not be terminated until the regulatory body has determined that the condition of the site has met the goals defined in the final decommissioning plan. A final status survey should be conducted by the operating organization and the results validated by the regulatory body. Section 9 provides additional guidance for the restricted and unrestricted release of sites.

3.12. The regulatory body should ensure that relevant documents and records are prepared by the operating organization, and specify the timeframe and quality of the appropriate documents to be kept before, during and after decommissioning. Recordkeeping is particularly important during facility operations for decommissioning planning (see Section 5), and where restrictions are imposed on the future use of sites or for the possible identification of potential causes of health effects (see Section 7).

OPERATING ORGANIZATION

3.13. The operating organization (i.e., the owner or the licensee) is responsible for selecting the decommissioning strategy and for preparing all the decommissioning related documents (e.g., decommissioning plan and safety and environment impact assessments), for submitting them for review according to national regulations, and for implementing the authorized final decommissioning plan. The operating organization should obtain regulatory approval prior to conducting the decommissioning activities. When a facility is taken out of service, the operating organization of the facility undergoing decommissioning is responsible for the safety of the facility during decommissioning, until the termination of the license or until responsibility for the facility is transferred to another organization.

3.14. After shutdown, the responsibility for the facility may be transferred to a different organization which becomes the operating organization of the facility for decommissioning. For such transfer of responsibility, the new operating organization should have the necessary resources, expertise and knowledge. Knowledge of the operational history of the facility should be maintained and passed to the new operating organization.

3.15. The operating organization is also responsible for the management of the overall decommissioning activities including management of the radioactive waste generated during decommissioning activities. It should ensure that they are carried out in compliance with relevant regulatory requirements. The decommissioning activities and protective measures to be taken during and after the decommissioning of the site should be specified by the operating organization in the decommissioning plan. Although the performance of specific tasks may be delegated to a subcontractor, the responsibility for safety remains with the operating organization.

3.16. During decommissioning, the operating organization should report any related information (e.g., monitoring data and radiological surveys) to the regulatory body on a scheduled basis, as stipulated by the regulatory control mechanism (e.g., license).

3.17. Early cooperation between the regulatory body and operating organization in the decommissioning process has been demonstrated to improve the planning and conduct of decommissioning, and can reduce the delays in obtaining regulatory approval of revised planning documents. The operating organization should engage the regulatory body as soon as they determine the facility is going to be shutdown and undergo decommissioning.

3.18. Consistent with the national framework, it is the obligation of the operating organization to engage the public and key interested parties early in the planning and during implementation of decommissioning.

4. DECOMMISSIONING STRATEGY

DEFINITION OF DECOMMISSIONING STRATEGIES

4.1. Three decommissioning strategies have been defined by the IAEA namely: immediate dismantling, deferred dismantling and entombment [22]. “No action” should not be regarded as an acceptable decommissioning strategy.

4.2. Immediate or 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. Modifications of these strategies are possible. These strategies are, in principle, applicable to all facilities, however their application to some facilities may not be appropriate owing to political concerns, safety or environmental requirements, technical considerations, local conditions or financial considerations.

4.3. The operating organization should define a decommissioning strategy on which the planning for decommissioning will be based. The strategy should be consistent with a national decommissioning and waste management policy, having due consideration of the graded approach relevant to the type and hazards associated with the facility.

4.4. In order to optimize selection of the decommissioning strategy for a facility or site, the decommissioning plan should identify the decommissioning strategy that have been considered, and then provide a justification document, detailing why the selected strategy represents the best strategy for the project under consideration.

Immediate dismantling

4.5. Immediate dismantling should commence shortly after shutdown, if necessary following a short transition period to prepare for implementation of the decommissioning strategy. Decommissioning should commence after the transition period and continue in phases or as a single project until an approved end state (e.g., the release of the facility or site from regulatory control) has been reached.

Deferred dismantling

4.6. As an alternative strategy, decommissioning may be deferred for a period of up to several decades, although more commonly for medical, industrial and research facilities, the period of deferment should be substantially less unless specific circumstances exist that justify such a long delay.

4.7. Deferred dismantling (sometimes called safe storage, safe store or safe enclosure) is a strategy in which a facility or site is placed in a safe condition for a period of time followed by decontamination and dismantling. The operating organization should ensure that the facility has been placed, and will be maintained, in a safe configuration and will be appropriately decommissioned in the future. During the shutdown and transition phases, facility specific actions should be undertaken to reduce and isolate the radioactive material (e.g., removal of radioactive materials, management of remaining operational or legacy waste) in order to prepare the facility/site for the safe enclosure period. During the safe enclosure period, a surveillance and maintenance programme should be implemented to ensure that the required level of safety is maintained and would be subject to the approval of the regulatory body.

4.8. For medical, industrial and research facilities, there are two strategies applicable as part of the deferred decommissioning strategy. The first is where controlled access to the radioactive areas is 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. This strategy will usually not require any dismantling operations. The second option, often called phased decommissioning, is where there are periods of deferral between active decommissioning phases. In this strategy, decommissioning is performed in phases to allow time for:

(a) Allocation of necessary resources;

(b) Resolution of technical issues;

(c) Decay of short half-life radionuclides to reduce occupational exposure or to release levels for buildings or clearance levels for materials, e.g., sale of recycled copper piping from a cyclotron; or

(d) Provision for adequate waste management capacity.

4.9. If the deferred dismantling strategy has been selected, it needs to be clearly demonstrated in the decommissioning plan that such a strategy will be implemented safely and will require minimum active safety systems, i.e., passive safety, radiological monitoring and human intervention and that future requirements for information, technology and funds have been taken into consideration. The potential ageing and deterioration of any safety related equipment and systems need also to be considered.

4.10. Although evaluation of the prevailing factors should clearly indicate one of the above mentioned strategies, constraints and over-ruling factors may occur in practice, and these may necessitate a combination of strategies or exclude one or more strategies from consideration.

4.11. Where the finance essential to complete a decommissioning project is not available at the outset, a phased deferred decommissioning strategy should be considered as a better strategy than failure to make progress due to lack of finance. Deferred dismantling in a series of phases should be considered as the strategy of choice where funds are released at defined intervals.

Entombment

4.12. Entombment is a strategy in which the remaining radioactive material is permanently encapsulated onsite. A low and intermediate level waste disposal facility is effectively established and the requirements and controls for the establishment, operation and closure of a waste disposal facility are applicable.

4.13. The selection of the entombment strategy is generally not appropriate for the decommissioning of medical, industrial and research facilities, since entombment results in restricted use with long-term controls and long-term associated liabilities.

SELECTION AND IMPLEMENTATION OF A DECOMMISSIONING STRATEGY

4.14. For the facilities being considered in this Safety Guide, consideration of the influencing factors detailed in this section should generally lead to a decision to select the strategy of immediate decommissioning, e.g., dismantling of the facility and removal of all radioactive material after shutdown or within a short period, as appropriate, to allow for decay. However, in some cases, e.g., decommissioning of more complex radioisotope production facilities, other strategies should be considered.

FACTORS INFLUENCING THE SELECTION OF A DECOMMISSIONING STRATEGY

4.15. An evaluation of the various decommissioning strategies should be performed, considering a wide range of factors. The factors that impact the selection of a decommissioning strategy are generally consistent for the full range of medical, industrial and research facilities. These factors could present as positive indicators or as constraints, e.g., whether funding is available or not. The impact of the factors also depends on country- and facility-specific conditions. Table 1 shows some positive indicators and constraints for selecting the decommissioning strategy.

4.16. The selection of a decommissioning strategy should be based and justified in terms of the facility and national factors. Ideally, the selection of a decommissioning strategy should be made during the design stage or alternatively as early as possible in the lifecycle of a facility. The selection and justification of a preferred decommissioning strategy should be made by analysing the weighted impact of the relevant factors. This justification should be documented and maintained as the basis of decommissioning planning throughout the lifecycle of a facility.

4.17. The following are regarded as general factors that have an influence on the selection of decommissioning strategies:

National policies and legal and regulatory framework

(a) Policies that address decommissioning on a national level;

(b) Legal framework covering regulatory functions and infrastructure, as well as requirements and standards pertaining to decommissioning; and

(c) Authorization/licensing processes to ensure regulation of the facility's full lifecycle, in particular, regulations for the planning and conduct of decommissioning.

Financial assurance

(a) Availability of adequate financial resources including suitable timely release of the funds to achieve effective decommissioning;

(b) Availability of funding mechanisms and potential for the funding mechanism to be adversely affected by the political or economic climate at the time when funds are required;

(c) Direct cost of implementing the decommissioning strategy;

(d) Indirect costs associated with the strategy (e.g., costs related to interested parties involvement and social acceptance); and

(e) Market availability for sale of recycled materials to support the decommissioning budget.

Conduct of decommissioning

(a) Reasons for permanent shutdown, if not consistent with the original planning basis (e.g., economic, political, and accident);

(b) Availability of suitable decommissioning technologies and techniques; and

(c) Re-development and reuse options for the facility and adjacent areas.

Waste management system

(a) National waste management policy and strategy;

(b) Presence or absence of national clearance levels to facilitate disposal or recycling/reuse of materials, e.g., demolition rubble or metals recycling;

(c) Amounts and categories of decommissioning waste; and

(d) Facility – specific waste management plans and availability of waste management and disposal facilities.

Health, safety and environmental impact

(a) Safety and health impact including optimization consideration;

(b) Environmental impact including impact of material/waste transportation;

(c) Physical status of the facility, e.g., expected integrity of buildings over time; and

(d) Radiological and hazardous material characteristics.

Knowledge management and human resources

(a) Availability of suitably qualified and experienced personnel (from facility or other decommissioning projects);

POSITIVE INDICATORS	CONSTRAINTS
Immediate dismantling	
Knowledge and expertise readily available	Ability to achieve timely employment of suitably experienced project manager or external contractors
Lifecycle cost saving	Early expenditure requirement
Minimization of public concern	Longer term liability
Release of the facility from regulatory control for further reuse	Potential for future better technology to deliver more efficient and economically decommissioning
Early hazard elimination	Demand for waste disposal and storage, if these facilities are not readily available or accessible
Deferred dismantling (Phased decommissioning)	
Decay of fission products and short half-life radionuclides	New hazards introduced that require management due to ageing and loss of integrity
Can spread the costs over time where finances are to be released at discrete time intervals	Overall costs increase
Can recover materials suitable for recycling with a re-sale value to supplement the decommissioning budget	Long-term regulatory oversight with regular inspection
More time to resource waste disposal or storage options/facilities	Requirement for safe storage/maintenance
More time to optimize planning for best use of resources	Longer term liability and cost increase

Social impact on extended employment of operators and local contractors	Pressure from local community

TABLE 1. Positive indicators and constraints for selecting the decommissioning strategy

(b) Lessons learned from previous decommissioning projects; and

(c) Operational history and adequacy of decommissioning related information (e.g., records, and drawings).

Social impacts and interested parties involvement

(a) Impacts on local communities from decommissioning process; and

(b) Public/interested parties concerns and perceptions and how effectively these can be resolved.

4.18. The decommissioning strategy should take into account that, until authorization has been given to implement the final decommissioning plan, the facility should be considered an operating facility. All applicable requirements for the facility should remain in place unless approved by the regulatory body on the basis of reduced hazards (e.g., the removal of radioactive material from the facility).

4.19. 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.

4.20. Prior to shutdown, the initial decommissioning strategy should have been agreed with the regulator. The decommissioning plan will then require review and updating, to include a comprehensive safety assessment and other supporting documentation, which should all be submitted for approval by the regulator.

