IAEA Safety Standards

for protecting people and the environment

Disposal of Radioactive Waste

Specific Safety Requirements

No. SSR-5

IAEA

International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

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

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

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

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

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

OTHER SAFETY RELATED PUBLICATIONS

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

Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications. Security related publications are issued in the **IAEA Nuclear Security Series**.

DISPOSAL OF RADIOACTIVE WASTE

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

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHRAIN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
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
LESOTHO
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
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''.

IAEA SAFETY STANDARDS SERIES No. SSR-5

DISPOSAL OF RADIOACTIVE WASTE

SPECIFIC SAFETY REQUIREMENTS

This publication includes a CD-ROM containing the IAEA Safety Glossary: 2007 Edition (2007) and the Fundamental Safety Principles (2006), each in Arabic, Chinese, English, French, Russian and Spanish versions. The CD-ROM is also available for purchase separately. See: http://www-pub.iaea.org/MTCD/publications/publications.asp

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2011

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
April 2011
STI/PUB/1449

IAEA Library Cataloguing in Publication Data

Disposal of radioactive waste. — Vienna : International Atomic Energy Agency, 2011.
p. ; 24 cm. — (IAEA safety standards series, ISSN 1020–525X ; no. SSR-5)
STI/PUB/1449
ISBN 978–92–0–103010–8
Includes bibliographical references.

1. Radioactive waste disposal — Safety measures. — 2. Radioactive waste disposal — Environmental aspects. — 3. Radioactive waste sites — Management. 4. Safety standards. I. International Atomic Energy Agency. II. Series.

IAEAL 10–00661

FOREWORD

by Yukiya Amano
Director General

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

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

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

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

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

DISCLAIMER

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. The process of developing, reviewing and establishing the IAEA standards involves the IAEA Secretariat and all Member States, many of which are represented on the four IAEA safety standards committees and the IAEA Commission on Safety Standards.

The IAEA standards, as a key element of the global safety regime, are kept under regular review by the Secretariat, the safety standards committees and the Commission on Safety Standards. The Secretariat gathers information on experience in the application of the IAEA standards and information gained from the follow-up of events for the purpose of ensuring that the standards continue to meet users' needs. The present publication reflects feedback and experience accumulated until 2010 and it has been subject to the rigorous review process for standards.

The accident at the Fukushima Daiichi nuclear power plant in Japan caused by the disastrous earthquake and tsunami of 11 March 2011 and the consequences of the emergency for people and the environment have to be fully investigated. They are already under study in Japan, at the IAEA and elsewhere. Lessons to be learned for nuclear safety and radiation protection and for emergency preparedness and response will be reflected in IAEA safety standards as they are revised and issued in the future.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

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

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

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

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

Safety Fundamentals

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

Safety Requirements

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

---

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

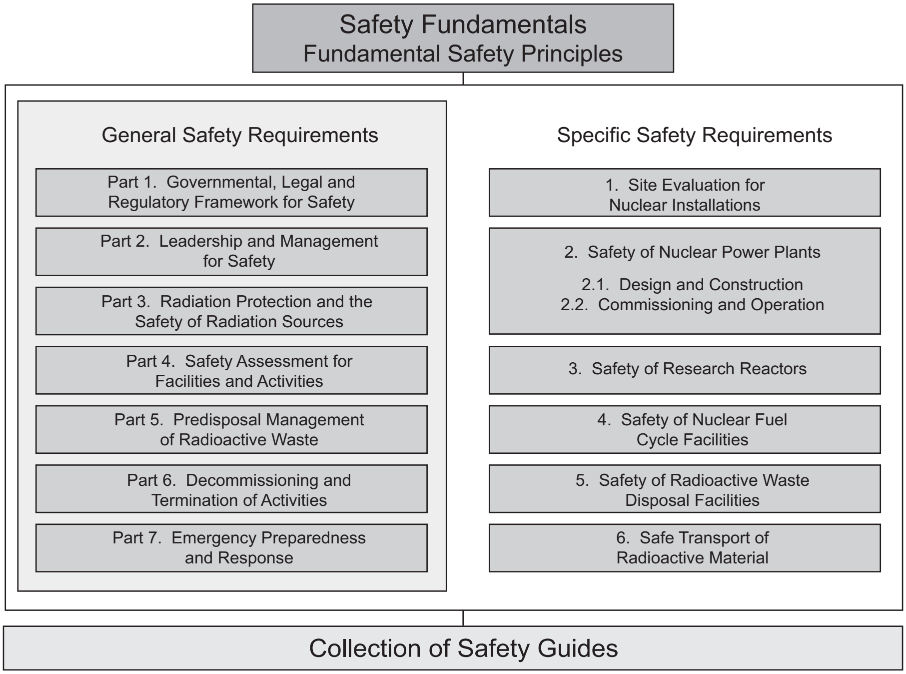

FIG. 1. The long term structure of the IAEA Safety Standards Series.

as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

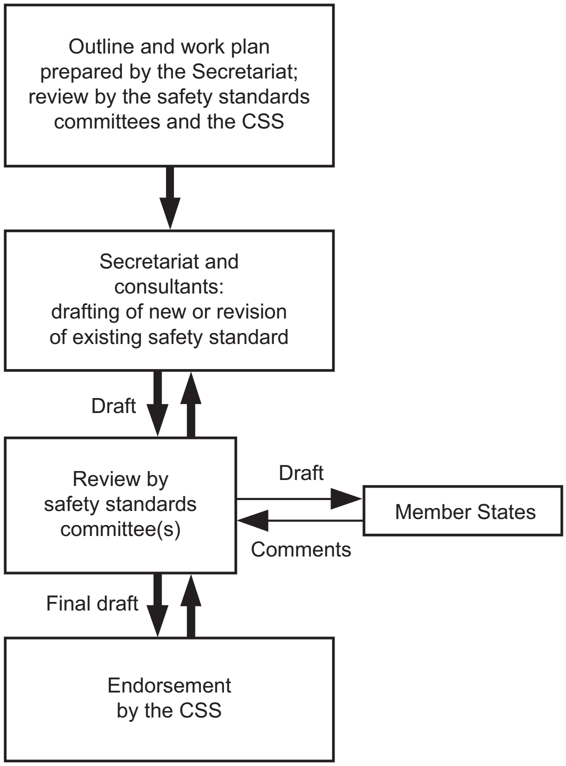

FIG. 2. The process for developing a new safety standard or revising an existing standard.

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

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

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

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

INTERPRETATION OF THE TEXT

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

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

General

1.1. Radioactive waste arises from the generation of electricity in nuclear power plants, from nuclear fuel cycle operations and from activities in which radioactive material is used. It also arises from activities and processes in which radioactive material of natural origin becomes concentrated in waste material and safety needs to be considered in its management. Radioactive waste can be generated by a wide range of activities varying from activities in hospitals to nuclear power plants to mines and mineral processing facilities.

1.2. The properties of radioactive waste are likewise varied, not only in terms of radioactive content and activity concentration but also in terms of physical and chemical properties. Its rate of generation is also varied. A common characteristic of all radioactive waste is its potential to present a hazard to people and to the environment, and it must, therefore, be managed so as to reduce any associated risks to acceptable levels. The potential hazard can range from large to trivial: a variation reflected in the management and disposal options necessary for various types of waste.

1.3. The safety principles to be applied in all activities for radioactive waste management are set out in the IAEA Safety Fundamentals [1]. These principles also form the ethical and conceptual basis for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2]. The requirements for radiation protection are set out in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the International Basic Safety Standards) [3]. Many of the safety requirements and concepts of protection adopted in the standards and in the Joint Convention [2] derive from the recommendations of the International Commission on Radiological Protection (ICRP) [4–7].

1.4. This Safety Requirements publication establishes safety requirements relating to the disposal of radioactive waste of all types. It sets out the safety objective and criteria for the protection of people and the environment against radiation risks arising from disposal facilities for radioactive waste in operation and after closure. In order to meet the criteria, measures may need to be taken in site selection and evaluation and in the design, construction, operation and closure of the disposal facility. The requirements are essential from a safety perspective and failure to meet any of the requirements would require action to be taken.

1.5. This Safety Requirements publication does not reiterate all the safety requirements in respect of the governmental, legal and regulatory framework, radiation protection and emergency planning that are established in other Safety Requirements publications. It is based on the premise that, in general, arrangements have to be in place to ensure that these related requirements are met. This Safety Requirements publication does set out some requirements that are closely related to these other thematic areas and which are of particular importance to the safety of radioactive waste disposal facilities. Guidance on the fulfilment of the safety requirements set out in this Safety Requirements publication is provided in several Safety Guides specific to different types of radioactive waste disposal facility.

1.6. The preferred strategy for the management of all radioactive waste is to contain it (i.e. to confine the radionuclides to within the waste matrix, the packaging and the disposal facility) and to isolate it from the accessible biosphere. This strategy does not preclude the discharge (i.e. controlled release) of effluents, arising from waste management activities, that contain residual amounts of radionuclides, or the clearance of materials that meet the relevant criteria. International safety standards have been established covering both of these circumstances [8, 9].

1.7. Radioactive waste may arise initially in various gaseous, liquid and solid forms. In waste management activities, the waste is generally processed to produce stable and solid forms, and reduced in volume and immobilized, as far as practicable, to facilitate their storage, transport and disposal. This Safety Requirements publication is concerned with the stage of disposal of solid or solidified materials, which is the last step in the process of radioactive waste management.

Concepts relating to disposal (and storage) of radioactive waste

1.8. The term 'disposal' refers to the emplacement of radioactive waste into a facility or a location with no intention of retrieving the waste[1]. Disposal options are designed to contain the waste by means of passive engineered and natural features and to isolate it from the accessible biosphere to the extent necessitated by the associated hazard. The term disposal implies that retrieval is not intended; it does not mean that retrieval is not possible.

1.9. By contrast, the term 'storage' refers to the retention of radioactive waste in a facility or a location with the intention of retrieving the waste. Both options, disposal and storage, are designed to contain waste and to isolate it from the accessible biosphere to the extent necessary. The important difference is that storage is a temporary measure following which some future action is planned. This may include further conditioning or packaging of the waste and, ultimately, its disposal. Guidance on the safe storage of radioactive waste is provided in Ref. [11].

1.10. A number of design options for disposal facilities have been developed and various types of disposal facility have been constructed in many States and are in operation. These design options have different degrees of containment and isolation capability appropriate to the radioactive waste that they will receive. The specific aims of disposal are:

(a) To contain the waste;
(b) To isolate the waste from the accessible biosphere and to reduce substantially the likelihood of, and all possible consequences of, inadvertent human intrusion[2] into the waste;
(c) To inhibit, reduce and delay the migration of radionuclides at any time from the waste to the accessible biosphere;
(d) To ensure that the amounts of radionuclides reaching the accessible biosphere due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times.

---

[1] Terminology used in this publication is defined and explained in the IAEA Safety Glossary [10] (see *http://www-ns.iaea.org/standards/safety-glossary.htm*).

[2] 'Human intrusion' refers to human actions that affect the integrity of a disposal facility and which could potentially give rise to radiological consequences. Only those human actions that result in direct disturbance of the disposal facility (i.e. the waste itself, the contaminated near field or the engineered barrier materials) are considered.

1.11. The balance between the importance of each of the above mentioned aims and the extent to which and the way in which they are accomplished will vary, depending on the characteristics of the waste and the type of disposal facility.

1.12. Disposal facilities are not expected to provide complete containment and isolation of waste over all time; this is neither practicable nor necessitated by the hazard associated with waste, which declines with time.

Types of disposal facility for radioactive waste

1.13. As indicated in para. 1.10, a number of design options for disposal facilities have been developed and various types of disposal facility have been constructed and are in operation around the world.

1.14. Within any State or region, a number of disposal facilities of different designs may be required in order to accommodate radioactive waste of various types. The classification of radioactive waste is discussed in an IAEA Safety Guide [12] and the different classes of radioactive waste are presented in the Annex. The following disposal options have been adopted in one or more States, corresponding to recognized classes of radioactive waste:

(a) Specific landfill disposal: Disposal in a facility similar to a conventional landfill facility for industrial refuse but which may incorporate measures to cover the waste. Such a facility may be designated as a disposal facility for very low level radioactive waste (VLLW) with low concentrations or quantities of radioactive content [12]. Typical waste disposed of in a facility of this type may include soil and rubble arising from decommissioning activities.
(b) Near surface disposal: Disposal in a facility consisting of engineered trenches or vaults constructed on the ground surface or up to a few tens of metres below ground level. Such a facility may be designated as a disposal facility for low level radioactive waste (LLW) [12].
(c) Disposal of intermediate level waste: Depending on its characteristics, intermediate level radioactive waste (ILW) can be disposed of in different types of facility [12]. Disposal could be by emplacement in a facility constructed in caverns, vaults or silos at least a few tens of metres below ground level and up to a few hundred metres below ground level. It could include purpose built facilities and facilities developed in or from existing mines. It could also include facilities developed by drift mining into mountainsides or hillsides, in which case the overlying cover could be more than 100 m deep.

(d) Geological disposal: Disposal in a facility constructed in tunnels, vaults or silos in a particular geological formation (e.g. in terms of its long term stability and its hydrogeological properties) at least a few hundred metres below ground level. Such a facility could be designed to receive high level radioactive waste (HLW) [12], including spent fuel if it is to be treated as waste. However, with appropriate design, a geological disposal facility could receive all types of radioactive waste.
(e) Borehole disposal: Disposal in a facility consisting of an array of boreholes, or a single borehole, which may be between a few tens of metres up to a few hundreds of metres deep. Such a borehole disposal facility is designed for the disposal of only relatively small volumes of waste, in particular disused sealed radioactive sources. A design option for very deep boreholes, several kilometres deep, has been examined for the disposal of solid high level waste and spent fuel, but this option has not been adopted for a disposal facility by any State.
(f) Disposal of mining and mineral processing waste: Disposal usually on or near the ground surface, but the manner and the large volumes in which the waste arises, its physicochemical form and its content of long lived radionuclides of natural origin distinguish it from other radioactive waste. The waste is generally stabilized in situ and covered with various layers of rock and soil.

