IAEA
SAFETY
STANDARDS
SERIES

Near Surface Disposal of Radioactive Waste

REQUIREMENTS

No. WS-R-1

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

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

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OTHER SAFETY RELATED PUBLICATIONS

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NEAR SURFACE DISPOSAL OF RADIOACTIVE WASTE

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

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SAFETY REQUIREMENTS

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FOREWORD
BY THE DIRECTOR GENERAL

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

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

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

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

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

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

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

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

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

PREFACE

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

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

The present Safety Requirements publication sets out the basic safety requirements related to the disposal of radioactive wastes in near surface repositories. It includes requirements for the protection of human health, for the assessment procedures needed to ensure that safety is achieved, and technical requirements for waste acceptance and for siting, design, construction, operation and closure of the repository and the post-closure phase. The requirements are derived from the basic principles for radioactive waste management set out in the Safety Fundamentals publication on The Principles of Radioactive Waste Management (Safety Series No. 111-F). Guidance on the implementation of the requirements is provided in a number of associated Safety Guides.

This Safety Requirements publication was developed through a series of consultants and Technical Committee meetings and reviewed by the Waste Safety Standards Advisory Committee (WASSAC), the Advisory Commission for Safety Standards (ACSS) and Member States.

The IAEA wishes to express its appreciation to all those who assisted in drafting and review.

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EDITORIAL NOTE

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Radioactive waste, as a source of ionizing radiation, represents a potential hazard to human health and must be carefully managed so as to reduce the associated risks to acceptable levels. The safety principles to be applied are set out in the RADWASS Safety Fundamentals publication "The Principles of Radioactive Waste Management" [1].

1.2. The present Safety Requirements publication is concerned with the disposal of certain types of solid or solidified radioactive wastes by emplacement near the surface of the earth. The term 'near surface disposal' encompasses a wide range of options, including disposal in engineered structures on the ground, disposal in simple earthen trenches a few metres deep, disposal in engineered concrete vaults and disposal in rock caverns several tens of metres below the earth's surface. In contrast, the term 'geological disposal' is generally used to describe disposal at depths of hundreds of metres. 'Disposal' is taken to mean the emplacement of waste in approved, specified facilities, without the intention of retrieving it.

1.3. In general, wastes suitable for disposal in near surface repositories are those containing short lived radionuclides and low concentrations of long lived radionuclides [2]. For wastes of this type, disposal in near surface facilities has been practised in a number of countries for several decades. Experience has shown that this is a realistic and practical method for the safe isolation of such wastes and for achieving the protection of human health and the environment, subject to appropriate regulation.

1.4. There are three phases associated with the lifetime of a near surface repository: pre-operational, operational and post-closure. The pre-operational phase includes the necessary siting and design studies and the period of construction of the repository. The operational phase includes the period of operations at the repository and the closure of the repository. The post-closure phase includes any activities following closure of the repository (for example, periods of active or passive controls). Activities related to each of these phases should be carried out consistent with the requirements of this Safety Requirements publication and with the guidance provided in the companion RADWASS Safety Guides [3, 4].

OBJECTIVE

1.5. The objective of this Safety Requirements publication is to set out the basic requirements that international experience has shown to be necessary for ensuring the safety of near surface radioactive waste repositories.

SCOPE

1.6. This Safety Requirements publication applies to the disposal of radioactive wastes in solid or solidified form in near surface repositories. The wastes to be put in these repositories are generally characterized as those whose activity is largely due to short lived radionuclides and which have low concentrations of long lived radionuclides. This publication does not cover the geological disposal of radioactive wastes, or the disposal of waste from mining and milling, or residual waste arising from restoration activities and remaining at the site.

1.7. This publication sets out safety requirements for use in planning new near surface repositories. It is recognized that existing and former repositories of this type might not comply with all of the safety requirements specified here. National authorities should review the safety of existing and former repositories and decide whether improvements are necessary in the light of the safety requirements presented here.

STRUCTURE

1.8. This Safety Requirements publication is structured in twelve Sections. They include requirements for the protection of human health and the environment (Section 2); the means for demonstrating compliance with safety requirements (Section 3); an outline of the organization and responsibilities for each of the parties involved (Section 4); a description of technical safety requirements for each of the main components and activities — for the waste (Section 5), for the site (Section 6), for the design of disposal facilities (Section 7), for construction (Section 8), for operation (Section 9), for closure (Section 10) and for the post-closure phase (Section 11) — and requirements for quality assurance during all disposal activities (Section 12). The Annex provides a brief discussion of some features of dose and risk criteria.

2. REQUIREMENTS FOR THE PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

GENERAL

2.1. Responsible radioactive waste management calls for the implementation of measures that will afford protection of human health and the environment in accordance with a national system of radiation protection that applies the latest internationally agreed principles and requirements for radioactive waste management and

radiation protection [1, 5–8]. These principles and requirements are relevant to all activities related to near surface disposal that involve or could result in radiation exposure. Particular attention needs to be given to the assessment of the various pathways by which humans might be exposed to radiation during the operation of a repository and after its closure, and to providing assurance that protection against such exposure complies with established requirements.

2.2. The disposal of radioactive waste in a near surface repository is part of a practice, as defined by the International Commission on Radiological Protection (ICRP) and in the Basic Safety Standards (BSS) [6], and radiation protection considerations are therefore governed by the concepts of justification, optimization and dose limitation. The generation and management of radioactive waste does not need to be justified separately since it should have been taken into account in the justification of the entire practice giving rise to the waste. The principles of optimization and dose limitation are applicable [1].