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

(a) Applying a graded approach to the decommissioning safety requirements;

(b) Completing and submitting any further license applications and obtaining approvals from relevant regulatory bodies;

(c) Communicating as appropriate with interested parties, both internal and external to the facility or site including regularly consulting with the regulators and establishing clear lines of communication;

(d) Ensuring early communication and implementation of radiation protection measures;

(e) Assigning roles and responsibilities and ensuring they are clearly understood by all persons involved in the decommissioning project;

(f) Where relevant, employing a suitably experienced project manager or contractors to deliver specific decommissioning roles/tasks;

(g) Performing required mock-up trials or providing additional training for specific staff groups relevant to their assigned decommissioning tasks (see Section 7);

(h) Ensuring all operators have a clear understanding of the work tasks to be carried out and are aware of the sequence in which the actions must be completed;

(i) Disseminating the outcome of the safety assessment and ensuring the availability of any required safety equipment; Ensuring training on the correct use of safety equipment;

(j) Securing availability and advance booking of any equipment to be hired for key tasks during the project, e.g., lifting equipment; Ensuring in advance that the written specifications for the hired equipment correspond to the actual item as supplied;

(k) Implementing the necessary physical protection, fire, and emergency preparedness measures, ensuring all operators are familiar with them, and ensuring that a mechanism is in place to update operators on any changes, as and when necessary;

(l) Agreeing and securing the routes for movement of materials/waste/containers and packages/equipment into/out of the decommissioning area;

(m) Agreeing to clearance levels and the measurement methodology with the regulator and ensure relevant operators are competent in compliance with what has been agreed;

(n) Implementing a suitable management system to be in force throughout the duration of the project; and

(o) Securing funds and agreeing to the timing for their release.

5. DECOMMISSIONING PLANNING DURING FACILITY LIFECYCLE

5.1. Decommissioning should be facilitated by planning and preparatory work undertaken during the entire lifecycle of the facility [23]. The benefits of decommissioning planning include the minimization of radiation exposures of workers and the public, protection of the environment during decommissioning, minimization of radioactive waste and timely release of the facility or site from regulatory control.

5.2. Figure 1 provides the facility decommissioning lifecycle model and its associated documents. The complexity of the medical, industrial and research facilities can also be defined based on the type of documents and tasks necessary during decommissioning planning. For example, a simple facility usually has a brief decommissioning plan prepared in-house by the operating organization, 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 more lengthy decommissioning plan prepared in-house by the operating organization or employs some external experts' assistance, typically does not require an extensive environmental impact assessment, has project management performed in-house or external to the operating organization, and involves some dismantling and demolition. Lastly, 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 sub-contractors.

5.3. Successful decommissioning depends on detailed and organized planning. Early decommissioning consideration and planning in the facility's lifecycle is important to avoid technical difficulties, higher decommissioning costs, and unnecessary exposures of operators and to minimize waste generation.

5.4. For new facilities, an initial decommissioning plan should be prepared at the time of the licence application for construction and/or commissioning of the facility. The degree of detail of the decommissioning plan will increase through the entire lifecycle of the facility. Early decommissioning arrangements should include financial assurance.

5.5. Many medical, industrial and research facilities have been operating for many years and decommissioning may not have been considered at the design, construction and operational stages. This should be recognized in the planning of decommissioning for such

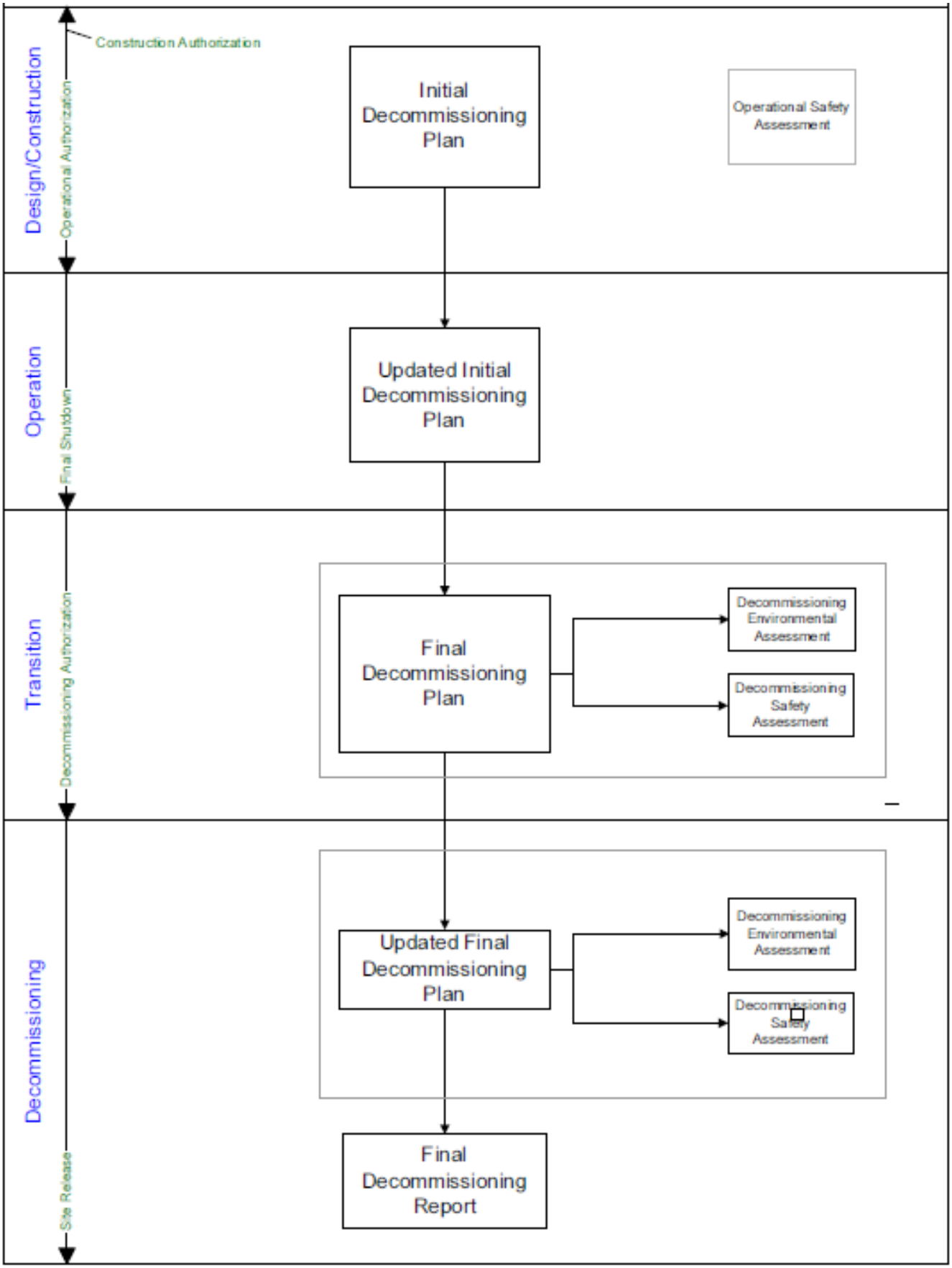

FIG. 1. Facility decommissioning lifecycle model

facilities and preparations should start as early as possible. For such facilities, modifications to buildings and systems should incorporate features that would facilitate decommissioning, enhance radiation protection to workers and the public and minimize environmental impacts.

5.6. A multi-facility site must have an overall decommissioning plan, which takes into account the interdependencies of the individual facilities and activities, the associated constraints and the individual facilities decommissioning plans.

DESIGN, CONSTRUCTION AND COMMISSIONING

5.7. During the design, construction and commissioning phase of a new facility, the decommissioning requirements must be considered [1][8]. This information may be useful in optimizing the design and operation of the facility to ease decommissioning. Examples of how decommissioning needs can be incorporated at the design phase include:

(a) Minimize the number and size of contamination zones by compartmentalization and confinement;

(b) Use smooth, seamless and non-absorbent work surfaces and flooring, and/or removable or strippable coatings in areas likely to become contaminated;

(c) Provide provisions for easy access to areas of the facility and to equipment and systems to facilitate decontamination, dismantling and removal;

(d) Design the facility to avoid undesired accumulation of chemical or radioactive materials and to facilitate in-situ decontamination of pipes, ducts, and tanks;

(e) Select materials that are resistant to neutron activation, e.g., in particle accelerators, that are resistant to degradation by chemicals in use and that have sufficient wear resistance to facilitate their decontamination at the end of their lifetime;

(f) Use proper ventilation and drainage systems to prevent or control the spread of contamination during operations and decommissioning;

(g) Consider lessons learned from previous similar decommissioning activities;

(h) Avoid underground pipelines and embedded pipes in building structures;

(i) Select processes to minimize the volumes of waste and secondary waste and to facilitate the easy retrieval of stored wastes;

(j) Provide adequate leak detection, e.g., for liquid waste tanks; and

(k) Consider operational design through work procedures to avoid contamination.

5.8. Although the abovementioned design considerations can significantly ease the decommissioning process, proper control of operations is also important so that leaks, spills and other events which could lead to contamination are minimized.

Initial decommissioning plan

5.9. An initial decommissioning plan should be prepared and submitted by the operating organization in support of the licence application for the construction of the facility or at the time of applying for an authorization to operate the facility. This initial decommissioning plan is likely to be a relatively brief document, but is necessary to ensure that sufficient funds will be available for decommissioning, to facilitate early planning for minimization of the need for decontamination, and to provide for early acquisition and maintenance of records important for decommissioning.

5.10. For facilities where the initial decommissioning plan has not yet been prepared, it should be prepared without undue delay. The plan should describe the preferred decommissioning strategy and address the feasibility of safely decommissioning the facility using currently available technologies. The plan should also include information on background radiological data for the site and any existing buildings. The plan should also define the resources necessary for decommissioning and waste management, as well as the methods to ensure their availability. Appendices I and II provide the content of an initial decommissioning plan.

5.11. The potential existing facilities and equipment that will be used during decommissioning should be identified at an early stage in the initial planning phase. This will enable the necessary steps to be taken to ensure that the facilities and equipment, e.g., ventilation and radiological detection instrumentation, are available when needed.

FACILITY OPERATION

5.12. The operation of a facility should include actions to facilitate its eventual decommissioning. These actions should include consideration of the following:

(a) Reduction of radiological hazard by the minimization of the radioactive inventory throughout the operational phase, e.g., by removal of all radioactive materials and radioactive waste from the facility for reuse and storage in an approved location or disposal, in accordance with regulatory requirements. Disused sealed sources, as a first option, should be returned to the original supplier. However, where radioactive materials are present in the form of activated materials, liquid or contaminated surfaces, the method of removal may require more comprehensive planning. The planning should also consider the methods for transport and the destination of the removed radioactive materials and sources;

(b) Prevent leaks and spills or where they do occur, prompt decontamination action to remediate them. Removal of contamination, where possible, but where decontamination is not achievable, records should be made of residual contamination and how this has been managed, e.g., by application of paint or a covering sealant;

(c) Identify and maintain equipment, systems and facilities that will be required to be in a good working order during decommissioning;

(d) Establish procedures and practices to limit cross-contamination or spread of contamination; and

(e) Set up a comprehensive record system, which should typically contain:

Operational records

(i) Retaining history and institutional knowledge, including retaining experienced personnel and records from the operational period will directly influence the progress of decommissioning;

(ii) Radiological and environmental monitoring results and discharges, including onsite and offsite monitoring of soil and sediment and ground and surface water, if required;

(iii) Residual contamination levels within the facility and any radiological sources; these records will include details of leaks, spills and any other events and the effectiveness of their remediation;

(iv) An inventory of radioactive and non-radioactive materials used at the facility which should assist with characterization. This record should incorporate details of change in radionuclide usage or work practices; and

(v) Event management, e.g., fires or releases, including the recording of actions, corrective measures and close-out.

Design Modifications

(i) Retention of as-built drawings and the updates of supporting engineering records; and

(ii) Evaluation of and recordkeeping of design modification and changes with respect to the future implication to decommissioning.

Waste Management

(i) Removal of operational waste prior to start of decommissioning;

(ii) Records to demonstrate compliance with waste acceptance requirements; and

(iii) While it is unlikely that these facilities would have an on-site waste disposal facility, records of operational waste that has been disposed on the site.

Legal requirements

(i) Prescribed records required to demonstrate compliance with all relevant regulatory conditions and requirements.

5.13. Early planning and coordinating with the relevant regulatory authorities on adequate long-term planning and a license programme will facilitate obtaining the necessary regulatory approvals in a timely manner, thus facilitating decommissioning.

Update of initial decommissioning plan

5.14. The initial decommissioning plan should be reviewed and updated periodically during operation, as prescribed by the regulatory body. A review should also be triggered by changes

in design process, waste management or disposal, financial conditions or modifications made to the equipment or building infrastructure that will impact the decommissioning plan, e.g., revisions to drainage arrangements or removal of asbestos. Revisions or amendments should also be made as necessary in the light of operational experience gained, new or revised safety requirements or technological developments, as well as changes to the strategy and end state.