1.15. This Safety Requirements publication applies to all of the above mentioned types of disposal and disposal facilities. Comprehensive guidance on meeting the requirements established in this Safety Requirements publication is given in IAEA Safety Guides, in each of which a particular type of disposal, as described above, is considered.

1.16. In accordance with the graded approach, as required in the International Basic Safety Standards and other standards [3, 13, 14], the ability of the chosen disposal system to provide containment of the waste and to isolate it from people and the environment will be commensurate with the hazard potential of the waste. The requirements set out in this Safety Requirements publication apply to all types of disposal facility. However, the extent of provisions necessary to meet the requirements will vary in accordance with the graded approach. This is reflected in the Safety Guides for the different types of facility mentioned in para. 1.14.

Disposal facility life cycle

1.17. The development (i.e. site selection and evaluation, and facility design and construction) of most types of disposal facility is likely to take place over extended periods of time. The period over which disposal facilities will be operated prior to closure will, in most cases, also extend over decades. Different activities will be conducted in this period of development, such as site selection and evaluation, and facility design and construction, with decisions being made to proceed to the next set of activities or the next step in the development of the facility.

1.18. Such a step by step approach enables: the ordered accumulation and assessment of the necessary scientific and technical data; the evaluation of possible sites; the development of disposal concepts; iterative studies for design development and safety assessment with progressively improving data; technical and regulatory reviews; public consultation and political decisions. However, the level of study and the process will depend on the facility and on national practices.

1.19. The step by step approach, together with the consideration of a range of options for the design and operational management of a disposal facility, is expected to provide flexibility for responding to new technical information and advances in waste management and material technologies. It also enables social, economic and political aspects of the disposal facility to be addressed, to ensure that all reasonable measures have been taken to further prevent, inhibit or delay releases to the environment.

1.20. This approach may include options for reversing a given step or even, for most types of facility, for retrieving waste after its emplacement, if this were considered to be appropriate.

1.21. The developers of disposal facilities may define a number of steps relating to their own programme needs. In this Safety Requirements publication, however, the step by step approach refers to the steps that are imposed by the regulatory body and by political decision making processes.

1.22. It is convenient to identify three periods associated with the development, operation and closure of a disposal facility: (i) the pre-operational period, (ii) the operational period and (iii) the post-closure period. Various activities will take place in these periods and some may be undertaken to varying degrees throughout part or all of the lifetime of the facility:

(i) The pre-operational period includes concept definition, site evaluation (selection, verification and confirmation), safety assessment and design studies. It also includes the development of those aspects of the safety case for safety in operation and after closure that are required in order to set the conditions of authorization, obtain the authorization and proceed with the construction of the disposal facility and the initial operational activities. The monitoring and testing programmes that are needed to inform operational management decisions are put in place.

(ii) The operational period begins when waste is first received at the facility. From this time, radiation exposures may occur as a result of waste management activities, and these are subject to control in accordance with the requirements for protection and safety. Monitoring, surveillance and testing programmes continue to inform operational management decisions and to provide the basis for decisions concerning the closure of the facility or parts of it. Safety assessments for the period of operation and the period after closure and the safety case are updated as necessary to reflect actual experience and increasing knowledge. In the operational period, construction activities may take place at the same time as waste emplacement in, and closure of, other parts of the facility. This period may include activities for waste retrieval, if considered necessary, prior to closure, activities following the completion of waste emplacement and the final closure and sealing of the facility.

(iii) The post-closure period begins at the time when all the engineered containment and isolation features have been put in place, operational buildings and supporting services have been decommissioned and the facility is in its final configuration. After its closure, the safety of the disposal facility is provided for by means of passive features inherent in the characteristics of the site and the facility and the characteristics of the waste packages, together with certain institutional controls, particularly for near surface facilities. Such institutional controls are put in place to prevent intrusion into facilities and to confirm that the disposal system is performing as expected by means of monitoring and surveillance. Monitoring may also be carried out to provide public assurance. The licence will be terminated after the period of active institutional control, when all the necessary technical, legal and financial requirements have been fulfilled.

1.23. This Safety Requirements publication is concerned with providing for the protection of people and the environment against the hazards associated with waste management activities relating to waste disposal, including hazards that could arise in the operational period and following closure. Assurance of this protection will be provided by the application of legal and regulatory requirements in the pre-operational and operational periods, and in some cases in the post-closure period.

1.24. The disposal system (i.e. the disposal facility and the environment in which it is sited) is developed in a series of steps in which the scientific understanding of the disposal system and of the design of the disposal facility is progressively advanced. Safety assessment is an important tool for guiding site selection and evaluation and for assisting with the design of the facility. It is also used for evaluating the prevailing level of understanding of the disposal system and for assessing the associated uncertainties through the various steps in the development of the facility. The extent and complexity of such an assessment will vary with the type of facility and will be related to the hazard potential of the waste.

1.25. Moreover, the development of disposal facilities that incorporate provisions in design or operation to facilitate reversibility, including retrievability, is considered in several national programmes for waste management. In some States, post-closure retrievability is a legal requirement and constitutes a boundary condition on the options available, which must always satisfy the safety requirements for disposal. No relaxation of safety standards or requirements could be allowed on the grounds that waste retrieval may be possible or may be facilitated by a particular provision. It would have to be ensured that any such provision would not have an unacceptable adverse effect on safety or on the performance of the disposal system. This subject is not extensively dealt with in this Safety Requirements publication.

1.26. The safety case (i.e. the collection of arguments and evidence to demonstrate the safety of a facility) for a disposal facility will be developed together with the development of the facility. This approach provides a basis for decisions relating to the development, operation and closure of the facility. It also allows the identification of areas of uncertainty on which attention needs to be focused to improve further the understanding of those aspects influencing the safety of the disposal system.

OBJECTIVE

1.27. The objective of this Safety Requirements publication is to set out the safety objective and criteria for the disposal of all types of radioactive waste and to establish, on the basis of the principles established in Ref. [1], the requirements that must be satisfied in the disposal of radioactive waste.

1.28. This Safety Requirements publication is intended for use by all persons responsible for, and concerned with, radioactive waste management and making decisions in relation to the development, operation and closure of disposal facilities, especially those persons concerned with the related regulatory aspects. Safety Guides provide comprehensive guidance on, and international best practices for, meeting the requirements in respect of different types of disposal facility.

SCOPE

1.29. This Safety Requirements publication applies to the disposal of radioactive waste of all types by means of emplacement in designed disposal facilities, subject to the necessary limitations and controls being placed on the disposal of the waste and on the development, operation and closure of facilities. The classification of radioactive waste is discussed in Ref. [12].

1.30. This Safety Requirements publication establishes requirements to provide assurance of the radiation safety of the disposal of radioactive waste, in the operation of a disposal facility and especially after its closure. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation. This is achieved by setting requirements on the site selection and evaluation and design of a disposal facility, and on its construction, operation and closure, including organizational and regulatory requirements.

1.31. Meeting these requirements forms a part of the wider process involved in selecting and evaluating a site and developing a disposal facility. Broader planning, financial, economic and social issues, as well as issues of conventional safety and environmental impacts, will also be considered in this wider process. This Safety Requirements publication does not address these broader issues, nor does it address the transport of waste to the site or environmental impacts other than radiological consequences.

1.32. Experience to date in selecting sites for disposal facilities has shown that acceptance of a disposal facility by a broad range of interested parties depends on a number of factors. The process of involving interested parties in decision making processes for disposal facilities is increasingly seen to be of great importance. The detailed consideration of such processes is, however, beyond the scope of this Safety Requirements publication.

STRUCTURE

1.33. The background to, the concepts of, and the safety objective for disposal are set out in Sections 1 and 2. The safety requirements for disposal facilities are set out in Sections 3–6. These requirements comprise 26 numbered ‘shall’ statements in bold type.

2. PROTECTION OF PEOPLE AND THE ENVIRONMENT

APPLICATION OF THE FUNDAMENTAL SAFETY PRINCIPLES

2.1. The IAEA Safety Fundamentals publication Fundamental Safety Principles [1] sets out the fundamental safety objective and safety principles that apply for all facilities and activities in radioactive waste management, including the disposal of radioactive waste. As stated in Ref. [1], the fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation.

2.2. The strategy adopted at present to achieve this fundamental safety objective in respect of the disposal of radioactive waste is to contain the waste and to isolate it from the accessible biosphere, to the extent that this is necessary. The biosphere is that part of the environment that is normally inhabited by living organisms, and in this Safety Requirements publication the ‘accessible biosphere’ is taken generally to include those elements of the environment, including groundwater, surface water and marine resources, that are used by people or accessible to people. The accessible biosphere is, therefore, that part of the environment that the objective, criteria and requirements set out in this Safety Requirements publication are established to protect.

2.3. By applying the strategy of containment and isolation of waste, it is implicit that if waste were to be disturbed after its disposal in a facility, then radiation doses might be incurred.

2.4. According to Ref. [1], disposal facilities are to be developed in such a way that people and the environment are protected both now and in the future (Ref. [1], Principle 7). In this regard, the prime consideration is the radiological hazard presented by radioactive waste. The ICRP developed the System of

Radiological Protection that applies to all facilities and activities, and this system was adopted in the International Basic Safety Standards [3].

2.5. The ICRP has elaborated the application of the System of Radiological Protection to the disposal of solid radioactive waste in its Publications 77 and 81 [5, 6], which it reconfirmed in Publication 103 [7]. This provides a starting point for the safety considerations discussed here in relation to disposal facilities. Environmental concerns and other non-radiological concerns are considered at the end of Section 2.

2.6. The safety objective and criteria set out in this section apply regardless of national boundaries. Transboundary issues are dealt with in the framework of existing conventions, treaties and bilateral agreements. Particular specific obligations apply to Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [2].

RADIATION PROTECTION IN THE OPERATIONAL PERIOD

2.7. The radiation safety requirements and the related safety criteria for the operational period of a disposal facility are the same as those for any nuclear facility or activity involving radioactive material and are established in the International Basic Safety Standards [3]. Disposal facilities receiving waste from nuclear fuel cycle facilities will generally be licensed nuclear facilities and have to operate under the terms of a facility licence. Disposal facilities for small quantities of waste (e.g. borehole facilities) may not be regarded as nuclear facilities in some States but have to be subject to an appropriate regulatory process and have to be licensed accordingly.

2.8. In radiation safety terms, the disposal facility is considered to be a source of radiation that is under regulatory control in a planned exposure situation. In the operational period, any radioactive release can be verified, exposures can be controlled and actions can be taken if necessary. The engineering means and practical means of achieving safety are well known, although their use in a disposal facility involves specific considerations. The primary goal is to ensure that radiation doses are as low as reasonably achievable and within the applicable system of dose limitation.

2.9. The optimization of protection (that is, the process of determining measures for protection and safety to make exposures, and the probability and magnitude of potential exposures, “as low as reasonably achievable, economic and social factors being taken into account”) is considered in the design of the disposal facility and in the planning of all operations [3].

2.10. Relevant considerations in the optimization of measures for protection and safety include: the separation of mining and construction activities from waste emplacement activities; the use of remote handling equipment and shielded equipment for waste emplacement, where necessary; the control of the working environment so as to reduce the potential for accidents and their potential consequences; and the minimization of the need for maintenance in supervised areas and controlled areas. Contamination is required to be controlled and prevented to the extent possible [3].

2.11. No releases of radionuclides, or only very minor releases (such as small amounts of gaseous radionuclides), may be expected during the normal operation of a radioactive waste disposal facility and hence there will not be any significant doses to members of the public. Even in the event of an accident involving the breach of a waste package on the site of a disposal facility, releases are unlikely to have any radiological consequences outside the facility.

2.12. The absence of radiological consequences of any significance outside the facility would be confirmed by means of safety assessment (see the requirements concerning the safety case and safety assessment, Requirements 12–14). Relevant considerations include the waste form (i.e. the packaging and the radionuclide content of the waste), the control of contamination on waste packages and equipment, and the monitoring and control of drainage water from the disposal facility, where applicable, and of the ventilation exhaust air from underground disposal facilities.

2.13. For a disposal facility, as for any other operational nuclear facility or facility where radioactive material is handled, used, stored or processed, an operational radiation protection programme, commensurate with the radiological hazards, is required to be put in place to ensure that doses to workers during normal operations are controlled and that the requirements for the limitation of radiation doses are met (see Ref. [3], paras 2.24–2.26, and Ref. [15]). In addition, emergency plans are required to be put in place for dealing with accidents and other incidents, and for ensuring that any consequent radiation doses are controlled to the extent possible, with due regard for the relevant emergency action levels [16].

2.14. The doses and risks associated with the transport of radioactive waste through public areas to a disposal facility are required to be managed in the same way as the doses and risks associated with the transport of other radioactive material. The transport of radioactive waste is subject to the requirements of the IAEA's Regulations for the Safe Transport of Radioactive Material [17].

RADIATION PROTECTION IN THE POST-CLOSURE PERIOD

2.15. The safety objective and criteria for the protection of people and the environment after closure of a disposal facility are as follows:

Safety objective

The safety objective is to site, design, construct, operate and close a disposal facility so that protection after its closure is optimized, social and economic factors being taken into account. A reasonable assurance also has to be provided that doses and risks to members of the public in the long term will not exceed the dose constraints or risk constraints that were used as design criteria.

Criteria

(a) The dose limit for members of the public for doses from all planned exposure situations is an effective dose of 1 mSv in a year [3]. This and its risk equivalent are considered criteria that are not to be exceeded in the future.
(b) To comply with this dose limit, a disposal facility (considered as a single source) is so designed that the calculated dose or risk to the representative person who might be exposed in the future as a result of possible natural processes[3] affecting the disposal facility does not exceed a dose constraint of 0.3 mSv in a year or a risk constraint of the order of 10^{-5} per year[4].
(c) In relation to the effects of inadvertent human intrusion after closure, if such intrusion is expected to lead to an annual dose of less than 1 mSv to those living around the site, then efforts to reduce the probability of intrusion or to limit its consequences are not warranted.

