INTERNATIONAL ATOMIC ENERGY AGENCY
DIVISION OF NUCLEAR FUEL CYCLE

IAEA SAFETY STANDARDS FOR UNDERGROUND DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES

November 1987

FOREWORD

The IAEA Safety Standards for Underground Diposal of High-Level Radioactive Wastes have been prepared with the objective of providing the Member States with basic guidance on protection of humans and the environment from the hazards associated with deep geological disposal of high-level radioactive wastes.

As part of an extensive Agency's programme in the field of radioactive waste disposal, the present publication reflects the needs for basic standards dealing specifically with high-level wastes. It is primarily concerned with setting standards for ensuring that radioactive waste will remain isolated from people for a considerable period of time. Thus, these basic requirements arising directly from radiation protection principles have been extended so as to deal with events and processes that can occur in the far future. However, technical requirements regarding the waste, the repository and the surrounding environs are also covered.

Since the main principles issue from activities carried out by other instructional bodies such as the International Commission on Radiological Protection, the present document should be seen in the light of other recommendations of the ICRP and other Agency's publications closely related to the subject, above all the Basic Radiation Protection Standards.

The necessity of a basic document in this area has been felt already for several years. To fulfil this task, the Agency reassured the previous activities of the ICRP and the OECD/NEA by developing this document. A first draft of the report was prepared in a consultant's meeting attended by P. Johnston (UK) in 1985 and was revised in two Advisory Group meetings in 1985 and 1986 and the Technical Review Committee on Underground Disposal (TRCUD) in 1987. The report was finalized by incorporation of comments received from the members of the Advisory Groups and TRCUD by a consultant (Z. Dlouhy) in 1985 and 1987.

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1. INTRODUCTION

Radioactive wastes arise from nuclear fuel cycle operations for the generation of electricity and from other activities in which radioactive materials are used. Ionizing radiation is recognized as a potential hazard to human health, and there is therefore a common concern in all countries that radionuclides from the wastes should not enter the environment in concentrations or quantities that would cause unacceptable health hazards.

Spent nuclear fuel (if disposed of as a waste), the highly-radioactive wastes from reprocessing spent nuclear fuel, and other wastes with similar characteristics are referred to as high-level radioactive wastes. They contain high concentrations of certain radionuclides that will remain radioactive for periods of time much longer than human lifetimes. In view of this long timescale, and in view of potential transboundary considerations, internationally acceptable standards* for the safety of radioactive waste disposal are essential. Further, the long times required to develop disposal systems imply that standards are needed now to guide the initial stages of site selection and disposal system design.

It is prudent to plan high-level waste disposal so as not to inflict undue burdens on future generations. In this regard, the responsibility for disposal should be borne by the society which has derived the direct benefits from the nuclear fuel cycle operations which generated the waste. The design of the waste disposal system should be such as to avoid economic, administrative or other problems after the time when control of the repository is relinquished.

The special attention that has been devoted to considering potential problems to future generations is an important feature of the developing policies for radioactive waste management. However, it should be

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*See Section 7 for a definition of the term 'standards'.

recognized that disposal of wastes from many other industrial and agricultural activities must also be considered in order to protect future generations and the environment. Many chemical wastes may be rendered harmless by using chemical methods, but others remain potentially toxic for all time. Since radioactive decay reduces the potential hazard of radioactive waste with time, isolating the radionuclides from the environment for an appropriate period of time has a decisive advantage.

It is recognized that radioactive waste disposal is only one, albeit the final, step in the sequence of operations in the nuclear fuel cycle that give rise to radiation exposure. All of these operations have to comply with the Basic Radiation Protection Standards adopted by the IAEA, and accordingly to be optimized both within each of these operations and within the system as a whole in order to keep radiation exposures as low as reasonably achievable.

This report is one document within the series of IAEA safety reports on underground disposal of radioactive waste. It is primarily concerned with setting standards for ensuring long-term safety of waste disposal.

