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IAEA SAFETY STANDARDS SERIES

Decommissioning of Medical, Industrial and Research Facilities

SAFETY GUIDE

No. WS-G-2.2

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

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IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

The regulatory related publications by means of which the IAEA establishes safety standards and measures are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (that is, of relevance in two or more of the four areas), and the categories within it are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides.**

Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

Safety Requirements (red lettering) establish the requirements that must be met to ensure safety. These requirements, which are expressed as 'shall' statements, are governed by the objectives and principles presented in the Safety Fundamentals.

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Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

or on request to the Safety Co-ordination Section, IAEA, P.O. Box 100, A-1400 Vienna, Austria.

OTHER SAFETY RELATED PUBLICATIONS

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

Reports on safety and protection in nuclear activities are issued in other series, in particular the **IAEA Safety Reports Series**, as informational publications. Safety Reports may describe good practices and give practical examples and detailed methods that can be used to meet safety requirements. They do not establish requirements or make recommendations.

Other IAEA series that include safety related sales publications are the **Technical Reports Series,** the **Radiological Assessment Reports Series** and the **INSAG Series**. The IAEA also issues reports on radiological accidents and other special sales publications. Unpriced safety related publications are issued in the **TECDOC Series**, the **Provisional Safety Standards Series**, the **Training Course Series,** the **IAEA Services Series** and the **Computer Manual Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**.

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

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FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of nuclear energy.

The following advisory bodies oversee the development of safety standards: the Advisory Commission on Safety Standards (ACSS); the Nuclear Safety Standards Advisory Committee (NUSSAC); the Radiation Safety Standards Advisory Committee (RASSAC); the Transport Safety Standards Advisory Committee (TRANSSAC); and the Waste Safety Standards Advisory Committee (WASSAC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed by experts on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA. Non-radiological aspects of industrial safety and environmental protection are also not

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explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

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PREFACE

Radioactive waste is produced in the generation of nuclear power and the use of radioactive materials in industry, research and medicine. The importance of the safe management of radioactive waste for the protection of human health and the environment has long been recognized, and considerable experience has been gained in this field.

The IAEA's Radioactive Waste Safety Standards Programme aimed at establishing a coherent and comprehensive set of principles and requirements for the safe management of waste and formulating the guidelines necessary for their application. This is accomplished within the IAEA Safety Standards Series in an internally consistent set of publications that reflect an international consensus. The publications will provide Member States with a comprehensive series of internationally agreed publications to assist in the derivation of, and to complement, national criteria, standards and practices.

The Safety Standards Series consists of three categories of publications: Safety Fundamentals, Safety Requirements and Safety Guides. With respect to the Radioactive Waste Safety Standards Programme, the set of publications is currently undergoing review to ensure a harmonized approach throughout the Safety Standards Series.

This Safety Guide addresses the subject of decommissioning of medical, industrial and research facilities where radioactive materials and sources are produced, received, used and stored. It is intended to provide guidance to national authorities and operating organizations, particularly to those in developing countries (as such facilities are predominant in these countries), for the planning and safe management of the decommissioning of such facilities.

The Safety Guide has been prepared through a series of Consultants meetings and a Technical Committee meeting.

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EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

This publication has been superseded by SSG-49.

CONTENTS

1. INTRODUCTION 1

Background (1.1–1.3) 1
Objective (1.4) 1
Scope (1.5–1.8) 1
Structure (1.9) 2

2. KEY ISSUES SPECIFIC TO DECOMMISSIONING 3

General (2.1–2.4) 3
Responsibilities (2.5) 3
Regulatory framework (2.6–2.7) 4
Safety (2.8–2.10) 4
Radiation protection considerations (2.11–2.13) 4
Waste management (2.14) 5

3. DECOMMISSIONING OPTIONS (3.1–3.5) 5

4. FACILITATING DECOMMISSIONING (4.1–4.4) 7

5. PLANNING AND SAFETY ASSESSMENT FOR DECOMMISSIONING 8

General (5.1–5.4) 8
Initial planning (5.5) 8
Ongoing planning (5.6) 10
Final planning (5.7–5.8) 10
Safety assessment for decommissioning (5.9) 11

6. CRITICAL TASKS OF DECOMMISSIONING 11

Characterization of the facility (6.1–6.6) 11
Source removal (6.7–6.8) 12
Decontamination (6.9–6.12) 13
Dismantling (6.13–6.16) 14
Final radiation survey (6.17) 14

7. MANAGEMENT DURING DECOMMISSIONING 15

This publication has been superseded by SSG-49.

Staffing and training (7.1–7.2) 15
Organization and administrative control (7.3–7.4) 15
Radiation protection (7.5–7.14) 15
On- and off-site monitoring (7.15) 17
Waste management (7.16–7.25) 17
Emergency planning (7.26–7.27) 19
Physical protection (7.28–7.29) 19
Quality assurance (7.30–7.31) 19

8. COMPLETION OF DECOMMISSIONING (8.1–8.3) 20

REFERENCES 22

ANNEX I: EXAMPLE OF THE CONTENTS OF A DECOMMISSIONING PLAN 25

ANNEX II: SAFETY ASSESSMENT SPECIFIC FOR DECOMMISSIONING 29

ANNEX III: EXAMPLE OF THE CONTENTS OF A FINAL RADIATION SURVEY REPORT 31

REFERENCES TO ANNEXES 33

CONTRIBUTORS TO DRAFTING AND REVIEW 35

ADVISORY BODIES FOR THE ENDORSEMENT OF SAFETY STANDARDS 37

This publication has been superseded by SSG-49.