2.3. In the operational phase of a near surface repository, the requirements for the radiological protection and safety of workers at the repository and of members of the public are similar to those applicable to other operating facilities in which radioactive materials are being handled. However, since radioactive waste repositories will continue to present a potential hazard to human health in the future after closure, particular safety requirements are needed to protect future generations.

OPERATIONAL PHASE

2.4. National radiation protection requirements shall take due account of the BSS [6] and shall apply to the operational phase of the repository.

2.5. In particular, the radiation protection of persons who are exposed as a result of operations at the waste repository shall be optimized and the exposures of individuals kept within dose limits. The dose limits for occupational exposure for workers and for members of the public prescribed in national regulations shall apply during the operational phase of a repository. Internationally endorsed values for these limits are contained in Schedule II of the BSS [6].

POST-CLOSURE PHASE

2.6. Radiological safety criteria for the post-closure phase shall be established. These shall be in the form of dose criteria or risk criteria or both. Risk is defined as

the product of the probability of receiving a dose and the probability that the dose will give rise to a deleterious health effect. The Annex provides a brief discussion of dose and risk criteria. Additional safety indicators may be considered appropriate by the national regulatory body.

2.7. For possible modes of evolution of the repository during the post-closure phase which are judged to be likely, the repository shall be designed so that projections of doses[1] or risks to members of the public do not exceed an appropriate fraction of the dose limit, 1 mSv/a, or its risk equivalent. The appropriate fraction, termed the dose or risk constraint, shall be determined by the regulatory body. Recently the ICRP has recommended that a value of no more than about 0.3 mSv in a year would be appropriate in this context [8].

2.8. Situations in which exposure could arise as a result of the occurrence of unlikely events that affect the repository, i.e. events with low associated probabilities, shall also be considered. The regulatory body shall decide whether the outcomes of unlikely events should be compared with a risk constraint or whether the probability of occurrence and the resulting dose should be considered separately [9].

2.9. Doses or risks for comparison with safety criteria for the post-closure phase shall be assessed by reference to the critical group, i.e. the group of individuals expected to incur the highest dose or risk, as appropriate. Consideration must be given to exposures that may occur in the future and therefore the critical group or groups shall be postulated on the basis of an analysis of events that could affect the repository at any time (see also para. 3.10).

2.10. The long term safety of near surface repositories shall be achieved through a combination of favourable site characteristics, engineered design features, appropriate form and content of waste, operating procedures and institutional controls. The disposal system is intended: in the first instance to isolate the waste from the accessible environment; in the second instance to control releases of radionuclides that reach the accessible environment; and finally to mitigate the consequences of any unacceptable releases to the accessible environment. Near surface disposal usually includes the continued surveillance of the site for a period after the closure of the repository and during this period such surveillance represents an important safety factor. For repositories located in rock caverns several tens of metres below the earth's

[1] The term 'dose' refers to the sum of the effective dose from external exposure in a given period and the committed effective dose from radionuclides taken into the body in the same period.

surface, it may be that adequate safety in the post-closure phase can be achieved without active institutional controls.

2.11. The effective and safe isolation of waste depends on the performance of the overall disposal system. The relative contributions of the different components of the system to the safety of the repository will vary depending on the disposal concept, the site conditions and the time since closure. For this reason, waste acceptance requirements and the design of engineered barriers will usually be determined for each site and disposal arrangement and be established on the basis of a site specific safety assessment. However, an alternative approach would be to establish requirements for waste acceptance and barrier design on a generic basis and to establish other requirements as needed for individual repositories.

PROTECTION OF THE ENVIRONMENT

2.12. The Safety Fundamentals state that: “Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment” [1]. It can normally be assumed that protection of humans against the radiological hazard from the waste, subject to an appropriate definition of the critical group, satisfies the need to protect the environment [1, 10]. Any non-radiological environmental impacts of radioactive waste management activities, such as chemical pollution or alteration of natural habitats, shall also be considered.

3. SAFETY ASSESSMENT AND COMPLIANCE WITH SAFETY REQUIREMENTS

GENERAL

3.1. Before construction of any repository, the operator shall perform a comprehensive and systematic assessment of the safety of the planned repository throughout its operating lifetime and the period following closure. This safety assessment shall be reviewed by the regulatory body. The regulatory body shall not authorize operation of a near surface repository until it is satisfied, on the basis of the safety assessment and other information, that the operator has demonstrated with reasonable assurance that the safety criteria will be met.

3.2. Safety assessment for the purpose of demonstrating compliance with safety requirements is an iterative process and further safety assessments are likely to be necessary at other times during the pre-operational, operational and post-closure phases of the repository, with account taken of experience and monitoring results obtained. Detailed guidance on safety assessment is provided in Ref. [4].

3.3. Safety assessment is a procedure for evaluating the performance of a disposal system and, in particular, its potential radiological effects on human health and the environment. The safety assessment of near surface repositories involves consideration of effects both during operation and in the post-closure phase. Potential radiological impacts following closure of the repository may arise from gradual processes, such as degradation of barriers, and from discrete events that could affect waste isolation. The potential for inadvertent human intrusion can be assumed to be negligible while active institutional controls are considered fully effective, but may increase afterwards. The acceptability of a repository will depend, among other factors, on the results of the safety assessments, which should provide a basis for giving reasonable assurance that the repository will meet the design objectives and safety criteria.

3.4. A safety assessment consists of:

(a) an estimate of system performance for all the situations selected;
(b) an evaluation of the level of confidence in the estimated performance;
(c) an overall assessment of compliance with safety requirements.

