

IAEA Safety Standards

for protecting people and the environment

Geological Disposal of Radioactive Waste

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Safety Requirements

No. WS-R-4



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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, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Safety standards are coded according to their coverage: nuclear safety (NS), radiation safety (RS), transport safety (TS), waste safety (WS) and general safety (GS).

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 P.O. Box 100, A-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 e-mail 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 in other publications series, in particular the **Safety Reports Series**. Safety Reports provide practical examples and detailed methods that can be used in support of the safety standards. Other IAEA series of safety related publications are the **Provision for the Application of Safety Standards Series**, the **Radiological Assessment Reports Series** and the International Nuclear Safety Group's **INSAG Series**. The IAEA also issues reports on radiological accidents and other special publications.

Safety related publications are also issued in the **Technical Reports Series**, the **IAEA-TECDOC Series**, the **Training Course Series** and the **IAEA Services Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. Security related publications are issued in the **IAEA Nuclear Security Series**.

GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Safety standards survey

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IAEA SAFETY STANDARDS SERIES No. WS-R-4

GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

SAFETY REQUIREMENTS

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INTERNATIONAL ATOMIC ENERGY AGENCY
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VIENNA, 2006

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FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

PREFACE

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

This Safety Requirements publication establishes requirements relating to the disposal of radioactive waste in geological disposal facilities. It sets out the objective and criteria for the protection of human health and the environment during the operation of geological disposal facilities and after such facilities are closed, and establishes the requirements for ensuring their safety. Failure to meet any of the requirements would require an action to be taken to provide for safety.

The safety requirements are derived from the IAEA Safety Fundamentals publications on The Principles of Radioactive Waste Management (Safety Series No. 111-F (1995)) and Radiation Protection and the Safety of Radiation Sources (Safety Series No. 120 (1996)), as well as international experience in the development of geological disposal facilities.

This Safety Requirements publication does not reiterate the requirements in respect of legal and governmental infrastructure, radiation protection and emergency planning that are established in other Safety Requirements publications. It is based on the premise that, in general, arrangements will be in place to ensure that these requirements are met.

It does establish some requirements closely related to these thematic areas that are of particular importance to the safety of geological disposal facilities. Guidance on the fulfilment of these requirements will be provided in a Safety Guide. This publication supersedes the IAEA publication on Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes (Safety Series No. 99 (1989)).

This publication is jointly sponsored with the OECD Nuclear Energy Agency (OECD/NEA). The IAEA and the OECD/NEA wish to express their appreciation to all those who assisted in the drafting and review of this publication.

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IAEA SAFETY STANDARDS

SAFETY THROUGH INTERNATIONAL STANDARDS

While safety is a national responsibility, international standards and approaches to safety promote consistency, help to provide assurance that nuclear and radiation related technologies are used safely, and facilitate international technical cooperation, commerce and trade.

The standards also provide support for States in meeting their international obligations. One general international obligation is that a State must not pursue activities that cause damage in another State. More specific obligations on Contracting States are set out in international safety related conventions. The internationally agreed IAEA safety standards provide the basis for States to demonstrate that they are meeting these obligations.

THE IAEA STANDARDS

The IAEA safety standards have a status derived from the IAEA's Statute, which authorizes the Agency to establish standards of safety for nuclear and radiation related facilities and activities and to provide for their application.

The safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment.

They are issued in the IAEA Safety Standards Series, which has three categories:

Safety Fundamentals

- Presenting the objectives, concepts and principles of protection and safety and providing the basis for the safety requirements.

Safety Requirements

- Establishing the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements, which are expressed as 'shall' statements, are governed by the objectives, concepts and principles of the Safety Fundamentals. If they are not met, measures must be taken to reach or restore the required level of safety. The Safety Requirements use regulatory language to enable them to be incorporated into national laws and regulations.

Safety Guides

- Providing recommendations and guidance on how to comply with the Safety Requirements. Recommendations in the Safety Guides are expressed as 'should' statements. It is recommended to take the measures stated 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. Each Safety Requirements publication is supplemented by a number of Safety Guides, which can be used in developing national regulatory guides.