2. OBJECTIVE AND SCOPE

The objective of this document is to present standards for disposal of high-level radioactive wastes into deep underground repositories. The document should be seen in conjunction with other IAEA reports relevant to the subject which provide guidance on underground disposal of radioactive wastes.

The standards presented here have been developed with the aim to establish internationally acceptable requirements for protection of humans and the environment from the hazards that are associated with the disposal of high-level radioactive waste. The standards are presented in two groups. In the former group are the basic requirements that arise directly from radiological protection principles. In the latter group, applied technical requirements are covered. The order of presentation of the standards within the document is based only on clarity of presentation, and does not indicate the relative importance of the individual standards.

The application of these standards ensures the long-term safety of the overall system of the disposal of high-level radioactive waste in deep underground repositories.

These standards do not include the operational requirements that must be met when wastes are being handled and emplaced, in accordance with the radiological, nuclear, environmental and conventional industrial safety standards.

These standards do not address the need for, nor the form or content of, any retrievability requirements that might be appropriate, either during the period of waste emplacement or during a subsequent testing or observation period prior to final sealing of the repository.

Because the scope of the document is limited to disposal of high-level wastes in deep underground repositories, these standards may not be suitable for disposal of other types of wastes or for disposal of high-level wastes by other means such as subseabed emplacement.

3. FUNDAMENTAL STANDARDS

The two overlying objectives of underground disposal of high-level radioactive waste are essentially:

- to isolate high-level waste from the biosphere over long time scales without relying on future generations the responsibility to maintain the integrity of the disposal system, or imposing upon them, significant constraints due to the existence of the repository (RESPONSIBILITY TO FUTURE GENERATIONS); and

- to ensure the long-term radiological protection of man and the environment in accordace with current internationally agreed radiation protection principles (RADIOLOGICAL SAFETY).

To meet these two broad basic objectives, the following fundamental standards can be formulated.

3.1 RESPONSIBILITY TO FUTURE GENERATIONS

3.1.1 Standard No. 1: Burden on future generations

> The burden on future generations shall be minimized by safely disposing of high-level radioactive wastes at an appropriate time, technical, social and economic factors being taken into account.

The radionuclide content of all radioactive wastes decreases naturally with time. Interim storage has a useful role for wastes with short-lived radionuclides, although this may imply additional radiation exposures during the interim storage period and a continuing financial commitment. Disposal of appropriately conditioned waste reduces the financial burden on future generations and avoids further occupational radiation exposures.

Since the present generations benefit from their exploitation of nuclear energy, it is reasonable that they should bear at least the financial burden of waste disposal.

The timing of disposal of high-level waste, however, will be decided by national authorities depending on a number of technical and socio-economic factors. These include the availability and development of suitable repository sites, the technical advantages to be gained from cooling during interim storage and, in the case of spent fuel, any desire not to discard prematurely constituents that might be useful to future generations. When high-level waste is stored, site specific research and development work should be carried out so that sites will be characterized and available for the disposal of high-level waste at an appropriate time.

3.1.2 Standard No. 2: Independence of safety from institutional control

> The safety of a high-level waste repository in the post-sealing period shall not depend on the need for any monitoring, surveillance or other institutional controls or remedial actions.

The standard concerning the minimization of burdens on future generations also implies that these generations should not have to take any action to protect themselves from the effects of waste disposal. Records are expected to be kept and monitoring may be carried out, for instance, as required by national authorities, but the safety of the repository must not rely on these measures.

3.1.3 Standard No. 3: Effects in the future

> The degree of isolation of high-level radioactive waste from the environment shall be such that there are no predictable future risks to human health or effects on the environment that would not be acceptable today.

This standard is derived from concern for future generations. In accordance with the basic standards of the IAEA, the risks to future individuals should be limited on the same basis as are those to individuals living now. Therefore, tne level of protection to be afforded to future individuals should not be less than that provided today.

Deep underground disposal in a variety of different geological formations can provide a very long period of isolation for wastes, it can minimize the probability of inadvertent intrusion and it can limit the release rate of radionuclides even in the far future.