3.5. In the operational phase and in the period after closure of the repository when monitoring is being maintained, compliance with safety requirements can be readily demonstrated and corrective actions can be implemented if needed. In the planning and design of the repository, consideration must also be given to safety in the period when active institutional control is no longer being maintained or is assumed to be not fully effective. In this period, demonstration of conformity with safety requirements depends on present day assessments of the robustness and future performance of the disposal system. The principal means of estimating performance in this period are:

(a) An assessment of the situations selected from a systematic review of the features, events and processes likely to affect the safety of the repository. The assessment is carried out by modelling the future behaviour of the repository system, its contents and the surrounding environment.
(b) A review of the anticipated performance of the various barriers and other components of the disposal system in these situations, with account taken of the quality of the design and construction of the repository.

3.6. Confidence that the disposal system will meet safety requirements must be derived from the nature and quality of the design and construction of the repository together with the results of the safety assessment. The system should be shown to be robust and capable of withstanding the effects of various possible events and failures. Robustness can be achieved through the implementation of sound technical and managerial principles that tend to eliminate or mitigate the effects of uncertainties.

3.7. Because of the uncertainties inherent in predicting future events, the use of the approaches outlined in para. 3.5 cannot provide absolute assurance that safety criteria will be met. The best that can be achieved is a reasonable assurance that the system will perform as it is designed to do and, therefore, that compliance with the safety criteria will be achieved. Reasonable assurance of compliance is most likely to be achieved by the use of multiple lines of reasoning, that is by supplementing the quantitative estimates of repository performance with other qualitative evidence that the repository will provide isolation of the wastes as designed. Examples of evidence that could be considered in this context are: the results of relevant natural analogue studies, evidence of robust design and defence in depth, use of limit or bounding analyses, and the results of independent peer reviews.

REQUIREMENTS FOR SAFETY ASSESSMENTS

3.8. The likely and unlikely events and processes to be considered in safety assessments shall be determined or approved by national regulatory authorities. The results of the safety assessment shall be compared with the safety requirements set out in Section 2.

3.9. In safety assessments of the post-closure phase, credit can be taken for whatever controls will be exercised during the period of institutional control (see Section 11). If such credit is taken, these controls, and the period of time for which they are assumed to be effective, shall be specified as conditions in the relevant licence or authorization (see Section 4).

3.10. Assessments of the impacts of a near surface repository shall be based on the assumption that the existing local or regional biosphere receives the radioactive material released. As a general guide, the assessment should be based on present day human habits and behaviour.

3.11. Safety assessments shall be well documented in conformity with national requirements and international recommendations [4]. The operator shall update the safety assessment on the basis of actual experience, significant design changes or new

safety information that could affect the conditions of the existing licence or authorization. The updated safety assessment shall be reviewed by the regulatory body.

4. ORGANIZATIONAL AND TECHNICAL SAFETY REQUIREMENTS

GENERAL

4.1. The siting, design, construction, operation and closure of new near surface repositories shall be carried out in accordance with the safety requirements set out in this publication. National authorities shall decide the extent to which the safety requirements shall apply to the operation and closure of existing near surface repositories.

4.2. Appropriate organizational and technical safety measures shall be introduced to achieve compliance of the disposal system with the safety requirements established by national authorities. Reference [11] sets out provisions for the establishment of a national system for radioactive waste management. Requirements specific to near surface radioactive waste disposal are established in the following paragraphs.

SPECIFIC REQUIREMENTS FOR NEAR SURFACE DISPOSAL

4.3. The national government shall designate the organizations involved in and responsible, technically, financially and legally, for each implementation phase of the near surface disposal system. In particular, the national government shall identify the organization(s) that will be responsible for post-closure control of the repository if such control is needed.

4.4. On the basis of the national policy and strategies for the safe disposal of radioactive waste, the regulatory body shall issue and update the rules, regulations, guidelines and criteria needed in the licensing process for near surface disposal, together with the necessary supporting documents. With regard to near surface disposal, the regulatory body shall discharge all its relevant responsibilities as established in Ref. [11].

4.5. The operator of a near surface repository shall have overall responsibility for its safety and shall carry out safety assessments and the activities needed for siting,

design, construction, operation and closure, as well as any measures needed in the post-closure phase, in compliance with the safety requirements and national legal framework. The operator shall impose the necessary acceptance requirements on waste to be received from waste generators (or the owners of the waste, if they are not the generators) including operators of the associated pre-disposal radioactive waste management facilities. The operator shall conduct, or otherwise commission, research and development to the extent necessary to ensure safety of the repository.

4.6. To verify compliance with quality assurance requirements, in particular those related to waste acceptance requirements, the operator of the waste repository shall wherever practicable conduct a periodic review of the procedures of the waste generators. The regulatory body should verify that these procedures are effective in ensuring compliance with the requirements.

4.7. In the case of a malfunction of the disposal system or a design error that could compromise the safety of the repository, the operator shall inform the regulatory body in a timely manner and initiate corrective actions, as necessary.

4.8. To ensure the safe management of the repository, the operator shall, before initiating disposal, demonstrate the adequacy of the financial provisions for all phases of the disposal activities, including post-closure institutional control, if needed. These provisions shall be regularly reviewed during the operational life of the repository and, if necessary, adjusted.