[3] Natural processes include the range of conditions anticipated over the lifetime of the facility and events that could occur with a lesser likelihood. However, extremely low probability events would be outside the scope of consideration.

[4] Risk due to the disposal facility in this context is to be understood as the probability of fatal cancer or serious hereditary effects.

(d) If human intrusion were expected to lead to a possible annual dose of more than 20 mSv (see Ref. [7], Table 8) to those living around the site, then alternative options for waste disposal are to be considered, for example, disposal of the waste below the surface, or separation of the radionuclide content giving rise to the higher dose.
(e) If annual doses in the range 1–20 mSv (see Ref. [7], Table 8) are indicated, then reasonable efforts are warranted at the stage of development of the facility to reduce the probability of intrusion or to limit its consequences by means of optimization of the facility's design.
(f) Similar considerations apply where the relevant thresholds for deterministic effects in organs may be exceeded.

2.16. It is recognized that radiation doses to people in the future can only be estimated and that uncertainties associated with these estimates will increase for periods farther into the future. Caution needs to be exercised in applying criteria for periods far into the future. Beyond such timescales, the uncertainties associated with dose estimates become so large that the criteria might no longer serve as a reasonable basis for decision making.

2.17. The primary goal of the disposal of radioactive waste is the protection of people and the environment in the long term, after the disposal facility has been closed. In this period, migration of radionuclides to the accessible biosphere, dispersion of radionuclides into the accessible biosphere and the consequent exposure of people may occur. This is a consequence of the slow degradation of engineered components and the slow transport of radionuclides from the facility by natural processes. Discrete events may lead to an earlier or greater release. Such events could be of either natural or human origin.

2.18. Optimization under constraints is the central approach adopted to ensure the safety of a waste disposal facility [6]. In this context, the optimization of protection is a judgemental process, social and economic factors being taken into account. The optimization is conducted in a structured but essentially qualitative manner, supported by quantitative analysis.

2.19. Different methods may be used to assess the impacts of the disposal of radioactive waste after closure of the disposal facility and to demonstrate compliance with national regulations expressed as constraints in terms of levels of dose and/or risk. This matter is addressed in the Safety Guide on the safety case and safety assessment for disposal[5].

ENVIRONMENTAL AND NON-RADIOLOGICAL CONCERNS

2.20. The assessment of conventional environmental impacts such as may occur in the construction and operational periods of a disposal facility, for example, impacts relating to traffic, noise, visual amenity, disturbance of natural habitats, restrictions on land use and social and economic factors, is outside the scope of this Safety Requirements publication. This Safety Requirements publication covers the protection of the environment against radiological hazards associated with the radioactive material in the disposal facility. The non-radiological toxic hazard also has to be assessed where this is significant, as discussed in the following paragraphs.

2.21. For the purposes of the current recommendations of the ICRP [4] and the requirements of the International Basic Safety Standards [3], it is assumed that, subject to the appropriate definition of exposed groups, the protection of people against the radiological hazards associated with a disposal facility will also apply the principle of protecting the environment [4–7]. The issue of the protection of the environment from harmful effects of ionizing radiation and the development of standards for this purpose are under discussion internationally [7].

2.22. Estimates of possible doses and/or risks due to the future migration of radionuclides from a disposal facility are indicators of the protection of people. On the basis of the assumption mentioned in para. 2.21, calculations to estimate doses in which account is taken of a range of possible environmental transfer pathways could already be considered to be indicators of environmental protection.

2.23. Additional indicators and comparisons, such as estimates of concentrations and fluxes of contaminants and their comparison with concentrations and fluxes of radionuclides of natural origin within the geosphere or biosphere, may also prove valuable in indicating a level of overall environmental protection that is

[5] A Safety Guide on the Safety Case and Safety Assessment for Disposal of Radioactive Waste is in preparation.

independent of assumptions about the habits[6] of people. Other factors to be considered may include the need for protection of groundwater resources and the ecological sensitivity of the environment into which contaminants might be released.

2.24. The impact of non-radioactive material present in a disposal facility has to be assessed in accordance with national or other specific regulations and this may be significant in some cases, for example, for some mining wastes and mixtures of radioactive and toxic wastes. If non-radioactive material may affect the release and migration of radioactive contaminants from the radioactive waste, then such interactions have to be considered in the safety assessment.

3. SAFETY REQUIREMENTS FOR PLANNING FOR THE DISPOSAL OF RADIOACTIVE WASTE

3.1. Requirements are established for ensuring that the safety objective and criteria for disposal facilities set out in Section 2 are fulfilled. The prime responsibility for safety rests with the operator [1], to whom the majority of the requirements apply. However, the assurance of safety and the development of a broader confidence in safety also require a competent regulatory process within a specified legal and regulatory framework and the allocation of responsibilities for pre-operational activities.

3.2. The operator[7] might be a single organization or one of a number of organizations involved, depending on the approach taken in the State. The safety requirements for the planning of a disposal facility apply to those elements that have to be in place prior to the development of the disposal facility, with the purpose of ensuring safety in the operational period and after closure.

---

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Indicators in Different Time Frames for the Safety Assessment of Underground Radioactive Waste Repositories, IAEA-TECDOC-767, IAEA, Vienna (1994).

[7] In the IAEA safety standards, ‘operator’ means any organization or person applying for authorization or authorized and/or responsible for nuclear, radiation, radioactive waste or transport safety when undertaking activities or in relation to any nuclear facilities or sources of ionizing radiation. This includes, inter alia, private individuals, governmental bodies, consignors or carriers, licensees, hospitals, self-employed persons, etc.

3.3. Safety in the operation of radioactive waste disposal facilities has to be achieved by means of a variety of engineered and operational controls similar to those used in other facilities in which radioactive material is handled, used, stored or processed. These include the containment and shielding for the radioactive waste and operational control over time of exposure and proximity to the waste. Protection of the public is provided for by preventing or controlling releases from the facility and by controlling access to the site. Operational monitoring programmes provide assurance of these various controls.

3.4. Safety after closure is achieved by developing a disposal system in which the various components work together to provide and to ensure the required level of safety. This approach offers flexibility to the designer of a disposal facility to adapt the facility's layout and engineered barriers so as to take advantage of the natural characteristics of the site and the barrier potential of the host geology, if applicable. Assurance of confidence in safety is also necessary and this may require the consideration of a number of complex issues, including the potential impact of operations on the performance of the disposal facility after closure.

3.5. The requirements in respect of the planning of disposal facilities for radioactive waste are set out under three headings for the governmental, legal and regulatory framework, the safety approach and the design concepts for safety.

GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK

Requirement 1: Government responsibilities

The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities shall be clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility.

3.6. This requirement derives from a principle established in the Fundamental Safety Principles (Ref. [1], Principle 2). It is also stipulated under the terms of the Joint Convention [2]. Requirements for establishing a national system for radioactive waste management are established in Ref. [18]. A project for the disposal of radioactive waste, especially for the development of a facility for the disposal of high level and long lived radioactive waste, has to be given special consideration within this infrastructure because of the relatively long period of time necessary for the development of such facilities.

3.7. Matters that have to be considered include:

(a) Defining the national policy for the long term management of radioactive waste of different types;
(b) Setting clearly defined legal, technical and financial responsibilities for organizations that are to be involved in the development of facilities for radioactive waste management, including disposal facilities of all types;
(c) Ensuring the adequacy and security of financial provisions for each disposal facility;
(d) Defining the overall process for the development, operation and closure of disposal facilities, including the legal and regulatory requirements (e.g. licence conditions) at each step, and the processes for decision making and the involvement of interested parties;
(e) Ensuring that the necessary scientific and technical expertise remains available both to the operator and for the support of independent regulatory reviews and other national review functions;
(f) Defining legal, technical and financial responsibilities and, if necessary, providing for any institutional arrangements that are envisaged after closure, including monitoring and ensuring the nuclear security of different types of waste that have been disposed of.

Requirement 2: Responsibilities of the regulatory body

The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.

3.8. General standards for the protection of people and the environment are usually set out in national policy or in legislation. The regulatory body has to develop regulatory requirements specific to each type of disposal facility for radioactive waste, including each type that is envisaged, on the basis of national policy and with due regard to the safety objective and criteria set out in para. 2.15. The regulatory body has to provide guidance on the interpretation of the national legislation and regulatory requirements, as necessary, and guidance on what is expected of the operator in respect of each individual disposal facility.

3.9. The regulatory body has to engage in dialogue with waste producers, the operators of the disposal facility and interested parties to ensure that the regulatory requirements are appropriate and practicable. It also has to maintain competent staff, to acquire capabilities for independent assessment and to undertake international cooperation, as necessary, to fulfil its regulatory functions.

3.10. The regulatory body has to document the procedures that it uses to evaluate the safety of each type of disposal facility, the procedures that operators are expected to follow in the context of licensing, important decisions prior to licensing and licence applications. It also has to document the procedures that it follows in reviewing submissions from operators to assess compliance with regulatory requirements.

3.11. Similarly, in respect of each individual disposal facility, the regulatory body has to set out the procedures that an operator is expected to follow in demonstrating compliance with the conditions for the development and operation of the facility. The regulatory body also has to set out the procedures that it follows to assess compliance with the conditions throughout all stages of the development, operation and closure of the facility.

Requirement 3: Responsibilities of the operator

The operator of a disposal facility for radioactive waste shall be responsible for its safety. The operator shall carry out safety assessment and develop and maintain a safety case, and shall carry out all the necessary activities for site selection and evaluation, design, construction, operation, closure and, if necessary, surveillance after closure, in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure.

3.12. The operator has to be responsible for developing a disposal facility that is practicable and safe and for demonstrating its safety, consistent with the requirements of the regulatory body. This task has to be undertaken in consideration of: the characteristics and quantities of the radioactive waste to be disposed of; the site or sites available; the mining, excavation, construction and engineering techniques available; and the legal and regulatory infrastructure and regulatory requirements. The operator also has to be responsible for developing a safety case, on the basis of which decisions on the development, operation and closure of the disposal facility have to be made (see Requirements 17–19).

3.13. The operator has to conduct or commission the research and development work necessary to ensure that the planned technical operations can be practically and safely accomplished, and to demonstrate this. The operator likewise has to conduct or commission the research work necessary to investigate, to understand and to support the understanding of the processes on which the safety of the disposal facility depends. The operator also has to carry out all the necessary investigations of sites and of materials and has to assess their suitability and obtain all the data necessary for the purposes of safety assessment.

3.14. The operator has to establish technical specifications that are justified by safety assessment, to ensure that the disposal facility is developed in accordance with the safety case. This has to include waste acceptance criteria (see Requirement 20) and other controls and limits to be applied during construction, operation and closure.

3.15. The operator has to retain all the information relevant to the safety case and the supporting safety assessment for the disposal facility and has to retain the inspection records that demonstrate compliance with regulatory requirements and with the operator's own specification. Such information and records have to be retained, at least up until the time when the information is shown to be superseded, or until responsibility for the disposal facility is passed on to another organization. This occurs, for example, at closure of the facility, when all relevant information and records have to be transferred to the organization assuming responsibility for the facility and its safety.

3.16. The operator has to cooperate with the regulatory body and has to supply all the information that the regulatory body may request. The need to preserve the records for long periods of time has to be taken into account in selecting the format and media to be used for records.

SAFETY APPROACH

Requirement 4: Importance of safety in the process of development and operation of a disposal facility

Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the

implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.

3.17. Disposal facilities for radioactive waste may be developed and operated over a period of several years or several decades. Key decisions, such as decisions on site selection and evaluation, and on the design, construction, operation and closure of the disposal facility, are expected to be made as the project develops. In this process, decisions are made on the basis of the information available at the time, which may be either quantitative or qualitative, and the confidence that can be placed in that information.

3.18. Decisions on the development, operation and closure of the facility are constrained by external factors, which include: national policy and preferences, the capacity and capability of existing storage and disposal facilities to accommodate waste, and the availability of suitable sites and geological formations to host planned new disposal facilities. An adequate level of confidence in the safety of each disposal facility has to be developed before decisions are taken.

3.19. At each major decision point, the implications for the safety of the available design options and operational options for the disposal facility have to be considered and taken into account. Ensuring safety, both in the operational stage and after closure, is the overriding concern at each decision point. If more than one option is capable of providing the required level of safety, then other factors also have to be considered. These factors could include public acceptability, cost, site ownership, existing infrastructure and transport routes.

3.20. Consideration has to be given to locating the facility away from significant known mineral resources, geothermal water and other valuable subsurface resources. This is to reduce the risk of human intrusion into the site and to reduce the potential for use of the surrounding area to be in conflict with the facility. The safety of the facility has to be considered at every step in the decision making process to ensure that safety is optimized in the sense discussed in the Appendix.

Requirement 5: Passive means for the safety of the disposal facility

The operator shall evaluate the site and shall design, construct, operate and close the disposal facility in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the facility is minimized.

3.21. In the operational stage of a disposal facility for radioactive waste, certain active control measures have to be applied. However, where passive features such as the shielding and containment provided by the packaging material can provide safety, then safety has to be ensured by such passive means.

3.22. To some extent, the safety of a disposal facility can depend on some future actions such as maintenance work or surveillance. However, this dependence has to be minimized to the extent possible. This is necessary because of the possibility that safety measures that depend on future actions, such as maintenance work or surveillance, will not be taken or will not be continued. The cumulative probability of the failure of such safety measures will gradually increase. Furthermore, and consistent with the Fundamental Safety Principles [1], disposal of radioactive waste is intended to discharge the responsibility for safety of the waste producers and the operator to the fullest extent possible, thereby minimizing the responsibilities that are retained or are passed on to successor organizations.

3.23. For a geological disposal facility, it is possible to provide for safety after closure by means of passive features. It is likewise possible to provide for the safety of a borehole disposal facility after closure by means of passive features, owing to the host geology. In the case of a near surface disposal facility, actions such as maintenance, monitoring or surveillance may be necessary for a period of time after closure to ensure safety.

