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A general framework for prospective radiological environmental impact assessment and protection of the public

(original title: Radiological Environmental Impact Assessment for Facilities and Activities; new title based on the proposal by WASSC)

DRAFT SAFETY GUIDE **DS427**

FOREWORD

[Click here to insert foreword]

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. In 2011, the IAEA published the Safety Requirements: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements No. GSR Part 3 (BSS) [1]. These standards superseded the International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources issued in 1996. The BSS are based on the IAEA's Fundamental Safety Principles [2] and the recommendations of the International Commission on Radiological Protection (ICRP) [3].

1.2. As part of the authorization process, the BSS identifies the requirement for a prospective assessment for protection of the public and protection of the environment against the impacts due to releases of radionuclides from facilities and activities[1]. This prospective assessment includes the consideration of expected exposures (e.g. due to releases during normal operation) and potential exposures (e.g. exposures due to conceivable[2] incidents) The present Safety Guide interprets and elaborates on the requirements in the BSS for performing assessments for protection of the public and protection of the environment for certain facilities and activities and in particular on Requirement 7 for notification and authorization, which states that "Any person or organization applying for authorization: […] shall, as required by the regulatory body, have an appropriate prospective assessment made for radiological environmental impacts, commensurate with the radiation risks associated with the facility or activity." [1]

1.3. In the framework of international legal instruments or national laws and regulations, authorities may also require that, for some activities or facilities, a decision process including a comprehensive initial assessment for protection of the environment is carried out at an early stage. In this case, the assessment for protection is generally part of a broader impact assessment process, which is generally referred to as an 'environmental impact assessment' (EIA) and covers not only environmental but biophysical, social, economic and other relevant effects of development proposals prior to major decisions being taken. Within that framework, the results of the assessment presented in this Safety Guide may be used to inform judgements on the acceptability of the risk of such impacts, as defined by the requirements and recommendations in the IAEA safety standards. Therefore, the assessment for protection of the public and protection of the environment is related to, and may be part of, more comprehensive assessments to be carried out during an authorization process and part of a decision process.

1.4. This Safety Guide presents and discusses approaches and methods applicable for facilities and activities, in order to assess the level of radiological protection to members of the public and the protection of the environment. The approaches and methods given in this

[1] Facilities and activities are defined in the IAEA Fundamental Safety Principles and the Safety Glossary [2, 4]. It is a general term encompassing all nuclear facilities and uses of all sources of ionizing radiation. The present guidance is pertinent to certain activities and facilities which are described under Scope.

[2] In the context of the Safety Guide, the term 'conceivable' means that the incidents to be considered are the result of a safety analysis, which includes the definition not only of the characteristic of the incident but its probability.

Safety Guide are to be considered adequate to carry out a prospective assessment of the level of public and environmental protection, as required in the BSS for planned exposure situation.

1.5. This Safety Guide is related to other guidance and reports published in the IAEA Safety Standards Series, Safety Reports Series, and Technical Reports Series: these are the Safety Guides on criteria for protection of the public and protection of the environment against radiation exposure [5, 6] and on regulatory control of radioactive releases to the environment [7], the Safety Report on methods and models to assess the impact of releases to the environment [8, 9] and Technical Reports relevant to environmental transfer parameter values [10, 11]. This Safety Guide provide a general framework that is consistent with and can be applied as a complement to other Safety Guides where radiological impact assessment is included, but discussed with less level of details, for example, in the frameworks of safety assessment for predisposal management of radioactive waste [Ref. to be added IAEA GSG-3] and safety assessment for the decommissioning of facilities using radioactive material [Ref. to be added IAEA WS-G-5.2].

OBJECTIVE

1.6. This Safety Guide provides recommendations and guidance on a general framework for performing prospective assessments of facilities and activities, as identified under Scope, to estimate and control, using criteria, the radiological effects on public and effects on the environment. This assessment is intended for planned exposure situations as part of governmental decision-making and the regulatory authorization processes for facilities and activities. The situations covered include expected exposures and potential exposures (this is explained in more details below and in Section 2).

1.7. This Safety Guide provides guidance and recommendations about the contents of such assessments, their use and the procedures for their implementation, as an aid to national regulatory bodies, persons or organizations and to other interested parties[3] applying for an authorization or being responsible for the operation of facilities and activities. It is recognized and discussed in this guidance that, for some aspects of the assessments, different States may have different approaches. This is due to the complexity and diversity of the options for management of environmental issues, which will depend on national circumstances.

SCOPE

1.8. This Safety Guide is applicable to evaluate prospectively exposures and risk of exposures due to radioactive releases to the environment —and, when relevant, direct external radiation—, from facilities and activities which are located at or projected for a specific site. The exposures considered include those which are expected to occur as a result of normal

[3] The term interested parties is used in the IAEA safety standards to mean, in a broad sense, a person or group having an interest in the performance of an organization. Interested parties have typically included the following: customers, owners, operators, employees, suppliers, partners, trade unions; the regulated industry or professionals; scientific bodies; governmental agencies or regulatory bodies (national, regional and local) whose responsibilities may cover nuclear energy; the media; members of the public (individuals, community groups and interest groups); and other States, especially neighbouring States that have entered into agreements providing for an exchange of information concerning possible transboundary impacts, or States involved in the export or import of certain technologies or materials.

operation (i.e. due to the authorized discharges) and also those which can be conceived, by mean of a safety analysis, as a result of an event or a sequence of events that might be an incident (i.e. potential exposures).