4.9. The operator shall maintain records as specified by the regulatory body. If the responsibility for a repository is transferred to another party, the previous operator shall supply the succeeding operator with all pertinent information needed to continue satisfactory operations and complete possible post-closure measures. The succeeding operator shall review pertinent information and shall obtain appropriate approval from the regulatory body to take over the responsibility for the repository.

4.10. In accordance with the applicable requirements of the regulatory body, the operator shall submit or make available documents describing the safety aspects of the repository.

4.11. The waste generator shall ensure that the waste packages are characterized and are in compliance with requirements specified by the regulatory body and the operator of the near surface repository.

4.12. The waste generator shall ensure and certify that delivery of the waste package to the operator is in a manner and form complying with specifications provided by the

operator, the requirements of the regulatory body, and applicable requirements for transport [12].

4.13. The waste generator shall provide all the information needed by the operator, duly documented, either delivered at the same time as the waste or in another appropriate way as may be agreed.

RADIOACTIVE WASTE GENERATION AND MANAGEMENT INTERDEPENDENCES

4.14. The basic steps in waste management from waste generation to disposal (such as pretreatment, treatment, storage and conditioning) are interdependent. Decisions relating to one step in radioactive waste management shall be taken with due consideration of the impacts and/or the needs at the other steps linked with safe disposal.

4.15. To apply the above requirement, co-ordination of activities, including exchange of information, between the waste generators, the repository operator and the regulatory body shall be established in accordance with national regulations. This applies, in particular, to exchange and review of documents such as those on criteria established by the regulatory body and specifications established by the operator, and technical documents provided by the waste generator. Past experience and new developments in the field of waste management and disposal shall be taken into account in regulations and continuing practices.

5. WASTE ACCEPTANCE REQUIREMENTS

GENERAL

5.1. Conditions for the acceptance of waste for disposal in the repository shall be specified. These requirements shall either be generically specified by the regulatory body or developed by the operator on the basis of either generic studies or site specific safety assessments, with account taken of appropriate radiological criteria, the conditions of operation, the planned duration of active institutional controls and the required characteristics of natural and engineered systems. If waste acceptance requirements are developed by the operator, they shall be reviewed and approved by

the regulatory body. The established requirements shall be made binding on the waste generators or consignors of waste to the repository. Important features of waste acceptance requirements are given in the following paragraphs.

RADIONUCLIDE CONTENT AND ASSOCIATED REQUIREMENTS

5.2. Authorized limits shall be established, as necessary, on radionuclide inventories and/or concentrations in individual waste packages and in the repository as a whole. The authorized limits shall be determined by means of appropriate safety assessment methods [4, 13].

5.3. The type, characteristics and contents of radionuclides in the waste packages shall be determined with the accuracy needed to provide a reasonable assurance of compliance with authorized limits and shall be documented accordingly. Methods for determining the activity of the radionuclides in the waste forms shall be approved by the national authorities.

5.4. External dose rates and surface contamination of the waste packages (or any overpack used during transport) shall comply with transport requirements [12] and with any other values derived in relation to the radiation protection of workers at the waste repository (see also paras 4.12 and 5.11).

5.5. Large volume or bulky waste such as contaminated soil or demolition rubble is occasionally disposed of without packaging. National safety requirements shall be adhered to in adopting this practice.

PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES

5.6. The waste packages shall be designed and constructed to have sufficient mechanical strength to bear designed loads in the near surface repository, and to be capable of withstanding, without unacceptable damage, any accidents that may reasonably be foreseen within the operational phase.

5.7. Chemical, biological or radiolytic processes may take place within the waste, giving rise to the generation of gas and/or heat, corrosion (with the accumulation of hazardous degradation products), and swelling of materials, depending on the contents of the waste. Requirements shall be established to ensure that such processes and products do not unacceptably impair the safety and containment characteristics of the waste package or surrounding barriers. The physical and chemical

characteristics of materials in waste packages shall be appropriately documented to ensure that these aspects are properly taken into account in safety assessments.

5.8. The quantity of free liquids in waste packages shall be limited. The waste or waste form need not be completely dry, but any moisture content shall be at levels that will not compromise the isolation of the radioactive waste in the repository.

5.9. The disposal of materials that could present chemical or biological hazards shall comply with applicable regulations and their properties shall be taken into account in safety analyses.

FIRE RESISTANCE

5.10. Waste acceptance requirements shall be established on the combustibility, pyrophoricity and other properties of waste packages to mitigate the potential impacts of fire and reduce the propagation of fire between waste packages.

CONFIGURATION AND IDENTIFICATION

5.11. The waste packages shall be compatible with handling, transport and emplacement equipment and shall comply with applicable transport requirements [12] (see also paras 4.12 and 5.4).

5.12. Package identification is necessary to ensure safe handling, emplacement, accountability, activity control and certification of compliance with prescribed specifications. For these reasons, waste packages dedicated for emplacement in a near surface repository shall be marked with a suitable identification unique to each package.

6. CHARACTERISTICS OF AN ACCEPTABLE SITE

GENERAL

6.1. The waste disposal system shall provide for the isolation of waste and the limitation of releases of radionuclides needed to ensure that the potential effects of waste disposal on humans and the environment are within acceptable limits and that the overall safety objective (Section 2) is met, with account taken of the waste

characteristics, institutional controls, engineered barriers and natural barriers associated with the site.

6.2. The site characteristics shall be taken into account in the safety assessment and the repository design. In determining the site characteristics that are important to the assessment of the design and safety, the following shall be considered as a minimum: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, climate and the impact of human activities [3].