The IAEA safety standards need to be complemented by industry standards and must be implemented within appropriate national regulatory infrastructures to be fully effective. The IAEA produces a wide range of technical publications to help States in developing these national standards and infrastructures.

MAIN USERS OF THE STANDARDS

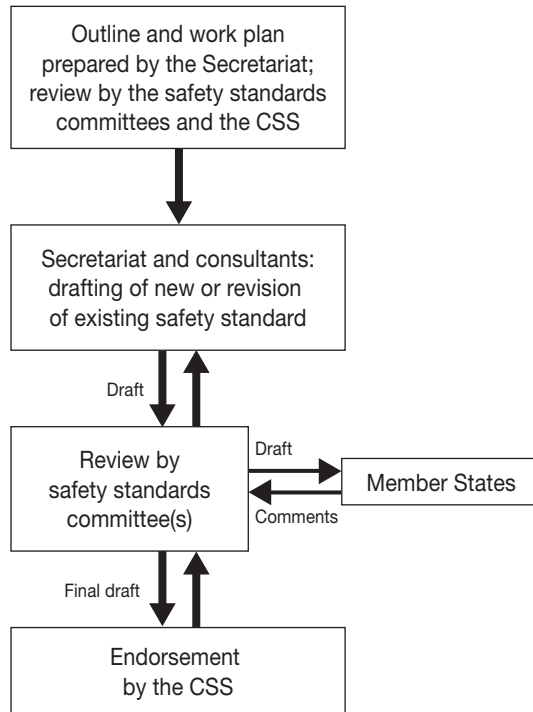
As well as by regulatory bodies and governmental departments, authorities and agencies, the standards are used by authorities and operating organizations in the nuclear industry; by organizations that design, manufacture for and apply nuclear and radiation related technologies, including operating organizations of facilities of various types; by users and others involved with radiation and radioactive material in medicine, industry, agriculture, research and education; and by engineers, scientists, technicians and other specialists. The standards are used by the IAEA itself in its safety reviews and for developing education and training courses.

DEVELOPMENT PROCESS FOR THE STANDARDS

The preparation and review of safety standards involves the IAEA Secretariat and four safety standards committees for safety in the areas of 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 entire safety standards programme. All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the CSS is appointed by the Director General and includes senior government officials having responsibility for establishing national standards.

For Safety Fundamentals and Safety Requirements, the drafts endorsed by the Commission are submitted to the IAEA Board of Governors for approval for publication. Safety Guides are published on the approval of the Director General.

Through this process the standards come to represent a consensus view of the IAEA's Member States. 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 standards. Some 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 International



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

Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

The safety standards are kept up to date: five years after publication they are reviewed to determine whether revision is necessary.

APPLICATION AND SCOPE OF THE STANDARDS

The IAEA Statute makes the safety standards binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA concerning any form of Agency assistance is required to comply with the requirements of the safety standards that pertain to the activities covered by the agreement.

International conventions also contain similar requirements to those in the safety standards, and make them binding on contracting parties. The Safety Fundamentals were used as the basis for the development of the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The Safety

Requirements on Preparedness and Response for a Nuclear or Radiological Emergency reflect the obligations on States under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

The safety standards, incorporated into national legislation and regulations and supplemented by international conventions and detailed national requirements, establish a basis for protecting people and the environment. However, there will also be special aspects of safety that need to be assessed case by case at the national level. For example, many of the safety standards, particularly those addressing planning or design aspects of safety, are intended to apply primarily to new facilities and activities. The requirements and recommendations specified in the IAEA safety standards might not be fully met at some facilities built to earlier standards. The way in which the safety standards are to be applied to such facilities is a decision for individual States.

INTERPRETATION OF THE TEXT

The safety standards use the form ‘shall’ in establishing international consensus requirements, responsibilities and obligations. Many requirements are not addressed to a specific party, the implication being that the appropriate party or parties should be responsible for fulfilling them. Recommendations are expressed as ‘should’ statements in the main text (body text and appendices), indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures) for complying with the requirements.