Although the principal objective of radiation protection is the achievement and maintenance of appropriately safe conditions for activities involving human exposure, the level of safety required for the protection of all human individuals is thought likely to be adequate to protect other species, although not necessarily individual members of those species. In the case of disposal of high-level waste deep underground, if humans are adequately protected as individuals then other living species are also likely to be sufficiently protected.

3.1.4 <u>Standard No. 4: Transboundary considerations</u>

> The regulations adopted by national authorities for radiation protection for individuals inside the borders of a country shall provide equal protection for individuals outside the country where the high-level waste disposal system is located.

Where high-level waste disposal may give rise to radiation exposures beyond the frontiers of the country where the disposal takes place, this standard has to be applied.

3.2 RADIOLOGICAL SAFETY

The mechanisms of radionuclide release from a disposal site are not the same for all environments, but generally the primary cause is degradation of conditioned waste and its container by water. For disposal into deep geological formations, the principal mechanism is likely to be transfer and dispersal by movement of groundwater, modified by reconcentration processes. They may be referred to as "normal" release processes which lead to a reasonably predictable radiation exposure pattern in space and time.

Other processes are not gradual and have to be thought of as probabilistic. They could, in some situations, dominate the overall safety assessment of disposal. For example, seismic and tectonic phenomena which modify water flows could be important considerations for disposal in some geological formations, and future human activities such as drilling and universal exploitation could have direct and indirect influences on some repositories.

The following Standards No. 5 and 6 are, respectively, intended to apply to these two situations of "normal" release processes and "probabilistic" processes. However, it is important to recognize that the standards are linked and have the same overall basis where expressed in terms of risk to an individual. This is explained in more detail in the notes to the Standard No. 6.

3.2.1 Standard No. 5: Dose upper bound

> For releases from a repository due to "normal" processes, the predicted annual dose to individuals of the critical group shall be less than a dose upper bound apportioned by national authorities from the annual dose limit of 1 mSv for prolonged exposures.

This standard follows from the policy of the IAEA, as stated in its Basic Safety Standards for Radiation Protection, in following the ICRP recommendations.

The application of individual dose limits to the doses that occur as a result of "normal" processes as described above is the same as for releases from other types of nuclear facilities. Two basic requirements are involved. First, the critical group, i.e. the members of the public whose exposure is reasonably homogeneous and is typical of individuals receiving the highest dose, must be identified. Second, the overall disposal system must provide assurance that the average dose in the critical group will not exceed the dose limit, taking into account possible exposures from other sources, including other repositories but excluding medical and natural sources. This allowance for other sources can be formalized by using a dose upper bound for that source rather than the dose limit. The dose upper bound is also intended to apply to the average dose in the critical group whether this occurs now or in the future.

The identification of the most highly exposed groups in the future becomes increasingly difficult with time. The dose upper bound may therefore need to be applied to hypothetical individuals who could live where exposures are likely to be greatest. In defining the habits of these hypothetical individuals, it may be assumed that their basic nutritional requirements and lifestyles are the same as those of people today.

The dose upper bound that serves as the design constraint for the repository should therefore be established taking account of doses from global, regional and other local sources, and reserving a prudent fraction of the dose limit for potential future sources.

3.2.2 Standard No. 6: Risk upper bound

> High level radioactive waste shall be disposed of so that the predicted risk in a year from a repository to an individual of the critical group from events not covered by Standard No. 5 is less than an upper bound of risk apportioned by national authorities from a limit of risk of one in a hundred thousand per year.

It has become clear during the development of safety assessments for high-level waste disposal that unlikely events described as "probabilistic" processes earlier in this Section, and their consequences have to be considered.

The judgement that is made as to the level of risk that should not be exceeded is that the risk upper bound from events not covered by the use of a dose upper bound should be no greater than the risk from doses at the dose upper bound. Risk here is defined as the probability that a serious somatic or genetic health effect will occur to a potentially exposed individual or his descendants. It is equal to the product of the probability of exposure at a particular annual dose rate, and the probability of a health effect arising from that annual dose.