3.24. Providing for the safety of a disposal facility after closure by means of passive features will entail proper closure of the facility and ending the need for its active management. The cessation of management means that the disposal facility, with its associated radiological hazard, is no longer under active control. It is the performance of the natural and engineered barriers that provides safety after closure, together, for a near surface disposal facility, with institutional controls.

3.25. In practice, even in those cases in which passive features are the primary means for providing a reasonable assurance of safety, institutional controls, including restrictions on land use, and a programme for monitoring may be necessary in the post-closure period. Institutional controls and monitoring are the subject of Requirements 21 and 22.

Requirement 6: Understanding of a disposal facility and confidence in safety

The operator of a disposal facility shall develop an adequate understanding of the features of the facility and its host environment and of the factors that

influence its safety after closure over suitably long time periods, so that a sufficient level of confidence in safety can be achieved.

3.26. Confidence has to be assured by the results of safety assessment for a disposal facility. The features of the facility and its host environment that provide for safety have to be identified, in addition to those factors that might be detrimental. It has to be demonstrated that these features and factors are sufficiently well characterized and understood. Any uncertainties have to be taken into consideration in the assessment of safety.

3.27. The purpose of this demonstration is to establish, with a high level of confidence, that the disposal facility and its host environment can be relied on to provide the necessary containment and isolation over the timescales envisaged. Certain features of the disposal facility and its environment may contribute to safety, but may be less quantifiable, such as the remoteness of the site. The reasoning with regard to such factors has to be based on more qualitative arguments, and such factors provide a safety margin.

3.28. An understanding of the features of a disposal facility and how it will perform over time is necessary in order to be able to demonstrate the dependability of certain design features. This demonstration is assisted if such design features are robust (i.e. their performance is of low sensitivity to possible events and processes causing disturbances). Sufficient evidence has to be obtained of their feasibility and effectiveness before construction activities are commenced.

3.29. In this regard, the range of possible events and processes causing disturbances that it is reasonable to include in such considerations has to be subject to agreement by the regulatory body and subsequent approval by inclusion in the safety case. These considerations permit the development of an understanding of whether or not such events and processes cause disturbances that could lead to the widespread loss of safety functions.

3.30. Understanding of the performance of the disposal system and its safety features and processes evolves as more data are accumulated and scientific knowledge is developed. Early in the development of the concept, the data obtained and the level of understanding gained have to assure sufficient confidence to be able to commit resources for further investigations. Before the start of construction, during emplacement of waste and at closure of the facility, the level of understanding has to be sufficient to support the safety case for fulfilling the regulatory requirements applicable for the particular stage of the project.

3.31. In establishing these regulatory requirements, it has to be recognized that there are various types and components of uncertainty inherent in modelling complex environmental systems. It also has to be recognized that there are, inevitably, significant uncertainties associated with projecting the performance of a disposal system over time.

DESIGN CONCEPTS FOR SAFETY

3.32. A disposal facility is designed to contain the radionuclides associated with the radioactive waste and to isolate them from the accessible biosphere. The disposal facility is also designed to retard the dispersion of radionuclides in the geosphere and biosphere and to provide isolation of the waste from aggressive phenomena that could degrade the integrity of the facility. The various elements of the disposal system, including physical components and control procedures, contribute to performing safety functions in different ways over different timescales.

3.33. Requirements are established in this section for ensuring that there is adequate defence in depth, so that safety is not unduly dependent on a single element of the disposal facility, such as the waste package; or a single control measure, such as verification of the inventory of waste packages; or the fulfilment of a single safety function, such as by containment of radionuclides or retardation of migration; or a single administrative procedure, such as a procedure for site access control or for maintenance of the facility.

3.34. Adequate defence in depth has to be ensured by demonstrating that there are multiple safety functions, that the fulfilment of individual safety functions is robust and that the performance of the various physical components of the disposal system and the safety functions they fulfil can be relied upon, as assumed in the safety case and supporting safety assessment. It is the responsibility of the operator to demonstrate fulfilment of the following design requirements to the satisfaction of the regulatory body.

Requirement 7: Multiple safety functions

The host environment shall be selected, the engineered barriers of the disposal facility shall be designed and the facility shall be operated to ensure

that safety is provided by means of multiple safety functions. Containment and isolation of the waste shall be provided by means of a number of physical barriers of the disposal system. The performance of these physical barriers shall be achieved by means of diverse physical and chemical processes together with various operational controls. The capability of the individual barriers and controls together with that of the overall disposal system to perform as assumed in the safety case shall be demonstrated. The overall performance of the disposal system shall not be unduly dependent on a single safety function.

3.35. The engineered and physical barriers that make up the disposal system are physical entities, such as the waste form, the packaging, the backfill, and the host environment and geological formation. A safety function may be provided by means of a physical or chemical property or process that contributes to containment and isolation, such as: impermeability to water; limited corrosion, dissolution, leach rate and solubility; retention of radionuclides; and retardation of radionuclide migration.

3.36. Active controls can also fulfil safety functions or contribute to confidence in natural and engineered barriers and safety functions. The presence of a number of physical and other elements performing safety functions gives assurance that even if any of them do not perform fully as expected (e.g. owing to an unexpected process or an unlikely event), a sufficient margin of safety will remain.

3.37. The physical elements and their safety functions can be complementary and can work in combination. The performance of a disposal system is thus dependent on different physical elements and on other elements that perform safety functions, which act over different time periods. For example, the roles of the waste package and the host geological formation for a geological disposal facility may vary in different time periods.

3.38. The safety case has to explain and justify the functions performed by each physical element and other features. It also has to identify the time periods over which physical components and other features are expected to perform their various safety functions, and also the alternative or additional safety functions that are available if a physical element does not fully perform or another safety function is not fulfilled.

Requirement 8: Containment of radioactive waste

The engineered barriers, including the waste form and packaging, shall be designed, and the host environment shall be selected, so as to provide containment of the radionuclides associated with the waste. Containment shall be provided until radioactive decay has significantly reduced the hazard posed by the waste. In addition, in the case of heat generating waste, containment shall be provided while the waste is still producing heat energy in amounts that could adversely affect the performance of the disposal system.

3.39. The containment of radioactive waste implies designing the disposal facility to avoid or minimize the release of radionuclides. Releases of small amounts of gaseous radionuclides and of small fractions of other highly mobile species from some types of radioactive waste may be inevitable. Such releases, nevertheless, have to be demonstrated to be acceptable by means of safety assessment. The containment may be provided by the characteristics of the waste form and the packaging and by the characteristics of other engineered components of the disposal system and the host environment and geological formation.

3.40. The containment of the radionuclides in the waste form and the packaging over a defined period has to ensure that the majority of shorter lived radionuclides decay in situ. For low level waste, such periods would be of the order of several hundred years; for high level waste the period would be several thousands of years. For high level waste, it also has to be ensured that any migration of radionuclides outside the disposal system would occur only after the heat produced by radioactive decay has substantially decreased.

3.41. Radioactive waste from mining and mineral processing may include radionuclides with very long half-lives. Providing assurance of the integrity of the containment features of disposal facilities for such waste over the corresponding timescales requires particular consideration. If the waste has activity levels for which the dose and/or risk criteria for human intrusion into such facilities (see para. 2.15) might be exceeded, alternative disposal options will have to be considered. Possible alternative options include, for example, disposal of the waste below the surface, or separation of the radionuclide content giving rise to the higher dose, as determined by the safety case for the disposal facility.

3.42. Containment is most important for more highly concentrated radioactive waste, such as intermediate level waste and vitrified waste from fuel reprocessing, or for spent nuclear fuel. Attention also has to be given to the durability of the waste form. The most highly concentrated waste has to be emplaced in a containment configuration that is designed to retain its integrity for a long enough period of time to enable most of the shorter lived radionuclides to decay and for the associated generation of heat to decrease substantially. Such containment may not be practicable or necessary for low level waste. The containment capability of the waste package has to be demonstrated by means of safety assessment to be appropriate for the waste type and the overall disposal system.

Requirement 9: Isolation of radioactive waste

The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short lived waste and at least several thousand years for intermediate and high level waste. In so doing, consideration shall be given to both the natural evolution of the disposal system and events causing disturbance of the facility.

3.43. For near surface facilities, isolation has to be provided by the location and the design of the disposal facility and by operational and institutional controls. For geological disposal of radioactive waste, isolation is provided primarily by the host geological formation as a consequence of the depth of disposal.

3.44. Isolation means design to keep the waste and its associated hazard apart from the accessible biosphere. It also means design to minimize the influence of factors that could reduce the integrity of the disposal facility. Sites and locations with higher hydraulic conductivities have to be avoided. Access to waste has to be made difficult to gain without, for example, violation of institutional controls for near surface disposal. Isolation also means providing for a very slow mobility of radionuclides to impede migration from disposal facilities.

3.45. Location of a disposal facility in a stable geological formation provides protection of the facility from the effects of geomorphological processes, such as erosion and glaciation. The disposal facility has to be located away from known areas of significant underground mineral resources or other valuable resources. This will reduce the likelihood of inadvertent disturbance of the facility and will avoid resources being made unavailable for exploitation.

3.46. In some cases, it may not be possible to provide sufficient assurance of separation from the accessible biosphere, owing to phenomena such as uplift, erosion and glaciation. In such cases, and if the remaining activity in the waste is still significant at the time such phenomena occur, the possibility of human intrusion has to be evaluated in determining the degree of isolation provided.

3.47. Over time periods of several thousand years or more, the migration of a fraction of the longer lived and more mobile radionuclides from the waste in a geological disposal facility (or in other facilities that may include longer lived radionuclides, such as borehole facilities) may be inevitable. The safety criteria to apply in assessing such possible releases are set out in para. 2.15. Caution needs to be exercised in applying criteria for periods far into the future. Beyond such timescales, the uncertainties associated with dose estimates become so large that the criteria might no longer serve as a reasonable basis for decision making. For such long time periods after closure, indicators of safety other than estimates of dose or individual risk may be appropriate, and their use has to be considered.

Requirement 10: Surveillance and control of passive safety features

An appropriate level of surveillance and control shall be applied to protect and preserve the passive safety features, to the extent that this is necessary, so that they can fulfil the functions that they are assigned in the safety case for safety after closure.

3.48. For geological disposal and for the disposal of intermediate level radioactive waste, the passive safety features (barriers) have to be sufficiently robust so as not to require repair or upgrading. The long term safety of a disposal facility for radioactive waste is required not to be dependent on active institutional control (see Requirement 22). For near surface disposal facilities, including those for radioactive waste from the mining and processing of minerals, measures for surveillance and control of the disposal facility might be instituted. These measures might include restrictions on access by people and animals, inspection of physical conditions, retention of appropriate maintenance capabilities, and surveillance and monitoring as a method of checking whether performance is as specified (i.e. checking for degradation). The intent of surveillance and monitoring is not to measure radiological parameters but to ensure the continuing fulfilment of safety functions.

4. REQUIREMENTS FOR THE DEVELOPMENT, OPERATION AND CLOSURE OF A DISPOSAL FACILITY

4.1. Section 4 establishes safety requirements relating to the step by step implementation of the planning measures mentioned previously that are necessary for safety and to assist in developing confidence in the safety of disposal facilities. The requirements are set out under three headings: (i) framework for disposal of radioactive waste; (ii) the safety case and safety assessment; and (iii) steps in the development, operation and closure of disposal facilities.

FRAMEWORK FOR DISPOSAL OF RADIOACTIVE WASTE

Requirement 11: Step by step development and evaluation of disposal facilities

Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system.

4.2. A step by step approach to the development of a disposal facility for radioactive waste refers to the steps that are imposed by the regulatory body and by political decision making processes (see para. 1.18). This approach is taken to provide an opportunity to ensure the quality of the technical programme and the associated decision making. For the operator, it provides a framework in which sufficient confidence in the technical feasibility and safety of the disposal facility can be built at each step in its development.

4.3. Confidence has to be developed and refined by means of iterative design and safety studies as the project progresses [19]. The process has to provide for: the collection, analysis and interpretation of the relevant scientific and technical data; the development of designs and operational plans; and the development of the safety case for safety in the operational stage and after closure. The step by step process provides access for all interested parties to the safety basis for the disposal facility. This facilitates the relevant decision making processes that enable the operator to proceed to the next significant step in the development of the facility, and on to its operation and, finally, its closure.

4.4. The step by step approach to the development of a disposal facility also allows opportunities for independent technical review, regulatory review, and political and public involvement in the process. The nature of the reviews and involvement will depend on national practices and on the facility in question. Technical reviews by, or on behalf of, the operator and the regulatory body may focus on site selection and evaluation and design options, the adequacy of the scientific basis and analyses, and whether safety standards and requirements have been met.

4.5. Alternative waste management options, the site selection and evaluation process and aspects of public acceptability, for example, may be considered in farther reaching reviews. Technical reviews have to be undertaken prior to selection of a disposal option, prior to selection of a site, prior to construction and prior to operation. Periodic reviews also have to be undertaken during the operation of the facility and following closure, up to termination of the facility licence.

THE SAFETY CASE AND SAFETY ASSESSMENT

4.6. The development of a safety case and supporting safety assessment for review by the regulatory body and interested parties is central to the development, operation and closure of a disposal facility for radioactive waste. The safety case substantiates the safety of the disposal facility and contributes to confidence in its safety. The safety case is an essential input to all important decisions concerning the disposal facility. It has to provide the basis for understanding the disposal system and how it will behave over time. It has to address site aspects and engineering aspects, providing the logic and rationale for the design, and has to be supported by safety assessment. It also has to address the management system put in place to ensure quality for all aspects important to safety.

4.7. At any step in the development of a disposal facility, the safety case also has to identify and acknowledge the unresolved uncertainties that exist at that stage and their safety significance, and approaches for their management.

4.8. The safety case has to include the output of the safety assessment (see paras 4.9–4.11), together with additional information, including supporting evidence and reasoning on the robustness and reliability of the facility, its design, the logic of the design, and the quality of safety assessment and underlying assumptions.