Safety related terms are to be interpreted as stated in the IAEA Safety Glossary (<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 within the 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 main text, is included in support of statements in the main text, or describes methods of calculation, experimental 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 standard. Material in an appendix has the same status as the main 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 published in standards that is under other authorship may be presented in annexes. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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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 other activities in which radioactive material is used. Radioactive waste presents a potential hazard to human health and the environment and it must be managed so as to reduce any associated risks to acceptable levels.

1.2. The principles to be applied in all radioactive waste management activities are set out in the IAEA Safety Fundamentals publication on the Principles of Radioactive Waste Management [1]. These principles formed the technical basis for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention) [2]. The relevant principles and requirements for radiation protection are set out in the Safety Fundamentals publication on Radiation Protection and the Safety of Radiation Sources [3] and in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the Basic Safety Standards) [4]. Many of the basic principles and concepts of protection adopted in these standards and in the Joint Convention [2] are derived from the recommendations of the International Commission on Radiological Protection (ICRP) [5–7].

1.3. The term ‘geological disposal’ refers to the disposal of solid radioactive waste in a facility located underground in a stable geological formation (usually several hundred metres or more below the surface) so as to provide long term isolation of the radionuclides in the waste from the biosphere. Disposal means that there is no intention to retrieve the waste, although such a possibility is not ruled out. Geological disposal was conceived of as a method for disposing of the more hazardous types of radioactive waste, including heat generating waste and long lived waste. Such waste includes spent nuclear fuel (if declared as waste under the national policy), high level waste (HLW) from the reprocessing of nuclear fuel, and other radioactive waste that generates significant amounts of heat or that contains concentrations of long lived radionuclides that are unsuitable for its disposal in near surface facilities. However, the actual types of waste to be disposed of in a particular geological disposal facility will be determined by the national policy and strategy for waste disposal. The defining

characteristic of the waste concerned is that it could pose a significant radiological hazard for periods of time well in excess of those for which surveillance and maintenance of the site — as would be required if it were to remain in surface or near surface disposal facilities — can be guaranteed.

The concept of geological disposal

1.4. Concentrating and containing radioactive waste and isolating it from the biosphere is the accepted strategy for its management [1]. Containment can be provided by a number of means, including containment by the waste form itself, waste packaging, backfill materials and the host geology. The depth of disposal and the characteristics of the host geological environment generally provide for isolation of the waste from the biosphere. The disposal of highly concentrated and long lived waste in a solid form in a geological disposal facility provides a high degree of containment of such waste and the necessary degree of isolation of the waste from the accessible environment. As such it is widely considered to be an appropriate method for the disposal of such waste as the final step in its management in this strategy.

1.5. Geological disposal facilities are designed to ensure both operational safety and post-closure safety. Operational safety is provided by means of engineered features and operational controls. Post-closure safety is provided by means of engineered and geological barriers; it does not depend on monitoring or institutional controls after the facility has been closed. That is, the facility is designed to be passively safe. This does not mean that monitoring could not be carried out, if the relevant authorities now or in the future decide to take such action. It is likely that institutional controls would be applied for a period after the closure of a geological disposal facility; for example, to contribute to the social acceptability of the geological disposal facility and for the purposes of nuclear safeguards.

1.6. The aims of geological disposal are:

- To contain the waste until most of the radioactivity, and especially that associated with shorter lived radionuclides, has decayed;
- To isolate the waste from the biosphere and to substantially reduce the likelihood of inadvertent human intrusion into the waste;
- To delay any significant migration of radionuclides to the biosphere until a time in the far future when much of the radioactivity will have decayed;

- To ensure that any levels of radionuclides eventually reaching the biosphere are such that possible radiological impacts in the future are acceptably low.

The aim of geological disposal is not to provide a guarantee of absolute and complete containment and isolation of the waste for all time.

