IAEA Safety Standards

for protecting people and the environment

The Management System for the Processing, Handling and Storage of Radioactive Waste

Safety Guide

No. GS-G-3.3

IAEA
International Atomic Energy Agency

THE MANAGEMENT SYSTEM FOR THE PROCESSING, HANDLING AND STORAGE OF RADIOACTIVE WASTE

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LATVIA
LEBANON
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
PAKISTAN
PALAU
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

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".

COPYRIGHT NOTICE

Printed by the IAEA in Austria
June 2008
STI/PUB/1329

IAEA Library Cataloguing in Publication Data

The management system for the processing, handling and storage of radioactive waste : safety guide. — Vienna : International Atomic Energy Agency, 2008.
p. ; 24 cm. (IAEA safety standards series, ISSN 1020–525X ; no. GS-G-3.3)
STI/PUB/1329
ISBN 978–92–0–102008–6
Includes bibliographical references.

1. Radioactive waste disposal — Safety measures — Management. 2. Radioactive wastes — Management. I. International Atomic Energy Agency. II. Series.

IAEAL 08–00511

IAEA SAFETY STANDARDS SERIES No. GS-G-3.3

THE MANAGEMENT SYSTEM FOR THE PROCESSING, HANDLING AND STORAGE OF RADIOACTIVE WASTE

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2008

FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Radioactive waste (referred to in this Safety Guide as waste) must be managed in such a way as to avoid imposing an undue burden on future generations; that is, the generations that produce the waste have to seek and apply safe, practicable and environmentally acceptable solutions for its long term management (Ref. [1], para. 3.29). Management systems play an important role in applying such solutions, and should be implemented for all stages of waste management, from waste generation to waste disposal. Management systems for managing and controlling radioactive waste are subject to the requirements established in Ref. [2]. Recommendations on meeting these requirements are presented in this Safety Guide and in Ref. [3].

1.2. This Safety Guide uses the term 'management system' instead of 'quality assurance'. The term management system reflects and includes the evolution in the approach from the initial concept of 'quality control' (controlling the quality of products) through 'quality assurance' (the system to ensure the quality of products) to 'quality management' (the system to manage quality). The management system is the set of interrelated or interacting elements that establishes policies and objectives and that enables those objectives to be achieved in a safe, efficient and effective way. The requirements for the management system established in Ref. [2] and the recommendations in the accompanying Safety Guide, Application of the Management System for Facilities and Activities [3], supersede the earlier code on quality assurance[1].

1.3. A management system should be used to ensure that adequate measures are in place to address technical issues relating to safety, protection of health, protection of the environment, security, quality and economics. Solutions to technical problems are provided by means of such processes as design and research and development, which are controlled by the management system. The management, in the management system:

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Quality Assurance for Safety in Nuclear Power Plants and other Nuclear Installations, Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q, IAEA, Vienna (1996).

(a) Should recognize the need to specify when activities in such processes are required to be conducted;
(b) Should require the scope of the activities to be carefully defined;
(c) Should require the activities to be carried out carefully;
(d) Should require the results to be evaluated and taken into account appropriately.

Technical issues may also have to be addressed so that managerial functions such as independent verification and checking may be carried out.

1.4. Managing radioactive waste involves a variety of technical and managerial activities and may extend over a very long period of time. These characteristics present a series of challenges to the development and implementation of effective management systems for a waste management programme, and give rise to the need for an integrated management system to deal with all matters that might affect the management of radioactive waste, including the financial provisions to carry it out. The following aspects warrant particular consideration in developing a management system for programmes for waste management facilities and activities:

(a) By definition, waste is material for which no further use is foreseen. The provision of funds and the organizational arrangements to manage waste could be given inadequate attention if they were to become decoupled from the benefits drawn from the activity that generates the waste. The organization and funding of the necessary waste management activities could be much more difficult to put into place later.
(b) Waste can be managed safely on an interim basis, in many cases for extended periods. As a consequence, the selection and implementation of definitive solutions may be postponed by a series of short term deferrals for additional assessment of the options.
(c) If definite end points for waste have not been selected, it may be difficult to define the preferable form of the waste material to be produced and held during storage, and the acceptable form for final disposition. In such a situation, the selection of methods to treat and package waste should balance two concerns. First, the foreclosure of future disposal options (e.g. by choosing to produce an interim waste form that is both unsuitable for disposal and difficult to convert to a form that is suitable for disposal) should be avoided. Second, uncertainty about the end point should not be used as a rationale for not taking steps to ensure that the waste is managed in a safe and environmentally acceptable manner pending disposal.

(d) Under the 'polluter pays' principle, the organization that generates the waste is responsible for ensuring that the waste is managed properly. In some jurisdictions, ownership (and hence ultimate responsibility) for waste is transferred when the waste changes hands. In other jurisdictions, waste always remains the responsibility of the original generator. Care should be taken to keep the responsibility clear and fulfilled at all times.

(e) Responsibility for waste for which the generator can no longer reasonably be held responsible commonly reverts to governmental authorities. The transfer and delineation of the limits of this responsibility, with its attendant costs, can become blurred if care is not exercised.

(f) Public and political sensitivities to decisions about the production and management of radioactive waste can impose constraints on the management arrangements, timings and technical decisions that are feasible.

(g) Waste may be managed by a series of organizations that carry out the sequence of required processing steps. For example, waste generated by one organization may be transferred to another for pretreatment, treatment and conditioning, to another for storage, and to yet another for disposal. Each of these organizations may have its own management system, so that the waste may be controlled under a series of different management arrangements. This could present challenges to maintaining continuous active oversight of the waste, which may be exacerbated by the potentially long term nature of some phases of waste management activities.

(h) Management systems for all waste management activities should encourage the adoption of unified approaches and solutions and international best practices because of the need to ensure continuity between successive human generations, and the uncertainty in the long term of organizational, national and international structures.

(i) The organizations involved in waste management may be publicly or privately owned, or a combination of both. The respective interests, driving factors and responsibilities of different types of organization may present challenges in harmonizing them into a coherent overall management system for a waste management programme. Whatever the arrangements are, safety and environmental protection should always be paramount.

(j) The long term nature of waste management operations means that particular attention should be paid to:

  (i) Maintaining public confidence that management supervision will be continuous;

(ii) Establishing confidence that the performance of the waste management facilities and activities will meet the requirements;
(iii) Estimating costs and establishing the funding arrangements that will be necessary to manage the waste in the long term.

1.5. This Safety Guide is issued as one of several IAEA safety standards that deal with management systems for the safety of facilities and activities. It provides recommendations on how to meet the requirements in Ref. [2] for waste management activities, from waste generation to storage, and is supplementary to the general recommendations provided in Ref. [3]. This Safety Guide has a companion standard [4] that provides recommendations on the development of management systems for the disposal of radioactive waste. Application of these requirements and recommendations relating to the management system will contribute to a high level of confidence that activities for waste management will be conducted in a coherent and controlled manner, that waste products will be of high and consistent quality, and that the characteristics of the products are well enough known that it will be possible to make subsequent decisions on whether they meet the waste acceptance criteria for future disposal facilities. Furthermore, if required, it should be possible to make decisions (e.g. on required remediation or on retrieval for further processing and recovery of valuable materials) with confidence about the waste products that have been disposed of. However, it should be recognized that the prime responsibility for properly executing a particular task (e.g. in waste segregation, characterization and clearance activities, or in the design, construction or operation of a conditioning plant for radioactive waste) rests with those who are assigned the task.

1.6. The management systems applied to meet requirements for the pretreatment, treatment, conditioning and storage of all forms of radioactive waste all contribute to applying the fundamental safety principles established in Ref. [1]. Requirements for legal and governmental infrastructure are established in Ref. [5]. Other technical requirements and recommendations relating to the management of radioactive waste are established in other IAEA safety related publications [6–8]. The basic requirements for radiation protection are established in Ref. [9] and the requirements for emergency preparedness and response in Ref. [10].

1.7. The development and maintenance of a safety culture in an organization is central to the management systems described in this Safety Guide. A management system should help rather than impede a waste management organization in achieving its objectives, fostering positive attitudes towards the

management system and the safety culture it supports. The importance of a strong safety culture has been recognized by IAEA Member States.

1.8. The precepts of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [11] should be considered in developing management systems for waste management activities, to give due recognition to the international aspects of waste management activities.

1.9. The management systems discussed in this Safety Guide are intended to apply to the long periods of storage of waste that may occur prior to disposal. Understanding and knowledge will continue to grow and should be managed continuously in the organization, the industry and the regulatory body, and in and among States. This Safety Guide will be revised in the light of knowledge and experience gained on new processes, technological developments, and changes in the skills and tasks of personnel, as well as other, unforeseen, changes.

OBJECTIVE

1.10. The objective of this Safety Guide is to provide recommendations on developing and implementing management systems for the pretreatment, treatment, conditioning and storage of radioactive waste.

SCOPE

1.11. This Safety Guide covers the management systems for the pretreatment (collection, segregation, chemical adjustment and decontamination), treatment (volume reduction, removal of radioactive material and change of composition), conditioning (immobilization, packaging and overpacking) and storage of radioactive waste.

1.12. This Safety Guide also covers management systems for related processes and activities in waste management, such as:

(a) Waste generation;
(b) Waste characterization;
(c) Use of controlled discharges;
(d) Clearance;

(e) Packaging strategies;
(f) Design and manufacture of containers;
(g) Handling of waste packages;
(h) Safety assessment;
(i) Regulatory authorization (e.g. licensing).

1.13. This Safety Guide covers management systems for managing all types of waste including operational waste. It covers waste from nuclear fuel cycle activities, including:

(a) Mining, milling and extraction;
(b) Uranium conversion;
(c) Uranium enrichment;
(d) Fuel fabrication;
(e) Reactor operation;
(f) Fuel reprocessing;
(g) Management of non-reprocessed spent fuel;
(h) Waste management;
(i) Decommissioning.

It also covers waste from non-nuclear-fuel-cycle activities, such as:

(a) Mining, milling, extraction and processing of non-uranium minerals and resources (i.e. waste containing naturally occurring radionuclides, such as in fertilizers, oil and gas);
(b) Activities in hospitals;
(c) Activities in laboratories;
(d) Activities in research facilities;
(e) Activities in industry;
(f) Decommissioning or cleanup of facilities used for activities no longer practised (e.g. workshops used for painting dials with radium).

1.14. This Safety Guide is intended to be used by organizations that are directly involved in, or that regulate, the facilities and activities described here in paras 1.11–1.13, and by the suppliers of nuclear safety related products that are required to meet some or all of the requirements established in Ref. [2]. It will also be useful to legislators and to members of the public and other parties interested in the nuclear industry.

STRUCTURE

1.15. This Safety Guide follows the structure of Ref. [2]. The key points for establishing a management system, including general considerations, safety culture, graded application of requirements and documentation of the management system, are discussed in Section 2. The roles and responsibilities of the management of an organization for the development and implementation of an effective management system are discussed in Section 3. Resource management, including the provision of financial resources, human resources and an infrastructure and working environment, is discussed in Section 4. Planning and control of the processes used for the specific activities of the organization, the control of documents and control of records, and the management of organizational change are discussed in Section 5. Section 6 addresses the measurement, assessment and improvement of the management system itself.

1.16. To aid the user, the corresponding requirements of Ref. [2] are quoted at the beginning of each section.

1.17. Appendix I gives an example of the overall management system for a programme of activities for waste management, incorporating the individual management systems of a series of operators that carry out successive steps in the processing, handling, storage and disposal of waste. Appendix II gives an example of the application of a graded approach to implementing management system procedures. Important safety related characteristics of waste products are detailed in Appendix III.

2. THE MANAGEMENT SYSTEM

GENERAL RECOMMENDATIONS

2.1. Reference [2] requires in paras 2.1–2.4 that:

> "2.1. A management system shall be established, implemented, assessed and continually improved. It shall be aligned with the goals of the organization and shall contribute to their achievement. The main aim of the management system shall be to achieve and enhance safety by:

— Bringing together in a coherent manner all the requirements for managing the organization;
— Describing the planned and systematic actions necessary to provide adequate confidence that all these requirements are satisfied;
— Ensuring that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to help preclude their possible negative impact on safety.

"2.2. Safety shall be paramount within the management system, overriding all other demands.

"2.3. The management system shall identify and integrate with the requirements contained within this publication:

— The statutory and regulatory requirements of the Member State;
— Any requirements formally agreed with interested parties (also known as 'stakeholders'[7]);
— All other relevant IAEA Safety Requirements publications, such as those on emergency preparedness and response [10] and safety assessment [12];
— Requirements from other relevant codes and standards adopted for use by the organization.