5.15. The plan should also be reviewed and revised when significant accidents or incidents occur that could affect facility characteristics. Comprehensive records of such events and their consequences will be required for future characterization of the facility, e.g., application of a concrete screed over decontamination arising from a major spill.

5.16. Updates of the initial decommissioning plan will become more detailed as the facility approaches the end of its operational life. The existing facilities and equipment identified for decommissioning should be reassessed during each update as to their viability to support the proposed activities and the end state.

Unanticipated shutdown and abandonment

5.17. Unanticipated shutdown or facility abandonment is not a common occurrence for larger nuclear facilities and is much more common for the smaller privately-owned medical, industrial and research facilities. If the cessation of operations of a facility is sudden, the facility should be brought to a safe configuration before an approved decommissioning plan is implemented. The decommissioning strategy should be reviewed on the basis of the situation that caused the sudden shutdown to determine whether revision is required (see Section 4).

5.18. Unanticipated shutdown is often due to circumstances, such as bankruptcy or damage to the facility building structure, such as due to fire, flood, ageing, building defects, problems with asbestos or other hazardous materials, and where it is no longer cost effective for the licensee to continue operations of the facility. Often following unanticipated shutdown, the licensee can still be contacted, and the regulator should enforce the requirement to have in place adequate financial provision for decommissioning.

5.19. Following the unanticipated shutdown, the regulator should continue to enforce the license conditions relevant to safety and protection of the public and the environment on the licensee, who will be expected to implement suitable interim emergency arrangements until such time as decommissioning commences.

5.20. A specific concern is the potential for a facility to be abandoned and for such knowledge to be unknown to the regulator for a long time period. National arrangements should be in place to avoid such an occurrence, ideally supported by suitable regulatory requirements. This might best be achieved through the establishment of an information network at the local level.

5.21. Where a facility has been abandoned and the licensee cannot be traced, national emergency arrangements should exist to ensure timely implementation of interim measures to facilitate the security of radioactive materials and to protect the public and the environment from any adverse affects arising from intrusion into, and subsequent damage to, the abandoned facility.

5.22. If further enquiries fail to identify someone to accept the decommissioning liabilities of the licensee, a national strategy should exist to ensure management of such liabilities, including the decommissioning of the facility. While regulatory requirements should require the licensee to demonstrate adequate financial provision for decommissioning, the requirement for a national strategy for liability management for abandoned facilities without financial provision to support the regulatory requirement is essential.

TRANSITION FROM OPERATION TO DECOMMISSIONING

5.23. When a facility ceases operation, the licence may require modification to authorize decommissioning. The transition from operation to decommissioning concerns the activities which are performed in order to prepare for decommissioning activities and starts generally after the final shutdown of the facility. The end of the transition period is defined by the date of issue of the decommissioning license (if required) or the approval of the final decommissioning plan.

5.24. Some preparatory activities relevant to decommissioning may be carried out after shutdown of the facility under the operational license. These include:

(a) Removal of the residual material and operational waste;

(b) Facility modification and preservation of systems for decommissioning;

(c) Decontamination; and

(d) Characterization.

These tasks are described in greater detail in Section 8.

5.25. The operating organization should retain the necessary resources, expertise and knowledge for decommissioning and should keep records and documentation relevant to the design, construction, operation and decommissioning process.

Final decommissioning plan

5.26. Prior to the conduct of decommissioning phase, a final decommissioning plan should be prepared and submitted to the regulatory body for approval. This plan defines how the project will be managed. For multi-facility sites, a site decommissioning plan should be developed for the entire site to ensure that interdependencies are taken into account in the planning for decommissioning of individual facilities.

5.27. For medical, industrial and research facilities, it is important that a graded approach should be applied to the development of the final decommissioning plan. The type of information and the level of detail in the plan should be commensurate with the type and status of the facility and the hazards associated with the decommissioning of the facilities.

5.28. For most medical, industrial and research facilities, a relatively simple final decommissioning plan with a logical and adequate justification should be sufficient. Examples of the content for a final decommissioning plan for a simple and complex facility are given in Appendices II and III, respectively. Such a plan should include either immediate decommissioning after shutdown of the facility or decommissioning after an appropriate period to allow for decay of short-lived radionuclides. Important tasks of decommissioning and management of the decommissioning plan are described in Section 8.

5.29. The operating organization should inform the regulatory body prior to shutdown. If a facility is shutdown, a final decommissioning plan should have been submitted for approval to the regulatory body in advance of the cessation of the authorized activities. However, if the facility ceases operation before an appropriate decommissioning plan has been prepared (e.g., in the case of a premature shutdown), the decommissioning plan should be completed as soon as possible and submitted to the regulatory body, unless an alternative schedule for the submission of the final decommissioning plan has been specifically authorized by the regulatory body. The operating organization should not implement the decommissioning plan until the regulatory body has approved it. The operating organization should ensure that the facility is maintained in a safe configuration until approval of the decommissioning plan.

5.30. The final decommissioning plan should state the methodology and criteria that the operating organization will use to demonstrate that the proposed end state has been achieved. For most medical, industrial and research facilities, this should be release for unrestricted use.

5.31. Any changes or revisions to the decommissioning plan that is outside the limits and conditions defined by the regulatory body should be submitted to the regulatory body for approval. Further changes to the decommissioning plan as approved by the regulator might be necessary once decommissioning has commenced. It should be submitted to the regulator for consideration and confirmation of acceptance before being implemented and the justification for the changes should be provided. The supporting safety assessment should also be reviewed when changes in techniques are to be utilised during decommissioning.

5.32. Interested parties should be provided with an opportunity to review the final decommissioning plan and to provide comments on the plan to the regulatory body prior to its approval. Such a requirement is only likely to be relevant for the larger, complex medical, industrial and research facilities, where completion of specific decommissioning tasks might impact adversely on the local population, e.g., dust, noise or increased traffic impacts.

Safety Assessment

5.33. In all phases of decommissioning of a facility, the workers, the public and the environment have to be properly protected from hazards resulting from the decommissioning activities for both normal and abnormal situations. As required by national regulations, the decommissioning plan must be supported by a safety assessment addressing the planned decommissioning activities and any abnormal situations.

5.34. The operating organization is responsible for preparing the safety assessment and submitting it to the regulatory body for review. It should consider occupational and public exposures ([2], para 5.2). In the case of medical facilities where the public access is regular, the public exposure during decommissioning should be assessed, optimized and controlled. The safety assessments must contain an analysis of both radiological and non-radiological hazards associated with decommissioning activities and demonstrate compliance with the regulatory requirements and criteria. The facility characterization including radiological and non-radiological hazards is an important input for safety assessment and for implementing a safe approach during the decommissioning activities.

5.35. The safety assessment should employ a systematic methodology to demonstrate compliance with safety requirements and criteria for decommissioning throughout the decommissioning process, including the release of material, buildings and sites from regulatory control. The safety assessment methodology for decommissioning is addressed in other IAEA Safety Standards [12].

5.36. The range of decommissioning activities for which a safety assessment is required is broad, and the scope, extent and level of details of safety assessments should be commensurate with the types of hazards and their potential consequences. A graded approach should therefore be applied to the development and review of safety assessments. The documentation and the level of safety assessment should be commensurate with the following factors:

(a) Scope of the safety assessment (e.g., for the final decommissioning plan or phases of decommissioning or for a part of a facility, a single facility at a multi-facility site or an entire site);

(b) Size and type of the facility;

(c) Physical and radiological state of the facility at the commencement of decommissioning activities;

(d) Radioactive source term of the facility;

(e) Complexity of decommissioning activities and extent to which decommissioning could adversely affect ongoing operations;

(f) Likelihood of hazards and their potential unmitigated consequences;

(g) Uncertainties;

(h) Safety requirements and criteria against which the results will be assessed; and

(i) Planned end state of the decommissioning of the facility (e.g., unrestricted or restricted release).

5.37. Postulated initiating events, which could lead to elevated radiation levels or a release of radioactive material and hazardous substances, should be identified. 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 proposed. The protective measures may 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 are either engineered or administratively controlled and will vary and evolve as progress is made in the decommissioning of the facility.

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

Environmental impact assessment

5.39. Environmental impact assessment is the process of identifying, predicting and evaluating the potential impacts to ecological systems, natural resources, and the biosphere of a proposal prior to major decisions being taken and commitments made [24]. Environmental impact assessment must consider the radiological and non-radiological (e.g., chemical) impacts of the decommissioning activities including impacts associated with discharges of radioactive effluents to the environment.

5.40. 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 activity should be included in the decommissioning plan.

5.41. If required by national legislation, the environmental impact assessment must be conducted to determine whether the potential environmental impacts due to the decommissioning of the facility comply with the national requirements. The environmental impact assessment must consider both the impact of the decommissioning activities and the

impact of any future restricted use of the facilities and site after the completion of the decommissioning on the public and the environment.

5.42. The environmental impact assessment evaluates the environmental consequences to workers, the public and the environment. The environmental impact assessment should include background information on the facility and its surrounding area, description of the decommissioning tasks, a summary of the evaluated decommissioning alternatives, the rational and impacts of selecting the preferred decommission strategy and any mitigation measures. The assessment should include all potential release pathways of radioactive airborne, liquid, solid or gaseous materials from all the decommissioning activities, and their potential impacts to the environment including air, soil and sediment, ground and surface water, where relevant. Where appropriate, consideration should also be given to transportation, geology and soils, water, ecological, air quality, noise, historic, visual, socioeconomic, public and occupational health, waste management (pre-disposal), and any cumulative impacts.

5.43. The results of the environmental impact assessment could be used to develop environmental protection applicable to decommissioning. The results could also lead to defined decommissioning mitigation measures based on the identified environmental impact. These mitigation measures should be reflected in the environmental protection programme and decommissioning procedures. The environmental impact assessment results could also inform radiation protection during decommissioning.

DECOMMISSIONING

5.44. This phase is the implementation and execution of the final decommissioning plan. Activities associated with decommissioning are described in Section 8, Decommissioning Tasks, which discusses surveillance and maintenance, selection of decommissioning techniques, decontamination, dismantling, demolition, soil and sediment and ground and surface water remediation, waste and material management during decommissioning, and surveys and inspections.

6. FUNDING

6.1. The operating organization must ensure adequate financial provisions are available to decommissioning the facility in accordance with the national regulatory framework. The decommissioning cost for the facility should be calculated. Additional information on estimating decommissioning costs is provided in other IAEA publications [25]. Especially in the case of deferred dismantling, where there may be long safe enclosure periods, these financial provisions should be reviewed periodically and adjusted as necessary to allow for inflation and other factors such as technological advances, waste costs and regulatory changes. In the case of restricted release, consideration should be made for continuing costs, such as surveillance and maintenance costs after the completion of decommissioning. Responsibility for this review may reside with the operating organization, the regulatory body or other parties, depending on the national legal framework. The review should be conducted by an entity independent of the operating organization.

6.2. The financial systems adopted by the operating organization should be sufficiently robust to provide for decommissioning needs in the event of a premature shutdown of the facility. The cost of decommissioning should reflect all activities described in the decommissioning plan, e.g., activities associated with planning, transition from operation to decommissioning, and conduct of decommissioning.

6.3. Where cost estimates are based on return of sealed sources to the manufacturer, periodic verifications with the manufacturer should be made to ensure that the agreement is still valid. If there are changes with the source return agreement or shipment arrangements, any cost impacts due to transportation and security requirements, packaging cost, or disposal cost 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 only covers the cost of source return transport and may not include costs incurred for source removal from the facility. These costs must be included as part of the decommissioning cost estimate.

FINANCIAL ASSURANCE

6.4. The projected facility lifecycle cost should include provision for decommissioning. It should be consistent with the chosen strategy, resulting in an accurate cost and schedule for the facility.

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

6.6. Financial assurance for decommissioning will be included as part of the license application, and needs to be in place prior to initiation of construction or operation of the facility. If financial assurance for an existing facility has not been obtained, appropriate funding provisions should be put in place as soon as possible. In any event, financial assurance has to be in place prior to approval for a license renewal or license extension.