4.9. The safety case may also include more general arguments relating to the disposal of radioactive waste and information to put the results of safety assessment into perspective. Any unresolved issues at any step in the development or in the operation or closure of the facility have to be acknowledged in the safety case and guidance has to be provided for work to resolve these issues.

4.10. Safety assessment is the process of systematically analysing the hazards associated with a disposal facility and assessing the ability of the site and the design of the facility to provide for the fulfilment of safety functions and to meet technical requirements. Safety assessment has to include quantification of the overall level of performance, analysis of the associated uncertainties and comparison with the relevant design requirements and safety standards. The assessments have to be site specific since the host environment of a disposal system, in contrast to engineered systems, cannot be standardized.

4.11. As site investigations and design studies progress, safety assessment will become increasingly refined and specific to the site. At the end of a site investigation, sufficient data have to be available for a complete assessment. Any significant deficiencies in scientific understanding, data or analysis that might affect the results presented also have to be identified in the safety assessment. Depending on the stage of development of the facility, safety assessment may be used in focusing research, and its results may be used to assess compliance with the safety objective and safety criteria.

Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility

A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step.

4.12. A facility specific safety case has to be prepared early in the development of a disposal facility to provide a basis for licensing decisions and to guide activities in research and development, site selection and evaluation and design. The safety case has to be developed progressively and elaborated as the project proceeds. It has to be presented to the regulatory body at each step in the development of the disposal facility. The regulatory body might require an update of, or revision to, the safety case before given steps can be taken, or such an update or revision may be necessary to gain political or public support for taking the next step in the development of the disposal facility or for its operation or closure. The formality and level of technical detail of the safety case will depend on the stage of development of the project, the decision in hand, the audience to which it is addressed and specific national requirements.

4.13. Safety assessment in support of the safety case has to be performed and updated throughout the development and operation of the disposal facility and as more refined site data become available. Safety assessment has to provide input to ongoing decision making by the operator. Such decision making may relate to subjects for research, development of a capability for assessment, allocation of resources and development of waste acceptance criteria.

4.14. Safety assessment also has to identify key processes relevant to safety and to contribute to the development of an understanding of the performance of disposal facilities. It has to support judgements with regard to alternative management options as an element of optimizing protection and safety. Such an understanding has to provide the basis for the safety arguments presented in the safety case. The operator has to decide on the timing and the level of detail of the safety assessment, in consultation with, and subject to the approval of, the regulatory body.

Requirement 13: Scope of the safety case and safety assessment

The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met.

4.15. The safety case for a disposal facility has to address safety both in operation and after closure. It may also address safety in transport, for which requirements are established in Ref. [17]. All aspects of operation relevant to safety are considered, including surface and underground excavation, construction and mining work, waste emplacement, and backfilling, sealing and closing operations. Consideration has to be given to both occupational exposure and public exposure resulting from conditions of normal operation and anticipated operational occurrences over the operating lifetime of the disposal facility.

4.16. Accidents of a lesser frequency, but with significant radiological consequences (i.e. possible accidents that could give rise to radiation doses over the short term in excess of annual dose limits (see Section 2)), have to be considered with regard to both their likelihood of occurrence and the magnitude of possible radiation doses. The adequacy of the design and of the operational features also has to be evaluated.

4.17. With regard to safety after closure, the expected range of possible developments affecting the disposal system and events that might affect its performance, including those of low probability, have to be considered in the safety case and supporting assessment by the following means:

(a) By presenting evidence that the disposal system, its possible evolutions and events that might affect it are sufficiently well understood;
(b) By demonstrating the feasibility of implementing the design;
(c) By providing convincing estimates of the performance of the disposal system and a reasonable level of assurance that all the relevant safety requirements will be complied with and that radiation protection has been optimized;
(d) By identifying and presenting an analysis of the associated uncertainties.

4.18. The safety case may include the presentation of multiple lines of reasoning based, for example, on studies of natural analogues and palaeohydrogeological studies, suitable characteristics of the site, properties of the host geological formation, engineering considerations, operational procedures and institutional assurances.

4.19. The performance of the disposal system under expected and less likely evolutions and events, which can be outside the design performance range of the disposal facility, has to be analysed in the safety assessment. A judgement of what is to be considered the expected evolution and less likely evolutions has to be discussed between the regulatory body and the operator. If necessary, sensitivity analyses and uncertainty analyses would be undertaken to gain an understanding of the performance of the disposal system and its components under a range of evolutions and events.

4.20. The consequences of unexpected events and processes may be explored to test the robustness of the disposal system. In particular, the resilience of the disposal system has to be assessed. Quantitative analyses have to be undertaken, at least over the time period for which regulatory requirements apply. However, the results from detailed models for safety assessment purposes are likely to be more uncertain for timescales extending into the far future.

4.21. For timescales extending into the far future, arguments may be needed to illustrate safety, on the basis, for example, of complementary safety indicators, such as concentrations and fluxes of radionuclides of natural origin in the geosphere and biosphere and bounding analyses. While such assessments cannot yield precise levels of possible doses or risks, the results may provide a tool to indicate the level of safety and verify that no alternative design would have obvious advantages.

4.22. The management systems established to provide assurance of quality in these design features and operational features have to be addressed in the safety case.

Requirement 14: Documentation of the safety case and safety assessment

The safety case and supporting safety assessment for a disposal facility shall be documented to a level of detail and quality sufficient to inform and support the decision to be made at each step and to allow for independent review of the safety case and supporting safety assessment.

4.23. The necessary scope and structure of the documentation setting out the safety case and supporting safety assessment will depend on the step reached in the project for the disposal facility and on national requirements. This includes consideration of the needs of different interested parties for information. Important considerations in documenting the safety case and supporting safety assessment are justification, traceability and clarity.

4.24. Justification concerns explaining the basis for the choices that have been made and the arguments for and against the decisions, especially those decisions concerning the main arguments for safety. Traceability concerns the ability of an independent qualified person to follow what has been done. The traceability has to enable technical and regulatory review. Justification and traceability both require a well-documented record of the decisions made and the assumptions made in the development and operation of a disposal facility, and of the models and data used in deriving a particular set of results for safety assessment purposes.

4.25. Clarity concerns good structure and presentation at an appropriate level of detail so as to allow an understanding of the safety arguments. This requires the results of work to be presented in the documents in such a way that interested parties for whom the material is intended can gain a good understanding of the safety arguments and their basis. Different types and styles of document may be necessary to provide material that is useful to different parties.

STEPS IN THE DEVELOPMENT, OPERATION AND CLOSURE OF A DISPOSAL FACILITY

Requirement 15: Site characterization for a disposal facility

The site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time. This shall include its present condition, its probable natural evolution and possible natural events, and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility.

4.26. An understanding of the site for a disposal facility has to be gained in order to present a convincing scientific description of the disposal system on which the more conceptual descriptions that are used in the safety assessment can be based. The focus has to be on features, events and processes relating to the site that could have an impact on safety and that are addressed in the safety case and supporting safety assessment. In particular, this has to demonstrate that there is adequate geological, geomorphological or topographical stability (as appropriate to the type of facility), and features and processes that contribute to safety. It also has to demonstrate that other features, events and processes do not undermine the safety case.

4.27. Characterization of the geological aspects has to include activities such as the investigation of: long term stability, faulting and the extent of fracturing in the host geological formation; seismicity; volcanism; the volume of rock suitable for the construction of disposal zones; geotechnical parameters relevant to the design; groundwater flow regimes; geochemical conditions; and mineralogy. The extent of characterization necessary will depend on the types of disposal facility and the site in question.

4.28. A graded approach has to be adopted, depending on the hazard potential of the waste and the complexity of the site and disposal facility design, in accordance with the guidance cited in footnote 5. Site characterization undertaken in an iterative manner has to provide input to, and has, in turn, to be guided by, the safety case. Additionally, investigation of, for example, natural background radiation and the radionuclide content in soil, groundwater and other media may contribute to a better understanding of the characteristics of the site of the disposal facility. It may also assist in the evaluation of radiological impacts on the environment by providing a reference for future comparisons.

4.29. Characterization of the surface environmental features has to include natural aspects, such as hydrological and meteorological aspects and flora and fauna. It also has to cover human activities in the vicinity of the site relating to normal residential settlement patterns and industrial and agricultural activities. Due regard has to be given to the probable natural evolution of the site, including effects of erosion and climate change.

Requirement 16: Design of a disposal facility

The disposal facility and its engineered barriers shall be designed to contain the waste with its associated hazard, to be physically and chemically compatible with the host geological formation and/or surface environment, and to provide safety features after closure that complement those features afforded by the host environment. The facility and its engineered barriers shall be designed to provide safety during the operational period.

4.30. The designs of disposal facilities for radioactive waste may differ widely, depending on the types of waste to be disposed of and the host geological formation and/or surface environment. In general, optimal use has to be made of the safety features offered by the host environment. This has to be done by designing a disposal facility that does not cause unacceptable long term disturbance of the site, is itself protected by the site and performs safety functions that complement the natural barriers.

4.31. The layout has to be designed so that waste is emplaced in the most suitable locations. In the event that fissile materials are present in the waste, maintaining a subcritical configuration has to be part of the design considerations. Key features, such as shafts and seals in geological disposal facilities, have to be appropriately located. Materials used in the facility have to be resistant to degradation under the conditions prevailing in the facility (e.g. conditions of chemistry and temperature) and selected also to limit any undesirable impacts on the safety functions of any element of the disposal system.

4.32. Disposal facilities, in particular disposal facilities for high level and intermediate level waste, are expected to perform over much longer timescales than the periods usually considered in engineering applications. Investigation of the ways in which analogous natural materials have behaved in geological formations in nature, or how ancient artefacts and structures have behaved over time, may contribute to confidence in the assessment of long term performance. Demonstration of the feasibility of fabrication of waste containers and of the construction of engineered barriers with the necessary features, for example, in underground laboratories, is important for the purpose of assessment and for contributing to confidence that an adequate level of performance can be achieved.

Requirement 17: Construction of a disposal facility

The disposal facility shall be constructed in accordance with the design as described in the approved safety case and supporting safety assessment. It shall be constructed in such a way as to preserve the safety functions of the host environment that have been shown by the safety case to be important for safety after closure. Construction activities shall be carried out in such a way as to ensure safety during the operational period.

4.33. Construction of a disposal facility can be a complex technical undertaking that might be constrained, particularly if it is carried out underground, by the conditions and the properties of the host geological formation and by the techniques that are available for underground excavation and construction. An adequate level of characterization has to be completed before construction is begun. Excavation and construction activities have to be carried out in such a way as to avoid unnecessary disturbance of the host environment. Sufficient flexibility in engineering techniques has to be adopted to allow for variations to be encountered, such as variations in rock conditions or groundwater conditions in underground facilities.

4.34. Excavation and construction of a disposal facility could continue after the commencement of operation of part of the facility and after the emplacement of waste packages. Such overlapping of construction and operational activities has to be planned and carried out so as to ensure safety, both in operation and after closure.

Requirement 18: Operation of a disposal facility

The disposal facility shall be operated in accordance with the conditions of the licence and the relevant regulatory requirements so as to maintain safety during the operational period and in such a manner as to preserve the safety functions assumed in the safety case that are important to safety after closure.

4.35. All operations and activities important to the safety of a disposal facility have to be subjected to limitations and controls and emergency plans have to be put in place. The various procedures and plans have to be documented and the documentation has to be subject to appropriate control procedures [13]. The safety case has to address and justify both the design and the operational management arrangements that are used to ensure that the safety objective and criteria set out in Section 2 are met. Additional, facility specific criteria may be established by the regulatory body or by the operator.

4.36. The safety case also has to demonstrate that hazards and other radiation risks to workers and to members of the public under conditions of normal operation and anticipated operational occurrences have been reduced as low as reasonably achievable. Active control of safety has to be maintained for as long as the disposal facility remains unsealed, and this may include an extended period after the emplacement of waste and before the final closure of the facility.

4.37. Fissile material, when present, has to be managed and has to be emplaced in the disposal facility in a configuration that will remain subcritical. This may be achieved by various means, including the appropriate distribution of fissile material during the conditioning of the waste and the proper design of the waste packages. Assessments have to be undertaken of the possible evolution of the criticality hazard after waste emplacement, including after closure.

Requirement 19: Closure of a disposal facility

A disposal facility shall be closed in a way that provides for those safety functions that have been shown by the safety case to be important after closure. Plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.

4.38. The safety of a disposal facility after closure will depend on a number of activities and design features, which can include the backfilling and sealing or capping of the disposal facility. Closure has to be considered in the initial design of the facility, and plans for closure and seal or cap designs have to be updated as the design of the facility is developed. Before construction activities commence, there has to be sufficient evidence that the performance of the backfilling, sealing and capping will function as intended to meet the design requirements.

4.39. The disposal facility has to be closed in accordance with the conditions set for closure by the regulatory body in the facility's authorization, with particular consideration given to any changes in responsibility that may occur at this stage. Consistent with this, the installation of closure features may be performed in parallel with waste emplacement operations.

4.40. Backfilling and the placement of seals or caps may be delayed for a period after the completion of waste emplacement, for example, to allow for monitoring to assess aspects relating to safety after closure or for reasons relating to public acceptability. If such features are not to be put in place for a period of time after the completion of waste emplacement, then the implications for safety during operation and after closure have to be considered in the safety case.

4.41. Availability of the necessary technical and financial resources to achieve closure has to be assured by means of Requirements 1–3.

5. ASSURANCE OF SAFETY

Requirement 20: Waste acceptance in a disposal facility

Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure.

5.1. Waste acceptance requirements and criteria for a given disposal facility have to ensure the safe handling of waste packages and unpackaged waste in conditions of normal operation and anticipated operational occurrences. They also have to ensure the fulfilment of the safety functions for the waste form and waste packaging with regard to safety in the long term. Examples of possible parameters for waste acceptance criteria include the characteristics and performance requirements of the waste packages and the unpackaged waste to be disposed of, such as the radionuclide content or activity limits, the heat output and the properties of the waste form and packaging.