1.9. It is beyond the scope of this Safety Guide to provide recommendations and guidance on equivalent prospective assessments of exposures resulting from the disposal of radioactive waste, the transport of radioactive material and the use of mobile radioactive sources. These types of facilities and activities have very specific aspects related, for example, to the long term delayed releases to geosphere in the case of disposal and, for mobile sources, the uncertain characteristics of the locations, which are not considered in the present guidance. Specific guidance on assessment for disposal and transport is given in [12] and [13].

1.10. The assessment for protection of the public and protection of the environment, as described within this Safety Guide is intended to be prospective in nature. For example, it can be used prior to siting, when granting an authorization during construction and prior to operation, or prior to a decommissioning process. The prospective assessment as described in this Safety Guide can serve to multiple purposes including, establishing the initial authorization basis with respect to public and environmental protection, and as an important input into the process of authorizing controlled discharges. The process to establish discharge limits and optimize the protection of the public is covered in a separated Safety Guide [7]. The assessment could also be applied for those existing facilities requesting changes in their operational processes before the implementation of any significant change affecting the level of discharges or of potential releases to the environment, or, if deemed necessary, in the framework of periodic safety reviews.

1.11. The assessment for protection described in this Safety Guide is not intended to assess retrospectively the radiological impact from discharges during operations or the consequences resulting from an actual accident. Nevertheless, the prospective assessment of potential exposures could provide preliminary information to be used in assessing the hazards and the related consequences for the purpose of establishing adequate level of emergency preparedness and response [14].

1.12. The prospective assessment of potential exposures for facilities and activities, as described in this Safety Guide, may require that accidents with very low probabilities of occurrence leading to consequences for the public and the environment are considered and criteria for potential exposures are fulfilled. However, even if a facility or activity meets these criteria, it does not preclude the need for an assessment of hazards in relation to preparedness and response for a nuclear or radiological emergency, in line with requirements in Ref. [14]. Other aspects of the consequences of large accidental releases to the environment such as social and economic effects and other effects on the environment and on ecosystems are out of the scope of this Safety Guide.

1.13. This Safety Guide does not discuss in detail the specifications and characteristics of the events and incidents to be considered during the assessment of potential exposures, or the methodology for their selection and analysis. Such specifications and processes for analysis for nuclear installations are discussed in detail, for example, in the Safety Guide [45] and in other related publications in the IAEA Safety Standards Series.

1.14. This Safety Guide is focused on defining a general framework and discussing the general aspects of the methodologies for the assessments, and does not discuss in detail the models or the use of data. In particular, the Safety Guide does not discuss the use of data from

radiological environmental monitoring programmes, which are normally undertaken at pre-operational stages (for instance, to establish baselines of activity concentrations in environmental media and to provide information and data for dose assessment purposes [16]) or during the operation of the facility and activity (i.e. to verify compliance, check the conditions of operation, provide warning of unusual or unforeseen conditions and check the predictions of environmental models [16]). For the purpose of this Safety Guide, it is assumed that monitoring programmes at the pre-operational and operational stages exist (or will exist) and provided (or will provide) the necessary information for adequate dose estimations and to verify that the models and assumptions used in prospective assessments are correct. The prospective assessment as described in this Safety Guide should also be used to inform the definition of the site specific environmental monitoring programme. The IAEA provides guidance for source and environmental monitoring programmes in Ref. [16] and [17].

1.15. The Safety Guide does not cover occupational exposures (i.e. of workers) or medical exposures (i.e. of patients). These categories of exposures and their inclusion in the authorization process are discussed in separate guidance provided by the IAEA [Ref. to be added: IAEA DS453 and IAEA DS399].

1.16. This Safety Guide only covers the risk of radiological impacts to the health of individuals in the members of the public due to radiation exposures during normal operations and due to potential exposures. If deemed necessary, the assessment described in this Safety Guide considers the effects of radiation resulting from normal operations on populations of flora and fauna.

1.17. The possible non-radiological impacts of facilities and activities, which are generally included in an EIA, such as the impacts on the environment from discharges of other hazardous substances (i.e. chemicals) and heated water, and of the construction of a facility, impacts on features of the environment such as historic monuments and cultural places or impacts on the landscape, as well as social and economic impacts, are not considered in the present Safety Guide. States are subject to the nationally and internationally relevant treaties, conventions, codes of conduct and regulations. States also have an obligation of diligence and duty of care and are expected to fulfil their national and international undertakings and obligations. International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection [2].