6.7. If a facility is decommissioned for a restricted use release, the financial assurance has to include costs associated with long-term monitoring, surveillance, and maintenance to ensure all necessary controls remain effective. Adequate financial assurance should be set aside to cover the entire period of time when long-term surveillance and maintenance is required regardless if the license is terminated.

7. DECOMMISSIONING MANAGEMENT

MANAGEMENT SYSTEM

7.1. The operating organization must establish, implement, assess and continually improve a decommissioning management system, appropriate to the size/complexity and impact of the project as defined by a graded approach (see Section 2). For larger more complex decommissioning projects, guidance on management systems is provided in other IAEA Safety Standards Series publications [26] [27]. Guidance specific to the management system for the decommissioning of a facility is also available in Ref. [28], Appendix VIII.

Integrated Management System

7.2. An integrated management system should provide a single framework for the arrangements and processes necessary to address all the goals of the operating organization. These goals include safety, health, environmental, security, quality and economic elements. General guidance on integrated management systems can be found in other IAEA Safety Standards Series publications [27].

7.3. The application of the management system requirements should take into account the graded approach for safety (e.g., in the need for and the level of detail of decommissioning documents).

7.4. The operating organization should plan and apply an appropriate management system before the commencement of decommissioning and should extend it to all phases of decommissioning. A description or reference to an approved management system, including a definition of its scope and extent, should be included in the decommissioning plan and be put into effect before the start of decommissioning. The system should include the maintenance and archiving of documents and records relating to decommissioning, and the performance of all work activities and operations for decommissioning**.**

SAFETY MANAGEMENT

7.5. Within the management system, safety is the most important issue, overriding all other demands ([26], para 2.2). Safety management refers to those aspects of the management system that are put in place to ensure that acceptable levels of safety are maintained during decommissioning. Safety management should include those arrangements made by the operating organization that are necessary to promote a strong safety culture and to achieve and maintain acceptable levels of safety. It is the management's responsibility to recognize the safety significance of the operating organization's activities and to promote a work safety culture throughout the organization.

7.6. Safety management should include such organizational elements as: the definition of the safety policy; identification of the main responsibilities within the operating organization; definition of the activities and competences necessary to ensure safety; and arrangements to ensure that the activities of the operating organization are conducted safely. Safety management should provide for monitoring of the implementation of the management system and should foster continuous improvement in safety performance. In addition, the management system should provide the framework that will enable individuals conducting decommissioning activities to carry out their tasks safely and successfully. All individuals have the responsibility and authority to bring any safety concerns to the decommissioning management. The decommissioning management needs to also ensure that appropriate authority for stopping work is provided.

7.7. To maintain effective management of safety, the operating organization should ensure that there is commitment to safety by all personnel. A fundamental principle for effective management of safety is the involvement of senior managers. The lead in safety matters should come from the highest levels of management. The safety policy of the operating organization and the behaviour and attitudes of senior managers should be exemplary and should permeate the operating organization at every level and extend to other organizations that perform delegated tasks. There should be no complacency at any level about the need for continuous attention to safety. The management should foster an attitude of willingness to learn in relation to safety matters and should promote an open exchange of information upward, downward and horizontally in the operating organization.

7.8. The operating organization should develop a safety policy to be implemented by all personnel in the operating organization. The safety policy should demonstrate the organization's commitment to a high level of safety and should be supported with reference to safety standards, the setting of targets and the provision of the resources necessary to attain these targets.

Process implementation

7.9. Arrangements should be put in place to ensure that safety related activities are adequately controlled. The level of control should depend on the impact of the task on safety, public health, and the environment. A specially authorized person, such as a qualified maintenance worker, may be required to carry out significant tasks which could impact safety. In addition, critical activities should be authorized in advance and should involve the use of a work permit system. Other control measures may include the use of hold points and verification stages for complex tasks.

7.10. Decommissioning activities should be carried out in accordance with approved procedures. The procedures should define how the activity should be carried out and, where appropriate, should identify the steps to be taken in the event of an abnormal occurrence. The procedures should be issued and controlled in accordance with the organization's management system. An emergency plan with procedures for its implementation should be prepared, as appropriate. These procedures should cover onsite and, where necessary, offsite responses, including the timely notification of appropriate government, regulatory and support organizations and the public.

Measurement, assessment and improvement

7.11. The safety performance of the operating organization should be periodically monitored to ensure that safety levels are being maintained. A review and audit system should be established to verify that the safety policy of the operating organization is being implemented effectively and that lessons learned from the organization's own experience and from that of others are implemented. Procedures for safety review should be maintained by the operating organization to provide an ongoing surveillance and audit of decommissioning safety. Assessments should be conducted by an entity independent of the operating organization.

ORGANIZATION AND ADMINISTRATIVE CONTROLS

7.12. The organizational structure to be employed during 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 amongst the various units. This is particularly necessary when subcontractors are used for dedicated decommissioning activities.

7.13. The responsibility for safety remains with the license holder. Mechanisms to control subcontractors appropriately must be established in written procedures. The license holder can delegate specific tasks to subcontractors to ensure tasks are performed safety, but cannot abdicate responsibility. Should the operating organization change after shutdown or during decommissioning, procedures must be established to ensure transfer of responsibility ([1], para. 7.2). The license holder maintains responsibility for safety and compliance with the license.

7.14. Administrative procedures from the operational phase of the facility may be relevant during decommissioning. These procedures should be reviewed and modified to ensure that they are appropriate to the decommissioning. The requirement for additional written procedures should be addressed. The administrative control procedures may be required to be endorsed by the regulatory body.

STAFFING AND QUALIFICATION

7.15. Based on an evaluation of the skills needed for decommissioning a facility, a team composed of decommissioning specialists and appropriate site personnel should be formed to

manage the decommissioning project. Although new competences may be required for decommissioning, attention should be given to preserving the knowledge of key personnel who are familiar with the facility during its operational phase.

7.16. The operating organization should have, or have access to, competent staff taking into consideration minimum requirements for each position to cover areas including safety requirements of the licence, radiation protection, manufacturing processes, engineering support (e.g., chemical, civil, electrical and mechanical engineering), quality assurance, waste management, physical protection, and project management. Specialized expertise may be necessary in other areas such as decontamination, dismantling and demolition, robotics and remote source handling, waste treatment and conditioning, and site characterization and restoration.

7.17. In some cases, contractors may be used to carry out all or some aspects of decommissioning. This is likely to occur when decommissioning is deferred or when specialized expertise is needed. Examples of such activities include the use of specific decontamination processes and dismantling/demolition activities. Appropriate levels of control, supervision and training should be provided to ensure safety, particularly when a large number of contractors is engaged.

7.18. All persons involved in decommissioning activities should be made familiar with the safety procedures for the safe and effective conduct of their duties. Specialized training may be needed in certain areas of work. For some activities, the use of mock-ups and models in training can improve efficiency and safety. Infrequently conducted activities may require planning.

7.19. Project specific training of staff should be commensurate with the size, complexity and nature of the decommissioning activities to be performed. Personnel should be competent to perform their assigned work safely. All project personnel who will perform decommissioning tasks should receive basic training in radiological protection and safety, and additionally specific training in:

(a) History of operation and characteristics of the facility to be dismantled;

(b) Description of the facility and zoning arrangement;

(c) Decommissioning procedures;

(d) Training in correct wearing of appropriate protective clothing and use of protective respiratory equipments (e.g., masks and pressurized suits);

(e) Radiation protection;

(f) Waste management; and

(g) Emergency preparedness.

PROJECT MANAGEMENT

7.20. The project management organizational structure should be described in an organization chart that describes how the organization of decommissioning and facility operation activities. The responsibilities, roles, authorities, and key personnel of the operating organization and the project management function should be clearly defined. The minimum qualifications for the key positions within the functional units should be established. Any decommissioning or safety oversight committees, especially in the case of a multi-facility site, should also be identified, including roles and responsibilities of each committee along with their authority.

7.21. A clear work breakdown structure (WBS) should be established for task management of the decommissioning project. The WBS should describe the project management hierarchy from top-level project description down to work packages and individual tasks and the reporting requirements to the project manager should be clearly specified.

7.22. The procedures for developing, approving, and controlling tasks, (e.g., work packages, permits and written procedures), should be documented in a project management manual with detailed descriptions of the responsibilities and the control mechanisms.

DOCUMENTATION AND RECORDKEEPING

7.23. The acquisition and retention of records and information relevant to the facility design, construction, operation, and site radiological conditions should be done throughout the lifetime of the facility. Experience in decommissioning indicates that a lack of attention to documentation and recordkeeping could result in a costly misallocation of resources and may present problems of safety. Accurate and relevant facility operating records should be kept to facilitate successful decommissioning. Records from the siting, design, construction, operation and shutdowns are essential to the planning of decommissioning. Although such

records need not be explicitly included in the decommissioning plan itself, the process of planning should review pertinent records to improve the adequacy and completeness of the decommissioning plan, and for regulatory body coordination with other involved government entities (e.g., if appropriate, consultations on environmental and archeological site history). During operations, records should be retained as appropriate to meet the needs of future decommissioning and as dictated by national requirements. Where long periods of storage are anticipated prior to final dismantlement and remediation, records should be periodically checked to confirm they are being preserved in a safe and retrievable media and format.

7.24. If required by the regulatory framework, the operating organization should periodically report to the regulatory authority detailing the radioactive waste inventory, transportation and disposal. Moreover, information such as radiological surveys, effluent and environmental monitoring and personnel monitoring data should be reported to the regulatory body, as required. At the completion of decommissioning, final decommissioning should be reported to document the end state of the facility, and references other documents. These documents should be prepared and archived in accordance with national regulations.

7.25. In the case of extended periods of safe enclosure (e.g., as might occur with the phased decommissioning of a particle accelerator), accurate and complete information relating to the location, configuration, quantities and types of radioactive materials remaining at the facility are essential and should be maintained during the safe storage period. For deferred decommissioning, the reports should specify the future maintenance and surveillance activities, as well as the means for the documentation and preservation of the results of these activities.

7.26. In the decommissioning phase, a system needs to be established to ensure that all records are maintained in accordance with the records retention requirements of the management system and the regulatory requirements throughout the entire project. These provisions should address adequate recordkeeping for the decommissioning activities including the nature and level of residual radioactivity, the decisions made and their rationale before and after decommissioning of the site, and information that verify that the release criteria have been met. Recordkeeping is particularly important where restrictions are imposed on the future use of sites.

SUBCONTRACTORS INVOLVEMENT

7.27. Decommissioning activities may involve additional organizations, including contractors and subcontractors who may not be familiar with the type of facility. Responsibilities and interfaces between the different organizations should be properly defined by the operating organization.

8. CONDUCT OF DECOMMISSIONING

8.1. Decommissioning conduct is the implementation of the decommissioning strategy and activities described in the final decommissioning plan. The conduct of decommissioning includes preparatory works related to decommissioning, as well as specific decommissioning tasks.

PREPARATION FOR DECOMMISSIONING

8.2. Depending on national circumstances, some of the preparatory works may already be performed during the transition phase as discussed in Section 5.

Removal of operational waste and residual material

8.3. Timely removal of the residual process material and operational radiological waste reduces the requirements for monitoring and surveillance and facilitates and increases space availability for decommissioning operations. Often space for waste and materials storage is very limited on medical, industrial and research sites and significant amounts of residual process material and operational radiological waste may be present in both planned and unplanned locations at the time of shutdown. These materials may be liquid, solid or gas and can give rise to hazards during decommissioning operations. The removal of these materials can be considered part of the transition to operation phase or part of decommissioning.

8.4. Residual material and operational radioactive waste should be removed from the facility prior to decommissioning, as the safety implications for some of the decommissioning tasks will be less onerous and the SSCs will be graded accordingly. If operational wastes or residual fluids remain, the safety assessment for the decommissioning tasks may be more complex and may make the decommissioning operations less efficient and increase doses to the operators.

8.5. Even when the bulk of the residual process material has been removed, a significant amount of radioactive contamination may remain in the process equipment. Preliminary clean-up or decontamination of process equipments may be performed during the transition phase.

8.6. Other issues, such as security, should be considered. For example, when it is not possible to remove the residual material from the facility, it is an option to move it to a designated storage area within the facility and downgrade the security in other areas of the facility. This may result in a significant cost reduction for the decommissioning project.