5.2. Modelling and/or testing of the behaviour of waste forms has to be undertaken to ensure the physical and chemical stability of the different waste packages and unpackaged waste under the conditions expected in the disposal facility, and to ensure their adequate performance in the event of anticipated operational occurrences or accidents.

5.3. Waste intended for disposal has to be characterized to provide sufficient information to ensure compliance with waste acceptance requirements and criteria. Arrangements have to be put in place to verify that the waste and waste packages received for disposal comply with these requirements and criteria and, if not, to confirm that corrective measures are taken by the generator of the waste or the operator of the disposal facility. Quality control of waste packages has to be undertaken and is achieved mainly on the basis of records, preconditioning testing (e.g. of containers) and control of the conditioning process. Post-conditioning testing and the need for corrective measures have to be limited as far as practicable.

Requirement 21: Monitoring programmes at a disposal facility

A programme of monitoring shall be carried out prior to, and during, the construction and operation of a disposal facility and after its closure, if this is part of the safety case. This programme shall be designed to collect and update information necessary for the purposes of protection and safety. Information shall be obtained to confirm the conditions necessary for the safety of workers and members of the public and protection of the environment during the period of operation of the facility. Monitoring shall also be carried out to confirm the absence of any conditions that could affect the safety of the facility after closure.

5.4. Monitoring has to be carried out at each step in the development and in the operation of a disposal facility. The purposes of the monitoring programme include:

(a) Obtaining information for subsequent assessments;
(b) Assurance of operational safety;

(c) Assurance that conditions at the facility for operation are consistent with the safety assessment;
(d) Confirmation that conditions are consistent with safety after closure.

Guidance is provided in Ref. [20]. Monitoring programmes have to be designed and implemented so as not to reduce the overall level of safety of the facility after closure.

5.5. A discussion of monitoring relating to the safety of geological disposal facilities after closure is given in an IAEA TECDOC[8]. Plans for monitoring with the aim of providing assurance of safety after closure have to be drawn up before the construction of a geological disposal facility to indicate possible monitoring strategies. However, plans have to remain flexible and, if necessary, they will have to be revised and updated during the development and operation of the facility.

Requirement 22: The period after closure and institutional controls

Plans shall be prepared for the period after closure to address institutional control and the arrangements for maintaining the availability of information on the disposal facility. These plans shall be consistent with passive safety features and shall form part of the safety case on which authorization to close the facility is granted.

5.6. The long term safety of a disposal facility for radioactive waste has not to be dependent on active institutional control. Even the violation of passive safety features cannot give rise to the criteria for intervention being exceeded. Additionally, the safety of the disposal facility has not to be dependent solely on institutional controls. Institutional controls cannot be the sole or main component of safety for a near surface disposal facility. The ability of the institutional controls to provide the contributions to safety envisaged in the safety case has to be demonstrated and justified in the safety case.

5.7. The risk of intrusion into a disposal facility for radioactive waste may be reduced over a longer timescale than that foreseen for active controls by the use of passive controls, such as the preservation of information by the use of markers and archives, including international archives.

---

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Monitoring of Geological Repositories for High Level Radioactive Waste, IAEA-TECDOC-1208, IAEA, Vienna (2001).

5.8. Institutional controls over a disposal facility for radioactive waste have to provide additional assurance of the safety and nuclear security of the facility. Examples include provision for preventing access to the site by intruders and post-operational monitoring capable of providing early warning of the migration of radionuclides from the disposal facility before they reach the site boundary.

5.9. Near surface disposal facilities are generally designed on the assumption that institutional control has to remain in force for a period of time. For short lived waste, the period will have to be several tens to hundreds of years following closure. Such controls will be either active or passive in nature. For near surface disposal of waste from mining and mineral processing that includes very long lived radionuclides, and which generally comprises large volumes, activity concentrations have to be limited so that ongoing active institutional control does not have to be relied on as a safety measure. Waste with activity concentrations above the limitations has to be disposed of below the ground surface.

5.10. The status of a disposal facility beyond the period of active institutional control differs from the release of a nuclear installation site from regulatory control after decommissioning inasmuch as release of the site of a disposal facility for unrestricted use is generally not contemplated. The site location and the facility design have to reduce the likelihood of intrusion.

5.11. For near surface disposal facilities, the waste acceptance criteria will limit any consequences of human intrusion to within the specified criteria (see para. 2.15), even if control over the site is lost. The dose constraint (see para. 2.15) adopted for doses to members of the public applies for the anticipated normal evolution of the site following the period of institutional control.

5.12. Geological disposal facilities have not to be dependent on long term institutional control after closure as a safety measure (see Requirement 5). Nevertheless, institutional controls may contribute to safety by preventing or reducing the likelihood of human actions that could inadvertently interfere with the waste or degrade the safety features of the geological disposal system. Institutional controls may also contribute to increasing public acceptance of geological disposal.

5.13. Disposal facilities may not be closed for several tens of years or more after operations have commenced. Plans for possible future controls and the period over which they would be applied may initially be flexible and conceptual in nature, but plans have to be developed and refined as the facility approaches closure. Consideration has to be given to: local land use controls; site restrictions or surveillance and monitoring; local, national and international records; and the use of durable surface and/or subsurface markers. Arrangements have to be made to be able to pass on information about the disposal facility and its contents to future generations to enable any future decisions on the disposal facility and its safety to be made.

5.14. While the facility remains licensed, the operator has to provide institutional controls. It is envisaged that the responsibility for whatever passive measures for institutional control are necessary following termination of the licence will have to revert to the government at some level.

Requirement 23: Consideration of the State system of accounting for, and control of, nuclear material[9]

In the design and operation of disposal facilities subject to agreements on accounting for, and control of, nuclear material, consideration shall be given to ensuring that safety is not compromised by the measures required under the system of accounting for, and control of, nuclear material [21–23].

5.15. The system of accounting for, and control of, nuclear material applies to materials that include significant quantities of fissile material in potentially extractable form [21–23]. Such materials, if declared to be waste, are likely to require disposal in a geological disposal facility for reasons of long term safety. Placement in a geological disposal facility would also provide long term passive nuclear security and would be consistent with the objective of IAEA nuclear safeguards. Requirement 23, therefore, applies in particular to geological disposal facilities.[10]

5.16. State systems of accounting for, and control of, nuclear material were developed primarily to provide for accountability for nuclear material, in order to detect its possible diversion for unauthorized or unknown purposes in the short and medium terms. As organized at present, IAEA nuclear safeguards activities depend on active surveillance and controls.

5.17. During the operation of a disposal facility for waste that includes fissile material, surveillance for the purposes of IAEA safeguards is aimed at ensuring

[9] State systems of accounting for, and control of, nuclear material are required by IAEA nuclear safeguards agreements.

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Issues in Radioactive Waste Disposal, IAEA-TECDOC-909, IAEA, Vienna (1996).

the continuity of knowledge concerning the fissile material and the absence of any undeclared activities at the site in relation to such material. For some radioactive waste, such as spent nuclear fuel, certain requirements for safeguards have to apply even after the waste has been sealed in a geological disposal facility.[11]

5.18. For a closed geological disposal facility, IAEA nuclear safeguards might, in practice, be applied by remote means (e.g. satellite monitoring, aerial photography, microseismic surveillance and administrative arrangements). Intrusive methods, which might compromise safety after closure, have to be avoided.

5.19. Since IAEA nuclear safeguards are internationally supervised, their continuation might increase confidence in the longevity of administrative controls and this would also help to prevent inadvertent disturbance of the geological disposal facility. The continuation of safeguards inspections and monitoring after closure of a geological disposal facility may, thus, be beneficial to augmenting confidence in safety after closure. A discussion of interface issues between the system of accounting for, and control of, nuclear material (and IAEA nuclear safeguards) and radioactive waste management is included in IAEA-TECDOC-909[10].

Requirement 24: Requirements in respect of nuclear security measures

Measures shall be implemented to ensure an integrated approach to safety measures and nuclear security measures in the disposal of radioactive waste.

5.20. Where nuclear security measures are necessary to prevent unauthorized access by individuals and to prevent the unauthorized removal of radioactive material, safety measures and nuclear security measures have to be implemented in an integrated approach [1, 13].

5.21. The level of nuclear security has to be commensurate with the level of radiological hazard and the nature of the waste [1, 13, 24, 25].

---

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Group Meeting on Safeguards Related to Final Disposal of Nuclear Material in Waste and Spent Fuel (AGM-660), Rep. STR-243 (Revised), IAEA, Vienna (1988).

Requirement 25: Management systems

Management systems[12] to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety.

5.22. An appropriate management system that integrates quality assurance programmes will contribute to confidence that the relevant requirements and criteria for site selection and evaluation, design, construction, operation, closure and safety after closure are met. The relevant activities, systems and components have to be identified on the basis of the results of systematic safety assessment. The level of attention assigned to each aspect has to be commensurate with its importance to safety. The management system is required to comply with the relevant IAEA safety standards on management systems [13, 14].

5.23. The management system specifies the role of management and the organizational structure to be used for implementing processes for all safety related activities. It also specifies the responsibilities and authorities of the various personnel and organizations involved in managing and implementing the processes and assessing the quality of all work relating to safety.

5.24. While the host environment of a disposal facility is important to safety, it cannot be designed or manufactured, but only characterized, and that to only a limited extent. The elements of the management system that provide assurance of the quality of the relevant safety related processes have to be designed with account taken of the nature of the host environment.

5.25. The design, characterization and assessment of a disposal facility have to include several sequential and sometimes overlapping steps with an increasing degree of detail and accuracy. However, a degree of irreducible uncertainty that is impossible to eliminate by any measures might always remain. The significance of this uncertainty is assessed in the evaluation of the safety case and supporting safety assessment.

[12] The term ‘management system’ includes all the initial concepts of quality control (controlling the quality of products) and its evolution through quality assurance (the system for ensuring the quality of products) and quality management (the system for managing quality).

5.26. The management system for a disposal facility has to provide for the preparation and retention of documentary evidence to illustrate that the necessary quality of data has been achieved; that components have been supplied and used in accordance with the relevant specifications; that the waste packages and unpackaged waste comply with established requirements and criteria; and that they have been properly emplaced in the disposal facility. The management system also has to ensure the collation of all the information that is important to safety and that is recorded at all steps of the development and operation of the facility, and the preservation of that information. This information is important for any reassessment of the facility in the future.

6. EXISTING DISPOSAL FACILITIES

6.1. Some disposal facilities that were developed and constructed and entered into operation before these requirements were established may not meet all the requirements. These facilities may be operational or non-operational. Some disposal facilities may have been abandoned. These would be considered ‘existing situations’ in which the government would have to take responsibility for the facilities. The requirements established in this Safety Requirements publication would have to be treated as guidelines for developing intervention objectives and planning activities if necessary in such situations.

Requirement 26: Existing disposal facilities

The safety of existing disposal facilities shall be assessed periodically until termination of the licence. During this period, the safety shall also be assessed when a safety significant modification is planned or in the event of changes with regard to the conditions of the authorization. In the event that any requirements set down in this Safety Requirements publication are not met, measures shall be put in place to upgrade the safety of the facility, economic and social factors being taken into account.

6.2. Periodic safety assessment for a disposal facility has to be aimed at providing an overall assessment of the status of protection and safety at the facility. It has to include an analysis of the operational experience acquired and possible improvements that could be made, with account taken of the existing situation and of whatever new technological developments or changes in regulatory control there might be. Periodic safety assessments cannot replace the activities for analysis, control and surveillance that are continuously carried out at disposal facilities.

6.3. Disposal facilities that were not constructed to present safety standards may not meet all the safety requirements established in this Safety Requirements publication. In assessing the safety of such facilities, there may be indications that safety criteria will not be met. In such circumstances, reasonably practicable measures have to be taken to upgrade the safety of the disposal facility. Possible options may include the removal of some or all of the waste from the facility, making engineering improvements, or putting in place or enhancing institutional controls. Evaluation of these options has to include broader technical, social and political issues.

Appendix

ASSURANCE OF COMPLIANCE WITH THE SAFETY OBJECTIVE AND CRITERIA

A.1. A well-designed, well-located and properly developed disposal facility for radioactive waste will provide a high level of assurance that radiological impacts in the period after closure will be low, both in absolute terms and in comparison with the impacts expected from any other options for radioactive waste management that are available at present.

A.2. A host geological formation and/or environment and site has to be identified that provide favourable conditions for the isolation of the waste from the accessible biosphere and the preservation of the engineered barriers (e.g. low groundwater flow rates and a favourable geochemical environment over the long term). The disposal facility has to be designed with account taken of the characteristics afforded by the host geological formation and/or environment and site, so as to optimize protection and safety and not to exceed the dose and/or risk constraints. The disposal facility then has to be developed in accordance with the assessed design so that the assumed safety characteristics of both the engineered barriers and the natural barriers are realized.

A.3. The optimization of protection and safety for a disposal facility for radioactive waste is a judgemental process that is applied to the decisions made in the development of the facility's design. Most important is that sound engineering design and technical features are adopted and sound principles of management are applied throughout the development, operation and closure of the disposal facility. Given these considerations, protection and safety can then be considered optimized, provided that:

(a) Due attention has been paid to the implications for long term safety of various design options at each step in the development and in the operation of the disposal facility;
(b) There is reasonable assurance that the assessed doses and/or risks arising from the generally expected range over the natural evolution of the disposal system do not exceed the relevant constraint, over timescales for which the uncertainties are not so large as to prevent meaningful interpretation of the results;

(c) The likelihood of events that might affect the performance of the disposal facility in such a way as to give rise to higher doses or greater risks has been reduced as far as reasonably possible by site selection and evaluation and/or design.

A.4. It is recognized that calculated possible radiation doses to individuals in the future due to a disposal facility are only estimates and that the uncertainties associated with the estimates will increase for timescales extending farther into the future. Nevertheless, estimates of possible doses and risks for long time periods can be made and can be used as indicators for comparison with the safety criteria.