The restriction of doses over a lifetime to 1 mSv per year on average implies a constraint of the average annual risk to a level less than about 10^{-5}. The ICRP has suggested that it seems reasonable to restrict the risk in a year to an individual of the critical group from events which are not covered by the use of a dose upper bound, so that it is also less than 10^{-5}.

The implication of this standard is that risks from events that are highly improbable will be very small compared to any risk upper bound, and analysis of such events need not be included in a risk assessment for a repository.

For some events, estimates of their probability of occurrence may only be very approximate. In these cases, upper limits to such estimates should be used initially in assessments; refined estimates only being needed if such events prove to be limiting.

3.2.3 Standard No. 7: Additional radiological safety

> All radiation exposures that may result from the disposal of high-level radioactive waste shall be as low as reasonably achievable, economic and social factors being taken into account. The dose and risk upper bounds as defined in Standards Nos. 5 and 6 shall be overriding constraints.

While the specification of upper bounds of dose and risk serves to ensure the required level of safety for an individual, it is recommended that all exposures should be as low as reasonably achievable below the upper bounds,

This recommendation is sometimes implemented in other radiation protection activities by a rigorous analysis of available alternatives to achieve an optimal balancing of radiological impacts, economic costs, and other factors. The principle that exposures should be kept as low as reasonably achievable remains valid for geologic disposal of high-level wastes, but application of the principle requires special considerations.

Many factors affect the siting and design of a high-level waste repository, including other operations within the waste management system, costs, social and environmental effects and political considerations, as well as radiological effects. The alternatives available when disposing of HLW in a geologic repository are likely to be quite limited. Fundamental decisions, including whether to reprocess spent fuel, and many aspects of site selection, must usually be made on the basis of social or institutional concerns. The major problem is that the uncertainties in projecting radiological effects may be quite large. Therefore, it is difficult to fully apply the requirement to keep doses as low as reasonably achievable in deciding between available options for the waste disposal system. Within the scope of this document, which is primarily concerned with the long-term safety of a high-level waste repository, the application of this standard may be quite limited.

Despite these difficulties, the principle of keeping doses as low as reasonably achievable should be followed throughout the processes of site selection, waste conditioning and repository design. Usually it will be necessary to do so in a qualitative manner, making significant use of engineering judgement rather than rigorous analyses of repository impacts. In particular cases, a decision-making methodology, such as multi-attribute analysis, may be helpful for distinguishing between alternatives.

4. TECHNICAL STANDARDS

4.1 Standard No. 8: Overall Systems Approach

> The long-term safety of high-level radioactive waste disposal shall be based on the multi-barrier concept, and shall be assessed on the basis of the performance of the disposal system as a whole. The safety of the overall system shall not depend on the functioning of one single barrier.

The entire disposal system consists of various components, such as the waste form, the containers, the backfill material, the host rock, the repository, and the surrounding geological formations. Because high-level waste presents a potential hazard for a very long timescale and because the difficulty of long-term predictions may lead to large uncertainties, it is necessary that the safety of waste disposal does not rest on one single component or barrier, but rather on the combined function of several barriers. If a barrier fails to function as designed, then the overall system should still be sufficient to meet the safety standards.

The overall-systems approach incorporates the idea that in the final analysis it is only the performance and safety of the disposal system as a whole at any given time in the future that has to be assured rather than the performance of all the individual components. This approach offers a great flexibility to the designer of a disposal system because a weakness in one barrier may be compensated for by the containment capability of other barriers. The overall-systems approach thus makes it possible to adapt the geological disposal concept to a variety of high-level waste forms and packages and to a variety of geological situations which are often different from country to country.

The standards do not specify minimum levels of performance to be achieved by individual barriers. If national authorities find it prudent to do so in order to permit timely design and development of certain engineered barriers, it should be realized that any performance assessment of components or subsystems of the overall disposal system will involve an iterative process.

During the site selection and conceptual design development stage, the minimum levels of performance can only be regarded as performance targets that may be changed in either direction. Once the site is characterized and engineered systems optimized at the final licensing stage, the performance requirements for the components become established.