"[7] Stakeholder: interested party; concerned party. 'Stakeholder' means an interested party — whether a person or a company, etc. — with an interest or concern in ensuring the success of an organization, business, system, etc. To 'have a stake in' something figuratively means to have something to gain or lose by, or to have an interest in, the turn of events. The term stakeholder is used in a broad sense to mean a person or group having an interest in the performance of an organization. Those who can influence events may effectively become interested parties — whether their 'interest' is regarded as 'genuine' or not — in the sense that their views need to be considered. Interested parties have typically included the following: customers, owners, operators, employees, suppliers, partners, trade unions, the regulated industry or professionals; scientific bodies; governmental agencies or regulators (local, regional and national) whose responsibilities may cover nuclear energy; the media; the public (individuals, community groups and interest groups); and other States, especially neighbouring States that have entered into agreements providing for an exchange of information concerning possible transboundary impacts, or States involved in the export or import of certain technologies or materials."

> "2.4. The organization shall be able to demonstrate the effective fulfilment of its management system requirements."

2.2. This Safety Guide provides specific recommendations for meeting the requirements of Ref. [2] on establishing management systems suitable for organizations that manage radioactive waste of all types. The development of the management system for an organization will also be influenced by:

(a) Internationally recognized standards such as ISO 9001:2000 [13] for quality management systems and ISO 14001:2004 [14] for environmental management systems;
(b) Guidance associated with the defined regulatory and statutory requirements of States;
(c) Standard practices of the nuclear industry;
(d) The organization's own standard practices.

2.3. Whichever codes, standards and requirements are used in developing the management system, the design of the management system should incorporate systems and processes both to comply with all requirements and to demonstrate the compliance. Assessments of the management system (see Section 6) should demonstrate that the management system is under control, and that the procedures for executing the processes that are controlled under the management system are producing the specified results to satisfy the requirements, thus establishing that the processes are executed correctly.

2.4. The management system should be developed to cover all activities to be carried out for the purposes of waste management, irrespective of whether they are individual or composite activities.

2.5. The management system should provide assurance that the activity (e.g. clearance) or the product (e.g. the waste package) will comply with all applicable requirements, respecting the principle of carrying out the work correctly the first time. The management system should include measures to be taken in the event that non-conforming waste packages are produced.

2.6. Processes should be developed and controlled to ensure that conditions, limitations or specifications relating to the waste or the activity are continuously met for as long as necessary. It may cost more to develop processes that will achieve this effectively, owing to the additional design and development work required. It may also be more onerous to operate such processes. However, product quality will be more consistent, and overall costs

and radiation doses may be lower because of the reduced need for remedial action (e.g. intrusive testing and reworking, and the associated handling) to deal with products that do not meet specifications.

2.7. The management system should include plans and arrangements for the management system itself to continue for as long as is required to maintain continuous control over the overall waste management programme, and to cover all stages of waste management from the generation of waste to its disposal. Emergency response drills, exercises and planned reviews of the adequacy of measures for emergency preparedness and response should be continued during periods of extended storage, when preparedness may decline in the seemingly static situation. The management system should also be designed to accommodate future technological advances that could have implications for the waste management programme.

2.8. Appendix I provides an example of a series of activities in radioactive waste management, illustrating the possible need for one or more management systems to cover all the stages of waste management from waste generation through the delivery of the waste package to the disposal facility.

SAFETY CULTURE

2.9. Reference [2] requires in para. 2.5 that:

> "The management system shall be used to promote and support a strong safety culture by:
>
> — Ensuring a common understanding of the key aspects of safety culture within the organization;
> — Providing the means by which the organization supports individuals and teams in carrying out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organization;
> — Reinforcing a learning and questioning attitude at all levels of the organization;
> — Providing the means by which the organization continually seeks to develop and improve its safety culture."

2.10. The management system should support the development, implementation and continued enhancement of a pragmatic and strong safety culture

[15–17] and should promote the adoption of best practices, regardless of the type, scale, complexity, duration and evolution of the activities for waste management. The management system for activities for radioactive waste management should support the safety culture and environmental protection culture throughout all levels of the organizations involved. The management system should establish an environment in which staff can raise safety issues without fear of harassment, intimidation, retaliation or discrimination.

GRADING THE APPLICATION OF MANAGEMENT SYSTEM REQUIREMENTS

2.11. Reference [2] requires in paras 2.6 and 2.7 that:

> "2.6. The application of management system requirements shall be graded so as to deploy appropriate resources, on the basis of the consideration of:
>
> — The significance and complexity of each product or activity;
> — The hazards and the magnitude of the potential impact (risks) associated with the safety, health, environmental, security, quality and economic elements of each product or activity;
> — The possible consequences if a product fails or an activity is carried out incorrectly.
>
> "2.7. Grading of the application of management system requirements shall be applied to the products and activities of each process."

2.12. Organizations involved in waste management should identify the relative importance of the various activities, facilities, equipment and waste products in meeting the overall safety, health, environmental, security, quality and economic requirements, with safety and environmental protection being of primary importance. Resources should then be selectively allocated and processes selectively designed to control the activities, facilities, equipment and waste products effectively and efficiently. Controls will vary for different facilities and activities.

2.13. Effective and efficient management involves the selective application of controls to activities on the basis of fundamental factors important to meeting the safety, health, environmental, security, quality and economic requirements, such as:

(a) The quantities and potential hazards (radiological and non-radiological, for example chemical) of the waste, and the necessary degree of isolation;
(b) The dispersibility and mobility of the waste forms involved and the necessary degree of containment;
(c) The interval before disposal;
(d) Experience with, and maturity of, the technology and the potential for future advances;
(e) The reliability of equipment and its function in relation to safety and environmental protection;
(f) The complexity and degree of standardization of the activities;
(g) The novelty and maturity of the activities;
(h) The size of the organization, the number and complexity of interfaces and the safety culture;
(i) Uncertainty about future public perception of radiation hazards and radioactive waste;
(j) Uncertainty about future government policy on the nuclear industry and radioactive waste management.

2.14. A graded approach may be adopted (e.g. on the basis of the findings of a hazard and operability studies (HAZOPS) assessment) in applying management system requirements to such aspects of waste management activities as the:

(a) Level of detail of work instructions and supporting documentation;
(b) Level of qualification and training of workers;
(c) Quantity, detail and retention times of records;
(d) Need for, and level of detail in, formal logbooks;
(e) Level of detail and frequency of testing, surveillance and inspection;
(f) Equipment to be included in status control for the facility;
(g) Key performance indicators to be measured;
(h) Equipment calibration requirements;
(i) Need to monitor the condition of equipment, stored waste and facility integrity;
(j) Traceability of items, including waste packages;
(k) Availability and conditions of storage of spare parts and the control of the associated records;
(l) Level of reporting and authority to act on non-conformances and to implement corrective actions;
(m) Scope, frequency and detail of assessments;
(n) Scope, frequency and detail of facility audits to monitor operational processes and levels of safety and environmental protection;

(o) Need for, and detail of, environmental monitoring.

2.15. Grading is intended to guide the degree of control applied to an item in relation to the importance of its required function. Grading should not be used as a justification for not applying all of the necessary management system elements or required quality controls, or for performing less than adequate technical assessments of items that are less evidently important to meeting the safety, health, environmental, security, quality and economic requirements. Grading should not be used to sanction less than adequate practices. Grading does not mean excluding determination of the adequacy of any activity affecting quality or safety. Grading means making the stringency of the controls by which the adequacy of such activities is evaluated commensurate with the importance of the activities.

2.16. Appendix II presents examples of the graded application of management system requirements, by illustrating possible differences in the level of controls used to manage radioactive waste produced in a mining operation versus those used to manage spent ion exchange resins generated in a nuclear power plant.

DOCUMENTATION OF THE MANAGEMENT SYSTEM

2.17. Reference [2] requires in paras 2.8–2.10 that:

> "2.8. The documentation of the management system shall include the following:
>
> — The policy statements of the organization;
> — A description of the management system;
> — A description of the structure of the organization;
> — A description of the functional responsibilities, accountabilities, levels of authority and interactions of those managing, performing and assessing work;
> — A description of the processes and supporting information that explain how work is to be prepared, reviewed, carried out, recorded, assessed and improved.
>
> "2.9. The documentation of the management system shall be developed to be understandable to those who use it. Documents shall be readable, readily identifiable and available at the point of use.

"2.10. The documentation of the management system shall reflect:

—The characteristics of the organization and its activities;
—The complexities of processes and their interactions."

2.18. Waste management activities may vary greatly in size and complexity, may involve a number of organizations and may continue over extended periods (e.g. a long standing industrial operation that generates waste, the operating and decommissioning periods in the lifetime of a nuclear power plant, the storage of waste awaiting disposal). Particular attention should be paid to ensuring that documents used to control work processes remain relevant, current, understandable and available to the diverse organizations and in the situations in which they are and will be used.

3. MANAGEMENT RESPONSIBILITY

GENERAL

3.1. The processes for fulfilling the responsibilities of senior management in relation to the management and control of radioactive waste are subject to the requirements established in Ref. [2], and the recommendations presented in this Safety Guide and provided in Ref. [3] should be considered.

MANAGEMENT COMMITMENT

3.2. Reference [2] requires in paras 3.1–3.5 that:

"3.1. Management at all levels shall demonstrate its commitment to the establishment, implementation, assessment and continual improvement of the management system and shall allocate adequate resources to carry out these activities.

"3.2. Senior management shall develop individual values, institutional values and behavioural expectations for the organization to support the implementation of the management system and shall act as role models in the promulgation of these values and expectations.

> "3.3. Management at all levels shall communicate to individuals the need to adopt these individual values, institutional values and behavioural expectations as well as to comply with the requirements of the management system.
>
> "3.4. Management at all levels shall foster the involvement of all individuals in the implementation and continual improvement of the management system.
>
> "3.5. Senior management shall ensure that it is clear when, how and by whom decisions are to be made within the management system."

3.3. The management responsible should recognize that a radioactive waste management programme may be affected by many factors. National and international policies and principles for waste management and industry norms and industry standards that currently constitute an accepted management system will evolve over the extended period of time for which waste management activities may continue. Policy decisions (e.g. regarding fuel reprocessing) and technological innovations and advances (e.g. in partitioning and transmutation) may lead to fundamental changes in the overall waste management strategy. However, management will retain its responsibility for all activities at all times, and continuous commitment by management will remain a prerequisite to ensuring safety and the protection of human health and the environment.

SATISFACTION OF THE EXPECTATIONS OF INTERESTED PARTIES

3.4. Reference [2] requires in para. 3.6 that:

> "The expectations of interested parties shall be considered by senior management in the activities and interactions in the processes of the management system, with the aim of enhancing the satisfaction of interested parties while at the same time ensuring that safety is not compromised."

3.5. Several broad considerations relating to satisfying the expectations of the many interested parties involved (e.g. the operator, national and local governments, the regulatory body, the public, the nuclear industry) should be taken into account in developing an overall waste management programme or the management system of an organization. The requirements of some

interested parties (e.g. the regulatory body) must be complied with, while the expectations and preferences of other interested parties may never be complied with entirely. Many issues may be sufficiently important to warrant consideration when developing the management system for waste management, such as:

(a) Legal aspects of some waste management activities (such as state or provincial laws and regulation of discharges from treatment facilities, occupational health regulations, hazardous material regulations, mining regulations);
(b) Restrictions on the transport of radioactive material and hazardous materials across local jurisdictional boundaries;
(c) Physical protection and security provisions that may be required, as appropriate, for nuclear and other radioactive material;
(d) Operational limitations, including those derived from agreements with local authorities or organizations or operating logistics;
(e) The needs, expectations and concerns of the organizations successively managing the waste (e.g. regarding the adequacy of the activities performed by organizations undertaking earlier steps and the ability of the subsequent organizations in the sequence to continue the work);
(f) Public attitudes, concerns and expectations about the safety of waste management activities in the long term (e.g. concern about the consequences of extended discharges, the adequacy and reliability of long term organizational arrangements, the degree of confidence in the long term performance of waste storage facilities and the ability to respond to problems that may arise);
(g) Other concerns of interested parties (e.g. cultural expectations about working hours and the composition of the workforce, social expectations about distributing risks and benefits, economic constraints if nuclear activities have a broad scope but are on a small scale, political choices about activities for sustainable development).

ORGANIZATIONAL POLICIES

3.6. Reference [2] requires in para. 3.7 that:

> "Senior management shall develop the policies of the organization. The policies shall be appropriate to the activities and facilities of the organization."

3.7. The management system for a waste management programme or organization should specify the requirement to create and periodically review the policies of the programme and organizations involved and the associated arrangements to do so. The policies of a waste management programme or organization should cover not only the safety, health, environmental, security, quality and economic aspects but also the items listed in para. 3.5.