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide is part of a set of publications prepared within the framework of the IAEA Radioactive Waste Safety Standards Programme, which addresses all the important areas of radioactive waste safety. This set includes Safety Fundamentals [1], Safety Requirements and Safety Guides in the IAEA Safety Standards Series.

1.2. Safety requirements for decommissioning of medical, industrial and research facilities are addressed in the Safety Requirements: Predisposal Management of Radioactive Waste Including Decommissioning [2]. Additional safety requirements are provided in other relevant IAEA Safety Standards [3, 4].

1.3. Many countries have facilities using radioactive materials and sources in a variety of medical, industrial and research applications. These facilities will need decommissioning at some stage, either at the end of their useful life or when they are no longer required. Guidance is therefore required for the safe management of the decommissioning of such facilities.

OBJECTIVE

1.4. The objective of this Safety Guide is to provide guidance to national authorities, including regulatory bodies, and operators to ensure that the decommissioning process for medical, industrial and research facilities where radioactive materials and sources are produced, received, used and stored is managed in a safe and environmentally acceptable manner.

SCOPE

1.5. This Safety Guide covers all aspects of the decommissioning of medical, industrial and research facilities where radioactive materials and sources are produced, received, used and stored. These facilities include:

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

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(b) industrial facilities, such as those producing radioisotopes, using irradiation and radiography devices, 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 those associated with the nuclear industry, pharmaceutics and medicine;
(d) teaching and research laboratories in universities and schools; and
(e) chemical processing facilities for ores with significant levels of natural radioactivity other than uranium and thorium ores.

1.6. This Safety Guide addresses the radiological hazards associated with decommissioning of the facility and the management of wastes and materials arising from the decommissioning operations.

1.7. Non-radiological hazards, such as those due to potential fire sources or resulting from the release of asbestos materials, can also arise during decommissioning activities. This Safety Guide, however, does not explicitly address these hazards, but it is important that they should be given due consideration during the planning process.

1.8. This Safety Guide is not applicable to fuel cycle facilities, nuclear power plants or research reactors. Guidance for decommissioning of nuclear power plants and research reactors is provided in Ref. [5].

STRUCTURE

1.9. Key issues specific to decommissioning, such as purpose and time-frame, responsibilities of the operator, regulatory framework, safety issues, radiation protection and waste management aspects, are outlined in Section 2. Options for decommissioning and criteria for selection of an option are discussed in Section 3. The approaches for facilitating decommissioning in initial facility design and any subsequent modifications are reviewed in Section 4. Section 5 addresses planning for decommissioning and safety assessment considerations. Critical decommissioning tasks, such as radiological and non-radiological hazards survey, source identification and removal, decontamination and dismantling strategies, and final radiation survey, are reviewed in Section 6. Management issues such as staffing, training, organization, radiation protection aspects of workers and the public, operational radiation monitoring and waste management are discussed in Section 7. Section 8 outlines the contents of the final decommissioning report and the importance of maintaining appropriate records. An example of the contents of a decommissioning plan is provided in Annex I. Safety assessment considerations are detailed in Annex II. An

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example of the contents of a final radiation survey report is discussed in Annex III. A list of references is also included.

2. KEY ISSUES SPECIFIC TO DECOMMISSIONING

GENERAL

2.1. The term decommissioning refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a nuclear facility (except for a repository, which is closed and not decommissioned). 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 preplanning and assessment to ensure safety during decommissioning operations.

2.2. Subject to national and regulatory requirements, some facilities may also be considered to be decommissioned if they are incorporated into an existing or new facility which is or will be under regulatory control. This could apply where the facility to be decommissioned is located on a site with other facilities, including where the whole site is still under regulatory control.

2.3. The time period required to achieve decommissioning will depend on the type of facility, the radionuclide inventory, the chosen decommissioning approach and the techniques employed. It will typically range from a few weeks in the case of some small laboratories to a few years for some large research facilities.

2.4. Decommissioning gives rise to issues which are in some respect different from the ones prevailing during the operation of the facility. These issues need to be considered in an appropriate way to ensure the overall safety of decommissioning activities.

RESPONSIBILITIES

2.5. The operator should establish and maintain a decommissioning plan commensurate with the type and status of the facility [2]. The operator of the facility is ultimately responsible for the safety of the facility during the decommissioning operations.

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REGULATORY FRAMEWORK

2.6. 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 operator should consult the regulatory body in the development and implementation of the decommissioning plan.

2.7. National regulatory authorities should provide guidance on radiological criteria for the removal of materials, facilities and sites from regulatory control.

SAFETY

2.8. During all phases of decommissioning, workers, the public and the environment should be properly protected from hazards resulting from the decommissioning activities. A thorough safety assessment of the hazards involved during decommissioning (including accident analysis, where necessary) should be conducted to define protective measures, part of a defence in depth system that takes into account the specifics of decommissioning. In some cases, such measures may be different from those in place during the operation of the facility.

2.9. Decommissioning of nuclear facilities often involves the removal, at an early stage, of significant quantities of radioactive material, including sources and operational waste. Even after this step, the total contamination and activation of the facility has to be taken into account in the safety assessment.

2.10. Activities such as decontamination and the progressive dismantling or removal of some existing safety systems are also of importance. These activities have the potential for creating new hazards. An important objective during decommissioning is, therefore, that the safety aspects of such activities are adequately assessed and managed so as to minimize the impact on safety.