The statement of performance levels during the development stage remain design targets to reflect the possibility for revision as the conceptual design work progresses.

4.2 THE WASTE

4.2.1 Standard No. 9: Radionuclide content

> Waste acceptance criteria shall be established for radionuclide content consistent with assumptions made in the repository design.

The radionuclide content is the "source term" for possible radionuclide release. It is therefore necessary that acceptance criteria for the radionuclide content are established in order to comply with the assumed source term values on which the repository design relies.

4.2.2 Standard No. 10: Nuclear criticality

> The high-level radioactive waste repository shall be designed and the waste emplaced such that any fissile material remains in a subcritical configuration.

Some high-level wastes may contain quantities of fissile materials sufficient to achieve nuclear criticality if improperly emplaced. It is therefore important that the repository is designed so as to avoid critical configurations.

Subcritical geometry is achieved by effective dilution of fissile materials during conditioning of the waste and/or by providing the necessary distance between waste packages containing fissile material. Where leaching and subsequent accumulation of fissile materials may occur, adequate consideration should be given to prevent criticality.

4.2.3 Standard No. 11: The waste form

> High-level radioactive waste to be emplaced in a repository shall be in a solid form with chemical and physical properties appropriate for the retention of radionuclides appropriate to the disposal system.

The waste form is the "source" from which radionuclides may be released. During an initial period after emplacement the outer container or other barriers can be relied upon to prevent water ingress. Thereafter the waste form and its surroundings will govern the releases. Thus, it is essential that the wastes are in a form which is compatible with the repository and the host rock.

4.3 THE REPOSITORY

4.3.1 Standard No. 12: Initial period of isolation

> **A high-level waste disposal system shall be designed in a way that aims at substantially complete isolation of radionuclides for an initial period of time.**

Substantially complete isolation of high-level radioactive waste cannot be maintained indefinitely. The initial period of time during which a high-degree of isolation is necessary depends on the type of waste and its decay characteristics as well as on the properties of the overall disposal system.

After the initial period of substantial isolation, barriers inherent in the geologic medium become of increasing importance.

4.3.2 Standard No. 13: Repository design and construction

> **A high-level radioactive waste repository shall be designed, constructed, operated and closed in such a way that the post-sealing safety functions of the host rock and its relevant surroundings are preserved.**

In the early stage of site confirmation and later during the construction of a repository, special attention should be given to the techniques used and to the execution of field work so that the isolation capabilities of the site will be diminished as little as possible. The consequences of disturbances caused should be assessed.

The impact of the waste and any engineered structure emplaced in the repository, on the characteristics of the hydrogeological environment should not impair those properties of the host rock which are relevant to safety.

4.4 THE SITE

4.4.1 Standard No. 14: Site Geology

> The repository shall be located at sufficient depth to adequately protect the emplaced waste from external events and processes, in a host rock having properties that adequately restrict the deterioration of physical barriers and the transport of radionuclides from the repository to the environment.

The location of the waste repository is of great importance to its long-term safe functioning. The size of the selected host medium shall be large enough to accommodate the repository and that part of the surrounding medium which is necessary for safety.

The most likely way radionuclides can migrate from the repository to the biosphere is by groundwater transport. For that reason, special emphasis must be placed on the hydrogeological and geochemical properties of the host medium to restrict nuclide transport by groundwater.

4.4.2 Standard.No. 15: Consideration of natural resources

> The repository site shall be selected, to the extent practicable, to avoid proximity to natural resources or materials which are not readily available from other sources.

Two considerations argue against locating a repository near valuable, or potentially valuable, natural resources. First is the desire to allow future generations to exploit natural resources for their own benefit. Location of a repository near such resources might preclude future use of those resources, or might require burdensome remedial actions to be taken to avoid disrupting the repository.

The second, and more important, consideration involves the possibility that knowledge of the repository location might not be available to a future individual or society seeking to develop natural resources. In this case, inadvertent intrusion into a repository could reduce its integrity leading to release of radionuclides to the environment.