3.8. Reviews of the policies of a waste management organization should take into account:

(a) Changes in legislation on waste management and environmental matters;
(b) Changes in regulations or in the regulatory body responsible for waste management and the environment;
(c) Changes in national policies for waste or for the environment;
(d) International developments (e.g. standards, conventions, agreements on information exchange);
(e) Technological advances;
(f) Lessons learned from experience;
(g) Non-conformances, corrective and preventive actions and results of assessments;
(h) Results of domestic and international assessments.

PLANNING

3.9. Reference [2] requires in paras 3.8–3.11 that:

> "3.8. Senior management shall establish goals, strategies, plans and objectives that are consistent with the policies of the organization.
>
> "3.9. Senior management shall develop the goals, strategies, plans and objectives of the organization in an integrated manner so that their collective impact on safety is understood and managed.
>
> "3.10. Senior management shall ensure that measurable objectives for implementing the goals, strategies and plans are established through appropriate processes at various levels in the organization.
>
> "3.11. Senior management shall ensure that the implementation of the plans is regularly reviewed against these objectives and that actions are taken to address deviations from the plans where necessary."

3.10. For the plans, goals and objectives that define the strategy for achieving the integrated safety, health, environmental, security, quality and economic objectives of the waste management programme or organization, interactions with all interested parties should be considered, as well as long term aspects such as:

(a) Providing adequate resources (the adequacy of resources for maintenance may need to be periodically reviewed over operational periods that may extend over decades), with consideration given to the amounts and types of waste to be managed in the future, and the storage and disposal options that have been adopted;
(b) Preserving technology and knowledge and transferring it to people joining the programme or the organization in the future;
(c) Retaining or transferring ownership of waste and waste management facilities;
(d) Succession planning for the programme's or organization's technical and managerial human resources;
(e) Continuing arrangements for interacting with interested parties.

RESPONSIBILITY AND AUTHORITY FOR THE MANAGEMENT SYSTEM

3.11. Reference [2] requires in paras 3.12–3.14 that:

> "3.12. Senior management shall be ultimately responsible for the management system and shall ensure that it is established, implemented, assessed and continually improved.
>
> "3.13. An individual reporting directly to senior management shall have specific responsibility and authority for:
>
> — Coordinating the development and implementation of the management system, and its assessment and continual improvement;
> — Reporting on the performance of the management system, including its influence on safety and safety culture, and any need for improvement;
> — Resolving any potential conflicts between requirements and within the processes of the management system.

> "3.14. The organization shall retain overall responsibility for the management system when an external organization is involved in the work of developing all or part of the management system."

3.12. In deciding on the manager to be responsible for the management system for a waste management programme or organization, senior management should ensure when defining duties that all the waste management activities are covered in a comprehensive and coherent manner, and that they are covered continuously over the period that the associated safety, health, environmental, security, quality and economic concerns continue.

4. RESOURCE MANAGEMENT

GENERAL

4.1. Resource management necessary for managing and controlling radioactive waste is subject to the requirements established in Ref. [2], and the recommendations presented in this Safety Guide and provided in Ref. [3] should be considered.

4.2. Reference [2] requires in paras 4.1–4.5 that:

> "4.1. Senior management shall determine the amount of resources necessary and shall provide the resources[9] to carry out the activities of the organization and to establish, implement, assess and continually improve the management system.
>
> "4.2. The information and knowledge of the organization shall be managed as a resource.
>
> "4.3. Senior management shall determine the competence requirements for individuals at all levels and shall provide training or take other actions to achieve the required level of competence. An evaluation of the

[9] 'Resources' includes individuals, infrastructure, the working environment, information and knowledge, and suppliers, as well as material and financial resources."

effectiveness of the actions taken shall be conducted. Suitable proficiency shall be achieved and maintained.

"4.4. Senior management shall ensure that individuals are competent to perform their assigned work and that they understand the consequences for safety of their activities. Individuals shall have received appropriate education and training, and shall have acquired suitable skills, knowledge and experience to ensure their competence. Training shall ensure that individuals are aware of the relevance and importance of their activities and of how their activities contribute to safety in the achievement of the organization's objectives.

"4.5. Senior management shall determine, provide, maintain and re-evaluate the infrastructure and the working environment necessary for work to be carried out in a safe manner and for requirements to be met."

PROVISION OF RESOURCES

4.3. Waste management activities will require resources in the areas of finance, human resources, and infrastructure and the working environment. Senior management should be responsible for making arrangements to provide adequate resources for waste management activities, to satisfy the demands imposed by the safety, health, environmental, security, quality and economic aspects associated with the full range of activities involved and the potentially long duration of the activities.

FINANCIAL RESOURCES

4.4. Funding arrangements for future waste management activities should be specified, and responsibilities, mechanisms and schedules for providing the funds should be established before the termination of the practice that generates the waste. According to the 'polluter pays' principle, the generator of the waste would fund its management.

4.5. Management systems for waste management activities should include provisions to deal with several funding challenges:

(a) For various reasons (e.g. bankruptcy, cessation of business), it may not be feasible to obtain the necessary funds from the waste generator,

especially if funds were not set aside at the time the benefits were received from the activity that generated the waste, or if ownership of the waste (e.g. ownership of spent imported radioactive sources) has been transferred to other parties. The need to apply the 'polluter pays' principle and the appropriate means of applying the principle through a tax mechanism could be considered in such cases.

(b) If funds are to come from public sources, this will compete with other demands for public funding, and it may be difficult to gain access to adequate funds on a timely basis.

(c) It may be difficult to make realistic estimates of costs for waste management activities that are still in the planning stage and for which no experience has been accumulated.

(d) It may be difficult to estimate anticipated costs for activities that will only begin in the long term, because they will depend strongly on assumptions made about future inflation rates, bank interest rates and technological developments.

(e) It may be difficult to set appropriate risk and contingency factors to be built into estimates of future costs, owing to the uncertainty associated with unforeseeable future changes in societal demands, political imperatives, public opinion and the nature of unplanned events that may require resources for dealing with them.

(f) Costs tend to rise, particularly in the absence of commercial competition.

(g) If several organizations are involved in the waste management activities, the necessary financial arrangements may be complex and variable. The establishment of an adequate degree of confidence in all the arrangements so that the necessary continuity of funding throughout the entire series of activities is ensured may be problematic.

Consideration should be given, for each waste stream, as to whether commercial arrangements are in place, and, if so, what they are and for how long they will be in force. This will enable the operator to tailor financial arrangements appropriately, taking into account the other funding challenges listed above.

HUMAN RESOURCES AND INDIVIDUAL COMPETENCE

4.6. The reliability and the effectiveness of waste management activities will depend on all personnel in all the organizations involved. At all times, personnel should carry out their assigned work competently and with a clear understanding of the consequences for safety and environmental protection of their tasks.

4.7. Human resource planning for waste management activities of long duration should incorporate measures to ensure the continuing availability of a sufficient number of competent personnel. This may influence decisions about required staffing levels, and the educational qualifications, skills and experience of new personnel. Additionally, in some States, personnel performing work in defined positions important to safety and environmental protection should be authorized (e.g. licensed) as required by the appropriate regulatory body.

4.8. Training programmes, procedures and succession plans should be established to ensure that suitable proficiency is achieved and maintained, and to avoid the potential loss of knowledge, practical experience and technical expertise over time.

4.9. Training and retraining should include familiarization with the management system of the organization.

4.10. Training and retraining needs should be reviewed on a planned basis and updated as required to respond to changes in technologies for waste management, legislative and regulatory requirements, and any other factors associated with waste management activities.

4.11. Retraining should be arranged to ensure that personnel adequately understand the implications of changes such as:

(a) Modifications to equipment;
(b) The installation of new equipment;
(c) Changes in procedures;
(d) Any tightening or relaxation of controls (e.g. on the number of waste packages that may be moved at any given time);
(e) The introduction of additional control points;
(f) Changes in regulatory requirements.

4.12. Accumulated experience, including lessons learned from incidents and events, should be reviewed periodically and used in revising training programmes and in future decision making.

INFRASTRUCTURE AND WORKING ENVIRONMENT

4.13. In designing facilities for long term waste management activities, consideration should be given to incorporating measures for ease of operation, maintenance of equipment and eventual decommissioning of the facility.

4.14. For long term waste management activities, future infrastructural requirements should be specified and plans should be made to ensure that these will be met. In such planning, consideration should be given to the continuing need for support services, for spare parts for equipment that may eventually no longer be manufactured, for equipment upgrades to meet new regulations and make operational improvements, and for the evolution and inevitable obsolescence of software.

4.15. Consideration should also be given to the need to develop monitoring programmes and inspection techniques for use during extended periods of storage of waste.

5. PROCESS IMPLEMENTATION

GENERAL

5.1. The processes for treating, handling and storing radioactive waste are subject to the requirements established in Ref. [2], and the recommendations presented in this Safety Guide and provided in Ref. [3] should be considered.

DEVELOPING PROCESSES

5.2. Reference [2] requires in paras 5.1–5.5 that:

> "5.1. The processes of the management system that are needed to achieve the goals, provide the means to meet all requirements and deliver the products of the organization shall be identified, and their development shall be planned, implemented, assessed and continually improved.
>
> "5.2. The sequence and interactions of the processes shall be determined.
>
> "5.3. The methods necessary to ensure the effectiveness of both the implementation and the control of the processes shall be determined and implemented.

"5.4. The development of each process shall ensure that the following are achieved:

— Process requirements, such as applicable regulatory, statutory, legal, safety, health, environmental, security, quality and economic requirements, are specified and addressed.
— Hazards and risks are identified, together with any necessary mitigatory actions.
— Interactions with interfacing processes are identified.
— Process inputs are identified.
— The process flow is described.
— Process outputs (products) are identified.
— Process measurement criteria are established.

"5.5. The activities of and interfaces between different individuals or groups involved in a single process shall be planned, controlled and managed in a manner that ensures effective communication and the clear assignment of responsibilities."

5.3. All the management and work processes necessary to satisfy the safety, health, environmental, security, quality and economic requirements associated with managing waste should be identified, developed, implemented, maintained and appropriately improved in a controlled fashion. As illustrated in Appendix I, the management system for a programme of waste management activities may incorporate the individual management systems of a series of operators carrying out successive steps in the processing, handling, storage and disposal of waste. In developing the management processes for waste management activities, care should be taken:

(a) To ensure the continuity of control of the waste and waste management activities;
(b) To maintain linkages and relationships between organizations if more than one organization is involved;
(c) To allow for the potentially long duration of the waste management activities.

5.4. The work processes required to manage waste consist of sequences of tasks that determine, alter, modify or otherwise affect important properties of the waste and any waste packaging and containers, and:

(a) May be manual or automated;

(b) May change the physical or chemical characteristics of the waste;
(c) May be performed at any stage from the generation of the waste to its ultimate disposition (e.g. discharge, clearance or disposal).

Strategy for developing integrated management system and work processes

5.5. In developing management system processes and work processes, the operator should integrate and ensure the coherence of the overall strategy of the waste management programme and the detailed processes, specific equipment and intended outputs that are important to safety, health, environmental, security, quality and economic aspects and the quality of the outputs. Requirements are established on the development of a waste management programme and the safety features for waste products and facilities, and recommendations are provided in Refs [6–8]. Basic requirements for radiation protection are established in Ref. [9] and requirements for emergency preparedness and response are established in Ref. [10].

5.6. As the best approach to developing a waste management strategy, the entire process by which waste is generated should be considered, as well as the subsequent treatment, storage and disposal of waste. By this means an integrated overall process will be developed. The development of detailed processes for waste management should be associated with the safety assessment process, and the design–assessment coupling of processes should be iterative; for example:

(a) Tentative waste product specifications should be developed when the entire sequence of waste management activities is first conceived;
(b) The level of safety and environmental protection provided by various combinations of processes, waste products and facility characteristics that are assumed to be possible should be assessed;
(c) The feasibility of implementing the various designs should be evaluated;
(d) A revised set of assumptions should be input into a new safety assessment.

The design–assessment cycle should be repeated, usually several times, which will result in a set of processes, waste products, facility specifications and associated safety assessments that will guide the development of the entire set of waste management activities.

5.7. Consideration should be given to which data are needed and to what variability and uncertainty in data are acceptable for the following:

(a) To characterize waste sufficiently at each step (if possible) in the overall waste management programme;
(b) To be valid over any extended period of storage of waste products;
(c) Before, during and after operations, to discharge, clear or dispose of waste.