A.5. In estimating doses to individuals in the future due to a disposal facility, the assumption is made that people will be present locally, and that they will make some use of local resources that may contain radionuclides originating from the waste in the disposal facility. It is not possible to predict the behaviour of people in the future with any certainty, and its representation in assessment models is necessarily stylized[13]. The rationale and possible approaches to the modelling of the biosphere and the estimation of doses arising from waste disposal facilities have been considered in the IAEA BIOMASS Project [26].

A.6. The possibility exists that in the future, an activity or activities undertaken by people could cause some type of intrusion into a disposal facility for radioactive waste. It is not possible to say definitively what form such an intrusion will take or what the likelihood of the intrusion event will be, owing to the unpredictability of the behaviour of people in the future. Nevertheless, the impact of certain generic intrusion events, such as construction work, mining or drilling, can be evaluated as reference scenarios.

A.7. Generic intrusion events such as construction work, mining or drilling could possibly occur, but will not necessarily occur. On this basis, an approach to evaluating the implications for safety of such events has been proposed by the ICRP, which makes use of the type of criteria set down in para. 2.15. An agreement would have to be reached with the regulatory body as to when such an approach was appropriate and exactly how the criteria would be used. Arbitrary decisions may have to be made as to what would be considered a normal activity that would be expected to occur and what would be considered intrusion events.

[13] An arbitrary representation of behaviour is assumed, often on the basis of present human habits.

A.8. In the event of inadvertent human intrusion into a disposal facility, a small number of individuals involved in activities such as drilling into the facility or mining could receive high radiation doses and exposures of other persons could also arise as a result of the intrusion. The doses and risks involved for any individuals authorized to take part in activities that deliberately disturb the disposal facility or its waste need not be taken into consideration in this context, as such activities would constitute planned exposure situations.

A.9. In general, the likelihood of inadvertent human intrusion into the waste will be low as a consequence of the chosen depth for a geological disposal facility. The likelihood will be low owing to institutional controls in the case of a near surface disposal facility, and because of the decision to site the facility away from known significant mineral resources or other valuable resources. The possible doses that would be received from such an inadvertent intrusion could be high. However, since the likelihood of inadvertent intrusion is low, the associated risk is likely to be outweighed by the higher level of protection and safety afforded by the disposal of waste in comparison with other strategies.

A.10. A disposal facility may be affected by a range of possible evolutions and events. Some evolutions and events may be judged to be relatively likely to occur over the period of assessment and some may be rather unlikely or very unlikely to occur. With a view to optimizing protection and safety, the design process will focus on ensuring that the disposal system provides for safety (i.e. through compliance with dose constraints and/or risk constraints). Such provision will be made in consideration of the expected evolution of the disposal system. Account will also be taken of uncertainties concerning that evolution and the natural events that are likely to occur over the period of assessment.

A.11. The achievement of a level of protection and safety such that calculated doses are less than the dose constraint is not in itself sufficient for the acceptance of a safety case for a disposal facility, since protection is also required to be optimized [3]. Conversely, an indication that calculated doses could exceed the dose constraint in some unlikely circumstances need not necessarily result in the rejection of a safety case. Over very long timescales, radioactive decay of the waste will reduce the hazard associated with a disposal facility. However, uncertainties could become much larger and calculated estimates of doses might exceed the dose constraint.

A.12. Comparison of doses with doses due to radionuclides of natural origin may provide a useful indication of the significance of such cases. Caution needs to be exercised in applying criteria for periods far into the future. Beyond such timescales, the uncertainties associated with dose estimates become so large that the criteria might no longer serve as a reasonable basis for decision making (see the criteria in para. 2.15).

A.13. The evaluation of whether or not the design of a disposal facility will provide an optimized level of protection and safety could require a judgement in which several factors would be considered. These factors might include, for example, the quality of the design of the facility and of the safety assessment, and any significant qualitative or quantitative uncertainties in the calculation of exposures in the long term.

A.14. In general, when irreducible uncertainties make the results of calculations for safety assessment purposes less reliable, then comparisons with dose constraints or risk constraints need to be treated with caution. For a disposal facility, the uncertainties mean that caution is necessary in considering possible human intrusion events and very low frequency natural events. Caution is also necessary in considering calculated doses for timescales extending into the far future. The robustness of the disposal system can be demonstrated, however, by making an assessment of reference events that are typical of very low frequency natural events.

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

[3] 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) (under revision).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press, Oxford and New York (1991).

[5] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological Protection Policy for the Disposal of Radioactive Waste, Publication 77, Pergamon Press, Oxford and New York (1997).

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste, Publication 81, Pergamon Press, Oxford and New York (1998).

[7] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection, Publication 103, Elsevier (2007).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory Control of Radioactive Discharges to the Environment, IAEA Safety Standards Series No. WS-G-2.3, IAEA, Vienna (2000).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection, 2007 Edition, IAEA, Vienna (2007).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Storage of Radioactive Waste, IAEA Safety Standards Series No. WS-G-6.1, IAEA, Vienna (2006).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna (2009).

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

[14] 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).
[15] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, Occupational Radiation Protection, IAEA Safety Standards Series No. RS-G-1.1, IAEA, Vienna (1999).
[16] 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).
[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2009 Edition, IAEA Safety Standards Series No. TS-R-1, IAEA, Vienna (2009).
[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards Series No. GSR Part 1, IAEA, Vienna (2010).
[19] OECD NUCLEAR ENERGY AGENCY, Confidence in the Long Term Safety of Deep Geological Repositories: Its Communication and Development, OECD, Paris (1999).
[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Environmental and Source Monitoring for Purposes of Radiation Protection, IAEA Safety Standards Series No. RS-G-1.8, IAEA, Vienna (2005).
[21] The Agency's Safeguards System, INFCIRC/66/Rev.2, IAEA, Vienna (1968).
[22] Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540(Corr.), IAEA, Vienna (1997).
[23] The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153(Corr.), IAEA, Vienna (1972).
[24] Code of Conduct on the Safety and Security of Radioactive Sources, IAEA, Vienna (2004).
[25] The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Rev.4(Corr.), IAEA, Vienna (1999).
[26] INTERNATIONAL ATOMIC ENERGY AGENCY, "Reference Biospheres" for Solid Radioactive Waste Disposal, IAEA-BIOMASS-6, IAEA, Vienna (2003).

Annex

RADIOACTIVE WASTE CLASSIFICATION

A–1. In accordance with the approach outlined in the Appendix of Ref. [A–1], six classes of waste are derived and used as the basis for the classification scheme:

(1) Exempt waste[1] (EW): Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes as described in Ref. [A–2].
(2) Very short lived waste (VSLW): Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared from regulatory control according to arrangements approved by the regulatory body for uncontrolled disposal, use or discharge. VSLW includes waste primarily containing radionuclides with very short half-lives often used for research and medical purposes.
(3) Very low level waste (VLLW): Waste that does not necessarily meet the criteria of EW, but which does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low levels of activity concentration. Concentrations of longer lived radionuclides in VLLW are generally very limited.
(4) Low level waste (LLW): Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. LLW may include short lived radionuclides at higher levels of activity concentration and long lived radionuclides, but only at relatively low levels of activity concentration.
(5) Intermediate level waste (ILW): Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs no provision or only limited provision for heat dissipation during its storage and disposal. ILW may contain long lived

[1] For the sake of consistency, the term ‘exempt waste’ has been retained from the previous classification scheme detailed in INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, Safety Series No. 111-G-1.1, IAEA, Vienna (1994). However, once such waste has been cleared from regulatory control, it is not considered to be radioactive waste.

radionuclides, in particular alpha emitting radionuclides, which will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires disposal at greater depths, in the order of tens of metres to a few hundred metres.

(6) High level waste (HLW): Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognized option for disposal of HLW.

REFERENCES TO THE ANNEX

[A–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna (2009).

[A–2] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

CONTRIBUTORS TO DRAFTING AND REVIEW

Abu-Eid, R.	Nuclear Regulatory Commission, United States of America
Avila, R.	Facilia AB, Sweden
Bennett, D.	TerraSalus Limited, United Kingdom
Bernier, F.	Federal Agency for Nuclear Control, Belgium
Besnus, F.	Institute for Radiological Protection and Nuclear Safety, France
Blommaert, W.	Federal Agency for Nuclear Control, Belgium
Bruno, G.	European Commission
Cooper, J.	Health Protection Agency, United Kingdom
Goldammer, W.	Strategic Consulting, Germany
Jensen, M.	Swedish Radiation Protection Authority, Sweden
Kawakami, H.	Japan Nuclear Energy Safety Organization, Japan
Louvat, D.	International Atomic Energy Agency
Metcalf, P.	International Atomic Energy Agency
Moeller, K.	Federal Office for Radiation Protection, Germany
Paltemaa, R.	Radiation and Nuclear Safety Authority, Finland
Pather, T.	National Nuclear Regulator, South Africa
Rana, D.	Bhabha Atomic Research Centre, India
Röhlig, K.	Clausthal University of Technology, Germany
Rowat, J.	International Atomic Energy Agency
Serres, C.	Institute for Radiological Protection and Nuclear Safety, France

Siraky, G.	International Atomic Energy Agency
Sugier, A.	Institute for Radiological Protection and Nuclear Safety, France
Summerling, T.	Safety Assessment Management Limited, United Kingdom
Weiss, W.	Federal Office for Radiation Protection, Germany

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. Two asterisks denote an alternate.

Commission on Safety Standards

Argentina: González, A.J.; *Australia*: Loy, J.; *Belgium*: Samain, J.-P.; *Brazil*: Vinhas, L.A.; *Canada*: Jammal, R.; *China*: Liu Hua; *Egypt*: Barakat, M.; *Finland*: Laaksonen, J.; *France*: Lacoste, A.-C. (Chairperson); *Germany*: Majer, D.; *India*: Sharma, S.K.; *Israel*: Levanon, I.; *Japan*: Fukushima, A.; *Korea, Republic of*: Choul-Ho Yun; *Lithuania*: Maksimovas, G.; *Pakistan*: Rahman, M.S.; *Russian Federation*: Adamchik, S.; *South Africa*: Magugumela, M.T.; *Spain*: Barceló Vernet, J.; *Sweden*: Larsson, C.M.; *Ukraine*: Mykolaichuk, O.; *United Kingdom*: Weightman, M.; *United States of America*: Virgilio, M.; *Vietnam*: Le-chi Dung; *IAEA*: Delattre, D. (Coordinator); *Advisory Group on Nuclear Security*: Hashmi, J.A.; *European Commission*: Faross, P.; *International Nuclear Safety Group*: Meserve, R.; *International Commission on Radiological Protection*: Holm, L.-E.; *OECD Nuclear Energy Agency*: Yoshimura, U.; *Safety Standards Committee Chairpersons*: Brach, E.W. (TRANSSC); Magnusson, S. (RASSC); Pather, T. (WASSC); Vaughan, G.J. (NUSSC).

Nuclear Safety Standards Committee

Algeria: Merrouche, D.; *Argentina*: Waldman, R.; *Australia*: Le Cann, G.; *Austria*: Sholly, S.; *Belgium*: De Boeck, B.; *Brazil*: Gromann, A.; **Bulgaria*: Gledachev, Y.; *Canada*: Rzentkowski, G.; *China*: Jingxi Li; *Croatia*: Valčić, I.; **Cyprus*: Demetriades, P.; *Czech Republic*: Šváb, M.; *Egypt*: Ibrahim, M.; *Finland*: Järvinen, M.-L.; *France*: Feron, F.; *Germany*: Wassilew, C.; *Ghana*: Emi-Reynolds, G.; **Greece*: Camarinopoulos, L.; *Hungary*: Adorján, F.; *India*: Vaze, K.; *Indonesia*: Antariksawan, A.; *Iran, Islamic Republic of*: Asgharizadeh, F.; *Israel*: Hirshfeld, H.; *Italy*: Bava, G.; *Japan*: Kanda, T.; *Korea, Republic of*: Hyun-Koon Kim; *Libyan Arab Jamahiriya*: Abuzid, O.; *Lithuania*: Demčenko, M.; *Malaysia*: Azlina Mohammed Jais; *Mexico*: Carrera, A.; *Morocco*: Soufi, I.; *Netherlands*: van der Wiel, L.; *Pakistan*: Habib, M.A.; *Poland*: Jurkowski, M.; *Romania*: Biro, L.; *Russian Federation*: Baranaev, Y.; *Slovakia*: Uhrik, P.; *Slovenia*: Vojnovič, D.; *South Africa*: Leotwane, W.; *Spain*: Zarzuela, J.; *Sweden*: Hallman, A.; *Switzerland*: Flury, P.; *Tunisia*: Baccouche, S.;

Turkey: Bezdegumeli, U.; *Ukraine*: Shumkova, N.; *United Kingdom*: Vaughan, G.J. (Chairperson); *United States of America*: Mayfield, M.; *Uruguay*: Nader, A.; *European Commission*: Vigne, S.; *FORATOM*: Fourest, B.; *IAEA*: Feige, G. (Coordinator); *International Electrotechnical Commission*: Bouard, J.-P.; *International Organization for Standardization*: Sevestre, B.; *OECD Nuclear Energy Agency*: Reig, J.; **World Nuclear Association*: Borysova, I.