5. ASSURANCE OF COMPLIANCE WITH THE STANDARDS

5.1 Standard No. 16: Safety Assessment

> Compliance of the overall disposal system with the radiological safety standards shall be demonstrated by means of safety assessments which are based on models that are validated as far as possible.

It is recognized that the long-term safety of a high-level radioactive waste disposal system cannot be demonstrated directly. However, it can be indirectly demonstrated by evaluation using predictive analyses based on technical and scientific data. Demonstration of compliance with numerical safety standards therefore involves safety assessment and comparison of the results of the assessment with the standards.

Safety assessments aiming at demonstrating compliance with dose or risk upper bounds should take account of uncertainties in predictions of the performance of the barriers. Two methods are available for these safety assessments:

- deterministic analyses modelling the evolution of disposal systems and estimating the consequences;
- probabilistic analyses assessing the consequences from a range of future events, to each of which is assigned a probability of occurrence.

These methodologies are not mutually exclusive, and in practice a comparative analysis with both techniques is likely.

The risks or consequences from disruptive events which might constitute a significant fraction of the total risks or consequences from waste disposal should be assessed.

In safety assessments aiming at comparison of several different design approaches, realistic scenarios, models and input data should be applied. Models to be used should be validated as far as possible against evidence from laboratory tests and field observations including natural analogues and site investigations whenever practicable.

More detailed information about safety and performance assessment methodologies and model validation is included in an IAEA specialized document (Ref: IAEA Safety Series Nos. 56 and 68).

5.2 Standard No. 17: Quality Assurance

> A quality assurance programme for components of the disposal system and for all activities from site confirmation through construction and operation to closure of the disposal facility shall be established to assure compliance with the standards.

The programme should contain provision to ensure identification of and compliance with requirements of appropriate recognized engineering and mining codes and regulations, standards, specifications and practices.

The programme should also define the organizational structure for implementing the quality assurance activities and clearly delineate the responsibility and authority of the various personnel and organizations involved for selecting the level of quality assurance required and assuring hat the quality assurance programmes are followed.

6. OTHER CONSIDERATIONS

6.1 Long Timescale Aspects

As expressed by Standard No. 3, the individual dose and risk upper bound applicable today should in principle be sustained indefinitely without a cut-off time for our responsibility for protection of human descendants. However, assurance of compliance with this standard in the long time scale introduces difficulties arising from uncertainties due to changes in the environmental conditions and living habits of future populations.

Describing the environmental conditions for the human species in the future becomes more and more speculative when the periods considered are tens of thousands of years from now. For example, glacial episodes have occurred in a cyclical fashion, and the next ice age may appear within about 10,000 years from now. Significant changes in the biosphere will undoubtedly occur through these periods. The detailed environmental conditions and nutritional needs of individuals in the distant future may be different from those of today.

Since neither the location nor the characteristics of far future human individuals can be predicted, dose and risk assessments may not be meaningful for periods longer than a few thousand years. This does not imply that the assessments for such longer time periods should not be made, but it indicates that other independent means may be needed to reinforce the conclusions of the dose and risk assessments as they enter the period of increasing uncertainty.

One means may be to assure that the repository is not going to change appreciably the radiation environment of the future population. The dose upper bound and risk upper bound are less than annual doses from natural background. Therefore, if the doses and risks from a high-level waste repository to far-future individuals who are assumed to have our characteristics and our nutritional needs are less than the respective upper bounds, then there is the assurance that doses from the environment of any future individual are not going to be appreciably changed by a contribution from the repository.

An additional means of assurance may be to compare far future concentrations or releases of radionuclides from the repository into the environment with concentrations or releases from natural sources such as the upper part of the earth's crust, toxicity of different radionuclides being taken into account in the comparison.

7. DEFINITIONS AND EXPLANATION OF TERMS USED

Barrier (natural or engineered): A feature which delays or prevents radionuclide migration from the waste and/or repository into its surroundings. Natural barrier is, in case of deep geological repositories, represented by the host rock. An engineered barrier is a feature made by or altered by man; it may be a part of the waste package and/or part of the repository.