GEOLOGY

6.3. The selected site shall be located in an area that has geological characteristics conducive to satisfying the requirements of Section 2 and para. 6.1 and contributing to the stability of the disposal system.

HYDROGEOLOGY

6.4. Favourable factors in selecting a site include those characteristics that restrict movement of radionuclides from the site to the accessible environment.

6.5. The repository shall be located so as to prevent unacceptable radioactive contamination of groundwater resources, taking into consideration the repository design and the present and likely future use of the resources.

GEOCHEMISTRY

6.6. The geochemical characteristics of groundwaters and geological media of the site shall be considered for their potential contribution to limiting migration of radionuclides from the repository. At the same time, they should not impair the longevity of engineered barriers.

TECTONICS AND SEISMICITY

6.7. The tectonics and seismicity of the site and, where appropriate, the region shall be such that significant tectonic processes and events such as faulting, seismic activity or vulcanism are not expected to occur with an intensity that would compromise the necessary isolation capability of the repository.

SURFACE PROCESSES

6.8. The frequency and intensity of processes affecting the stability of land forms such as flooding, erosion, landsliding or weathering shall be such that they would not significantly affect the ability of the disposal system to isolate the radioactive waste.

6.9. For disposal facilities at or on the land surface, the site shall be well drained and have topographic and hydrological features such that there is little potential for flooding. The implications of existing or projected surface water reservoirs and any anticipated alterations of surface water drainage that could affect groundwater flow conditions in the vicinity of the repository shall be evaluated for the required period of time as indicated or approved by the regulatory body.

METEOROLOGY AND CLIMATE

6.10. The climate characteristics of the site, particularly precipitation and evaporation, and potential effects of expected extreme meteorological conditions shall be evaluated for their impact on repository design and water flow in the repository environment. Consideration should be given to any effects due to possible climate change during the post-closure phase.

IMPACT OF HUMAN ACTIVITIES

6.11. The disposal site shall be located such that activities that can be reasonably expected to take place at or near the site would not be likely to compromise the isolation capability of the repository. Consideration shall be given, in particular, to the resource and development potential of the site and its immediate surroundings.

6.12. Good access routes shall be constructed and maintained to allow transport of the waste to the site. Land use and ownership of land shall be considered in connection with foreseeable development and regional planning in the area of interest.

7. DESIGN OF DISPOSAL FACILITIES

7.1. The repository shall be designed to provide adequate isolation of disposed waste for the required period of time, with account taken of the waste characteristics, the characteristics of the site and the safety requirements applicable to the repository.

7.2. The design of the repository shall minimize the need for active maintenance after site closure and complement the natural characteristics of the site to reduce any environmental impact. The design shall take into account operational requirements, the closure plan (see para. 10.2) and other factors contributing to waste isolation and stability of the repository, such as protection of the waste from external events.

7.3. Near surface disposal facilities may include engineered barriers which, together with the emplacement medium and its surroundings, isolate the waste from humans and the environment. The engineered barriers include the waste package and other human made features such as vaults, covers, linings, grouts and backfills, which are intended to prevent or delay radionuclide migration from the repository to the surroundings.

7.4. Although disposal is usually defined as the emplacement of waste in an approved location without the intention of retrieval, some jurisdictions may nevertheless require that retrievability be designed into a repository. If the ability to retrieve waste is a design requirement, it shall be considered in the design process in such a way as not to compromise long term performance capabilities.

7.5. The design of a near surface repository shall allow for implementation of a monitoring programme to verify the containment capability of the disposal system during operation and, as necessary, after closure of the repository. Arrangements for monitoring shall not compromise the long term performance of the disposal system.

8. CONSTRUCTION

8.1. Construction of a near surface repository includes activities such as: site preparation, erection of buildings and structures, initial excavation and construction of trenches or waste disposal modules and drainage networks, excavation of rock cavities, underground building and installation of any monitoring systems.

8.2. Construction work shall begin only after appropriate authorization by the regulatory body. This will usually mean after the detailed design has been approved, the necessary licensing procedures have been completed and an appropriate quality assurance programme has been established. Continued construction may extend through the operational phase to provide additional disposal space for waste as it is received. Any necessary modifications to the design of the repository during construction shall be subject to regulatory approval.

8.3. Part of the construction work is safety related. This shall be specified in the detailed design, with all appropriate specifications for materials, technologies and control methods. If construction work extends into the operational phase, provision shall be made to preserve the integrity of the operational part of the repository.

9. OPERATION

GENERAL

9.1. The operation of a near surface repository comprises commissioning, waste reception, waste emplacement, engineering and all associated tasks, which may include temporary storage or final conditioning of wastes in accordance with the design assumptions and the conditions set out in licences or authorizations granted by the regulatory body. Operation shall not be started until authorization has been granted by the regulatory body.

9.2. Recognized technical and managerial principles shall be applied to achieve safe operations. In particular, proper control shall be maintained during commissioning and during the receipt and emplacement of waste. Appropriately qualified personnel shall be recruited and trained and effective security arrangements shall be established.

9.3. The regulatory body shall provide guidance necessary to establish an environmental monitoring programme, including monitoring of releases and external exposure, and to assess the environmental impact of operations. It shall ensure by inspection on the site that the operations are carried out in accordance with established procedures as specified or referred to in the relevant licence or authorization and in existing regulations.

9.4. Information shall be recorded by the operator during the operational stage of the repository for use in operation of the repository or in any of the subsequent stages. Key information shall be stored as required by the regulatory body. Such information shall cover, as a minimum, identification of containers, location of emplacement of waste packages, radionuclide content, the principal characteristics of the waste and the identities of its consignor and originator. Consideration shall be given to the form of the records to ensure that information is available when needed without interruption or loss.