RADIATION PROTECTION CONSIDERATIONS

2.11. In the course of decommissioning, consideration should be given to the radiation protection of both workers engaged in the decommissioning operations and the public who may be exposed to radiation from discharges to the environment, from

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the release of solid materials, and as a result of any subsequent occupancy of the decommissioned site.

2.12. National radiation protection requirements should be established with due regard for the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) and the recommendations of the International Commission on Radiological Protection [3, 6].

2.13. Guidance on the regulatory control of radioactive discharges to the environment has also been developed in the IAEA Safety Standards Series and is relevant for the planning of decommissioning operations [7].

WASTE MANAGEMENT

2.14. Decommissioning invariably involves the generation of radioactive waste which may be different from normal operational waste. Generation of radioactive waste from the decommissioning process should, subject to safety considerations, be kept to the minimum practicable [1]. For example, appropriate decontamination and dismantling techniques and the reuse or recycling of materials can reduce the waste inventory. The necessary waste management systems, including storage and/or disposal facilities, should be established to cope with the decommissioning waste before starting decommissioning activities.

3. DECOMMISSIONING OPTIONS

3.1. The following decommissioning options should be considered individually or in combination:

(a) immediate decommissioning, i.e. prompt removal of all radioactive materials from the facility to a predesignated place;
(b) delayed decommissioning to take advantage of the natural decay of radionuclides. Controlled access to the radioactive areas may be permitted 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; and
(c) phased decommissioning with periods of deferral between active decommissioning phases. In this option, decommissioning is performed in stages to allow time for:

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— allocation of necessary resources;
— provision for adequate waste management capacity; and
— resolution of technical issues.

3.2. The selected option should be justified by developing the decommissioning plan in compliance with safety requirements. The selection of a preferred decommissioning option should be made by analysing components such as:

(a) compliance with laws, regulations and standards which should be applied during decommissioning;
(b) characterization of the facility, including the design and operational history as well as the radiological inventory after final shutdown and how this changes with time;
(c) the associated radiological and non-radiological hazards;
(d) the physical status of the nuclear facility and its evolution with time, including, if applicable, an assessment of the integrity of buildings, structures and systems for the anticipated duration of the deferred dismantling;
(e) adequate arrangements for waste management, such as storage and disposal;
(f) adequacy and availability of financial resources required for the safe implementation of the decommissioning option;
(g) availability of experienced personnel and proven techniques, including decontamination, cutting and dismantling, as well as remote operating capabilities;
(h) lessons learned from previous, similar decommissioning projects;
(i) the environmental and socioeconomic impact, including public concerns about the proposed decommissioning activities; and
(j) the anticipated development and use of the facility and the area adjacent to the site.

This list contains many issues which have greater or lesser significance, dependent on the specific circumstances for decommissioning in each country. To aid in the development of options, a number of these components are further developed in the paragraphs below.

3.3. For the facilities being considered in this Safety Guide, consideration of the above factors should generally lead to immediate decommissioning, i.e. dismantling of the facility and removal of all radioactive materials after shutdown or within a short period, as appropriate, to allow for decay. However, in some cases, e.g. decommissioning of more complex radioisotope manufacturing facilities, other options should be considered.

3.4. The problems encountered in decommissioning most medical, industrial and research facilities can usually be resolved with proven decontamination and

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dismantling technologies, allowing immediate site release. Therefore, conversion of such a facility into a disposal facility will not generally be necessary or appropriate.

3.5. If phased decommissioning is selected, the guidance given in Ref. [5] is relevant.

4. FACILITATING DECOMMISSIONING

4.1. The initial facility design and any subsequent modifications should include consideration of future decommissioning requirements [2, 8]. Reference [9] summarizes the worldwide experience gained through various decommissioning projects. This information may be useful in optimizing the design and operation of the facility to ease decommissioning.

4.2. Examples of how decommissioning needs can be incorporated at the design stage include:

(a) the use of smooth, seamless and non-absorbent work surfaces and flooring, and/or removable or strippable coatings in areas likely to become contaminated;
(b) provision for easy access to areas of the facility and to equipment to facilitate decontamination and dismantling;
(c) provision for adequate access for the manipulation of decontamination and dismantling equipment;
(d) provision for in situ decontamination of pipes, ducts, tanks, etc., with the design of such networks so as to avoid areas where contamination can become entrapped;
(e) careful selection of materials for use in areas where activation can occur, such as in particle accelerators;
(f) proper ventilation and drainage systems to prevent or control the spread of contamination during operations and decommissioning; and
(g) consideration of lessons learned from previous decommissioning activities.

4.3. Although the above mentioned design considerations can significantly ease the decommissioning process, proper control of operations is also important so that spills, accidents and other events which could lead to significant contamination are minimized.

4.4. After commissioning of the facility, a records retention system should be established to contain the following:

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(a) pre-operational and relevant operational environmental and radiological data;
(b) operational history including any spills/accidents and their remediation; and
(c) details of significant modifications to the facility and its components, including relevant facility drawings.

5. PLANNING AND SAFETY ASSESSMENT FOR DECOMMISSIONING

GENERAL

5.1. A decommissioning plan shall be developed for each nuclear facility to show that decommissioning can be accomplished safely [2]. The plan should also take into account the radiological conditions of the facility and its complexity.

5.2. An example of the contents of a decommissioning plan for a relatively complex facility, based on Ref. [9], is presented in Annex I. Plans for smaller or less complex facilities may require a simpler, less comprehensive plan.

5.3. Flow charts for a typical decommissioning project are presented in Figs 1 and 2. Important components of the decommissioning project are described in the following paragraphs and sections.