Development of geological disposal facilities

1.7. The development (i.e. the siting, design and construction), operation and closure of a geological disposal facility are likely to take place over several decades. Current plans for geological disposal in several States envisage that a disposal facility is developed in a series of steps. Such a step by step approach involves: 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 and safety assessment with progressively improving data; technical and regulatory reviews; public consultations; and political decisions. 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 in responding to new technical information, advances in waste management and materials technologies, and in enabling social, economic and political aspects to be addressed. This approach may include options for reversing a given step in the development or even retrieving waste after its emplacement if this were to be appropriate. The developers of geological disposal facilities may define a number of steps related to their own programme needs. In this publication, however, the step by step approach refers mainly to the steps that are imposed by the regulatory and political decision making processes.

1.8. It is convenient to identify three periods associated with the development, operation and closure of a geological disposal facility: pre-operational, operational and post-closure. Various activities will take place during these periods and some may be undertaken to varying degrees throughout part or all of the lifetime of the facility:

- The *pre-operational period* includes concept definition, site investigation and confirmation, environmental impact assessments, site selection, design studies and development of those aspects of the safety case for operational and post-closure safety that are required in order to obtain the authorization to proceed with the construction of the geological disposal facility and the initial operational activities.



- 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 radiation protection and safety. In this period, monitoring and testing programmes, on the basis of which the decision to close the geological disposal facility is taken, continue, and the post-closure aspects of the safety case are further developed. During 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.
- The *post-closure period* begins at the time when all access routes from the surface are sealed. After closure, the safety of the geological disposal facility is ensured by passive means inherent in the characteristics of the site and the facility and those of the waste packages. However, institutional controls, including some monitoring, may continue in order to provide public assurance, for example.

1.9. This publication establishes requirements for protecting people and the environment from the hazards associated with waste management activities related to disposal, i.e. hazards that could arise during the operational period and following closure. Assurance of this protection will be provided by the application of legal and regulatory requirements on the planning, development and assessment activities that are carried out during the pre-operational and operational periods.

1.10. The safety of a geological disposal facility after closure depends on a combination of the site features and the quality of the facility's design, as well as that of the waste packages, and on the proper implementation of the design. This involves the deployment of competent professional staff in the planning, siting and design and in the implementation of the design. Ensuring the required level of safety and quality entails developing the geological disposal facility in an integrated manner, on the basis of sound scientific understanding, good engineering, the application of sound technical and managerial principles, and thorough and robust safety assessments, and with the application of quality assurance (QA) to all of these elements. The *geological disposal system* (the disposal facility and the geological 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 geological disposal facility is progressively advanced. At each step, safety assessment is important in

evaluating the prevailing level of understanding of the disposal system and assessing the associated uncertainties.

1.11. The basis for this understanding of the disposal system and the key arguments for its safety, and an acknowledgement of the existing unresolved uncertainties and of their safety significance and approaches for their management is incorporated into a *safety case* (a collection of arguments and evidence to demonstrate the safety of a facility), which is 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 and allows the identification of areas on which attention needs to be focused to further improve the understanding of those aspects influencing the safety of the geological disposal system.

OBJECTIVE

1.12. The objective of this Safety Requirements publication is to set down the protection objectives and criteria for geological disposal and to establish the requirements that must be met to ensure the safety of this disposal option, consistent with the established principles of safety for radioactive waste management.

1.13. This publication is intended for use by those involved in the management of radioactive waste and in making decisions regarding the development, operation and closure of geological disposal facilities, especially those concerned with the related regulatory aspects. A Safety Guide will provide comprehensive guidance on international best practices for meeting the requirements.

SCOPE

1.14. Geological disposal, as a concept, encompasses a range of options, including disposal in specially mined and engineered facilities, disposal in pre-existing mines and excavations, and disposal in deep boreholes. The distinctive feature of geological disposal is the depth of emplacement, usually taken to be hundreds of metres below ground level. This is in contrast to near surface disposal or disposal in rock caverns several tens of metres below ground level, which is considered to be a type of near surface disposal. This Safety Requirements publication applies specifically to the disposal of radioactive