CONTROL OF OPERATION

9.5. The operator shall prepare a set of rules, incorporating limits and conditions, to ensure that the repository is operated safely in compliance with national regulations. These rules shall reflect consideration of:

(a) protection criteria for occupationally exposed workers and members of the public in normal operation and accidents;
(b) the limiting assumptions used in the safety assessment;
(c) regulatory requirements for operation.

9.6. Operations shall be carried out in accordance with written procedures and instructions to ensure that identified limits and conditions for operations are observed. The operator shall ensure that these procedures and instructions are carefully and properly followed by the workers. This will ensure that appropriate attention is given to safety, especially during the modification of equipment or operating procedures.

9.7. The operator shall establish procedures for prescribed actions in the event of:

(a) emergencies or non-routine occurrences;
(b) receipt of waste which is found not to conform to the waste acceptance requirements.

The procedures shall specify when reports should be made to the regulatory body.

COMMISSIONING

9.8. The operator shall carry out a commissioning programme, prior to the routine disposal operation, to ensure that the repository and its associated installed equipment function as required by the approved design specification.

RECEIPT OF WASTE

9.9. The operator shall ensure that only those wastes which comply with the waste acceptance requirements, as established by the operator and approved by the regulatory body, are accepted for disposal.

9.10. The waste generators shall make available to the operator of the repository, by an agreed means, information to demonstrate that each consignment of waste has been or

can be accepted as complying with the waste acceptance requirements. All information necessary for operational decisions on appropriate means of handling the waste in the repository shall be included. The waste generator shall provide with each waste consignment such documentation as is required by the operator or the regulatory body.

EMPLACEMENT OF WASTE

9.11. Waste shall be emplaced in accordance with the established limits and conditions, in accordance with the operating procedures and instructions, and consistent with the design concept of the repository.

CONTROL OF RELEASES

9.12. The operator shall be responsible for ensuring the provision and maintenance of adequate monitoring to measure radioactive releases during repository operation, and shall take necessary actions to ensure that the requirements established by national authorities are met. Due account shall be taken of the guidance on control of releases given in Ref. [6].

EMERGENCY PREPAREDNESS

9.13. The operator shall prepare appropriate on-site and, if necessary, off-site emergency plans. Such emergency plans shall be tested at appropriate intervals in accordance with the national regulations.

RECRUITMENT AND TRAINING OF PERSONNEL

9.14. The operator shall define and analyse tasks and activities to be performed for the safe operation of the repository. The operator shall implement an organizational structure and shall clearly delineate the responsibilities and authorities of personnel. The appropriate number of staff and the necessary qualifications and experience shall be determined for posts at all relevant levels of the organization. The operator shall provide for the recruitment of personnel with adequate expertise and shall ensure consistency in the standard of this expertise across the range of disciplines needed.

9.15. A training programme shall be established to ensure that personnel involved at all levels of operation of the repository have the requisite competence. The training

programme shall identify the activities that are significant for safety, provide for the acquisition of the knowledge and practical experience needed for these activities and foster the development of a safety culture (see Ref. [11]). The programme shall be regularly updated to incorporate experience gained from analysing system performance, incidents encountered, the major modifications carried out and personnel performance. Retraining shall be carried out on a continuing basis during repository operation in order to minimize the potential for human error. The training programme shall be such that operational personnel have a high degree of awareness of the design features of the repository that are significant for safety.

SECURITY ARRANGEMENTS

9.16. All reasonable precautions shall be taken to prevent persons from carrying out unauthorized actions that jeopardize the safety of the repository. Arrangements shall be made to ensure that only designated persons have access to the site. Provision shall be made to detect and prevent any unauthorized entry into the security sensitive areas. The level of security arrangements shall reflect the potential for damage to the repository or the waste. Arrangements and appropriate liaison shall be established with competent authorities to obtain timely assistance.

REVIEWS

9.17. In compliance with regulatory requirements, the operator shall make periodic and systematic reviews and updates of all repository safety assessments and of the closure plan to be submitted for approval by, or as information to, the regulatory body. Where necessary, the safety of the repository shall be reassessed. Periodic and systematic reviews shall also be made for all arrangements and documents relevant to:

(a) the operation of the repository;
(b) the evaluation of the environmental impact;
(c) the limitation of radiation dose to occupationally exposed workers and the public.

9.18. In addition, in accordance with regulatory requirements, reviews shall be conducted by the operator and submitted to the regulatory body covering responsibilities, the results of quality assurance audits, operating conditions including experimental testing, frequency of environmental sampling and analysis, occupational health and safety, and record maintenance. Consideration shall be given to the necessary frequency of these reviews.

10. CLOSURE

GENERAL

10.1. Closure of a repository is a systematic action that is conducted after the receipt of waste ceases and waste emplacement operations have been completed with the intention of providing a final configuration for the disposal system.

10.2. At the latest, before commencing closure operations, the operator shall submit to the regulatory body a detailed closure plan and obtain approval prior to its execution. This detailed closure plan shall include an updated safety assessment based on available pertinent data indicating the safe post-closure performance of the repository. In particular, the closure plan shall describe any controls intended for the post-closure phase, including the radiological monitoring plan, the surveillance programme and the record keeping system, and shall identify the organization responsible for implementing these (see Section 11).

10.3. The closure method, including the materials and techniques to be used, and its expected performance shall be outlined in the closure plan. The closure method shall be optimized in the light of available materials and techniques, so as to enhance confidence in the safety assessment.