Site Characterization

8.7. Early in the planning stage for decommissioning, characterization surveys should be conducted to determine the inventories and locations of radioactive materials (e.g., sealed sources, radioactive liquids, irradiated and contaminated structures and components) at the facility. The characterization survey includes determination of the inventory and reviewing records completed during the operational phase. The characterization survey should include information on any remaining radioactive materials, operational radioactive wastes, chemical and hazardous materials at the facility.

8.8. The results of the characterization survey should be used as the basis and 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 which documents the information and data obtained during the characterization process. This characterization report should be made available for audits or inspections. This characterization report should be summarized or referenced in the decommissioning plan.

Operational/historical information of the facility

8.9. A baseline survey of the site, including information on radiological conditions, should ideally be performed prior to construction and commissioning of a new facility. This information can then be used to determine background conditions during the end state survey. For facilities for which a baseline survey has not been performed in the past, which is common for many medical, industrial and research facilities, data from analogous, non-impacted areas with similar characteristics should be used to provide baseline data.

8.10. For many simple facilities, the most useful historical data for characterization surveys is found in records of accidents and incidents in the workplace that have occurred during the lifetime of the facility. Such records often detail the adequacy of decontamination carried out at that time, and identify management techniques that may have been utilised to deal with fixed or non-readily removable contamination, such as application of paint or a concrete screed.

8.11. The historical information review should include capture of knowledge of the workers who have been employed throughout the lifetime of the facility, and may include contact with both existing and former employees. This data capture is especially important where historical records are either absent or inadequate.

Radiological characterization

8.12. Radiological characterization should be conducted to identify the inventory and location of the radioactive and other hazardous materials throughout the facility. The information collected by means of these surveys should be used as a basis for detailed planning of the decommissioning activities, including determination of the physical boundaries and possible interactions of the proposed decommissioning tasks. The facility may be a part of a larger facility, e.g., a hospital, university or research establishment. In this case, the physical boundaries for the decommissioning activities should also be clearly defined.

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

8.14. Adequate surveys should be conducted to determine the radionuclides, maximum and average dose rates, and contamination levels throughout the facility and, if appropriate, in the soil and sediments and ground and surface water. Contamination levels should be determined for the inner and outer surfaces of equipment and in the depth of structures, soil and sediments. Special surveys may be required to determine the penetration depth in concrete structures, soil and sediments and extent of contamination which is needed for the selection of

appropriate decommissioning techniques and methods. For completeness, contamination in shielded or self-shielded components, such as inside pipes and equipment should be determined.

8.15. Results of such surveys will assist in the preparation of radiation and contamination maps. Some of these results and maps may be available from surveys performed during the facility's operational period. However, such surveys may need to be updated to account for radiological decay and the in-growth of daughter products.

8.16. Radiological characterization data should include zone description (e.g., facility, environment, soil and sediment and ground and surface water), contamination and dose rate levels, chemical and physical forms of materials. The radioactive waste inventory, including waste that has both radionuclides and hazardous constituents, should be determined by type, waste category, processing status, location and radiological conditions. Characterization surveys should also identify adjacent uncontaminated zones. During decommissioning activities, special attention should be given to prevent cross contamination of such zones.

The following are special cases where care should be taken during characterization:

(a) Where unplanned shutdown occurred;

(b) Where radioactive waste was buried;

(c) With liquid or gaseous effluents or ponds/tanks which were utilized for storage or evaporation;

(d) Where previous decontamination/remediation occurred and facilities are reused; and

(e) Where underground or buried piping and liquid storage and drain collection systems existed.

Non-radiological characterization

8.17. For medical, research and some industrial facilities, the hazards associated with non-radiological materials may greatly outweigh any radiological hazards e.g., biological or chemical contaminants. The inventory of non-radiological hazardous materials should be conducted given due consideration prior to establishing the most appropriate decontamination and dismantling methods.

8.18. An inventory of all hazardous chemicals present in the facility should be conducted. Records of their presence should be maintained as part of the operational records program. Hazardous materials such as asbestos, mercury, volatile organic compounds (VOCs) and polychlorinated biphenyls (PCBs) require special consideration. Material which will move rapidly through the groundwater should be identified to prevent harm to the public and to the environment. Consideration should also be given to the compatibility of chemicals which are present or which may be introduced during decommissioning.

Non-radiological characterization of sites/facilities should cover:

(a) Inventory of site/facility by zone (e.g., chemical, composition and physical form and location);

(b) Prevailing environmental conditions of soil and sediment and ground and surface water;

(c) Non-radioactive waste inventory, type, waste description, processing status, location, and records; and

(d) Facility and site conditions that could give rise to occupational hazards or stresses, e.g., asbestos and dust forming materials.

8.19. A comprehensive list of all non-radiological hazardous materials should be compiled to include information on quantities, volumes, and physical and chemical properties. Consideration should be given to avoidance of the generation of wastes during decommissioning activities that will have mixed radiological and non-radiological properties, making them unsuitable for acceptance at the disposal facility.

Engineering evaluations (physical characterization)

8.20. The condition of various SSCs should be determined for decommissioning planning and for ensuring safety during decommissioning. The level and extent of engineering evaluations depend on:

(a) Condition of the SSCs;

(b) Extent of inspection and maintenance of SSCs;

(c) Safety functions or requirements of SSCs during decommissioning;

(d) Modifications needed for decommissioning, e.g., additional floor loading capability; and

(e) End state of decommissioning, e.g., reuse of building or structures versus demolition.

Assessment areas which should be covered include:

(a) Evaluation of building structures' integrity;

(b) Evaluation of required loading capabilities;

(c) Availability and adequacy of SSCs, e.g., alarm and communication systems, ventilation systems, and cranes;

(d) Adequacy and integrity of utilities required for decommissioning, e.g., electrical supply, effluent drainage systems, pressurized air, and breathing air; and

(e) Processes and utility interfaces with other facilities in the case of multi-facility sites.

8.21. The benefits of an engineering evaluation may identify significant safety issues that could impact decommissioning. Typical examples include:

(a) High activity sealed source equipment located in a basement room at the time of building construction with no means for removal; or

(b) Where decommissioning of equipment is to be made in a multi-storey building and there was no early planning for decommissioning. This failure to identify the complex engineering requirements to remove the source (e.g., removal of a lift from its shaft and use of specialized lifting equipment or the strengthening of a floor or use of spreader plates to distribute the weight loading during dismantling of equipment) can substantially increase the predicted cost estimate.

Facility modifications and decommissioning infrastructure

8.22. According to the decommissioning strategy to be implemented, establishment and/or modifications of infrastructure needed to facilitate immediate dismantling or, in some cases, to prepare the facility for deferred decommissioning should be carried out. Areas such as shielded radioactive source stores or bunkers for linear accelerators should be retained for

temporary storage of radioactive waste or the residues of dismantling operations where suitable storage arrangements are not already in existence.

For immediate dismantling, the main modifications may involve:

(a) Upgrade of SSCs that are important for ensuring safety during decommissioning, e.g., filtration and ventilation systems;

(b) Creation of buffer storage areas for equipment, materials and waste;

(c) Installation of additional monitoring equipment;

(d) Modification of existing or establishment of new waste processing facilities; and

(e) Establishment of new access routes for personnel and equipment to the facility.

For deferred dismantling, the main modifications may involve:

(a) Establishment or upgrade of static confinement system;

(b) Creation of storage areas for equipment, materials and waste; and

(c) Establishment of additional security measures.

8.23. The management system in place during operation should be reviewed and revised to ensure that all equipment necessary for safety is periodically monitored to detect any degradation and maintain its safety function. Some of this equipment will be available from the operational period of the facility but it should be assessed both for suitability in the changing circumstances of decommissioning and also for the extension of the period of use.

8.24. As part of this exercise in reviewing the required systems for decommissioning, it is vital to identify systems that are not required to support the decommissioning strategy so that the surveillance and maintenance carried out on these systems can cease and the operating organization will see a cost saving in this area.

DECOMMISSIONING TASKS

8.25. Decommissioning tasks may include isolation of equipment, dismantling, decontamination, demolition and soil remediation in the vicinity of the facility.

The objectives of these decommissioning tasks include:

(a) Reduction of potential onsite and offsite hazards during decommissioning activities;

(b) Reduction of exposure dose rates to permit manual or semi-remote dismantling and demolition;

(c) Re-classification of waste to a less hazardous and, possibly, a less expensive category;

(d) Volume reduction of waste for disposal;

(e) Salvage of equipment, materials or facilities permitting unrestricted use; and

(f) Reduction in decommissioning cost.

8.26. Supporting tasks that were conducted during facility operation and that will continue during the decommissioning could include waste processing, storage and disposal, environmental monitoring, surveillance and maintenance of equipment and systems.

Surveillance and maintenance of structures, systems and components

8.27. Maintenance of the safety related SSCs should be carried out both during the decommissioning phases and, if deferred decommissioning is the selected strategy, from shutdown until completion of decommissioning.

8.28. If activities for decontamination and dismantling are deferred in part or in whole for any reason, safety should be ensured through a proper surveillance and maintenance programme.

8.29. In a phased decommissioning, prior to placing a facility in a safe-store or surveillance and maintenance mode, the risk of potential incidents should be minimized. The following activities should continue to be performed during this phase and records of such activities should be kept:

(a) Maintenance of appropriate systems for physical protection commensurate with the security risk;

(b) Monitoring, surveillance and control, commensurate with the level of hazard; and

(c) Maintenance of SSCs, such as ventilation and containment systems, mechanical handling and monitoring equipment.

Selection and implementation of decommissioning techniques

8.30. Suitable decommissioning techniques should be established as part of decommissioning planning. For most medical, industrial and research facilities, decommissioning techniques typically should employ proven technologies and procedures. Facility and site specific features may require techniques to be developed but the aim should be to select proven techniques that are commercially available.

8.31. Viable techniques should be evaluated and considered in terms of applicability. New decommissioning techniques should be justified and demonstrated as capable of obtaining the desired outcome from both a performance and safety perspective. In this case, benefits can be taken from computer-based, as well as physical mock-ups to select decommissioning techniques, to evaluate options, to aid in its design and to train personnel.

8.32. SSCs for which little attention has been given or for which access is limited may have resulted in system degradation. Such systems present special consideration when decommissioning techniques are considered. Examples include liquid storage tanks and remote handling systems. Some possible problems associated with liquid storage tanks include difficulty in accessing, characterizing, retrieving sludge and tank clean-up.

8.33. Before any decommissioning technique is selected, an evaluation of its suitability should be conducted. The following factors may influence the suitability of the decommissioning techniques:

(a) Cost–benefit analysis comparing the radiological safety benefits and waste management benefits of the decommissioning technique with the expected costs;

(b) Potential impact on workers and the environment, e.g., giving preference to techniques that do not generate airborne radioactivity;

(c) Types and properties (e.g., size, shape, contamination limits and accessibility) of the equipment and structures to be dismantled;

(d) Decontamination factor and cutting rate likely to be achieved;

(e) Reliability of the dismantling equipment and tools and its simplicity to operate, decontaminate and maintain in operation;

(f) Compatibility of existing SSCs with decontamination solutions and processes to ensure they will not be degraded and become ineffective;

(g) Impact on adjacent systems and structures and on other work in progress;

(h) Methods available for controlling radiological and non-radiological hazardous materials;

(i) Availability of waste containers and the associated handling systems and routes for disposal; and

(j) Time and schedule constraints.

Decontamination and dismantling

8.34. Decontamination is the removal or reduction of radioactive contamination in or on materials, items, buildings and areas of a facility. Decontamination is usually performed using decontamination agents (e.g., liquid solutions, foam, and gel) The overall decontamination strategy should be optimized, taking into account the benefits which result from reduced public and worker exposures, the costs of the decontamination operation including treatment of generated wastes, and the costs saved by avoiding waste disposal costs.

8.35. Decontamination of buildings may be necessary after dismantling. A methodology has to be developed and implemented to remove the contamination using the appropriate tools according to the objective to be achieved. Decontamination may involve specific techniques, e.g., removal of a concrete layer using a hydraulic hammer, scabbler or other industrial demolition equipment.