Burden: In this document the term burden means all of the (1) financial costs, (2) administrative, research and other resource commitments, and (3) radiological, social and other impacts which society must provide or endure in connection with disposal of radioactive waste. Burden does not have the meaning formerly used in radiation protection terminology and thus is not limited to the quantity of radioactive substances carried within a human body or organ.

Conditioning of waste: Those operations that transform waste into a form suitable for transport and/or storage and/or disposal. The operations may include converting the waste to another form, enclosing the waste in containers, and providing additional packaging.

Confinement (or isolation): The segregation of radionuclides from the human environment and the restriction of their release into that environment in unacceptable quantities or concentrations.

Containment: The retention of radioactive material in such a way that it is effectively prevented from becoming dispersed into the environment or only released at a specified rate.

<u>Criticality:</u> The conditions in which a system is capable of sustaining a nuclear chain reaction

<u>Deterministic analysis</u>: A technique for studying a system behaviour mathematically using the laws of science and engineering provided that all system parameters, events and features are deterministically (as opposed to probabilistically) defined.

<u>Disposal system</u>: A combination of a geological environment, a repository and waste packages emplaced within the repository.

<u>Dose</u>: Throughout this report, the term 'dose' is used to denote the sum of the effective dose equivalent resulting from external exposure during one year and the committed effective dose equivalent from that year's intake of radionuclides.

<u>High-level waste</u>:

(i) The highly radioactive materials, containing mainly fission products, as well as some actinides, which are separated during chemical reprocessing of irradiated fuel

(ii) Spent reactor fuel, if it is declared a waste.

(iii) Any other waste with a radioactivity level comparable to (i) or (ii).

<u>Host rock</u>: A geological formation in which a repository is located.

<u>Multibarrier system</u>: A system using two or more independent barriers to isolate the waste from the human environment. These can include the waste form, the container (canister), other engineered barriers and the emplacement medium and its environment.

<u>Near-field region</u>: The excavated repository including the waste package, backfills or sealing materials, and those parts of the host medium whose characteristics have been or could be altered by the repository or its content.

<u>Optimization</u>: As used in radiation protection practice, the process of reducing the expected health effect deriving from radiation exposure of a population, through the use of protective measures, to a level as low as reasonably achievable, economic and social factors being taken into account.

<u>Post-sealing period</u>: The period after a waste repository has been shut down and sealed.

<u>Probabilistic analysis</u>: A statistical analysis technique for studying the expected behaviour of a system with parameters whose values are uncertain, with events whose occurrences are random, and with features which may or may not be present.

<u>Quality assurance</u>: Planned and systematic actions necessary to provide adequate confidence that an item, facility or person will perform satisfactorily in service.

<u>Radionuclide migration</u>: The movement of radionuclides through pores and/or fractures of a geological medium due to fluid flow and/or by diffusion.

<u>Repository</u>: An underground facility in which waste are emplaced for disposal.

<u>Risk</u>: In this document risk denotes the probability of a health effect for an individual or his descendants. It is equal to the product of the probability of exposure at a particular annual dose rate, and the probability of a health effect arising from that annual dose.

Standards: Basic requirements which must be met in order to satisfy the objective of protecting humans and their environment from any unacceptable detriment which might arise from disposal of radioactive wastes.

Standards in this document are requirements set up by the IAEA for fundamental aspects of disposal system performance, i.e. those aspects which determine the acceptability of a disposal system. Failure to comply with any standard would result in an unacceptable disposal system. Standards include, for example, numerical or qualitative requirements for protection of the environment.

Validation of a model: Comparison of calculations based on a conceptual model and the computer code derived from it with field observations and experimental measurements.

Waste form: The physical and chemical form of the waste (e.g. liquid, incorporated in concrete, glass, etc.) without its packaging.

Waste package: The waste form and any container(s) as prepared for handling, transportation, storage and/or disposal. A cask or overpack may be a permanent part of the waste package or it may be re-usable for any waste management step.

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