It should be borne in mind that previously unrecognized variations (e.g. in the composition of waste streams or in background radiation levels during monitoring for clearance purposes) could necessitate adjustment of the design of processes or in the specifications of the materials currently being used for waste products.

PROCESS MANAGEMENT AND CONTROL OF PRODUCTS

5.8. Reference [2] requires in paras 5.6–5.10 and 5.14–5.20 that:

> "5.6. For each process a designated individual shall be given the authority and responsibility for:
>
> — Developing and documenting the process and maintaining the necessary supporting documentation;
> — Ensuring that there is effective interaction between interfacing processes;
> — Ensuring that process documentation is consistent with any existing documents;
> — Ensuring that the records required to demonstrate that the process results have been achieved are specified in the process documentation;
> — Monitoring and reporting on the performance of the process;
> — Promoting improvement in the process;
> — Ensuring that the process, including any subsequent changes to it, is aligned with the goals, strategies, plans and objectives of the organization.
>
> "5.7. For each process, any activities for inspection, testing, verification and validation, their acceptance criteria and the responsibilities for carrying out these activities shall be specified. For each process, it shall be specified if and when these activities are to be performed by designated individuals or groups other than those who originally performed the work.

"5.8. Each process shall be evaluated to ensure that it remains effective.

"5.9. The work performed in each process shall be carried out under controlled conditions, by using approved current procedures, instructions, drawings or other appropriate means that are periodically reviewed to ensure their adequacy and effectiveness. Results shall be compared with expected values.

"5.10. The control of processes contracted to external organizations shall be identified within the management system. The organization shall retain overall responsibility when contracting any processes.

"5.14. Specifications and requirements for products, including any subsequent changes, shall be in accordance with established standards and shall incorporate applicable requirements. Products that interface or interact with each other shall be identified and controlled.

"5.15. Activities for inspection, testing, verification and validation shall be completed before the acceptance, implementation or operational use of products. The tools and equipment used for these activities shall be of the proper range, type, accuracy and precision.

"5.16. The organization shall confirm that products meet the specified requirements and shall ensure that products perform satisfactorily in service.

"5.17. Products shall be provided in such a form that it can be verified that they satisfy the requirements.

"5.18. Controls shall be used to ensure that products do not bypass the required verification activities.

"5.19. Products shall be identified to ensure their proper use. Where traceability is a requirement, the organization shall control and record the unique identification of the product.

"5.20. Products shall be handled, transported, stored, maintained and operated as specified, to prevent their damage, loss, deterioration or inadvertent use."

5.9. In the management system for a waste management programme, care should be taken to ensure the continuity of control of the waste and waste management activities, and to ensure that the linkages and relationships between all the organizations involved are maintained.

5.10. If the waste being managed has long term safety, health, environmental, security, quality and economic implications, it should be recognized that people in future generations who were not originally interested parties will inherit responsibility for managing the waste and the associated processing, handling, storage or disposal facilities. The management system should be sustainable and should include provision for its own review in a planned manner to maintain confidence that it will evolve to accommodate changes in management philosophies and strategies to meet the needs of future interested parties.

Control of work processes

5.11. Work processes affecting the safety, health, environmental, security, quality and economic requirements of waste management activities and the quality of the outputs (e.g. discharged or cleared materials, packaged waste) should be controlled so that:

(a) The applicable prerequisites, including environmental conditions, physical parameters, equipment characteristics and personnel competences, are satisfied;
(b) All process variables are kept within specified acceptance criteria.

Control of work processes may be achieved through the design of the work process, validation, the use of operating procedures and work instructions, process surveillance and monitoring, and product inspection and testing. Paragraphs 5.12–5.38 provide recommendations on applying several of these approaches to the control of specific processes used in activities for waste management.

Design of work processes

5.12. In the design of work processes, the detailed sequence of steps in the activities for waste management as well as issues relating to the specific work processes and products (e.g. waste packages) should be considered; for example:

(a) Use of special handling tools and techniques, protective clothing or facilities for radiation protection;
(b) Emplacement of packages in storage facilities and the use of associated handling devices and special storage conditions such as retrievability and in situ repackaging;
(c) Testing and assay requirements (e.g. equipment, methods or materials);
(d) Design of waste packages and containers (e.g. possible multipackage designs and criteria for transport, storage and disposal), with detailed specifications of the package structure and the packaging (container) material;
(e) Design of transport packages and containers, and of storage facilities that are being designed in advance of the final disposal facility (owing to the uncertainty associated with its design);
(f) The possible failure of waste packages and containers due to long term interactions between packaging material and the storage environment;
(g) The possible compromising of the integrity of waste packages and containers during extended storage;
(h) The possible need to modify or re-engineer the design of waste packages and containers to incorporate new technology or to be compatible with new storage or disposal arrangements.

5.13. In experiments and pilot scale tests that are carried out to support the design of a sequence of work processes that are to be implemented on a production scale, the aim should be:

(a) To provide assurance that it will be possible to quantify, either by direct measurement or by process control, the important waste form parameters (e.g. mass of fissile material, isotopic composition, chemical composition and physical state, decay heat) necessary to control the intermediate processes involved in treating, handling, storing, transporting and disposing of the waste;
(b) To determine those process variables that are critical to the acceptability of the end product.

Validation of work processes

5.14. Validation of work processes should include:

(a) Determining the process variables that should be controlled to ensure the adequacy of waste management activities, including outputs;
(b) Establishing the limits or tolerances for the process variables;

(c) Determining adequate control methods for the process variables, including the frequency of required sampling and testing of waste forms and packages during production;
(d) Establishing a test programme to verify the specified level of quality of the waste at various stages of processing, with a view to ensuring the required quality of the final outputs (e.g. discharged or cleared materials, final waste package), and determining the susceptibility of waste packages to degradation under postulated storage, handling or disposal conditions.

5.15. Process validation should be performed in accordance with documented and approved procedures, and the results should be reported. Appropriate reports and records should be made available to all subsequent waste processors, operators of storage facilities and consignors (originators of shipments) and to the management responsible for the waste disposal facility.

Special processes

5.16. Special processes are processes for which:

(a) The output from the process depends strongly on the control of the process or the skill of operators, or both (e.g. inspection results from radioassay);
(b) It is not possible fully to confirm the conformity of the output with the specified acceptance criteria by inspection or testing after the process has been conducted and the output is still under control (e.g. the welding of lids onto waste containers).

Special processes used in waste management include:

(i) Analytical methods such as sampling protocols for waste characterization or process control;
(ii) Monitoring of discharges;
(iii) Monitoring for clearance purposes;
(iv) Non-destructive examination and testing;
(v) Welding;
(vi) Heat treatment;
(vii) Painting and coating of containers of waste that generate high radiation fields.

5.17. All special processes used should be validated (i.e. demonstrated to be effective using methods and conditions that are representative of the intended application, as witnessed by an expert in the discipline), and any limitations should be documented.

5.18. In validating non-destructive gamma or neutron radioassay techniques:

(a) Algorithms for validating radionuclide content should be validated with empirical data;
(b) Objects to be measured (e.g. waste or waste packages) should exhibit attenuation properties and moderating properties according to the standards used in developing the method or calibrating the equipment;
(c) Assay errors should be quantified for each material to be measured.

5.19. Special processes should be performed by qualified personnel and should be authorized in accordance with approved procedures. The results should be recorded. Where industry standards apply for special processes, the requirements of such standards should be complied with. When any changes are made in environmental samples and conditions, methods, equipment and qualification of personnel, the special processes should be revalidated.

Inspection and testing

5.20. Inspection and testing are important elements for controlling work processes. They should be planned, documented, executed and recorded to ensure that important parameters of waste management processes are controlled, and that waste products meet design specifications. Acceptance criteria should be specified for each inspection step in the activities for the control of waste streams.

5.21. If it would be difficult or impossible to verify work processes on completion, or if this would be too late, the design of the workflow should include 'hold points' at which the acceptability of important results should be verified before work proceeds. Procedures should specify that work should not proceed beyond hold points until designated inspection personnel have confirmed its acceptability. The degree of independence of inspection personnel should be commensurate with the significance for safety and environmental protection of the parameters being inspected. Hold points may be waived if full justification on grounds of safety and environmental protection or quality is documented and approved.

5.22. Inspections carried out as part of waste management activities should include:

(a) Inspection at source of items important to safety and environmental protection for which the quality is difficult to verify upon receipt;
(b) Inspection on receipt of items important to safety and environmental protection, including verification of related certification and documentation;
(c) Inspection, and testing on receipt, of characteristics of commercial grade items that are important to safety and environmental protection;
(d) Inspection of installed items that are important to safety, environmental protection or waste isolation, including witnessing of equipment and/or system operational tests;
(e) Post-installation acceptance inspection for structures, systems and components being accepted in this fashion;
(f) In-process inspection of waste treatment and waste immobilization processes;
(g) Inspection of processes used for qualification or acceptance of waste forms (e.g. non-destructive assay or real time radiography);
(h) In-process inspection of waste packaging processes;
(i) Final inspection of waste forms and waste packages destined for storage and transport;
(j) Inspection of characteristics of waste packages that are critical to complying with the transport regulations;
(k) Regular and non-invasive inspection of the integrity and identification of waste packages in storage;
(l) Regular inspection to verify the operability of equipment or systems used for the prevention, detection or mitigation of accidents.

The operating organization for waste management may itself carry out internal inspections in the course of controlling and improving its processes. Other bodies (such as the regulatory body or independent organizations or experts) may independently carry out external inspections to maintain confidence that the operating organization is conducting its operations in an acceptable manner.

5.23. For tests designed to verify the required durability of a waste package, analytical methods should be used that have been demonstrated to be effective on the materials to be tested and demonstrated to be representative of (or more severe than) the environmental conditions that the waste package will encounter in storage or subsequent disposal.

Design of waste products

5.24. Waste product specifications should identify the required radiological, physical and chemical characteristics of the product and should identify discharged or cleared materials resulting from activities in radioactive waste management. In waste product specifications, the feasibility of satisfying the waste acceptance criteria of all the successive waste management processes should be taken into account. The final waste product specifications should also be consistent with the values used in safety assessments for the activities, especially assessments involving extended storage and disposal. Specification of product characteristics alone may be insufficient, given the impracticality of testing active treated wastes. In such cases, waste product specifications should also identify the feed material and the acceptable variation in the feed composition (or other materials to be incorporated into the product), so that any unexpected variation in the feed prompts a non-conformance designation or a reassessment. The critical operating parameters of any processes that produce the product should also be defined (e.g. maximum cure temperatures).

5.25. Investigations that are performed to support the design and that employ simulated waste or waste constituents should be focused on ensuring that:

(a) The waste compositions examined are representative of the actual waste to be processed;
(b) Any anticipated conditions that may result in a significant reduction in the quality of the waste product or in the waste to be processed are included.

5.26. The specification for the final waste product should be derived and agreed upon between all the interested parties and affected parties. These normally include:

(a) The source or the generator of the waste;
(b) The owner of the waste (where appropriate);
(c) Organizations operating the waste pretreatment and treatment facilities;
(d) Packagers;
(e) Consignors;
(f) The regulatory body;
(g) The provider of the final disposal facility.

The specification should be used by any organizations that supply services or products. The characteristics of waste products that are important to safety and environmental protection are specified in Appendix III.

5.27. The design of non-intrusive systems and methods for chemical analysis that are used to characterize waste should be such as to allow the systems and methods to be used to examine waste packages that have degraded after extended storage.

5.28. Information about the design of waste products that was considered important to safety, health, environmental, quality, security and economic aspects should be retained and controlled for as long as any concern about the waste persists.

Status of waste, equipment, tools and materials

5.29. Procedures should be established to ensure that the status of waste being processed and the status of equipment, tools, materials and other items important to safety or waste isolation are known and controlled at all times so that:

(a) Required tasks, inspections or tests are not inadvertently omitted;
(b) Non-conforming equipment is not installed, used or relied upon;
(c) Tools or items of test equipment of indeterminate status (e.g. possibly damaged, defective or out of calibration) are not used;
(d) Non-conforming materials and items (e.g. immobilizing agents, waste forms, containers) are identified, segregated and not processed further until the non-conformance is resolved.

5.30. The status of an item should be either marked directly on the item, or stated in documents traceable to the item, or indicated by means of tags, travellers (i.e. a document accompanying the item in which its characteristics and history are recorded), stamps, inspection records or other suitable means. In the procedures, the need for transfer of the identification of an item if it may be divided or modified should be taken into account. Identification marks on waste packages should be of a permanent type that will withstand the conditions in which the waste packages will be stored for the timescales over which this will take place.