8.36. Dismantling is one of the processes used during decommissioning. Dismantling may be aided at certain stages through the reduction in the need for radiological controls by means of the partial or total decontamination of the SSCs necessary to be dismantled. There are many well-proven techniques and methods available for dismantling including mechanical cutting, blasting and drilling. Further information on these technologies, as well as their advantages and disadvantages can be found in other IAEA publications.

8.37. Special tools and devices may be needed during the dismantling activities. In such cases, these tools and devices, together with the techniques for their operation and maintenance, should be tested in simulated conditions before their use. Maintenance and periodic testing of these tools and devices should be included in the design and deployment strategy for them. Dismantling of some facilities may require the use of remotely controlled equipment.

8.38. Dismantling has the potential for creating new hazards, and therefore, necessary steps should be taken to ensure safety during the operation [1]. In the dismantling strategy, provisions should be made for:

(a) Reduction in size of objects/components to facilitate their further management;

(b) Facilitating access to radiation sources or other radioactive material; and

(c) Segregation of contaminated components from less contaminated or not contaminated items, in order to reduce radiation hazards to workers and to minimize waste.

8.39. Decontamination and dismantling techniques should be chosen such that the protection of workers, the public and the environment is optimized. Before any decontamination and dismantling strategy is undertaken or techniques are selected, an evaluation of its effectiveness should be performed. This evaluation should include:

(a) Estimated doses to workers;

(b) Availability of facilities required for decontamination and their eventual decommissioning;

(c) Size and geometry of SSCs;

(d) Type and characteristics of the contamination;

(e) Consideration of the possible generation of aerosols;

(f) Target decontamination levels;

(g) Consideration of the likelihood that available techniques will achieve the target decontamination level on particular components;

(h) Ability to demonstrate by measurement that the target decontamination level has been reached;

(i) Any possible deleterious effect of decontamination on equipment and system integrity;

(j) Cost of the technique compared with the expected benefit;

(k) Estimate of the volume, nature, category and activity of any liquid or solid wastes that will be produced and how it can be minimized;

(l) Consideration of the compatibility of these wastes with existing treatment, conditioning, storage and disposal systems and discharge limits;

(m) Any possible onsite and offsite consequences as a result of decommissioning activities; and

(n) Non-radiological hazards (e.g., the toxicity of solvents used).

Demolition

8.40. Depending on the decommissioning endpoint, demolition of the building structure may need to be undertaken. In many cases, techniques deployed for decontamination, dismantling and clean-up are aimed at making the demolition of the building structure a non-radiological activity.

8.41. Where demolition of structures involves radioactively contaminated material, the safety considerations established previously for decommissioning activities should be applied. In such a case, specific techniques such as water spray or large containment systems should be implemented to reduce the impact on the environment.

8.42. Suitable segregation techniques should be employed when demolishing infrastructures with different levels of contamination, otherwise unnecessarily large volumes of contaminated waste will be generated. Before demolition commences, a campaign of sampling should be carried out to provide a comprehensive radiological characterization that will facilitate minimization of the volumes of radioactive waste.

8.43. Where infrastructures, walls or soil are contaminated, specialized demolition contractors should be appointed, who should carry out the work in full compliance with radiological protection requirements consistent with the national legislation. A prior radiological evaluation to determine the hazard level should be carried out to assess possible doses to the workers and releases to the environment.

8.44. During demolition, dust control techniques should be adopted to minimize the generation of dust and prevent its dispersion to adjacent areas and to the environment. Demolition operations should be supported by an air monitoring programme.

Waste and material management

8.45. Decommissioning invariably involves the generation of radioactive waste. In the course of decommissioning, waste may be generated in forms that are not typical of the types of materials and waste routinely handled during the operational phase of the facility.

8.46. The decommissioning project team should be made aware of and trained in the methods necessary to minimize the waste generated in the decommissioning tasks. The radiation exposure to workers and the public may vary according to the waste minimization strategy. An integrated approach should be used to balance waste minimization goals with the objective of optimizing protection.

8.47. For more complex decommissioning projects, it is important to have a detailed waste and material management plan that covers all anticipated waste and material categories [29]. Such a plan could be based on the operational waste management plan with provisions for additional waste categories associated with decommissioning activities. Some of the waste categories may require new disposal end points. Where space for waste storage is limited, the waste management plan should anticipate the time required for processing high volumes of waste to ensure it does not impact decommissioning activities or the operations of existing facilities at a multi-facility site. Operating organizations should ensure that the waste management plan, which is part of the decommissioning plan, is implemented and maintained.

8.48. Consideration should also be given to minimizing cross-contamination and the generation of waste including secondary waste. Appropriate techniques for decontamination, dismantling, clean-up, demolition and remediation should be applied and materials should be reused or recycled in order to minimize the amount of radioactive waste to be managed. If existing waste processing systems cannot cope with the waste generated during decommissioning in the volumes estimated, the construction of new waste processing and storage facilities should be considered. Waste and material should be segregated in accordance with applicable handling, processing, reuse and disposal options. Segregation is essential to optimize waste management and to reduce double handling.

8.49. The removal of materials from regulatory controls (i.e., clearance) should be accomplished in compliance with criteria established by the regulatory body. The waste management plan should identify these applicable clearance criteria and methodology for

clearance of material, as well as arrangements for segregating radiological, non-radiological and hazardous wastes. Part of the waste and materials arising during the decommissioning operations may be sufficiently low in activity concentration for clearance consideration. Clearance, (i.e., the removal of radioactive materials or radioactive objects within authorized practices from any further regulatory control by the regulatory body), may be granted by the regulatory body for the release of material from the practice [16]. Some waste may be suitable for disposal in conventional landfill sites, while some materials such as steel and concrete may be suitable for recycling or reuse.

8.50. The following factors should be considered in the development of the waste management plan:

(a) Origin, amount, category and nature of the waste;

(b) Generation of secondary waste and its minimization;

(c) Mixed waste and the presence of non-radiological hazardous materials, such as asbestos;

(d) Traceability;

(e) Availability of waste recycling or treatment plants, and storage and disposal facilities;

(f) Compliance to the Waste Acceptance Criteria (WAC) of disposal facilities and storage;

(g) Possibilities for removal of waste from the regulatory control regime (clearance);

(h) Possibilities for reuse and recycling of materials, equipment and buildings;

(i) Special requirements for the packaging and transportation of radioactive wastes, e.g., activated materials; and

(j) Potential impact of wastes on workers, the public and the environment.

8.51. Waste generated during decommissioning may require additional interim storage onsite. A separate authorization of such activities may be required from the regulatory body in order to permit such storage. The problems encountered in decommissioning most medical, industrial and research facilities can usually be resolved with proven decontamination and

dismantling technologies, allowing immediate facility release. Therefore, conversion of such a facility into a waste storage facility should not generally be necessary or appropriate.

8.52. Where disposal is considered and no suitable waste disposal sites are available, the following decommissioning options should be evaluated in the preparation of the decommissioning plan:

(a) Preparing and maintaining the facility in safe enclosure; or

(b) Dismantling the facility and storing the generated waste in appropriate temporary waste storage facilities.

8.53. Pre-disposal management of radioactive waste is provided in other IAEA Safety Standards Series publications [29]. Transport of radioactive waste offsite should conform to national regulations. Transport of radioactive material is provided in other IAEA Safety Standards Series publications [18].

Authorized discharges and environmental monitoring

8.54. Discharges to the environment must be appropriately monitored and authorized [13]. During decommissioning, radioactive and non-radioactive effluent may be generated. Discharge of effluents requires authorization of the regulatory body and control in compliance with appropriate national regulations. In general, the expected discharges of effluents should be less than during operation of the facility but may be different in form and in radionuclide composition.

8.55. Discharge authorizations require discharge and environmental monitoring to be performed. During the operational period, discharge points (e.g., stacks) for effluents and environmental monitoring are routinely used. Environmental monitoring may include the use of dosimetry to measure offsite dose and the periodic sampling of water, soil, vegetation to demonstrate compliance with regulatory requirements. The adequacy of the programmes should be evaluated to ensure compliance during the decommissioning. If determined to be insufficient, appropriate modifications should be performed. Guidance on the regulatory control of discharges of radioactive effluents to the environment is provided in IAEA safety standards [14][15][31][16].

8.56. For some medical, industrial and research facilities, there is no need for offsite radiological monitoring and in many countries, no regulatory requirement during normal operation to carry out offsite radiological monitoring. However, onsite monitoring is performed routinely as part of the identification and management of radiological hazards. The programme of onsite monitoring should be reviewed prior to commencement of decommissioning activities and should be modified to reflect the changes in work activities.

Soil and sediment and ground and surface water remediation

8.57. For complex sites, operations may cause contamination of soil, sediment, and ground and possibly, surface waters. Contamination may result from effluents, leakage from buildings, piping and liquid storage systems, incidents and waste burial. Remediation may be required in order to meet the facility's end state. Remediation may involve treatment of soil, sediment or liquids which are contaminated with both radiological and non-radiological hazardous chemicals. Guidance on the remediation process for areas affected by past activities and accidents is provided in other IAEA Safety Standards Series publications [10][11].

On–site inspections

8.58. The regulatory body should perform regulatory inspections during decommissioning to ensure compliance with safety requirements and license conditions and to ensure that the decommissioning activities are being conduct in accordance with the approved decommissioning plan [31]. A regulatory inspection plan should be developed and should be focused on:

(a) Physical condition of the facility, especially surveillance of the integrity and/or the availability of relevant SSCs including protective barriers;

(b) Adequacy of the operator's procedure for the control of each phase of decommissioning;

(c) Competencies of human resources and training;

(d) Execution of decontamination and dismantling activities (human performance);

(e) Ongoing verification of radiological condition and the residual radioactivity;

(f) Decommissioning records;

(g) Environmental monitoring, radiological monitoring and surveillance, including plans for radiation protection for workers and the public;

(h) Removal of radioactive material;

(i) Strategy for management of radioactive material and waste including radioactive waste;

(j) Non-conformities, events and related corrective actions; and

(k) Physical protection, safeguards and access control.

8.59. Appropriate actions (including enforcement action) should be taken whenever safety requirements and conditions for authorization are not met. When non-compliances are discovered, the actions required by the regulatory body should reflect the safety significance of the non-compliance. Serious cases should result in activities at the site being restricted or curtailed. Minor breaches may simply require remedial action.

Confirmatory and in-process survey

8.60. The regulatory body may opt to collect samples or perform in-process surveys during decommissioning inspection to provide independent validation whether certain release criteria have been achieved. Upon completion of decommissioning, the operating organization should conduct the final survey by collecting and analyzing samples or perform radiological surveys in accordance with the approved plan. The regulatory body should review the final radiological survey documentation and, if necessary, perform an independent confirmatory survey to ensure that the end state criteria have been met.

Physical Protection and Safeguards

8.61. Appropriate physical protection for the facility, commensurate with the associated threat, has to be maintained throughout decommissioning [1]. If the facility contains materials subject to safeguards during decommissioning, the operating organization must adhere to the national requirements and international agreements. Operating organizations should implement the necessary decommissioning activities in order to remove the physical protection and safeguards requirements, as soon as possible. Where security measures are necessary to prevent the unauthorized access of individuals and the unauthorized removal of radioactive material, both safety and security are to be approached in an integrated manner.

Emergency Preparedness

8.62. In addition to provisions for protection against normal exposures, the decommissioning plan should specify provisions for minimizing the occurrence and/or mitigating the consequences of credible accidents/incidents during the decommissioning process, e.g., fire, power failure, equipment failure and major spills of radioactive materials. Credible accident scenarios are identified by the safety assessment (see Section 5). If the accident/incident is of such a nature that an emergency response is required (intervention) other applicable IAEA safety standards should be invoked [10].

8.63. An appropriate programme for emergency planning, commensurate with the hazards, must be established and described in the decommissioning plan [1]. This programme should include situations involving unforeseen events. Such a program should be submitted with the decommissioning plan and is subject to approval by the regulatory body. The operating organizations should ensure that procedures are prepared for implementation in accordance with the emergency programme. Procedures should be in place to report any accidents/incidents significant to safety to the regulatory body in a timely manner. Personnel should be trained in emergency procedures, and provision should be made for regular testing and updating of these procedures by conducting exercises periodically. Guidance for emergency preparedness and response is provided in other IAEA Safety Standards Series publications [32] [33].