5.4. Decommissioning planning comprises three phases: initial, ongoing and final. Detailed considerations applicable to these phases are given in an IAEA publication [5]. Although the components of these plans for each phase will be common, the level of detail will increase as the plan moves towards finalization and implementation.

INITIAL PLANNING

5.5. An initial decommissioning plan should be prepared and submitted by the operator in support of the licence application for the construction of the facility. For facilities where the initial decommissioning plan has not yet been prepared, it should be prepared without undue delay. The initial decommissioning plan need not be elaborate. The plan should describe the preferred decommissioning option and address the feasibility of safely decommissioning the facility using currently available

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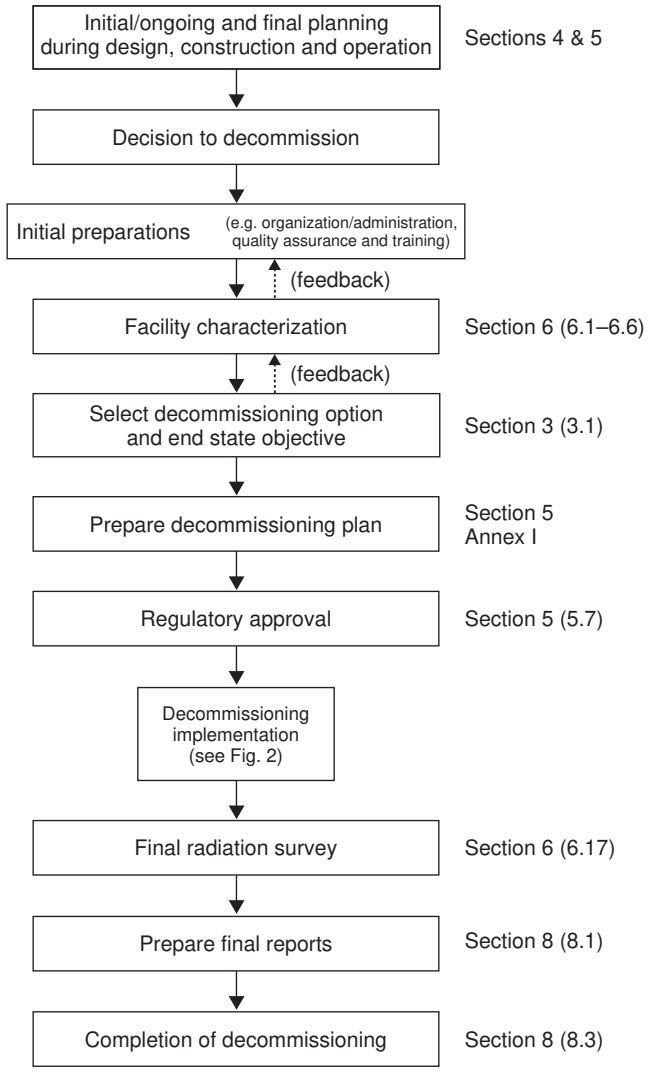

FIG. 1. Flow chart for a typical decommissioning project.

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.

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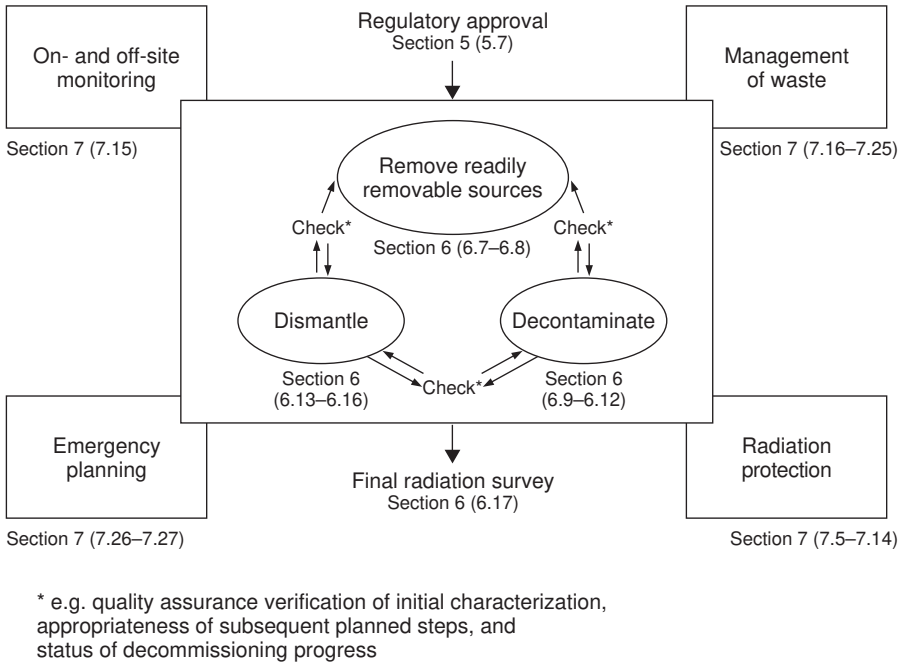

FIG. 2. Flow chart for decommissioning implementation.

ONGOING PLANNING

5.6. The initial decommissioning plan should be reviewed periodically and, as appropriate, updated and made more comprehensive with respect to technological developments, the operating history of the facility, amendments in regulatory requirements, significant abnormal events, and the requirements for and availability of resources.