THE CLOSURE PROCESS

10.4. The closure process shall include the decontamination and removal or sealing of redundant structures, systems or equipment, the disposal of decontamination waste, the updating of disposal archives, and the implementation or continuation of monitoring, as needed.

10.5. For disposal on or close to the ground surface, closure may include the placement of a final cover on the disposal system or structure, whereas for tunnel or rock cavity disposal it may include sealing of engineered access routes such as shafts or drifts.

10.6. The closure plan shall be consistent with any need to maintain and repair the accessible elements of the repository during the possible institutional control period in accordance with the principle of not imposing undue burdens on future generations [1].

10.7. The closure process shall include the collation of all the information recorded during the previous phases that might be necessary for potential corrective actions in the future, or for reassessing the safety of the repository if it is warranted in the future. Some of the information will also be necessary to ensure that future generations know of the existence of the site.

10.8. After the closure activities have been finalized, the regulatory body shall, in accordance with national regulations, confirm that the activities have been performed in an acceptable manner and that the closed repository is in a proper condition, that the appropriate documentation is available, and that provision has been made for post-closure controls.

11. POST-CLOSURE PHASE

GENERAL

11.1. As far as is reasonable, and in accordance with the principle of not imposing undue burdens on future generations [1], the safety of a closed repository shall not rely on institutional controls that necessitate extensive and continuing active measures. However, controls maintained over a repository after closure may enhance its safety, in particular by preventing intrusion. The controls can be: active, for example monitoring, surveillance (and, if necessary, corrective actions); or passive, for example land use control; or a combination of both. The following provisions shall apply to any such controls that are planned.

11.2. The nature and maximum duration of controls as a means of ensuring compliance with safety criteria shall be specified by or agreed to by the regulatory body. In selecting this period, consideration shall be given to the radioactive decay of the waste and its potential hazard, projected activities and historical experience of the retention of information.

11.3. The duration and effectiveness of the active and passive controls shall be taken into account in the safety assessment for the repository. The operator shall provide evidence that, in the period after any withdrawal of controls over the repository, the radiological consequences of events that could affect the isolation and/or containment capability of the repository would be in compliance with the prescribed safety requirements.

11.4. The organization(s) responsible for the implementation of active or passive controls shall be clearly identified. As described in the following paragraphs, the responsible organization shall effect controls as defined in the closure plan so as to prevent intrusion into the repository, to maintain the repository as necessary, to monitor the state of the repository as well as of the local environment, to retain records and to take corrective actions if necessary.

ACTIVE CONTROLS

11.5. Active controls intended to apply for a period of several decades to a few hundred years have been adopted by some countries. The regulatory body may, at its discretion or where required by law, require the continuation of active controls to strengthen confidence that the site complies with national laws and regulations.

11.6. The responsible organization shall take measures to reduce the access to the site by people, animals and plants that could compromise the isolation system by intrusion.

11.7. The responsible organization shall implement an appropriate maintenance programme. Maintenance of the disposal system may need both routine and non-routine work. Preventive maintenance on a routine or planned basis may include items such as periodic inspection of drainage systems to ensure continued functioning, maintenance of covering vegetation, removal of plants that would grow deep roots if these could damage the integrity of the cover, periodic inspection/repair of security fences, and maintenance (and, if necessary, replacement) of instrumentation. Non-routine work may be needed to repair damage due to erosion in unusually severe weather conditions, to repair damage done by burrowing animals, or to repair other degradation of accessible barriers.

11.8. The responsible organization shall implement an appropriate post-closure monitoring programme, which shall be approved by the regulatory body. This programme shall deal with:

(a) radiological and other monitoring of the repository and its surrounding area in order to verify the absence of unacceptable radiological impacts (for example, with respect to the leachate limits, if appropriate), and to confirm, as far as possible, the assumptions made in the safety assessment;
(b) other measurements of system parameters to confirm that the performance of the isolation system is as expected.

11.9. If an unplanned release of radioactive materials to the environment is detected, intervention measures shall be taken, if necessary, to control the release and mitigate its effects.

PASSIVE CONTROLS

11.10. The responsible organization shall implement passive controls to help in ensuring maintenance of knowledge of the repository through restrictions on land use for certain types of activities and periods of time, and retention of necessary records relevant to land use restrictions.

11.11. The regulatory body shall consider a system of passive control measures as a means to maintain awareness in the long term of the location of the closed near surface repository and the nature of its contents. Record storage can contribute to this end. International co-operation in maintaining duplicate records in diverse locations may also be beneficial.

12. QUALITY ASSURANCE

GENERAL

12.1. A comprehensive quality assurance programme shall be applied to all safety related activities, structures, systems and components of the disposal system. This includes all related activities, from planning through siting, design, construction, operation, the various steps in the safety assessment process, closure, long term record keeping and institutional control activities associated with the repository. This will help to provide assurance that the relevant safety requirements and criteria are met.

12.2. The elements of the quality assurance programme shall take account of the potential effects of activities, structures, systems and components on the safety of the repository and shall be designed accordingly. Activities, structures, systems and components important to safe operation and disposal shall be identified on the basis of results of a systematic safety assessment of the operational and post-closure phases of the repository.

12.3. At all times from the start of construction to the end of active institutional controls, there shall be a designated operator having overall responsibility for the repository (see Section 4). The operator shall be responsible for the establishment and implementation of the overall quality assurance programme, including obtaining the necessary approvals from the regulatory body. The operator may delegate to other organizations the work of establishing and implementing all, or part, of the programme but shall retain responsibility for its overall effectiveness, without prejudice to the contractors' obligations and legal responsibilities.