9. COMPLETION OF DECOMMISSIONING

9.1. Before completing decommissioning, the operating organization should address certain termination considerations which the regulatory body will evaluate in determining whether to terminate the facility's license and release the site for unrestricted or restricted use.

DEMONSTRATION OF THE ACHIEVEMENT OF THE END STATE CRITERIA

9.2. The regulator should require that a final status survey be conducted to demonstrate that the goals in the final decommissioning plan have been met and any additional requirements have been met ([1], para 3.8).

Final Radiological Survey

9.3. At the completion of decontamination and dismantling activities, a final radiological survey of the facility should be performed to demonstrate that the decommissioning

objectives in the final decommissioning plan have been fulfilled and that the facility meets the national regulatory framework criteria for residual radioactivity for restricted or unrestricted release. The design and implementation of the survey should be reviewed with the regulatory body during the planning period for the survey. The operating organization should develop procedures that describe the approach for conducting surveys and the activities for demonstrating compliance with the release requirements. These procedures should be submitted to the regulatory body for review. The survey may be carried out in phases, as decommissioning work is completed, to enable parts of the facility or site to be released from regulatory control prior to final site release.

9.4. The survey criteria established by the regulatory body should be in terms of measurable quantities that can readily be compared with field measurements and the results of sampling. The radionuclides present will influence the methods adopted.

9.5. Instruments used for the final radiological survey should be properly selected, maintained and calibrated to ensure quality of the data. Custody for samples collected for the final survey should be properly specified and maintained. The analytical laboratory used should be accredited with appropriate management systems and a quality control program to ensure analytical results are defensible.

9.6. The survey data should be documented in a final radiological survey report and submitted to the regulatory body for approval. The results of the survey will be a major portion of the final decommissioning reporting documents. An example of the content of the final radiological survey report is provided in Appendix IV.

INSPECTION BY THE REGULATORY BODY

9.7. The regulatory body needs to perform inspections of the remaining parts of the facility and the site being considered for release from regulatory control. This should include review of the final survey procedures performed, independent radiological survey and analysis of compliance with the release criteria for the site or review of the implementation of restrictions at the site.

9.8. When the objectives of the site release have been accomplished according to the defined end state, the regulatory body should formally notify the operating organization, other relevant competent authorities and interested parties of the decision to release the site from regulatory control. In the event of a decision for restricted use, the notification should specify

the restrictive measures and their associated time frames, and the entities responsible for the implementation, monitoring and regulatory control of these restrictions and of the release of the site for restricted use.

PREPARATION OF THE FINAL DECOMMISSIONING REPORT

9.9. After the completion of the planned decommissioning activities, a final decommissioning report, possibly consisting of several reports, has to be prepared and submitted to the regulatory body for review. Alternatively, as in the case of simple facilities, this final decommissioning report could be a summary of these reports. Appendix V provides an example of these documents. After successful completion of the decommissioning activities, the facility and the site can be released from regulatory control or incorporated into another regulated facility. At that point, the authorization or permit or decommissioning license, issued at the beginning of decommissioning, is terminated.

RECORD RETENTION SYSTEM

9.10. On completion of decommissioning, appropriate records should be retained as specified by the regulatory body. The records should include key decommissioning information such as confirmation of the completion of decommissioning in accordance with the approved plan, allowing either unrestricted or restricted reuse of the facility or site.

9.11. The decommissioning expertise and knowledge obtained during the implementation of the project should be preserved and relevant records and documentation kept (i.e., records relevant to the design, construction, operation and decommissioning processes) so that such information can be transferred to any supporting or successor operating organization.

9.12. The key records that should be retained for future use are the final decommissioning plan and its subsequent amendments and the final decommissioning report.

9.13. The regulatory body should specify a period for which the records associated with decommissioning are maintained.

9.14. If certain restrictions are placed on the license termination of the site or facility, the restrictions should be documented and established as part of the institutional controls so future uses of the site are not contrary to the restrictions. An example of such documentation is a land deed restriction.

CONTROL OVER THE FACILITY RELEASED WITH RESTRICTIONS

9.15. If waste remains onsite after completion of decommissioning activities, e.g., in interim storage, the site may be released partially or with restrictions, as described below.

9.16. If it would be necessary to apply restrictions on the use of, or access to, the remaining parts of the facility or site to achieve compliance with the appropriate release criteria, the regulatory body has to ensure that an appropriate mechanism is in place to demonstrate compliance with these restrictions. Specific restrictions should be established where necessary:

(a) To control the removal of material from the restricted site, if that material cannot be released from regulatory control; and

(b) To control the potential uses of a site or potential exposure pathways.

9.17. In the case of restricted release of the facility or site from the regulatory control, appropriate arrangements for continuous controls are needed to ensure the protection of human health and the environment. These controls are subject to approval by the regulatory body.

9.18. The responsibility for implementing and maintaining these controls has to be clearly assigned to an organization or institution. The program for the implementation of measures to comply with the remaining regulatory requirements and for the monitoring of this compliance has to be in place, as approved by the regulatory body.

9.19. A surveillance and maintenance plan for the area released with the restrictions should be prepared by the operating organization and subject to 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 implementation of the long-term surveillance and maintenance plan. The regulatory body should ensure there is a means for monitoring compliance with the long-term surveillance and maintenance requirements by the institutional control organizations.

9.20. A program for interim storage or the final disposal of the waste from the site should be prepared and approved by the regulatory body, defining the activities, schedule and the final waste destination. Assessment of the safety implications to workers, the public and the

environment due to the presence of the waste stored onsite should be performed. Based on this information, a revised or new, separate authorization, including requirements for the final decommissioning up to unrestricted release of the site should be issued for the waste storage facility, according to the applicable regulations.

LICENSE TERMINATION OR AMENDMENT AND FUTURE SITE REUSE

9.21. Prior to terminating the license, the regulatory body should coordinate with other regulatory bodies that have authority or responsibilities for other issues or aspects related to the site. In addition, public communication should be considered.

9.22. The regulatory body should verify or validate that the site meets the release criteria. In cases where the site or facility does not comply with the initially approved release criteria, a reassessment of the situation should be performed by the operating organization and presented to the regulatory body for review and approval. For unrestricted site release, the regulatory body should formally terminate the license and keep appropriate documentation on the decommissioning and license termination process. For restricted site release, the regulatory body should also evaluate and approve measures for institutional control, including maintenance and long-term surveillance and financial arrangements. Requirements for institutional controls may be included as an amended license or as part of a legally enforceable document.

9.23. If specific restrictions are required to be imposed upon future facility owners or facility users, these restrictions should be included in a legal document and such restriction should be enforceable.

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APPENDIX I: APPLICATION OF GRADED APPROACH TO DECOMMISSIONING PLANS

Content of plan	Simple	Intermediate	Complex
Introduction	Yes	Yes	Yes
Facility Description	Simple description of facility or source; Rarely should consider past incidents resulting in soil or structure contamination.	Description of facility including floor plan; Radiological history and current status; May involve some soil or structure contamination.	Description of facility, site, and location; Description of design and operation; Radiological history and current status.
Decommission Strategy	Immediate, often simple methodology using existing workers (with additional training); (Consider benefits of decay for short half-life radionuclides).	Prefer immediate but may require a deferred strategy; (Consider benefits of decay for short half-life radionuclides).	May require phased approach; must consider global site plan; (Consider benefits of decay for short half-life radionuclides).
Regulatory Requirements	Only limited requirements may be relevant.	Additional regulatory requirements than for a simple facility.	Comprehensive and extensive regulatory requirements; May require application for new regulatory authorization, e.g., for new waste routes.
Decommissioning Tasks			
A. Characterization	Small radiological inventory but non-radiological hazards may be greater than radiological hazard, e.g., biological or chemical hazards; Task usually completed by in-house staff.	Moderate inventory; May or may not involve contamination; Task usually completed by in-house staff.	Large or diverse inventory; Requires extensive characterization, usually necessitating survey and sample analysis; Often also requires survey external to the facility; May be carried out by in-house staff or external contractors.

Content of Plan	Simple	Intermediate	Complex
B. Source Removal	Some simple facilities only involve one or more sealed sources, although may also have an unsealed source inventory; Often easy to remove without resulting contamination.	Source removal may require manufacturer involvement and innovative engineering and additional radiation protection procedures; Consider transport and security requirements for large activity sources.	Source removal may require an extended period of planning, and utilise complex engineering procedures, requiring additional radiation protection; Consider transport and security arrangements.
Conduct of Decommissioning			
A. Decontamination	Often not required unless source leaked or unsealed sources have been in use; Decontamination usually carried out by existing in-house staff.	Often not needed for sealed sources unless leaking; Likely when unsealed sources have been in use; Decontamination usually carried out by existing in-house staff.	Often extensive contamination or activation of structures and equipment; May also require remediation of ground or decontamination of drains or ventilation systems.
B. Dismantling	Often not required.	Possible (e.g., fume hoods/glove box/ High Efficiency Particulate Air (HEPA) filtration cabinets).	Most likely for equipment and structures, e.g., hot cells and ventilation systems; Usually requires contractors to carry out task.
C. Demolition	Not required.	Possible (e.g., concrete shielding) although often not required.	Probable for concrete construction used in buildings and shielding; Demolition usually carried out by external contractors.
D. Compliance and Environmental Monitoring	Often not required or minimal requirement.	May be required but only for a short period/or for confirmation.	Often required over an extended time period during/post decommissioning and safe storage.
E. Surveillance and Maintenance of Items related to Safety	Usually not required or a very nominal requirement; Prescribed as part of a safety case.	Usually not required or only for a brief time period; Prescribed as part of a safety case.	Required especially when a deferred strategy is selected; Prescribed as part of a safety case.

Content of Plan	Simple	Intermediate	Complex
Safety Assessment	Often a fairly simple safety assessment required.	Moderate requirement, but can be more complex when original design drawings are unavailable for high activity sealed source removal.	Complex safety assessment to include dose modelling to assess the hazards; Requires regular updating as the decommissioning project progresses to reflect changes and revised conditions.
Management System	Usually an in-house project manager oversees the project; Regarding quality management, typically no additional requirement beyond quality assurance systems in place from operational phase.	May be in-house staff or an external contractor; Regarding quality management, modest additional quality assurance requirements may be needed.	Usually an experienced contractor is appointed to perform project management duties and oversee technical operations on behalf of the operating organization; The operating organization can only delegate the task and not the legal responsibility; The project typically involves close coordination of the work carried out by both in-house staff and external contractors; Regarding quality management, extensive additional quality assurance requirement; Close integration of in-house staff and contractors needed.
Environmental Impact Assessment	Usually not required, Some simple analysis needed; No environmental impact stated in decommissioning plan.	Often not required or only a nominal requirement may be necessary to demonstrate no or limited environmental impact.	Usually necessary to draft environmental impact assessment and to demonstrate the appropriate options and techniques have been selected.

Content of Plan	Simple	Intermediate	Complex
Emergency Planning	Nominal additional requirements; Often only required for a brief time period.	Modest additional requirement; Often applicable for only a short time period.	May be a complex set of arrangements depending on the number and nature of possible accident/incident scenarios.
Physical Protection and Safeguards	Often existing operational arrangements sufficient with minimal modification.	May require some additional security and safeguard arrangements as decommissioning proceeds.	Usually require new security/safeguards to be introduced as decommissioning proceeds; Often should review and revise arrangements at different phases of a staged or deferred strategy.
Final Radiological Survey Design	Usually a simple task to complete the survey, resulting in unrestricted use of the facility.	Complexity depends on the radionuclide inventory; A moderate survey requirement usually leads to final unrestricted release of the facility.	May require complex survey and sampling to satisfy the regulator that decommissioning end points have been achieved; On rare occasions, may result in restricted release of the facility from regulatory controls.

APPENDIX II: EXAMPLE OF CONTENT OF A FINAL DECOMMISSIONING PLAN FOR A SIMPLE FACILITY

For facilities involving small radiation applications, the decommissioning plan should be relatively simple and provide a logical and adequate justification for the proposed decommissioning strategy [1, 2, 3, and 4]. The decommissioning activities should include facility characterization, disassembly of equipment and removal of materials and radiation sources from the facility to an appropriate location, radiation monitoring, quality assurance, final radiation survey and documentation.