FINAL PLANNING

5.7. The final decommissioning plan should be submitted by the operator for regulatory approval before final shutdown of the facility. If the facility is shut down before an appropriate decommissioning plan has been established, the plan should be completed immediately and submitted for regulatory approval. For more complex situations, such as phased decommissioning, further guidance may be taken from Ref. [5].

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5.8. For most medical, industrial and research facilities, a relatively simple decommissioning plan with a logical and adequate justification will be sufficient. Such a plan would include either immediate decommissioning after shutdown of the facility or decommissioning after an appropriate period to allow for decay of short lived radionuclides. The decommissioning activities should include facility characterization, disassembly of equipment, removal of contaminated materials and radiation sources, radiation and contamination monitoring (including airborne contamination monitoring), quality assurance, final radiation survey and documentation. Important tasks of decommissioning and management of the decommissioning plan are described in later sections.

SAFETY ASSESSMENT FOR DECOMMISSIONING

5.9. In all phases of decommissioning, the workers, the public and the environment should be protected from hazards associated with the decommissioning processes. Radiological and non-radiological hazards involved in the proposed decommissioning activities should be identified in a formal safety assessment, including an accident analysis where necessary, leading to the definition of protective measures to ensure the safety of the workers, the public and the environment. The protective measures may require the established safety systems for operational facilities to change but the acceptability of such changes should be clearly justified in the safety assessment. Some specific considerations on carrying out safety assessments are given in Annex II.

6. CRITICAL TASKS OF DECOMMISSIONING

CHARACTERIZATION OF THE FACILITY

6.1. A survey of radiological and non-radiological hazards is an important input for safety assessment and for implementing a safe approach during the decommissioning activities.

6.2. Characterization surveys 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

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facility may be a part of a larger nuclear or non-nuclear facility, e.g. a hospital, university or research establishment. In this case, the physical boundaries for the decommissioning activities should also be clearly defined.

6.3. The extent of the 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.

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

6.5. Material samples should be taken, as appropriate, during the characterization process. Selective sampling should be performed, for example, in the case of particle accelerators to verify any calculations used in estimating the activation of components or migration of contamination. Samples may also be taken to estimate the extent of migration of radioactive contaminants into structural materials such as concrete.

6.6. In addition to characterizing the radioactive material inventory, an inventory of all hazardous material present in the facility should also be performed. Hazardous materials such as asbestos require special consideration to prevent harm to human health.

SOURCE REMOVAL

6.7. At the beginning of decommissioning, all readily removable radioactive sources should be removed for reuse, storage in an approved location or disposal, in accordance with regulatory requirements. Where possible, sealed sources can be returned to the original supplier.

6.8. The removal of sources will normally result in a significant reduction of the radiation hazards. In the case of facilities using mainly sealed sources, this is relatively easy to accomplish. However, where sources 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 sources.

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DECONTAMINATION

6.9. Decontamination is the removal or reduction of radioactive contamination in or on materials, items, buildings and areas of a nuclear facility. Through decontamination, radiation doses to workers and any other persons in the vicinity of the materials may be reduced.

6.10. Decontamination can lead to a minimization of the volume of the categories of material that will be classified or disposed of as radioactive waste.

6.11. The overall decontamination strategy should be optimized, taking into account the benefits which result from reduced public exposures, the additional exposures to workers engaged in decontamination operations, the costs of the decontamination operation including treatment of generated wastes, and the costs saved by avoiding waste disposal costs.

6.12. Before any decontamination strategy is undertaken or a decontamination technique is selected, an evaluation of its effectiveness should be performed. This evaluation should include:

(a) estimated doses to workers;
(b) consideration of the possible generation of aerosols;
(c) target decontamination levels;
(d) consideration of the likelihood that available techniques will achieve the target decontamination level on particular components;
(e) an ability to demonstrate by measurement that the target decontamination level has been reached;
(f) the availability of facilities required for decontamination and their eventual decommissioning;
(g) the cost of the technique compared with the expected benefit;
(h) size and geometry of components, systems or structures;
(i) type and characteristics of the contamination;
(j) an estimate of the volume, nature, category and activity of any liquid or solid wastes;
(k) consideration of the compatibility of these wastes with existing treatment, conditioning, storage and disposal systems and discharge limits;
(l) any possible deleterious effect of decontamination on equipment and system integrity;
(m) any possible on-site and off-site consequences as a result of decommissioning activities; and
(n) non-radiological hazards (e.g. the toxicity of solvents used).

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DISMANTLING

6.13. Dismantling is one of the processes used during decommissioning. However, it has the potential for creating new hazards, and therefore necessary steps should be taken to ensure safety during the operation [2]. In the dismantling strategy, provision should be made for:

(a) a reduction in size of the objects/components to facilitate their management, i.e. decontamination, handling, etc.;
(b) facilitating access to radiation sources or other radioactive material for further management; and
(c) segregation of contaminated equipment, structures and materials from those which are less contaminated or not contaminated, in order to reduce radiation hazards to workers in subsequent handling and also to reduce the quantity of waste requiring final disposal.

6.14. In selecting the dismantling strategy, consideration should be given to:

(a) simplicity and reliability of the techniques and equipment;
(b) minimizing the generation of radioactive liquid and solid waste;
(c) using proven technology wherever practicable; and
(d) minimizing possible adverse effects on adjacent and interconnected systems, structures, areas and operations, e.g. controlling the spread of contamination.

6.15. Where proven technology is not available, special techniques may be required. These techniques should be tested in simulated operations.

6.16. Dismantling of some facilities may require the use of remotely controlled equipment. Guidance may be found in Ref. [5]. Further guidance on available dismantling technology is provided in other IAEA publications [10–13].