5.31. Equipment status indicators (and positive controls when appropriate) should be used to prevent inadvertent operation that could cause a loss of

control over waste or an accident, or could render safety systems inoperable. The authority for attaching and removing markings, tags, labels, stamps and tamper indicating devices should be specified when establishing operational rules and procedures.

5.32. It should be readily possible to establish the history of an item through documentation at any time. The uniqueness of the identification of items should be established and documented on the basis of the importance to safety and environmental protection or waste isolation, and the identification should be traceable to the associated records. The durability of physical identification should be controlled for items that may need to be stored in corrosive conditions, or for items that may need to be stored for an extended time and then retrieved.

5.33. Where the characterization of heterogeneous waste streams is based on process information, records should be kept of the contents of individual waste packages and containers. Subsequent to the closure of a container and final non-destructive testing or radioassay, tamper indicating devices should be attached to the waste package or container to ensure that it can be verified that the radionuclide content remains as recorded.

5.34. If the reports and records from the production of waste packages do not make it clear that the waste packages meet the acceptance criteria for disposal (e.g. because the waste packages were produced prior to the setting of acceptance criteria for a disposal facility), it should be verified that the waste packages are adequately characterized and that they meet the disposal requirements. If the waste packages do not meet the requirements, the need to rework the packages and the need to evaluate the organization (and the intended processing methods) that will perform the reworking to bring the waste to a qualified condition should be considered.

Storage

5.35. Storage of waste packages is a very specific stage of waste management that could be of long duration and could challenge management systems. Prior to placing waste packages in a storage facility, measures should be taken to ensure that:

(a) Waste packages are properly identified;
(b) Waste packages do not show signs of unacceptable deterioration;
(c) The required documentation and records are available and acceptable;

(d) All processes for waste treatment and packaging have been accomplished satisfactorily;
(e) Levels of surface contamination and surface dose rates meet requirements;
(f) Measures for criticality control for fissile material are in place;
(g) The intended movements of waste packages within the storage facility can be performed safely, preclude inadvertent criticality and minimize occupational exposures;
(h) Procedures are in place for:
    (i) Monitoring the integrity of waste packages;
    (ii) Controlling cooling and heating and performing the associated monitoring;
    (iii) Maintaining surveillance of the operational status of equipment for accident detection and mitigation of consequences;
    (iv) Ensuring that waste packages can be readily identified, located and accessed.

5.36. The inventory of radionuclides and the relevant properties and history of the waste forms should be fully documented so that the stability of the waste, its radiological properties and, in cases where gas may be generated, the internal pressures of waste packages may be predicted or determined at any time during storage. The history of the waste (e.g. origin, state of degradation when conditioned, treatment processes undergone) will be important in determining its properties in the future and in tracing any recurrent or systematic fault.

5.37. Consideration should be given to the possible need to relocate the waste packages if problems arise after they have been placed in storage (e.g. threats to the integrity of packages or problems associated with criticality or decay heat).

5.38. The availability of any specialized equipment that may be required over a long time period while waste packages are in storage or that may be required in the future should be assessed.

CONTROL OF DOCUMENTS

5.39. Reference [2] requires in paras 5.12 and 5.13 that:

> "5.12. Documents[10] shall be controlled. All individuals involved in preparing, revising, reviewing or approving documents shall be specifically assigned this work, shall be competent to carry it out and shall

be given access to appropriate information on which to base their input or decisions. It shall be ensured that document users are aware of and use appropriate and correct documents.

"5.13. Changes to documents shall be reviewed and recorded and shall be subject to the same level of approval as the documents themselves."

5.40. Documents should be periodically reviewed and kept up to date as equipment, information technology, industrial practices and regulatory requirements evolve. In cases where the very long term control of documents is needed (e.g. for extended storage pending disposal), the possible evolution of language and educational levels in future generations should also be taken into account.

CONTROL OF RECORDS

5.41. Reference [2] requires in paras 5.21 and 5.22 that:

"5.21. Records shall be specified in the process documentation and shall be controlled. All records shall be readable, complete, identifiable and easily retrievable.

"5.22. Retention times of records and associated test materials and specimens shall be established to be consistent with the statutory requirements and knowledge management obligations of the organization. The media used for records shall be such as to ensure that the records are readable for the duration of the retention times specified for each record."

Content of records

5.42. Records should be created and managed to preserve knowledge of the results of waste management activities; these may be needed in the future to implement both the expected waste management option and other options that may have to be implemented. These records should include information on:

"[10] Documents may include: policies; procedures; instructions; specifications and drawings (or representations in other media); training materials; and any other texts that describe processes, specify requirements or establish product specifications."

(a) The origin of the waste and the processes that generated it;
(b) Pretreatment of the waste;
(c) Clearance of the waste;
(d) Discharge of the waste;
(e) Characterization of the waste;
(f) Treatment and conditioning of the waste;
(g) Design of the containers and/or packages and of equipment, structures, systems and components for the pretreatment, treatment, conditioning and storage of the waste;
(h) Procurement of the containers and/or packages and of equipment, structures, systems and components for the pretreatment, treatment, conditioning and storage of the waste;
(i) Packaging and overpacking;
(j) Physical and radiological inventories of the stored waste;
(k) Form and content of the stored waste (e.g. radioisotopes, hazardous materials and chelating agents);
(l) Data needed for a national inventory of waste (if one exists);
(m) Records of non-conformances and corrective actions on the waste;
(n) Modifications to waste packages;
(o) Records generated during storage of the waste;
(p) Assessment, inspection and verifications relating to all activities;
(q) Non-conformances and corrective actions relating to all activities;
(r) Training and qualification of personnel relating to all activities;
(s) Trends in operating performance;
(t) Environmental monitoring;
(u) Information on accidents and other incidents and defects;
(v) Safety assessments;
(w) Authorizations (e.g. licences).

Retention of records

5.43. Arrangements should be made to ensure that records are maintained for the period of time for which the activities and products associated with radioactive waste management remain an issue for safety, the protection of human health and the environment, and security. Retention periods may vary depending on the nature of the facilities and activities in which the waste was generated and on the half-lives of the radionuclides involved (e.g. for waste from a nuclear medicine laboratory rather than from a nuclear power plant), and they should be approved as required by the appropriate national authorities or the regulatory body.

5.44. The records from radioactive waste management that need to be retained for an extended period should be subject to a regular systematic review to examine the implications of any changes that have occurred in regulatory requirements and in legislative, organizational, technical and scientific circumstances.

5.45. Records from waste management activities that need to be retained for an extended period should be stored in a manner that minimizes the likelihood and consequences of loss, damage or deterioration due to unpredictable events such as fire, flood or other natural or human initiated occurrences. Storage arrangements for records should meet the requirements prescribed by the national authorities or the regulatory body. This retention status should be periodically reassessed. When unpredictable events lead to the inadvertent destruction of records, the status of surviving records should be examined and the importance of their retention and their necessary retention periods should be re-evaluated.

Recording media and record keeping

5.46. The quality of the recording media and the conditions of storage for records relating to radioactive waste management should be such that the information will be preserved throughout the required retention period. Records of enduring value should be stored on materials of the highest available archival quality. Where records are preserved electronically, the records should be retrievable and readable for the entire retention period required. This may require periodic updates of software, or the use of a controlled non-proprietary form and/or system. Irrespective of the storage media used, consideration should be given to the storage of multiple copies in several diverse locations with independent protection systems.

Transfer of information between organizations

5.47. When an organization transfers waste to another organization responsible for the next step in managing the waste, records of information about the waste that relates to safety and environmental protection should be made available to the receiving organization. The information to be transferred between organizations should be set out in an interface document that describes and specifies the interactions between the organizations.

PURCHASING

5.48. Reference [2] requires in paras 5.23–5.25 that:

> "5.23. Suppliers of products shall be selected on the basis of specified criteria and their performance shall be evaluated.
>
> "5.24. Purchasing requirements shall be developed and specified in procurement documents. Evidence that products meet these requirements shall be available to the organization before the product is used.
>
> "5.25. Requirements for the reporting and resolution of non-conformances shall be specified in procurement documents."

5.49. In planning for procurement, consideration should be given to the availability and quality of equipment (e.g. monitoring instrumentation), materials and other items important to safety and environmental protection over the extended periods of waste storage. Consideration should also be given to the fiscal policies and financial arrangements and controls that may be required.

COMMUNICATION

5.50. Reference [2] requires in paras 5.26 and 5.27 that:

> "5.26. Information relevant to safety, health, environmental, security, quality and economic goals shall be communicated to individuals in the organization and, where necessary, to other interested parties.
>
> "5.27. Internal communication concerning the implementation and effectiveness of the management system shall take place between the various levels and functions of the organization."

5.51. In establishing the internal and external communication processes used for programmes and organizations in waste management, it should be recognized that the communication may need to be sustained over a long period of time.

5.52. Internal communication should cover such aspects as:

(a) Management policy, objectives and strategy;
(b) The management system and associated processes and procedures for conducting waste management activities;
(c) The current status of waste management activities and plans for the future;
(d) Technical and quality issues (e.g. problems having long term implications and their resolution, planned improvements and innovations);
(e) Radiological issues (e.g. trends in doses and in releases to the environment, evaluation of accidents and other incidents);
(f) Regulatory and statutory issues (e.g. new requirements for waste management, radiation related requirements and environmental requirements, and planned measures to meet the requirements).

5.53. External communication should include information on such aspects as:

(a) Present status of operations and plans for the future;
(b) Health and safety and the environmental, security and economic impacts of the waste management activities;
(c) Changes in management arrangements and the continuity of responsible management;
(d) Maintenance of adequate financial resources to support the waste management activities;
(e) Opportunities for, and results from, public involvement in decision making;
(f) Responses to questions and concerns.

MANAGING ORGANIZATIONAL CHANGE

5.54. Reference [2] requires in paras 5.28 and 5.29 that:

> "5.28. Organizational changes shall be evaluated and classified according to their importance to safety and each change shall be justified.
>
> "5.29. The implementation of such changes shall be planned, controlled, communicated, monitored, tracked and recorded to ensure that safety is not compromised."

5.55. Roles and responsibilities for safety and environmental protection in waste management may change within waste management programmes and organizations. Responsibilities for waste may change between States (e.g.

following agreements on the repatriation of waste from fuel reprocessing or of spent sealed sources). The challenges presented by change are greater for waste management activities that will continue for a long period of time. Management systems for waste management programmes and organizations should be designed to ensure continuity in managing the waste management activities, and should be able to cope with possible changes in, for example:

(a) The ownership of waste and waste management facilities;
(b) Management arrangements;
(c) The regulatory body.

When management arrangements are changed (e.g. if public organizations are privatized, if new organizations are created, if existing organizations are combined or restructured, if responsibilities are transferred between organizations, or if operating organizations undergo internal reorganization of the management structure or the reallocation of resources), consideration should be given to the possible need to restructure the management system.

6. MEASUREMENT, ASSESSMENT AND IMPROVEMENT

GENERAL

6.1. The processes for measurement, assessment and improvement applicable to the management and control of radioactive waste are subject to the requirements established in Ref. [2], and the recommendations presented in this Safety Guide and provided in Ref. [3] should be considered. It should be noted that the assessment discussed in this section is an assessment of management systems; it is not the same as the safety assessment referred to in previous sections.

MONITORING AND MEASUREMENT

6.2. Reference [2] requires in para. 6.1 that:

> "The effectiveness of the management system shall be monitored and measured to confirm the ability of the processes to achieve the intended results and to identify opportunities for improvement."

6.3. Monitoring and measurement of the effectiveness of the management system should be considered for all phases of radioactive waste management. Planning should be done to ensure that these activities will be continued during extended periods of waste storage.

SELF-ASSESSMENT

6.4. Reference [2] requires in para. 6.2 that:

> "Senior management and management at all other levels in the organization shall carry out self-assessment to evaluate the performance of work and the improvement of the safety culture."

Assessment of management processes

6.5. In assessments of the management processes in a waste management programme or organization, the following should be considered:

(a) Any changes in organizational structure or in the assignment of responsibilities and financial liabilities that could have an effect on the management and control of waste management activities. Such changes will have to be considered at the national and even possibly the international level.
(b) The continuation of assessments over extended periods of waste storage.

Assessment of work processes

6.6. Where assessments are performed on work processes used in a waste management programme or a waste management organization, the following aspects should be confirmed:

(a) Process variables and controls have not changed from those values established in the original validated processes accepted by the regulatory body;
(b) Required inspections and measurements are being performed and the associated records are being maintained;

(c) The ownership and characteristics of waste are traceable through any jurisdictional transfers of waste, and proper controls are implemented during storage;
(d) The instrumentation used to monitor or control waste management activities has not degraded in service and has not been modified without proper change control;
(e) Critical parameters of the waste acceptance criteria or specifications are being controlled within established limits;
(f) Facilities are being operated in accordance with the requirements;
(g) Waste management activities are conducted in conformity with their safety and environmental assessments;
(h) Waste packages and/or containers qualified by performance based testing are used within their qualification limits;
(i) Requirements resulting from regulatory authorizations and associated conditions that relate to waste acceptance criteria and/or specifications have been addressed and are being met.