Radiation Safety Standards Committee

**Algeria*: Chelbani, S.; *Argentina*: Massera, G.; *Australia*: Melbourne, A.; **Austria*: Karg, V.; *Belgium*: van Bladel, L.; *Brazil*: Rodriguez Rochedo, E.R.; **Bulgaria*: Katzarska, L.; *Canada*: Clement, C.; *China*: Huating Yang; *Croatia*: Kralik, I.; **Cuba*: Betancourt Hernandez, L.; **Cyprus*: Demetriades, P.; *Czech Republic*: Petrova, K.; *Denmark*: Øhlenschlæger, M.; *Egypt*: Hassib, G.M.; *Estonia*: Lust, M.; *Finland*: Markkanen, M.; *France*: Godet, J.-L.; *Germany*: Helming, M.; *Ghana*: Amoako, J.; **Greece*: Kamenopoulou, V.; *Hungary*: Koblinger, L.; *Iceland*: Magnusson, S. (Chairperson); *India*: Sharma, D.N.; *Indonesia*: Widodo, S.; *Iran, Islamic Republic of*: Kardan, M.R.; *Ireland*: Colgan, T.; *Israel*: Koch, J.; *Italy*: Bologna, L.; *Japan*: Kiryu, Y.; *Korea, Republic of*: Byung-Soo Lee; **Latvia*: Salmins, A.; *Libyan Arab Jamahiriya*: Busitta, M.; *Lithuania*: Mastauskas, A.; *Malaysia*: Hamrah, M.A.; *Mexico*: Delgado Guardado, J.; *Morocco*: Tazi, S.; *Netherlands*: Zuur, C.; *Norway*: Saxebol, G.; *Pakistan*: Ali, M.; *Paraguay*: Romero de Gonzalez, V.; *Philippines*: Valdezco, E.; *Poland*: Merta, A.; *Portugal*: Dias de Oliveira, A.M.; *Romania*: Rodna, A.; *Russian Federation*: Savkin, M.; *Slovakia*: Jurina, V.; *Slovenia*: Sutej, T.; *South Africa*: Olivier, J.H.I.; *Spain*: Amor Calvo, I.; *Sweden*: Almen, A.; *Switzerland*: Piller, G.; **Thailand*: Suntarapai, P.; *Tunisia*: Chékir, Z.; *Turkey*: Okyar, H.B.; *Ukraine*: Pavlenko, T.; *United Kingdom*: Robinson, I.; *United States of America*: Lewis, R.; **Uruguay*: Nader, A.; *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 Electrotechnical Commission*: Thompson, I.; *International Labour Office*: Niu, S.; *International Organization for Standardization*: Rannou, A.; *International Source Suppliers and Producers Association*: Fasten, W.; *OECD Nuclear Energy Agency*: Lazo, T.E.; *Pan American Health Organization*: Jiménez, 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.; **Capadona, N.M.; *Australia*: Sarkar, S.; *Austria*: Kirchnawy, F.; *Belgium*: Cottens, E.; *Brazil*: Xavier, A.M.; *Bulgaria*: Bakalova, A.; *Canada*: Régimbald, A.; *China*: Xiaoqing Li; *Croatia*: Belamarić, N.; **Cuba*: Quevedo Garcia, J.R.; **Cyprus*: Demetriades, P.; *Czech Republic*: Ducháček, V.; *Denmark*: Breddam, K.; *Egypt*: El-Shinawy, R.M.K.; *Finland*: Lahkola, A.; *France*: Landier, D.; *Germany*: Rein, H.; *Nitsche, F.; **Alter, U.; *Ghana*: Emi-Reynolds, G.; **Greece*: Vogiatzi, S.; *Hungary*: Sáfár, J.; *India*: Agarwal, S.P.; *Indonesia*: Wisnubroto, D.; *Iran, Islamic Republic of*: Eshraghi, A.; *Emamjomeh, A.; *Ireland*: Duffy, J.; *Israel*: Koch, J.; *Italy*: Trivelloni, S.; **Orsini, A.; *Japan*: Hanaki, I.; *Korea, Republic of*: Dae-Hyung Cho; *Libyan Arab Jamahiriya*: Kekli, A.T.; *Lithuania*: Statkus, V.; *Malaysia*: Sobari, M.P.M.; **Husain, Z.A.; *Mexico*: Bautista Arteaga, D.M.; **Delgado Guardado, J.L.; **Morocco*: Allach, A.; *Netherlands*: Ter Morshuizen, M.; **New Zealand*: Ardouin, C.; *Norway*: Hornkjøl, S.; *Pakistan*: Rashid, M.; **Paraguay*: More Torres, L.E.; *Poland*: Dziubiak, T.; *Portugal*: Buxo da Trindade, R.; *Russian Federation*: Buchelnikov, A.E.; *South Africa*: Hinrichsen, P.; *Spain*: Zamora Martin, F.; *Sweden*: Häggblom, E.; **Svahn, B.; *Switzerland*: Krietsch, T.; *Thailand*: Jerachanchai, S.; *Turkey*: Ertürk, K.; *Ukraine*: Lopatin, S.; *United Kingdom*: Sallit, G.; *United States of America*: Boyle, R.W.; Brach, E.W. (Chairperson); *Uruguay*: Nader, A.; *Cabral, W.; *European Commission*: Binet, J.; *IAEA*: Stewart, J.T. (Coordinator); *International Air Transport Association*: Brennan, D.; *International Civil Aviation Organization*: Rooney, K.; *International Federation of Air Line Pilots' Associations*: Tisdall, A.; **Gessl, M.; *International Maritime Organization*: Rahim, I.; *International Organization for Standardization*: Malesys, P.; *International Source Supplies and Producers Association*: Miller, J.J.; **Roughan, K.; *United Nations Economic Commission for Europe*: Kervella, O.; *Universal Postal Union*: Bowers, D.G.; *World Nuclear Association*: Gorlin, S.; *World Nuclear Transport Institute*: Green, L.

Waste Safety Standards Committee

Algeria: Abdenacer, G.; *Argentina*: Biaggio, A.; *Australia*: Williams, G.; **Austria*: Fischer, H.; *Belgium*: Blommaert, W.; *Brazil*: Tostes, M.; **Bulgaria*: Simeonov, G.; *Canada*: Howard, D.; *China*: Zhimin Qu; *Croatia*: Trifunovic, D.; *Cuba*: Fernandez, A.; *Cyprus*: Demetriades, P.; *Czech Republic*: Lietava, P.; *Denmark*: Nielsen, C.; *Egypt*: Mohamed, Y.; *Estonia*: Lust, M.; *Finland*: Hutri, K.; *France*: Rieu, J.; *Germany*: Götz, C.; *Ghana*: Faanu, A.; *Greece*: Tzika, F.; *Hungary*: Czoch, I.; *India*: Rana, D.; *Indonesia*: Wisnubroto, D.; *Iran, Islamic*

Republic of: Assadi, M.; *Zarghami, R.; *Iraq*: Abbas, H.; *Israel*: Dody, A.; *Italy*: Dionisi, M.; *Japan*: Matsuo, H.; *Korea, Republic of*: Won-Jae Park; **Latvia*: Salmins, A.; *Libyan Arab Jamahiriya*: Elfawares, A.; *Lithuania*: Paulikas, V.; *Malaysia*: Sudin, M.; *Mexico*: Aguirre Gómez, J.; **Morocco*: Barkouch, R.; *Netherlands*: van der Shaaf, M.; *Pakistan*: Mannan, A.; **Paraguay*: Idoyaga Navarro, M.; *Poland*: Wlodarski, J.; *Portugal*: Flausino de Paiva, M.; *Slovakia*: Homola, J.; *Slovenia*: Mele, I.; *South Africa*: Pather, T. (Chairperson); *Spain*: Sanz Aludan, M.; *Sweden*: Frise, L.; *Switzerland*: Wanner, H.; **Thailand*: Supaokit, P.; *Tunisia*: Bousselmi, M.; *Turkey*: Özdemir, T.; *Ukraine*: Makarovska, O.; *United Kingdom*: Chandler, S.; *United States of America*: Camper, L.; **Uruguay*: Nader, A.; *European Commission*: Necheva, C.; *European Nuclear Installations Safety Standards*: Lorenz, B.; **European Nuclear Installations Safety Standards*: Zaiss, W.; *IAEA*: Siraky, G. (Coordinator); *International Organization for Standardization*: Hutson, G.; *International Source Suppliers and Producers Association*: Fasten, W.; *OECD Nuclear Energy Agency*: Riotte, H.; *World Nuclear Association*: Saint-Pierre, S.

IAEA
International Atomic Energy Agency

No. 22

Where to order IAEA publications

In the following countries IAEA publications may be purchased from the sources listed below, or from major local booksellers. Payment may be made in local currency or with UNESCO coupons.

AUSTRALIA
DA Information Services, 648 Whitehorse Road, MITCHAM 3132
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

BELGIUM
Jean de Lannoy, avenue du Roi 202, B-1190 Brussels
Telephone: +32 2 538 43 08 • Fax: +32 2 538 08 41
Email: jean.de.lannoy@infoboard.be • Web site: http://www.jean-de-lannoy.be

CANADA
Bernan Associates, 4501 Forbes Blvd, Suite 200, Lanham, MD 20706-4346, USA
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 1-5369 Canotek Rd., Ottawa, Ontario, K1J 9J3
Telephone: +613 745 2665 • Fax: +613 745 7660
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

CHINA
IAEA Publications in Chinese: China Nuclear Energy Industry Corporation, Translation Section, P.O. Box 2103, Beijing

CZECH REPUBLIC
Suweco CZ, S.R.O., Klecakova 347, 180 21 Praha 9
Telephone: +420 26603 5364 • Fax: +420 28482 1646
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

FINLAND
Akateeminen Kirjakauppa, PO BOX 128 (Keskuskatu 1), FIN-00101 Helsinki
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

FRANCE
Form-Edit, 5, rue Janssen, P.O. Box 25, F-75921 Paris Cedex 19
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: formedit@formedit.fr • Web site: http://www. formedit.fr

Lavoisier SAS, 145 rue de Provigny, 94236 Cachan Cedex
Telephone: + 33 1 47 40 67 02 • Fax +33 1 47 40 67 02
Email: romuald.verrier@lavoisier.fr • Web site: http://www.lavoisier.fr

GERMANY
UNO-Verlag, Vertriebs- und Verlags GmbH, Am Hofgarten 10, D-53113 Bonn
Telephone: + 49 228 94 90 20 • Fax: +49 228 94 90 20 or +49 228 94 90 222
Email: bestellung@uno-verlag.de • Web site: http://www.uno-verlag.de

HUNGARY
Librotrade Ltd., Book Import, P.O. Box 126, H-1656 Budapest
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472 • Email: books@librotrade.hu

INDIA
Allied Publishers Group, 1st Floor, Dubash House, 15, J. N. Heredia Marg, Ballard Estate, Mumbai 400 001,
Telephone: +91 22 22617926/27 • Fax: +91 22 22617928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell, 2/72, Nirankari Colony, Delhi 110009
Telephone: +91 11 23268786, +91 11 23257264 • Fax: +91 11 23281315
Email: bookwell@vsnl.net

ITALY
Libreria Scientifica Dott. Lucio di Biasio “AEIOU”, Via Coronelli 6, I-20146 Milan
Telephone: +39 02 48 95 45 52 or 48 95 45 62 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Website: www.libreriaaeiou.eu

JAPAN
Maruzen Company, Ltd., 13-6 Nihonbashi, 3 chome, Chuo-ku, Tokyo 103-0027
Telephone: +81 3 3275 8582 • Fax: +81 3 3275 9072
Email: journal@maruzen.co.jp • Web site: http://www.maruzen.co.jp

REPUBLIC OF KOREA
KINS Inc., Information Business Dept. Samho Bldg. 2nd Floor, 275-1 Yang Jae-dong SeoCho-G, Seoul 137-130
Telephone: +02 589 1740 • Fax: +02 589 1746 • Web site: http://www.kins.re.kr

NETHERLANDS
De Lindeboom Internationale Publicaties B.V., M.A. de Ruyterstraat 20A, NL-7482 BZ Haaksbergen
Telephone: +31 (0) 53 5740004 • Fax: +31 (0) 53 5729296
Email: books@delindeboom.com • Web site: http://www.delindeboom.com

Martinus Nijhoff International, Koraalrood 50, P.O. Box 1853, 2700 CZ Zoetermeer
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: http://www.nijhoff.nl

Swets and Zeitlinger b.v., P.O. Box 830, 2160 SZ Lisse
Telephone: +31 252 435 111 • Fax: +31 252 415 888
Email: infoho@swets.nl • Web site: http://www.swets.nl

NEW ZEALAND
DA Information Services, 648 Whitehorse Road, MITCHAM 3132, Australia
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: http://www.dadirect.com.au

SLOVENIA
Cankarjeva Zalozba d.d., Kopitarjeva 2, SI-1512 Ljubljana
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: http://www.cankarjeva-z.si/uvoz

SPAIN
Díaz de Santos, S.A., c/ Juan Bravo, 3A, E-28006 Madrid
Telephone: +34 91 781 94 80 • Fax: +34 91 575 55 63
Email: compras@diazdesantos.es, carmela@diazdesantos.es, barcelona@diazdesantos.es, julio@diazdesantos.es
Web site: http://www.diazdesantos.es

UNITED KINGDOM
The Stationery Office Ltd, International Sales Agency, PO Box 29, Norwich, NR3 1 GN
Telephone (orders): +44 870 600 5552 • (enquiries): +44 207 873 8372 • Fax: +44 207 873 8203
Email (orders): book.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: http://www.tso.co.uk

On-line orders
DELTA Int. Book Wholesalers Ltd., 39 Alexandra Road, Addlestone, Surrey, KT15 2PQ
Email: info@profbooks.com • Web site: http://www.profbooks.com

Books on the Environment
Earthprint Ltd., P.O. Box 119, Stevenage SG1 4TP
Telephone: +44 1438748111 • Fax: +44 1438748844
Email: orders@earthprint.com • Web site: http://www.earthprint.com

UNITED NATIONS
Dept. I004, Room DC2-0853, First Avenue at 46th Street, New York, N.Y. 10017, USA
(UN) Telephone: +800 253-9646 or +212 963-8302 • Fax: +212 963-3489
Email: publications@un.org • Web site: http://www.un.org

UNITED STATES OF AMERICA
Bernan Associates, 4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4346
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com · Web site: http://www.bernan.com

Renouf Publishing Company Ltd., 812 Proctor Ave., Ogdensburg, NY, 13669
Telephone: +888 551 7470 (toll-free) • Fax: +888 568 8546 (toll-free)
Email: order.dept@renoufbooks.com • Web site: http://www.renoufbooks.com

Orders and requests for information may also be addressed directly to:

Marketing and Sales Unit, International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 (or 22530) • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: http://www.iaea.org/books

10-08871

Safety through international standards

"Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them."

Yukiya Amano
Director General

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–103010–8
ISSN 1020–525X