FINAL RADIATION SURVEY

6.17. The decommissioning plan should include provisions for a final radiation survey. The purpose of this survey is to ensure that the radiation protection objectives have been fulfilled. The survey data should be documented in a final survey report. This report should form part of the basis for the application for release of the facility/site from regulatory control. The results of the survey should be included in the final decommissioning report. An example of the table of contents of a final radiation survey report for a relatively complex and/or large nuclear facility is provided in Annex III.

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7. MANAGEMENT DURING DECOMMISSIONING

STAFFING AND TRAINING

7.1. In some cases, contractors may be used to carry out all or some aspects of the decommissioning activities. This is likely to occur when decommissioning is deferred or when plant personnel may not have the required expertise. Financial considerations may also necessitate a greater use of contractors. 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.

7.2. The 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.

ORGANIZATION AND ADMINISTRATIVE CONTROL

7.3. There should be a clear delineation of authorities and responsibilities for the decommissioning operation amongst the key personnel. The knowledge and experience of the operating personnel should be utilized to the maximum extent possible in the preparation of the decommissioning plan.

7.4. As appropriate, key personnel from the operational phase of the facility should be retained to help in performing the decommissioning operations. They will have the necessary background knowledge of the facility, including design and modifications made, its operating history and incidents relevant to decommissioning that may have occurred during its life.

RADIATION PROTECTION

7.5. The radiation exposure of workers and the public should be kept as low as reasonably achievable [3]. Tasks involving radiation exposure should be planned in advance, and likely individual and collective doses should be estimated. Consideration should be given to ways and means of reducing doses by selecting different possible approaches.

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

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7.7. An appropriate radiation monitoring system commensurate with the complexity of the facility and the radiological hazards should be in place. Monitoring of workers engaged in activities involving radioactivity should be performed during decommissioning operations.

7.8. Those individuals charged with the responsibility for radiation protection should have the resources, competence and independence necessary to effect an adequate radiation protection programme.

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

(a) equipment for radiation shielding, prevention of personnel contamination and minimization of intake of radioactive materials (e.g. by providing local ventilation and filtration systems);
(b) personal dosimeters to record radiation doses received by workers;
(c) monitoring equipment for external dose rate and surface contamination surveys for use in workplaces, and for checking components and materials during decontamination, dismantling and handling; and
(d) appropriate monitoring equipment for airborne radioactive substances in the workplace.

7.10. Arrangements should be made for the zoning of areas according to radiation and contamination levels as a means of controlling radiation doses and reducing the spread of contamination.

7.11. Records should be kept of the radiation protection measures adopted and of radiation surveys conducted.

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

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

7.14. Where the facility does not have the necessary radiation protection expertise, action should be taken by the operator to gain such knowledge. Guidance is available in Ref. [3].

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ON- AND OFF-SITE MONITORING

7.15. The requirements for on-site and off-site monitoring should be specified in the decommissioning plan. On-site monitoring should be planned for specific decommissioning activities. All potential radioactive release points should be monitored. Off-site monitoring may be necessary to demonstrate the adequacy of the control over the release of radioactive materials to the environment. The off-site monitoring programme which exists for the operational period may require modification appropriate to the conditions existing during decommissioning.

WASTE MANAGEMENT

7.16. A waste management plan, which is part of the decommissioning plan, should be developed giving consideration to the different categories of waste generated during decommissioning and to their safe management.

7.17. Consideration should be given to optimizing waste management, and minimizing cross-contamination and secondary waste generation. The different categories of waste should be managed through pathways that are proven to be adapted to their characteristics and toxicity (radiological and non-radiological).

7.18. Significant reductions in radioactive waste volumes can be achieved through decontamination programmes, controlled dismantling techniques, contamination control, sorting of waste materials, effective processing and, in some cases, administrative controls. Reuse and recycle strategies have the potential of reducing the amounts of waste to be managed. Similarly, the release of low activity materials from regulatory control (clearance) as ordinary waste or for reuse and recycling can also substantially reduce the amount of material which has to be considered waste.

7.19. 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 keeping radiation exposure as low as reasonably achievable.

7.20. The waste management plan should address the question of whether existing waste management systems are capable of coping with anticipated decommissioning waste which arises during decontamination, dismantling and demolition. If not, new facilities may have to be provided.

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7.21. 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.

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

(a) origin, amount, category and nature of waste that will be generated during decommissioning (relatively large quantities of radioactive waste may be generated in a short time);
(b) possibilities for removal of waste from the regulatory control regime;
(c) possibilities for reuse and recycling of materials, equipment and premises;
(d) the generation of secondary waste and its minimization to the extent practicable;
(e) the presence of non-radiological hazardous materials, e.g. asbestos;
(f) availability of waste recycling or treatment plants, and storage and disposal facilities;
(g) any special requirements for the packaging and transportation of radioactive wastes, e.g. activated materials;
(h) traceability of the origin and nature of the wastes arising from the decommissioning process; and
(i) the potential impact of wastes on the workers, the public and the environment.

7.23. A large part of the wastes and other materials arising during the decommissioning process may be sufficiently low in activity concentration for regulatory control to be wholly or partly removed. Some wastes may be suitable for disposal in normal landfill sites while some materials, such as steel and concrete, may be suitable for recycling or reuse outside of the nuclear industry. The removal of regulatory controls shall be done in compliance with criteria established by the national regulatory authority. Guidance on criteria for the removal of regulatory controls and on the management of the regulatory process for removal of controls is being developed in other IAEA Safety Standards.