6.7. The conformance of waste packages to the waste specifications or acceptance criteria for storage should be independently verified by personnel other than those who prepared the waste packages. The manner in which such verifications are carried out will vary according to the type of waste package. For low level radioactive waste packages that can be handled manually, verification may consist of directly examining and measuring the characteristics of the individual waste packages. This method is unlikely to be acceptable when dealing with intermediate level radioactive waste or high level radioactive waste because of the high radiation fields this waste generates. For packages containing waste of these types, verification should be carried out using a combination of more indirect methods, such as:

(a) Surveillance of the waste management processes (e.g. waste immobilization by cementation, testing of package closure welds);
(b) Sample checks on activities critical to the quality of waste packages (e.g. production of metal used to fabricate metal containers, preparation of concrete for overpacks);
(c) Remote measurement of radiation fields of packages;
(d) Sample examination of the data recorded for each waste package.

INDEPENDENT ASSESSMENT

6.8. Reference [2] requires in paras 6.3–6.6 that:

"6.3. Independent assessments shall be conducted regularly on behalf of senior management:

— To evaluate the effectiveness of processes in meeting and fulfilling goals, strategies, plans and objectives;
— To determine the adequacy of work performance and leadership;
— To evaluate the organization's safety culture;
— To monitor product quality;
— To identify opportunities for improvement.

"6.4. An organizational unit shall be established with the responsibility for conducting independent assessments. This unit shall have sufficient authority to discharge its responsibilities.

"6.5. Individuals conducting independent assessments shall not assess their own work.

"6.6. Senior management shall evaluate the results of the independent assessments, shall take any necessary actions, and shall record and communicate their decisions and the reasons for them."

6.9. Assessments to verify the implementation and effectiveness of the management system of a waste management programme or an individual waste management organization may be performed by:

(a) An organizational unit within the organization itself, provided that the assessors do not assess their own work, are independent of cost pressure or production pressure and are independent of the line management responsible for managing and implementing the process being assessed;
(b) The waste generator;
(c) Other organizations in the waste management programme;
(d) The operator of the disposal facility;
(e) The responsible national authorities and international organizations;
(f) A separate organization employed by the waste generator;
(g) One or more equivalent qualified organizations in a peer review.

MANAGEMENT SYSTEM REVIEW

6.10. Reference [2] requires in paras 6.7–6.10 that:

"6.7. A management system review shall be conducted at planned intervals to ensure the continuing suitability and effectiveness of the management system and its ability to enable the objectives set for the organization to be accomplished.

"6.8. The review shall cover but shall not be limited to:

— Outputs from all forms of assessment;
— Results delivered and objectives achieved by the organization and its processes;
— Non-conformances and corrective and preventive actions;
— Lessons learned from other organizations;
— Opportunities for improvement.

"6.9. Weaknesses and obstacles shall be identified, evaluated and remedied in a timely manner.

"6.10. The review shall identify whether there is a need to make changes to or improvements in policies, goals, strategies, plans, objectives and processes."

6.11. In conducting planned reviews of the management system, consideration should be given to whether the structure and content of the management system are still suitable, adequate and effective, especially if the waste management activities will continue for a long time. In such management system reviews, account should be taken of experience from managing the waste management facilities and programme and of experience from other facilities and programmes, both in the State and in other States.

6.12. Reviews of the management system for a waste management programme or for an individual waste management organization should be performed:

(a) For all aspects of the management system on a scheduled periodic basis (e.g. no less frequently than once every three years). The frequency should only be reduced, especially during certain phases such as extended storage pending disposal, with justification and with the agreement of the regulatory body.
(b) Whenever there are major changes in the organization or the applicable legislation.
(c) Whenever there are major changes in waste management activities.

(d) Whenever significant conditions adverse to quality are detected in the management system.
(e) To verify the adequacy of any corrective action that has been implemented.

6.13. Reviews may be focused on, for example:

(a) The waste management activities under the control of the organization being assessed;
(b) The quality of waste packages produced by the organization, as determined by the physical processes directly associated with the waste management activities that led to the production and storage of waste packages.

NON-CONFORMANCES AND CORRECTIVE AND PREVENTIVE ACTIONS

6.14. Reference [2] requires in paras 6.11–6.16 that:

> "6.11. The causes of non-conformances shall be determined and remedial actions shall be taken to prevent their recurrence.
>
> "6.12. Products and processes that do not conform to the specified requirements shall be identified, segregated, controlled, recorded and reported to an appropriate level of management within the organization. The impact of non-conformances shall be evaluated and non-conforming products or processes shall be either:
>
> —Accepted;
> —Reworked or corrected within a specified time period; or
> —Rejected and discarded or destroyed to prevent their inadvertent use.
>
> "6.13. Concessions granted to allow acceptance of a non-conforming product or process shall be subject to authorization. When non-conforming products or processes are reworked or corrected, they shall be subject to inspection to demonstrate their conformity with requirements or expected results.

"6.14. Corrective actions for eliminating non-conformances shall be determined and implemented. Preventive actions to eliminate the causes of potential non-conformances shall be determined and taken.

"6.15. The status and effectiveness of all corrective and preventive actions shall be monitored and reported to management at an appropriate level in the organization.

"6.16. Potential non-conformances that could detract from the organization's performance shall be identified. This shall be done: by using feedback from other organizations, both internal and external; through the use of technical advances and research; through the sharing of knowledge and experience; and through the use of techniques that identify best practices."

Non-conformances

6.15. A procedure should be established to control non-conforming items and processes; this should include:

(a) Segregation of non-conforming items to prevent them from being used or transferred to another organization before the non-conformance is resolved;
(b) Positive identification of non-conforming items and process equipment (e.g. tagging, labelling, stickers, marking);
(c) Resolution of the non-conformance (e.g. rework, repair, use as is or reject) and determination of the causes for the non-conformance so that corrective actions can be taken to prevent the non-conformance from recurring.

6.16. The consequences of the non-conformance of an item should be evaluated to assess whether the item can be accepted and used as it is or whether it should be reworked or repaired to bring it back into conformity with specified requirements. If none of these options is practicable, the item should be rejected.

6.17. In the case of a waste package for which neither repair nor rejection is a viable option, consideration may need to be given to reworking the package, by repackaging, overpacking or taking other measures to bring it into compliance with the requirements for waste storage and/or disposal as specified in the acceptance criteria. Any non-compliance found at a later stage (e.g. a design fault, defective package material or damage affecting the integrity of the

package) should be rectified as far as possible. If rectification of the non-compliance is not possible, its effect on further steps in waste management should be subjected to a detailed analysis and any possible consequences identified should be dealt with by other means.

Corrective actions

6.18. Non-conformance data should be periodically analysed to identify quality trends, and should be reported to the responsible manager for review and corrective action to remove the underlying causes of the non-conformances.

Preventive actions

6.19. Waste management organizations should establish procedures for identifying potential non-conformances and for taking action to prevent their occurrence. This is particularly important when waste management activities are carried out by a number of organizations, when organizational arrangements change and in periods of extended storage.

IMPROVEMENT

6.20. Reference [2] requires in paras 6.17–6.18 that:

> "6.17. Opportunities for the improvement of the management system shall be identified and actions to improve the processes shall be selected, planned and recorded.
>
> "6.18. Improvement plans shall include plans for the provision of adequate resources. Actions for improvement shall be monitored through to their completion and the effectiveness of the improvement shall be checked."

6.21. Experience and lessons learned from incidents and events and from accumulated knowledge should be reviewed periodically and should be used in deciding on improvements to the management system and the waste management activities themselves. Benchmarking by interaction with other operators regionally, nationally and internationally, as appropriate and practicable, may also give rise to ideas for improvements that warrant consideration. Action plans should be developed that identify how, where and when improvements may be made to the management system and to work

processes. These plans should specify how the improvements will be evaluated to demonstrate that they have been achieved.

Appendix I

EXAMPLE OF A SERIES OF ACTIVITIES IN RADIOACTIVE WASTE MANAGEMENT CONTROLLED BY SEVERAL MANAGEMENT SYSTEMS

I.1. Principles of a management system are:

(a) Establishing a management system;
(b) Management responsibility;
(c) Resource management;
(d) Process implementation;
(e) Measurement, assessment and improvement.

I.2. Management system procedures that should be established and applied include:

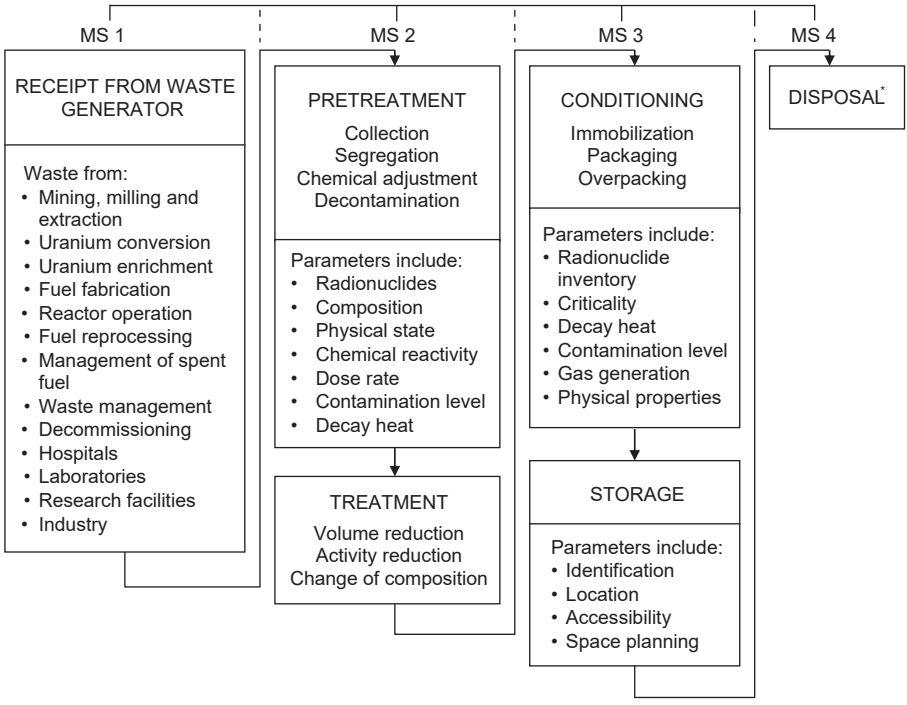
(a) Documentation and record keeping;
(b) Grading;
(c) Developing and controlling processes;
(d) Inspection and testing;
(e) Purchasing;
(f) Non-conformance actions and corrective actions;
(g) Management system review.

I.3. Specific waste management topics are:

(a) Waste generation;
(b) Pretreatment;
(c) Characterization;
(d) Treatment;
(e) Conditioning;
(f) Storage;
(g) Control of discharges;
(h) Clearance;
(i) Packaging strategies;
(j) Design and manufacture of containers;
(k) Handling of waste packages;
(l) Safety assessment;
(m) Authorization by the regulatory body;

(n) Site evaluation, design, construction, operation, closure and the post-closure stage of the waste disposal facility.

I.4. Figure 1 shows an example of a series of activities in radioactive waste management controlled by several management systems.



* Disposal is outside the scope of this Safety Guide, but the management system for disposal should be taken into account in the management system for waste processing, handling and storage activities because of the high level of interdependence of all the steps in managing waste.

FIG. 1. Example of a series of activities in radioactive waste management controlled by several management systems. (MS represents the individual management system for each phase or process.)

Appendix II

EXAMPLE OF THE GRADED APPLICATION OF MANAGEMENT SYSTEM REQUIREMENTS

II.1. Table 1 depicts a simplified and hypothetical example of the graded application of management system requirements to two different activities:

(a) Maintaining sump pumps in a uranium mine;
(b) Treating spent resins from an ion exchanger in a nuclear power plant.

II.2. Different levels of control were implemented on selected aspects (training, inspection and records) associated with the successive steps in each activity. Each aspect was assigned a grade between A and E. An aspect that receives a grade A requires the high level of control that is appropriate for a complex, multistaged and potentially high consequence step. An aspect that receives a grade E requires the lower level of control that is adequate for a single and relatively simple step having low possible consequences. The nature and extent of the provisions that are made to satisfy the management system requirements were then determined as a function of the assigned grades.