1. INTRODUCTION

2. FACILITY DESCRIPTION

    2.1. Site location and description of the site and facility

    2.2. Building, systems and equipment description

    2.3. Facility and site radiological characterization

    2.4. Facility operational history

3. DECOMMISSIONING STRATEGY

    3.1. Objectives

    3.2. Decommissioning strategies

    3.3. Selection and justification of preferred strategy

4. DECOMMISSIONING MANAGEMENT

    4.1. Management system

    4.2. Safety management

    4.3. Organizational and administrative controls

    4.4. Staffing and qualification

    4.5. Project management

4.6. Quality management

4.7. Documentation and recordkeeping

4.8. Contractors involvement

4.9. Decommissioning schedule

5. CONDUCT OF DECOMMISSIONING

5.1. Contaminated structures, systems and equipment

5.2. Surface and subsurface soil and sediment

5.3. Ground and surface water

5.4. Decontamination and dismantling techniques and technologies

5.5. Surveillance and maintenance

6. WASTE MANGEMENT PROGRAMME

6.1. Identification of waste streams

6.2. Solid radioactive waste

6.3. Liquid radioactive waste

6.4. Waste containing both radionuclides and other hazardous material

6.5. Clearance

7. COST ESTIMATE

8. RADIATION PROTECTION

9. SAFETY ASSESSMENT

9.1. Identification of hazards and initiating events

9.2. Evaluation of occupational and public exposure during decommissioning

9.3. Evaluation of potential exposure

10. FINAL SURVEY DESIGN

    10.1. Map or drawing of the area to be surveyed

    10.2. Sampling parameters

    10.3. Background/baseline levels

    10.4. Types of Equipment, instruments, techniques and procedures

    10.5. Methodology for evaluating the survey results

    10.6. Records that will be maintained

    10.7. Release guidelines established

11. SUMMARY

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APPENDIX III: EXAMPLE OF CONTENT OF A FINAL DECOMMISSIONING PLAN FOR A COMPLEX FACILITY

The following list of elements of a final decommissioning plan for a relatively complex facility has been developed based on several reference publications: Ref [1, 2, 3, and 4]. Some of these elements (e.g., safety assessment and environmental impact assessment) are usually incorporated into the decommissioning plan by reference and a short summary is provided in the decommissioning plan.

1. INTRODUCTION

2. FACILITY DESCRIPTION

    2.1. Site location and description of the site and facility

    2.2. Building, systems and equipment description

    2.3. Facility and site radiological characterization

    2.4. Facility operational history

3. DECOMMISSIONING STRATEGY

    3.1. Objectives

    3.2. Decommissioning strategies

    3.3. Selection and justification of preferred strategy

4. DECOMMISSIONING MANAGEMENT

    4.1. Management system

    4.2. Safety management

    4.3. Organizational and administrative controls

    4.4. Staffing and qualification

    4.5. Project management

4.6. Quality management

4.7. Documentation and recordkeeping

4.8. Contractors involvement

4.9. Decommissioning schedule

5. CONDUCT OF DECOMMISSIONING

5.1. Contaminated structures, systems and equipment

5.2. Surface and subsurface soil and sediment

5.3. Ground and surface water

5.4. Decontamination and dismantling techniques and technologies

5.5. Surveillance and maintenance

6. WASTE MANGEMENT PROGRAMME

6.1. Identification of waste streams

6.2. Solid radioactive waste

6.3. Liquid radioactive waste

6.4. Waste containing both radionuclides and other hazardous material

6.5. Clearance

7. COST ESTIMATE

8. RADIATION PROTECTION

9. SAFETY ASSESSMENT

9.1. Identification of hazards and initiating events

9.2. Evaluation of occupational and public exposure during decommissioning

9.3. Evaluation of potential exposure

10. ENVIRONMENTAL IMPACT ASSESSMENT

11. EMERGENCY PLANNING

12. PHYSICAL PROTECTION AND SAFEGUARDS

13. FINAL SURVEY DESIGN

    13.1. Map or drawing of the area to be surveyed

    13.2. Sampling parameters

    13.3. Background/baseline levels

    13.4. Types of equipment, instruments, techniques and procedures

    13.5. Methodology for evaluating the survey results

    13.6. Records that will be maintained

    13.7. Release guidelines established

14. SUMMARY

REFERENCES

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Decommissioning of Nuclear Power Plants and Research Reactors, IAEA Safety Standards Series No. WS-G-2.1, IAEA, Vienna (1999).

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[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Standard Format and Content for Safety Related Decommissioning Documents, IAEA Safety Report No. 45, IAEA, Vienna (2005).

[8] NUCLEAR ENERGY AGENCY, Achieving the Goals of the Decommissioning Safety Case, Working Party on Decommissioning and Dismantling (WPDD) 3, (2005).

APPENDIX IV: EXAMPLE OF THE CONTENTS OF THE FINAL RADIOLOGICAL SURVEY REPORT

The final radiological survey report presents the final conditions at the facility and the site at the conclusion of the physical decommissioning activities. The report is a part of the final decommissioning reporting documentation and includes the final radiological survey plan.

The final radiological survey report includes:

1. Final Radiological Survey Plan

    1.1. Location of the facility

    1.2. Type of facility

    1.3. Site and facility description such as facilities, buildings, and any remaining subsurface structures that have been included in the final survey and facilities remaining in operations and their interdependencies

    1.4. Survey design justification based on:

        1.4.1. Initial radiological characterization including background levels

        1.4.2. Site radiological characterization information including additional sampling, as necessary

        1.4.3. Identification of potential contaminant sources

        1.4.4. Locations including significant ratios between radionuclides (radiological characterization)

        1.4.5. Survey areas including their classification

    1.5. Survey design details including:

        1.5.1. Types of surveys

        1.5.2. Type of instrumentation, techniques for use and their sensitivity

        1.5.3. Sample plan (e.g., map, type and number of measurements and analyses performed)

        1.5.4. Procedures for recording measured data and analytical results

        1.5.5. Procedures for data evaluation, comparison with established guidelines, and reporting consistent with national regulatory framework

        1.5.6. Quality assurance

2. Conduct of Survey and Survey Results

2.1. Summary of survey including changes from the Final Radiological Survey Plan

2.2. Sampling performed (e.g., map, type and number of measurements and analyses performed)

2.3. Measured data and analytical results

2.4. Data evaluation, comparison with established guidelines, and reporting consistent with national regulatory framework

2.5. Quality assurance

3. Summary and Conclusion

3.1. Concise description of the final radiological situation at the facility including any areas that were not surveyed

3.2. Identification of all areas, systems and components that can be released for unrestricted use

3.3. Description of any institutional controls that will be required for any areas that have not been released including overview drawings and maps

REFERENCES

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

APPENDIX V: EXAMPLE OF THE CONTENTS OF THE FINAL DECOMMISSIONING REPORTING DOCUMENTS

These final decommissioning reporting documents could include:

1. Final decommissioning plan, updates and any related authorizations
   (including decommissioning safety assessments and decommissioning environmental impact assessments and their updates)

2. Final radiological survey report
   (for restricted use, list of designated structures, areas and equipment and description of restrictions and eventual removal of controls, if applicable)

3. Radiation exposure documentation; and

4. Waste management documentation.

ANNEX ONE: LIST OF GROUPING OF FACILITIES BASED ON THE LEVEL OF HAZARD

Level of Hazard → Type of facility ↓	Simple	Intermediate	High
Medical	- Radio-immune assay laboratory - Radiotracer laboratory - Linear accelerator - Mobile diagnostic unit - Nuclear medicine clinic without Radio-pharmacy - Remote after-loading unit	- Blood irradiator - Gamma knife - Nuclear medicine department with radiopharmacy - Radiotherapy department - Large hospital facility with cancer unit and a cyclotron	
Industrial	- Radiotracer unit - Sealed source used in crop harvesting - Portable instruments, e.g., moisture density gauges or chemical detectors - Fixed gauges, e.g., level, thickness or flow measurements - Industrial radiography - Well-logging - Radiochemistry labs - Irradiation of gem stones - Lightning conductors	- Small irradiator - Radioactive waste treatment facility for low level waste -Manufacture and maintenance facilities for luminescent control panels for aeroplanes - Military equipment	- Medical isotope production facility - Large industrial irradiator - Radiochemical manufacturing and research and development facility (hot cells) - Source manufacturing facility including source encapsulation in hot cells and recycling - A large facility with many diverse uses of sealed and unsealed radionuclides
Academic and Research	- Chemistry or physics laboratory - Cell labelling unit - Small scale agricultural field trials	- Animal research facility - Laboratory with glove boxes - Particle accelerator facility with research and development laboratories - Nuclear research laboratory with hot cells	

ANNEX TWO: A SUGGESTED APPROACH FOR COUNTRIES WITHOUT A STRATEGY, POLICY, AND LEGAL AND REGULATORY FRAMEWORK FOR DECOMMISSIONING OF MEDICAL, INDUSTRIAL AND RESEARCH FACILITIES

In some cases, the national policy and strategy for decommissioning of simple facilities may not be established. The regulatory body should develop a framework to safely decommission these facilities.

THE LEGAL AND REGULATORY FRAMEWORK

The regulatory framework of a country should include provision for safe decommissioning of facilities where radioactive materials and sources are produced, received, used and stored [2]. If a regulatory framework for decommissioning is not in place, decommissioning activities should be planned and managed on a case by case basis in consultation with the regulatory body. In such cases, the operating organization should consult the regulatory body on the development and implementation of the decommissioning plan. Decommissioning activities should be regulated and enforced.

Decommissioning should be included in each Member State's national legal framework as an important part of the overall nuclear and radiation safety program. Infrastructures should be established within such legal framework that provides a government entity with legal authority, defines organizational structure, and delineates roles and responsibilities for both the government entity and the private organization conducting decommissioning. Other national laws and regulations that may impact the decommissioning process include the following:

(a) Radiation and environmental protection;

(b) Waste management;

(c) Transport of radioactive material;

(d) Release and clearance criteria; and

(e) Management system requirements.

Regulations should contain provisions for a comprehensive decommissioning program including requirements for initial planning, routine update, conducting decommissioning activities, and final release of a facility from regulatory control.

The regulations should make regulatory provisions for specific release criteria (non-restricted release and restricted release) and the termination process of a site for unrestricted or restricted use. The regulatory framework should also provide the basis for establishing any restrictions that may be placed upon the use of, or access to, the site before, during and, if necessary, after completion of decommissioning.

For restricted release, credible and acceptable timeframes for institutional control that could be considered in the formulation and implementation of decommissioning should be defined within the legal framework.

To ensure success and timely decommissioning of facilities, additional requirements such as financial assurance need to be ensured within the legal framework in order that adequate funding mechanisms are available and that responsibilities are assigned for the financing of decommissioning, clean-up activities, including surveillance and maintenance of restrictive measures. Adequate financial assurance for decommissioning should be required for all facilities where radioactive materials are involved to ensure safe and timely decommissioning.

There should be legal provision for the regulatory body to review and approve the proposed activities as part of the decommissioning plan, its supporting documents, and analysis that are developed by the operating organization responsible for implementing the decommissioning project. The type of documents and analysis that are required in support of the decommissioning should be discussed and provided in guidance so there is a clear expectation.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Planning and Management for the Decommissioning of Research Reactors and Other Small Nuclear Facilities, Technical Reports Series No. 351, IAEA, Vienna (1993).

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CONTRIBUTORS TO DRAFTING AND REVIEW

Batandjieva, B.	International Atomic Energy Agency
Chang, L.	US Nuclear Regulatory Commission, United States of America
Griffiths, C.	Consultant, United Kingdom
Jova Sed, L.	Consultant, Cuba
Ljubenov V.	International Atomic Energy Agency
O'Donnell, P.	International Atomic Energy Agency
Rowat, J.	International Atomic Energy Agency
Visagie, A.	South African Nuclear Energy Corporation, South Africa
Watson, B.	US Nuclear Regulatory Commission, United States of America
Wong, M.	International Atomic Energy Agency

BODIES FOR THE ENDORSEMENT OF SAFETY STANDARDS

Commission on Safety Standards

Nuclear Safety Standards Committee

Radiation Safety Standards Committee

Transport Safety Standards Committee

Waste Safety Standards Committee