7.24. Transport of radioactive waste off-site should conform to national regulations. International recommendations on transport of radioactive material are provided in Ref. [14].

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7.25. The management and staff involved in the decommissioning project should be made aware of and trained, if necessary, in the methods of minimizing the waste generated in the tasks assigned. Such methods include installation of contamination control tents, containment of spills and segregation of radioactively contaminated wastes from those wastes that are not radioactively contaminated.

EMERGENCY PLANNING

7.26. The decommissioning plan should specify provisions for minimizing the occurrence and/or mitigating the consequences of credible incidents during the decommissioning process, e.g. fire, power failure, equipment failure and spills of radioactive materials.

7.27. As long as radioactive material remains on-site and a potential exists for accidents to occur, procedures to cope with emergencies should be required. Plans should be made to deal with such emergencies and the staff should be trained in contingency procedures.

PHYSICAL PROTECTION

7.28. A physical protection system for nuclear facilities against sabotage and unauthorized human intrusion and for the physical security of nuclear materials should be in place during decommissioning. The level of protection should be commensurate with the nature of the remaining materials, the associated hazards and the value/attractiveness of the materials.

7.29. The physical protection system should limit access to radioactive material or facilities to only the essential individuals. This can be achieved by designating areas and by providing hardware (e.g. security devices) and procedures (including organization of guards where necessary).

QUALITY ASSURANCE

7.30. An appropriate quality assurance programme should be planned and initiated by the operator before the commencement of decommissioning. A description of the quality assurance programme, including a definition of its scope and extent, should be included as part of the decommissioning plan and be put into effect before the start of decommissioning. All significant changes affecting systems, structures and

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components important to safety during the operation should be documented for use in the planning for decommissioning. Guidance on a quality assurance programme for decommissioning is given in Ref. [15].

7.31. As discussed previously, the progress of decommissioning should be documented by the decommissioning operator (traceability). All radioactive materials that were present at the beginning of decommissioning have to be properly accounted for, and their ultimate destination has to be identified. Moreover, information such as results of radiological surveys and personnel monitoring data should be reported to the regulatory body, as required. At the completion of decommissioning, a final decommissioning report including all the elements of traceability should be prepared (see Section 8).

8. COMPLETION OF DECOMMISSIONING

8.1. On completion of decommissioning, a final decommissioning report should be prepared [2]. It should provide confirmation that decommissioning is completed. It should contain, as appropriate, the following information:

(a) description of the facility;
(b) decommissioning objectives;
(c) radiological criteria used as a basis for the removal of regulatory controls from the equipment, buildings or site, or for any other control regime approved by the regulatory body;
(d) description of the decommissioning activities;
(e) description of any remaining buildings or equipment not decommissioned or partially decontaminated;
(f) description of structures, areas or equipment designated for restricted use;
(g) final radiation survey report;
(h) inventory of radioactive materials along with radionuclides present, including amounts and types of waste generated during decommissioning and where the waste is presently located in storage and/or disposal;
(i) inventory of materials, equipment and premises released from regulatory control;
(j) summary of any abnormal events that occurred during decommissioning;
(k) summary of occupational and public doses resulting from the decommissioning; and
(l) lessons learned.

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8.2. Appropriate records should be retained on completion of decommissioning. These should be held and maintained for purposes such as confirming that decommissioning has been completed in accordance with the approved plan, recording the disposition of wastes, materials and premises and responding to possible liability claims. The following is an example of the kind of records which should be retained in an integrated manner, commensurate with the complexity of the facility being decommissioned and the associated hazard potential:

(a) the decommissioning plan and its subsequent amendments;
(b) the facility characterization report;
(c) the final decommissioning report (see para. 8.1);
(d) quality assurance records, including relevant completed work packages and work plans;
(e) engineering drawings, photographs and videos produced during and on completion of decommissioning;
(f) manufacturing and construction as-built records, including engineering drawings for any installation or construction work done to assist with, or as part of, decommissioning;
(g) personnel dose records;
(h) radiation survey records; and
(i) details of significant abnormal events during decommissioning and the actions taken.

8.3. Upon successful completion of the decommissioning option selected, the facility and the site can be released from regulatory control or incorporated into another regulated facility.

This publication has been superseded by SSG-49.

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

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[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Standards Series No. ST-1, IAEA, Vienna (1996).

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Annex I

EXAMPLE OF THE CONTENTS OF A DECOMMISSIONING PLAN

The following example of the contents of a decommissioning plan for a relatively complex and/or large nuclear facility is based on Ref. [A-1]. In the case of a relatively less complex nuclear facility, it is intended primarily as a guide and as a checklist for topics that could be considered. Some aspects may not apply and others may not require the degree of detail appropriate to a large nuclear facility.