II.3. Note that the graded application of the requirements for a management system can only properly be achieved by first assessing the actual processes that are to be implemented with regard to those factors (listed in para. 2.13) that are important to the organization in meeting its overall requirements. Procedures, training programmes, records management provisions, etc., can then be established that will make the processes both effective and efficient. Many common aspects of waste management activities that can be applied in a graded manner in this fashion are listed in para. 2.14. When changes are made to a management system that has been established on a reasoned basis, care should be exercised to retain a sufficient level of confidence that the requirements will continue to be met.

TABLE 1. OUTLINE OF OPERATIONAL ACTIVITY

Mining	Nuclear power plant
Underground sump pumps are brought to the surface for maintenance. Waste mud and scale segregated from the pumps are disposed of.	Resin in the ion exchangers that is approaching its saturation level is either reconditioned for further use or treated, packaged and stored for eventual disposal.

Step 1: Initial inspection of equipment and/or material

	Mining		Nuclear power plant	
	Grade	Description	Grade	Description
Description of step	Pumps brought to the surface are placed in a receiving area and checked for surface contamination with a handheld monitoring device. If the contamination is above a certain limit, the pump is sent for decontamination before being sent to the maintenance workshop.		The external field of an ion exchange resin column is measured with a remote monitoring instrument. If the measurement indicates that the resin may be approaching its saturation limit, the resin is inspected and a decision is taken on whether the resin can be reconditioned to bring it back to a usable condition or whether it should be prepared for eventual disposal as radioactive waste.	
Training	C	A training programme is required to train and qualify personnel to use the radiation measuring equipment; such training should be provided.	A	Inspecting the resin involves taking a sample from the ion exchanger and using specialized inspection equipment to analyse it. The results of this analysis should be assessed and categorized. This requires a high degree of experience, and specialized training to conduct the inspection and to assess and categorize the data should be provided. The required training should include qualification in radioactivity analysis.
Records	C	Measurements of the surface contamination on the pump are recorded on a preprinted form that serves as the record.	A	The inspection equipment produces a graphic printout. An analysis report from the analyst that includes the categorization of the data is attached to the printout. The analysis report supports the decision making for the further steps (reconditioning or preparation for disposal).

TABLE 1. OUTLINE OF OPERATIONAL ACTIVITY (cont.)

Step 2: Segregation and decontamination and/or reconditioning of equipment and/or material for reuse

	Mining		Nuclear power plant	
	Grade	Description	Grade	Description
Description of step	Contaminated pumps are segregated and sent to a decontamination bay for washing with a high pressure water jet. A handheld contamination monitoring device is used to measure the contamination levels.		Resin to be reconditioned is treated in a multistage chemical reduction process until specified reconditioning levels are obtained. The resin is then put into storage for reuse. (Resin to be prepared for disposal is discussed under steps 3 and 4.)	
Training	E	The operator should undergo on the job training in the washing process and training in safety and environmental protection and/or radiation protection.	C	Specialized training should be put in place for personnel operating the resin reconditioning equipment.
	C	A training programme should be put in place to train and qualify personnel to use the radiation measuring equipment.		
Records	C	Measurements are recorded on a preprinted form that serves as the record.	C	A form is completed specifying which reconditioning procedure was used to return the resin to a usable condition.

TABLE 1. OUTLINE OF OPERATIONAL ACTIVITY (cont.)

Step 3: Waste processing

	Mining		Nuclear power plant	
	Grade	Description	Grade	Description
Description of step	Contaminated material (i.e. mud and oxidized scale) removed from the pump surface by the washing process is deposited into the wash bay sump, from where it will be pumped to a tailings impoundment.		Resin to be disposed of is chemically treated and immobilized in a solid form.	
Training	E	On the job training to operate the pump for the wash bay sump should be provided.	B	Training to operate the equipment for the chemical treatment and immobilization process should be provided.
	B	Training and qualification in the use of radiation measuring equipment should be provided.		
Inspection	D	The pump is measured after washing, using a handheld instrument to determine the contamination level.	B	Samples of the chemically treated and immobilized waste are taken for confirmatory testing.
Records	E	If the activity measured on the washed pump is below the allowable level, the pump is sent to the workshop for maintenance. If it is above the limit, washing is repeated until a level below the allowable limit is reached. A form is completed recording the measurements.	C	A record is generated of the key process parameters and chemicals used to treat and immobilize the resin.

TABLE 1. OUTLINE OF OPERATIONAL ACTIVITY (cont.)

Step 4: Waste packaging

	Mining		Nuclear power plant	
	Grade	Description	Grade	Description
Description of step	No packaging of the mining sump pump waste (mud and scale) is required because the waste product will be pumped to a tailings impoundment.		The immobilized resin is sealed in stainless steel canisters. The welding of the cap onto the canister is inspected using dye penetrant testing. The canisters are then placed into purpose built concrete drums which, when sealed, form the waste packages. The activity of the sealed concrete drum (waste package) is measured using a handheld instrument.	
Training	Not applicable		A B B	Training on how to fill and seal a canister should be provided. Training and qualification for the inspector for dye penetrant testing should be provided. Training and qualification in the use of handheld radiation measuring equipment should be provided.
Records	Not applicable		C C C	A record of the dye penetrant test is produced and maintained. A record of the contents of the waste package and the external activity level of the package is produced. The record of the process and chemicals that were used to reduce the resin is attached to the waste package.

TABLE 1. OUTLINE OF OPERATIONAL ACTIVITY (cont.)

Step 5: Waste storage and/or disposal

	Mining		Nuclear power plant	
	Grade	Description	Grade	Description
Description of step	The mining pump sump waste is pumped to a tailings impoundment.		The resin waste packages from the nuclear power plant are stored for eventual emplacement in a disposal facility.	
Training	D	The operator should undergo on the job training in the pumping process.	B	Specialized training, including training in radiation protection measures, should be provided to the operator of the waste transfer and storage equipment.
Records	C	Pumping measurements are recorded on a preprinted form that serves as the record.	C	A form is completed specifying where the waste packages have been stored, and is cross-referenced to the records of the chemical treatment and immobilization processing and the canister seal testing.

Appendix III

CHARACTERISTICS OF WASTE PRODUCTS THAT ARE IMPORTANT TO SAFETY AND ENVIRONMENTAL PROTECTION

WASTE COMPOSITION

III.1. The composition of waste should be known with sufficient accuracy that nuclear and conventional safety and environmental protection are not compromised. Toxic or hazardous constituents should be characterized by analytical means or from knowledge of the processes, so that hazards associated with the storage and transport of waste can be identified. Where appropriate, the leachability of radionuclides and toxic materials and the generation rates for volatile organic compounds and other hazardous gases should be determined. The waste composition should also be determined if potential migration pathways from the facility are predicted.

CHEMICAL INSTABILITY

III.2. Waste exhibiting the following properties should be immobilized and/or stabilized or should be packaged as a potential accident initiator (and with more stringent qualification of containers, for example):

(a) Flammability;
(b) Corrosivity;
(c) Reactivity;
(d) Pyrophoricity;
(e) Rapid oxidation promotion;
(f) Biodegradability.

III.3. Chemically incompatible waste forms should be carefully controlled. The amount of mobilizing agents such as chelating compounds, particularly stable ones, should be kept to a minimum.

IMMOBILIZATION AND/OR STABILIZATION

III.4. Waste containing hazardous constituents that are mobile in the environment, or constituents that enhance the mobility of radionuclides, should

be immobilized or stabilized. If hazardous constituents are not immobilized or stabilized, it should be demonstrated for a facility storing the waste that the constituents cannot migrate in a hazardous form or concentration to the accessible environment. Although low and intermediate level radioactive waste is generally treated to achieve chemical stability, such waste is frequently not converted to a homogeneous monolithic state. It is disposed of in disposal facilities where the containers are expected to degrade over time, and the lithospheric attributes of the disposal site may be expected to provide the ultimate confidence that the radionuclides and hazardous waste constituents will be contained. In some instances, natural barriers are not expected to provide the ultimate assurance of containment. In such cases, waste conditioning and waste characterization become critical fields for the application of management resources. This is because the chemical and physical properties of the waste should be consistent with the assumptions made about the modelling of contaminant migration and transport after containers fail in the environment of the disposal facility.

III.5. High level radioactive waste and waste containing long lived radionuclides (such as transuranic waste) are frequently immobilized to prevent migration of radionuclides from the disposal facility to the accessible environment. The leach resistant and chemically inert characteristics of the waste form should be verified by testing and process control. Process control is of major importance for immobilized waste forms. Control of input waste chemistry, additives, temperatures, time at temperature, etc., determines the consistency of the characteristics of the final waste form. Where solidified high level waste is contained in integral containers (i.e. the waste form is not separable from the container, such as with vitrified waste), which are required by the assumptions in the safety and environmental assessments for the disposal facility to maintain their integrity for hundreds of years, structural integrity of the containers should be ensured.

III.6. Products such as vitrified high level radioactive waste generate significant decay heat and may generate significant internal pressure from off-gassing. They may also be required to resist corrosion of the materials used for container construction and seals in the geological setting, and this should be carefully controlled.

III.7. The acceptability of all immobilization processes should be verified by leach (hydrolysis) testing to ensure that the stability of the waste form meets the assumptions made in the safety and environmental assessments for the disposal facility.

STRUCTURAL STABILITY

III.8. Structural stability of the waste form should be ensured for maintaining the physical integrity of the waste form during handling, transport, storage and disposal. The waste form should maintain its physical dimensions and properties to the required degree under conditions of a compressive load, chemical reactions and biodegradation. Stability can be achieved by means of selection of an appropriate solidification agent, by removal of potential chemical contaminants and biological materials, and by elimination of the void spaces in the waste package.

III.9. Provided that the waste is not mixed with compressible or degradable material, the waste itself may be adequate to provide long term structural stability, as with sealed radiation sources, certain reactor components and contaminated concrete. However, in other cases the waste will not provide adequate structural stability and will require some form of processing to improve its characteristics.

RESPIRABLE FRACTION

III.10. Where waste forms are not monolithic, consideration should be given to controlling the respirable fraction, in order to reduce the consequences of potential releases (if the integrity of the container is not preserved under all conditions). This is especially true for alpha emitting waste, owing to its more significant biological effects through inhalation.

DISTRIBUTION OF ACTIVITY

III.11. Limits may need to be established on the distribution of activity within a container to control surface dose rates and to prevent criticalities. Where required, these limits should be derived from the safety and environmental assessments of the disposal facility. They should reflect the need to reduce the dilution and dispersion elements of radioactive waste management, which is justifiable on environmental and economic grounds. The waste form should not be artificially manipulated by dilution, or by insertion of concentrated sources into a non-radioactive matrix, for the express purpose of compliance with activity limits alone.

REFERENCES

[1] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for the Disposal of Radioactive Waste, IAEA Safety Standards Series No. GS-G-3.4, IAEA, Vienna (2008).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety, IAEA Safety Standards Series No. GS-R-1, IAEA, Vienna (2000).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, including Decommissioning, IAEA Safety Standards Series No. WS-R-2, IAEA, Vienna (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Low and Intermediate Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.5, IAEA, Vienna (2003).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of High Level Radioactive Waste, IAEA Safety Standards Series No. WS-G-2.6, IAEA, Vienna (2003).

[9] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[10] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).

[11] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, INFCIRC/546, IAEA, Vienna (1997).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment and Verification, IAEA Safety Standards Series No. GS-R-4, IAEA, Vienna (in preparation).

[13] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Quality Management Systems — Requirements, ISO 9001:2000, ISO, Geneva (2000).

[14] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Environmental Management Systems — Requirements with Guidance for Use, ISO 14001:2004, ISO, Geneva (2004).

[15] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Safety Culture, INSAG-4, IAEA, Vienna (1991).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Developing Safety Culture in Nuclear Activities: Practical Suggestions to Assist Progress, Safety Reports Series No. 11, IAEA, Vienna (1998).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture, IAEA-TECDOC-1329, IAEA, Vienna (2002).