SITING

12.4. A quality assurance programme for all activities associated with siting shall be established early in the siting process. It shall provide for the production and retention of documentary evidence to illustrate that the necessary quality of data on the site has been achieved.

DESIGN, CONSTRUCTION AND OPERATION

12.5. During design, construction and operation of the repository, a design control process shall be adhered to, with special attention given to control of changes to barrier design, waste characteristics and operating procedures, to ensure that they do not have unacceptable consequences for safety.

WASTE ACCEPTANCE

12.6. The quality assurance programme shall recognize that the safety of the repository with respect to waste acceptance depends on both activities undertaken by the operator and activities undertaken by the waste generators (see Sections 4 and 5).

12.7. Waste generators shall provide the documentation necessary to comply with the operator's requirements with respect to the nature and the proper performance of any treatment, determination of radionuclide content, preparation of consignment documentation or other actions that could affect the safety of disposal.

12.8. The operator shall review the quality of information supplied by the waste generator and the quality assurance programme of the waste generator so as to provide an adequate level of assurance of the acceptable characteristics of the waste. This may include audits and checks on operations and processes that produce or treat waste.

CLOSURE AND POST-CLOSURE

12.9. There shall be a quality assurance programme developed for and applied to structures, systems, components and activities related to closure and post-closure of the repository. In particular, this programme shall provide for the collection and preservation of all the information recorded during the previous phases that could be important for safety in the future.

ROLE OF THE REGULATORY BODY IN QUALITY ASSURANCE

12.10. The regulatory body shall develop or endorse quality assurance requirements for near surface disposal of radioactive waste. In principle, the quality assurance requirements for design, construction and operation of near surface disposal facilities will be similar to those for other nuclear facilities [14]. However, certain activities that are specific to near surface disposal, such as waste reception and closure, and those related to the post-closure phase may need special emphasis. The regulatory body shall review the operator's quality assurance programme and systematically inspect its implementation and quality control records.

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Annex

DOSE AND RISK CRITERIA FOR THE POST-CLOSURE PHASE

A–1. Radiological safety criteria are required for the operational and post-closure phases of the repository. In this context, Principle 4 in Ref. [A–1] states: "Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today." Therefore, safety criteria developed for the post-closure phase need to provide for these considerations. This Annex provides a brief discussion of some features of dose and risk criteria for the post-closure phase.

A–2. Following closure of a repository, radionuclides may be released from the repository to the human environment over long time periods. This inevitably introduces a number of uncertainties as the rate of release will depend upon events and processes that have probabilities of occurrence. Also, the future status of the biosphere is uncertain. In other words, there are a number of potential exposure scenarios and this means that it is difficult to apply standards that are based solely on dose limitation. As an example, if a human intrusion into the repository were assumed to occur, the dose received could exceed the dose limit. However, the probability of such human intrusion could be kept low by selecting a suitable site and/or by exercising controls over the site in the post-closure phase. Therefore safety criteria for some scenarios need to be framed in such a way that they take the probability of occurrence or the uncertainty of the event into account.

A–3. Principle 1 in Ref. [A–1] states: "Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health." Acceptable levels of protection are usually derived by taking into account the relevant recommendations of international bodies such as the IAEA and the International Commission on Radiological Protection (ICRP) [A–2 to A–7].

A–4. The BSS explicitly state that radioactive waste management facilities are included within their scope and hence their requirements can be used for the operational phase. However, the dose limits within the BSS do not apply to potential exposures.

A–5. The dose limit of l mSv/a given in the BSS for members of the public from all controlled sources is based on the advice of the ICRP. The ICRP established risk coefficients for exposure to low levels of ionizing radiation. These risk coefficients represent the chance of contracting a radiation induced deleterious health effect (for

example, fatal cancer) per unit dose. The ICRP derived a value of 5×10^{-2} Sv^{-1} for contracting fatal cancer from exposure to radiation at low doses and dose rates, for a population of all ages [A–7]. Hence, exposure at the dose limit of 1 mSv/a is equivalent to a chance of 5×10^{-5} a^{-1} of contracting a radiation induced fatal cancer.

A–6. A limit on the chance of contracting a radiation induced health effect could therefore achieve the same purpose as a dose limit, but it could be applied to a much wider range of situations as it could take into account the probability of receiving the dose.

A–7. This leads to the concept of risk, where risk is defined as:

risk = (probability of receiving dose) × (probability that the dose will give rise to a deleterious health effect)

Therefore, for a likely event a risk of 5×10^{-5} a^{-1} would afford the same level of protection against contracting fatal cancer as a dose limit of 1 mSv/a.

A–8. The principal advantages of a risk based approach include the following:

(a) it takes probabilities as well as consequences into account;
(b) it provides a basis for comparing the effects of different scenarios in terms of significance;
(c) it integrates the effects of all types of scenarios.

A–9. However, the concept of risk is not easy to grasp and has a number of drawbacks. Firstly, individuals in the future are at risk from one or more different scenarios but, at any point in time, only one scenario is actually occurring. Secondly, it is difficult to assign values to the probabilities, and thirdly, for similar risks, people may attach greater significance if higher doses are possible even though the probability of occurrence is very small. This has led to the proposal that probabilities of occurrence and the resulting doses should be disaggregated (see para. 2.8 of the main text).

REFERENCES TO ANNEX

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