For facilities involving small nuclear applications, the decommissioning plan should be relatively simple and provide a logical and adequate justification for the proposed decommissioning strategy. 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
   - Physical description of the site and facility
   - Operational history
   - Systems and equipment
   - Radioactive and toxic material inventory
   - Facility and site characterization

3. LEGAL FRAMEWORK AND GUIDES
   - Statutes, laws and decrees
   - Nuclear regulations
   - Radiation protection regulations
   - Environmental regulations
   - Industrial legislation
   - Local regulations
   - Other administrative provisions
   - International guidelines

4. DECOMMISSIONING STRATEGY
   - Objectives
   - Decommissioning alternatives
   - Safety principles and criteria
   - Waste types, volumes and routes

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Dose estimates
Cost estimates
Financial arrangements
Selection and justification of preferred option

5. PROJECT MANAGEMENT
Resources
Organization and responsibilities
Review and monitoring arrangements
Training and qualifications
Reporting
Records and documentation

6. DECOMMISSIONING ACTIVITIES
Description and schedule of phases and tasks
Source removal
Decontamination activities
Dismantling
Waste management
Surveillance and maintenance programmes

7. SAFETY ASSESSMENT
Dose predictions for tasks — estimation of individual and collective doses
Demonstration that radiological exposure for tasks is as low as reasonably achievable
Radiation monitoring and protection systems
Emergency arrangements
Management of safety
Risk analysis
Operating rules, instructions and work procedures
Justification of safety for workers, general population, and environment
Physical security and materials control

8. ENVIRONMENTAL IMPACT ASSESSMENT

9. QUALITY ASSURANCE PROGRAMME

10. RADIATION PROTECTION AND SAFETY PROGRAMME

11. DETAILED COST ESTIMATES AND FINANCIAL ARRANGEMENTS
Scheduling

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Cost estimates
Contingencies and allowances
Financing and funding

12. CONTINUED SURVEILLANCE AND MAINTENANCE (for deferred stages of decommissioning)

13. FUTURE DECOMMISSIONING ACTIVITIES (for deferred stages of decommissioning)

14. FINAL RADIATION SURVEY PROPOSAL

15. OUTLINE OF THE FINAL SITE REPORT
Summary of work
Site release criteria
Demonstration of compliance with requirements

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Annex II

SAFETY ASSESSMENT SPECIFIC FOR DECOMMISSIONING

Radioactive materials inventory

Detailed guidance on conducting an assessment for predisposal waste management will be given in a future Safety Guide. Its application to decommissioning includes some specific considerations for which the safety assessment could be further developed.

The removal of radioactive sources and the treatment of operational waste are often considered at the end of the operational phase or at an early stage in the decommissioning process. This reduces the radioactive inventory significantly.

In the event that radioactive sources are not removed as part of operations or early in the decommissioning process, the safety assessment should take this into account. When radioactive sources as well as the operational waste have been removed, it is also important to locate and estimate the quantities of residual radionuclides present and their physical and chemical form. Special attention must be given to the potential for contamination due to the production and release of dust on aerosol of radioactive liquids and to the large quantity of waste in general arising during decommissioning operations.

Radiation protection

Decommissioning shall be performed in compliance with specified national requirements for radiation protection and other safety and environmental protection requirements. The relevant recommendations of international bodies, in particular the IAEA and ICRP, should be taken into account. In relation to radiological protection aspects, Ref. [A-2] should be applied.

Deferred dismantling

The half-lives of radionuclides which are present in significant amounts should be considered in determining the length of time for which various decommissioning activities might be deferred so as to fulfil the appropriate radiological criteria. There may be benefits to be gained from deferred dismantling by having a period of safe enclosure. Deferral of dismantling, decontamination and demolition may reduce the quantities of radioactive waste produced and the radiation exposure to site personnel.

There may be disadvantages in delaying decontamination, dismantling and demolition. If deferred dismantling is being considered for a prolonged period of

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time, due regard should be given to gradual deterioration of the structures, systems and components designed to act as barriers between the radionuclide inventory and the environment. This deterioration may also apply to systems that could be necessary during plant dismantling. The safety assessment should consider the requirement for maintenance or replacement of these systems (mechanical handling systems, ventilation, power supply and waste handling systems), and the implications for safety due to deterioration should be evaluated. To implement safe enclosure, new systems and structures may have to be installed or existing systems and structures modified. The integrity of these new systems and structures should be assessed over the prolonged period of safe enclosure (deferred dismantling).

Non-radiological safety

The safety assessment may identify a number of significant non-radiological hazards during the decommissioning phase which are not normally encountered during the operational phase of a facility. These include, for example, hazardous materials which may be used during decontamination, demolition and dismantling activities and the lifting and handling of heavy loads. Most of these non-radiological hazards will be covered by regulations, but a good safety culture will help to ensure that such tasks are carried out safely.

General results of the safety assessment

The safety assessment should identify the actions that are necessary to ensure continuous safety during all phases of decommissioning. Such actions may be protective measures which are engineered or administrative arrangements which will provide the necessary defence in depth as identified in Ref. [A-3]. This defence in depth is essential; for example, when actions are taken during deferred dismantling (safe enclosure). The elements of defence in depth will vary and evolve as progress is made in the decommissioning of the facility.

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Annex III

EXAMPLE OF THE CONTENTS OF A FINAL RADIATION SURVEY REPORT

INSTALLATION NAME

INSTALLATION DESCRIPTION
Type and location of installation
Site description
Ownership
Installation description proper

BACKGROUND
Reason for decommissioning
Management approach

OPERATING HISTORY
Licensing and operations
Processes performed
Waste disposal practices

DECOMMISSIONING ACTIVITIES
Objectives
Results of previous surveys
Decontamination and dismantling procedures

FINAL SURVEY PROCEDURES
Sampling parameters
Background/baseline levels identified
Major contaminants identified
Release guidelines established
Equipment and procedures selected
Instruments and equipment
Instrument use techniques
Procedures followed

SURVEY FINDINGS
Summary of findings
Techniques for reducing/evaluating data

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Statistical evaluation
Comparison of findings with guideline values and conditions
Assessment of acceptability

SUMMARY

ATTACHMENTS
Detailed survey data with drawings

This publication has been superseded by SSG-49.

REFERENCES TO ANNEXES

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