CONTRIBUTORS TO DRAFTING AND REVIEW

Annanmaki, M.	Radiation and Nuclear Safety Authority, Finland
Baldev, R.	Indira Gandhi Centre for Atomic Research, India
Bannai, T.	International Atomic Energy Agency
Benítez Navarro, G.	Centro de Protección e Higiene de las Radiaciones, Cuba
Bragg, K.	International Atomic Energy Agency
Chandraker, K.	Atomic Energy Regulatory Board, India
Garcin, R.	Eskom, South Africa
Hasson, R.	Department of Energy, United States of America
Hertl, B.	Ministry of Environment, Slovenia
Hodgkinson, D.	Quintessa Ltd, United Kingdom
Ichimura, T.	International Atomic Energy Agency
Kayser, P.	Permanent Mission of Luxembourg
Kim, H.	Korea Hydro and Nuclear Power Co. Ltd, Republic of Korea
Kim, S.	Korea Institute of Nuclear Safety, Republic of Korea
Krasny, D.	Bohunice nuclear power plant, Slovakia
Kulkarni, Y.	Bhabha Atomic Research Centre, India
Lavender, C.	HM Nuclear Installations Inspectorate, United Kingdom
Lee, Y.	Korea Atomic Energy Research Institute, Republic of Korea
Linsley, G.	International Atomic Energy Agency

Louvat, D.	International Atomic Energy Agency
McCarthy, G.	The University of Melbourne, Australia
Metcalf, P.	International Atomic Energy Agency
Orihel, M.	Bohunice nuclear power plant, Slovakia
Pieroni, N.	International Atomic Energy Agency
Quesada Bueno, J.	Empresa Nacional de Residuos Radiactivos SA, Spain
Rowat, J.	International Atomic Energy Agency
Rubino, G.	SOGIN S.p.A., Italy
Santos Callejo, A.	Consejo de Seguridad Nuclear, Spain
Stephens, M.	Atomic Energy of Canada Ltd, Canada
Tyrer, M.	HM Nuclear Installations Inspectorate, United Kingdom

BODIES FOR THE ENDORSEMENT OF IAEA SAFETY STANDARDS

An asterisk denotes a corresponding member. Corresponding members receive drafts for comment and other documentation but they do not generally participate in meetings.

Commission on Safety Standards

Argentina: Oliveira, A.; *Australia*: Loy, J.; *Brazil*: Souza de Assis, A.; *Canada*: Pereira, J.K.; *China*: Li, G.; *Czech Republic*: Drábová, D.; *Denmark*: Ulbak, K.; *Egypt*: Abdel-Hamid, S.B.; *France*: Lacoste, A.-C. (Chairperson); *Germany*: Majer, D.; *India*: Sharma, S.K.; *Israel*: Levanon, I.; *Japan*: Abe, K.; *Korea, Republic of*: Eun, Y.-S.; *Pakistan*: Hashmi, J.; *Russian Federation*: Malyshev, A.B.; *South Africa*: Magugumela, M.T.; *Spain*: Azuara, J.A.; *Sweden*: Holm, L.-E.; *Switzerland*: Schmocker, U.; *United Kingdom*: Weightman, M.; *United States of America*: Virgilio, M.; *European Commission*: Waeterloos, C.; *IAEA*: Karbassioun, A. (Coordinator); *International Commission on Radiological Protection*: Holm, L.-E.; *OECD Nuclear Energy Agency*: Tanaka, T.

Nuclear Safety Standards Committee

Argentina: Sajaroff, P.; *Australia*: MacNab, D.; *Austria*: Sholly, S.; *Belgium*: Govaerts, P.; *Brazil*: de Queiroz Bogado Leite, S.; **Bulgaria*: Gladychev, Y.; *Canada*: Newland, D.; *China*: Wang, J.; *Croatia*: Valčić, I.; **Cyprus*: Demetriades, P.; *Czech Republic*: Böhm, K.; *Egypt*: Aly, A.I.M.; *Finland*: Reiman, L. (Chairperson); *France*: Saint Raymond, P.; *Germany*: Herttrich, M.; **Greece*: Camarinopoulos, L.; *Hungary*: Vöröss, L.; *India*: Kushwaha, H.S.; *Iran, Islamic Republic of*: Alidousti, A.; **Iraq*: Khalil Al-Kamil, A.-M.; *Ireland*: Hone, C.; *Israel*: Hirshfeld, H.; *Italy*: Bava, G.; *Japan*: Nakamura, K.; *Korea, Republic of*: Kim, H.-K.; *Lithuania*: Demčenko, M.; *Mexico*: González Mercado, V.; *Netherlands*: Jansen, R.; *Pakistan*: Habib, M.A.; *Paraguay*: Troche Figueredo, G.D.; **Peru*: Ramírez Quijada, R.; *Portugal*: Marques, J.J.G.; *Romania*: Biro, L.; *Russian Federation*: Shvetsov, Y.E.; *Slovakia*: Uhrik, P.; *Slovenia*: Levstek, M.F.; *South Africa*: Bester, P.J.; *Spain*: Zarzuela, J.; *Sweden*: Hallman, A.; *Switzerland*: Aeberli, W.; **Thailand*: Tanipanichskul, P.; *Turkey*: Bezdegumeli, U.; *Ukraine*: Bezsalyi, V.; *United Kingdom*: Vaughan, G.J.; *United States of America*: Mayfield, M.E.; *European Commission*: Vigne, S.; *IAEA*: Feige, G. (Coordinator); *International Organization for Standardization*:

Nigon, J.L.; *OECD Nuclear Energy Agency*: Reig, J.; **World Nuclear Association*: Saint-Pierre, S.

Radiation Safety Standards Committee

Argentina: Rojkind, R.H.A.; *Australia*: Melbourne, A.; **Belarus*: Rydlevski, L.; *Belgium*: Smeesters, P.; *Brazil*: Rodriguez Rochedo, E.R.; **Bulgaria*: Katzarska, L.; *Canada*: Clement, C.; *China*: Yang, H.; *Costa Rica*: Pacheco Jimenez, R.; *Cuba*: Betancourt Hernandez, L.; **Cyprus*: Demetriades, P.; *Czech Republic*: Petrova, K.; *Denmark*: Ohlenschlager, M.; **Egypt*: Hassib, G.M; *Finland*: Markkanen, M.; *France*: Godet, J.; *Germany*: Landfermann, H.; **Greece*: Kamenopoulou, V.; *Hungary*: Koblinger, L.; *Iceland*: Magnusson, S. (Chairperson); *India*: Sharma, D.N.; *Indonesia*: Akhadi, M.; *Iran, Islamic Republic of*: Rastkhah, N.; **Iraq*: Khalil Al-Kamil, A.-M.; *Ireland*: Colgan, T.; *Israel*: Laichter, Y.; *Italy*: Bologna, L.; *Japan*: Yoda, N.; *Korea, Republic of*: Lee, B.; *Latvia*: Salmins, A.; *Malaysia*: Rehir, D.; *Mexico*: Maldonado Mercado, H.; *Morocco*: Tazi, S.; *Netherlands*: Zuur, C.; *Norway*: Saxebol, G.; *Pakistan*: Mehboob, A.E.; *Paraguay*: Idoyago Navarro, M.; *Philippines*: Valdezco, E.; *Portugal*: Dias de Oliviera, A.; *Romania*: Rodna, A.; *Russian Federation*: Savkin, M.; *Slovakia*: Jurina, V.; *Slovenia*: Sutej, T.; *South Africa*: Olivier, J.H.I.; *Spain*: Amor, I.; *Sweden*: Hofvander, P.; *Switzerland*: Pfeiffer, H.J.; **Thailand*: Wanitsuksombut, W.; *Turkey*: Okyar, H.; *Ukraine*: Holubiev, V.; *United Kingdom*: Robinson, I.; *United States of America*: Miller, C.; *European Commission*: Janssens, A.; *Food and Agriculture Organization of the United Nations*: Byron, D.; *IAEA*: Boal, T. (Coordinator); *International Commission on Radiological Protection*: Valentin, J.; *International Labour Office*: Niu, S.; *International Organization for Standardization*: Perrin, M.; *OECD Nuclear Energy Agency*: Lazo, T.; *Pan American Health Organization*: Jimenez, P.; *United Nations Scientific Committee on the Effects of Atomic Radiation*: Crick, M.; *World Health Organization*: Carr, Z.; *World Nuclear Association*: Saint-Pierre, S.

Transport Safety Standards Committee

Argentina: López Vietri, J.; *Australia*: Sarkar, S.; *Austria*: Kirchnawy, F.; *Belgium*: Cottens, E.; *Brazil*: Mezrahi, A.; *Bulgaria*: Bakalova, A.; *Canada*: Faille, S.; *China*: Qu, Z.; *Croatia*: Kubelka, D.; *Cuba*: Quevedo Garcia, J.R.; **Cyprus*: Demetriades, P.; *Czech Republic*: Ducháček, V.; *Denmark*: Breddan, K.; **Egypt*: El-Shinawy, R.M.K.; *Finland*: Tikkinen, J.; *France*: Aguilar, J.; *Germany*: Rein, H.; **Greece*: Vogiatzi, S.; *Hungary*: Sáfár, J.; *India*: Agarwal, S.P.; *Iran, Islamic Republic of*: Kardan, M.R.; **Iraq*: Khalil

Al-Kamil, A.-M.; *Ireland*: Duffy, J. (Chairperson); *Israel*: Koch, J.; *Italy*: Trivelloni, S.; *Japan*: Amano, M.; *Korea, Republic of*: Kim, Y.-J.; *Malaysia*: Sobari, M.P.M.; *Netherlands*: Van Halem, H.; *New Zealand*: Ardouin, C.; *Norway*: Hornkjøl, S.; *Pakistan*: Rashid, M.; *Paraguay*: More Torres, L.E.; *Philippines*: Kinilitan-Parami, V.; *Portugal*: Buxo da Trindade, R.; *Romania*: Vieru, G.; *Russian Federation*: Ershov, V.N.; *South Africa*: Jutle, K.; *Spain*: Zamora Martin, F.; *Sweden*: Dahlin, G.; *Switzerland*: Knecht, B.; **Thailand*: Wanitsuksombut, W.; *Turkey*: Ertürk, K.; *Ukraine*: Sakalo, V.; *United Kingdom*: Young, C.N.; *United States of America*: Brach, W.E.; Boyle, R.; *European Commission*: Venchiarutti, J.-C.; *International Air Transport Association*: Abouchaar, J.; *IAEA*: Wangler, M.E. (Coordinator); *International Civil Aviation Organization*: Rooney, K.; *International Federation of Air Line Pilots' Associations*: Tisdall, A.; *International Maritime Organization*: Rahim, I.; *International Organization for Standardization*: Malesys, P.; *United Nations Economic Commission for Europe*: Kervella, O.; *Universal Postal Union*: Giroux, P.; *World Nuclear Transport Institute*: Green, L.

Waste Safety Standards Committee

Argentina: Siraky, G.; *Australia*: Williams, G.; *Austria*: Hohenberg, J.; *Belgium*: Baekelandt, L.; *Brazil*: Heilbron, P.; **Bulgaria*: Simeonov, G.; *Canada*: Lojk, R.; *China*: Fan, Z.; *Croatia*: Subasic, D.; *Cuba*: Salgado Mojena, M.; **Cyprus*: Demetriades, P.; **Czech Republic*: Lieteva, P.; *Denmark*: Nielsen, C.; **Egypt*: El-Adham, K.E.A.; *Finland*: Ruokola, E.; *France*: Cailleton, R.; *Hungary*: Czoch, I.; *India*: Raj, K.; *Indonesia*: Yatim, S.; *Iran, Islamic Republic of*: Ettehadian, M.; **Iraq*: Abass, H.; *Israel*: Dody, A.; *Italy*: Dionisi, M.; *Japan*: Ito, Y.; *Korea, Republic of*: Park, W.; **Latvia*: Salmins, A.; *Lithuania*: Paulikas, V.; *Mexico*: Aguirre Gómez, J.; *Morocco*: Soufi, I.; *Netherlands*: Selling, H.; **Norway*: Sorlie, A.; *Pakistan*: Rehman, R.; *Paraguay*: Facetti Fernandez, J.; *Portugal*: Flausino de Paiva, M.; *Romania*: Tuturici, I.; *Russian Federation*: Poluektov, P.P.; *Slovakia*: Konečný, L.; *Slovenia*: Mele, I.; *South Africa*: Pather, T. (Chairperson); *Spain*: Sanz, M.; *Sweden*: Wingefors, S.; *Switzerland*: Zurkinden, A.; *Turkey*: Özdemir, T.; *Ukraine*: Iievlev, S.; *United Kingdom*: Wilson, C.; *United States of America*: Camper, L.; *European Commission*: Hilden, W.; *IAEA*: Hioki, K. (Coordinator); *International Organization for Standardization*: Hutson, G.; *OECD Nuclear Energy Agency*: Riotte, H.; *World Nuclear Association*: Saint-Pierre, S.

Safety through international standards

"The IAEA's standards have become a key element of the global safety regime for the beneficial uses of nuclear and radiation related technologies.

"IAEA safety standards are being applied in nuclear power generation as well as in medicine, industry, agriculture, research and education to ensure the proper protection of people and the environment."

Mohamed ElBaradei
IAEA Director General

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–102008–6
ISSN 1020–525X