STRUCTURE

1.18. Section 2 gives explanations of the main concepts and terms used in the Safety Guide. Section 3 describes the safety requirements related to the assessment for protection of the public and protection of the environment for governments, national regulatory bodies and licensees stemming from other IAEA standards. Section 4 gives the framework in which the assessments are done. Section 5 describes the general methodology needed to carry out assessment for protection of the public and protection of the environment for normal operations and for consideration of potential exposures to the public. Appendix I presents criteria which could be used for consideration of potential exposure. Considerations on the radiological protection of flora and fauna are discussed in Annex I. Annex II presents considerations on assessment of potential exposures on public. Examples of national

approaches to consider exposures resulting from normal operation and potential exposures of members of the public are presented in Annex III.

2. EXPLANATION OF CONCEPTS AND TERMS

2.1. Section 2 provides an explanation of some of the concepts and terms used in this Safety Guide. While approaches may be in principle consistent with these concepts and terminology, the use of the terms defined in this section could differ from those used in States.

PLANNED EXPOSURE SITUATIONS: EXPECTED EXPOSURES AND POTENTIAL EXPOSURES

2.2. BSS defines a planned exposure situation as "a situation of exposure that arises from the planned operation of a source or from a planned activity that results in an exposure from a source. In planned exposure situations, exposure at some level can be expected to occur. If exposure is not expected to occur with certainty, but could result from an accident or from an event or a sequence of events that may occur but is not certain to occur, this is referred to as 'potential exposure' " (BSS para 1.20 (i)) [1]. The magnitude and extent of these exposures can usually be predicted. Both exposures and potential exposures can and should be taken into account at the planning or design stage [5].

DECISION PROCESS

2.3. In the context of this Safety Guide the term decision process refers to the procedures carried out by the government or governmental agencies to decide whether an activity or a facility will be undertaken, continued or changed[4]. It could also apply to areas of national policy such as whether to embark on a nuclear power programme [19]. A formal decision process is normally conducted at the early stages of a programme of development and, mainly, for activities or facilities that are foreseen to need a thorough assessment of their potential impact to the environment. For some nuclear installations national or international regulations identify this decision process with the term 'environmental impact assessment', which is explained later.

AUTHORIZATION PROCESS (OR LICENSING PROCESS)

2.4. Authorization is a term defined in the BSS as a formal procedure established in the national regulatory framework by which a regulatory body or other governmental body grants written permission, at different stages of the lifetime of a facility or the development of an activity.

2.5. The authorization of a facility or an activity, in the form of a registration or licence [1], could be granted for design, siting, construction, operation, decommissioning activities and when modifications in the conditions of operation of activities and facilities are considered.

[4] The term decision process proposed in this Safety Guide encompasses different terms used by the States with similar or equivalent meanings, such as 'decision-making', 'decision-in-principle' and in some cases 'justification' processes.

ENVIRONMENTAL IMPACT ASSESSMENT

2.6. Environmental impact assessment (EIA) is not defined in the IAEA safety standards although it is included in many international instruments and national legislations and regulations [20–27]. In the context of this Safety Guide, an EIA refers to a national decision process for identifying, describing and assessing prospectively the effects and the risk of effects of a proposed activity or facility on the environment.

2.7. The effects related to radioactive releases from activities and facilities to the environment likely to be considered in an EIA generally include radiological effects on human health and, in some cases, effects on flora and fauna. Non-radiological impacts such as the physical impact of the construction of the facility on the environment, social and economic impacts, the impact on historic monuments and cultural places, endangered species or the landscape, which are generally included in an EIA are not considered in the present guidance but are subject to the nationally and internationally applicable regulations.

2.8. In general, an EIA requires the involvement of the organizer of the proposed activity or facility, relevant governmental agencies, the regulatory body and a number of interested parties, including public.

ENVIRONMENT AND PROTECTION OF THE ENVIRONMENT

2.9. The BSS [1] defines the environment as the "conditions under which people, animals and plants live or develop and which sustain all life and development; especially such conditions as affected by human activities". Usually, environment includes ecosystems which comprise biotic and abiotic components.

2.10. The Fundamental Safety Principles [2] state that "the present system of radiation protection generally provides appropriate protection of ecosystems in the human environment against harmful effects of radiation exposure. The general intent of the measures taken for the purposes of environmental protection has been to protect ecosystems against radiation exposure that would have adverse consequences for populations of a species (as distinct from individual organisms)".

2.11. BSS specifies that the protection of the environment means protection and conservation of non-human species, both animal and plant, and their biodiversity; environmental goods and services such as the production of food and feed; resources used in agriculture, forestry, fisheries and tourism; amenities used in spiritual, cultural and recreational activities; media such as soil, sediments, water and air; and natural processes.

2.12. The system of protection and safety described in the BSS [1] defines a framework to assess, manage and control exposure to radiation for humans which generally provides for appropriate protection of the environment from harmful effects of radiation. However, the BSS acknowledges that some national regulations may require the explicit demonstration (rather than the assumption) of the protection of the environment. The BSS also mentions that the assessment of impacts on the environment needs to be viewed in an integrated manner with other features of the system of protection and safety and that the approach to the protection of people and protection of the environment is not limited to the prevention of radiological effects on humans and on other species [1].

2.13. The BSS states that the protection of the environment is an issue necessitating assessment, allowing for flexibility in incorporating into decision making processes, the results of environmental assessments that are commensurate with the radiation risks. BSS establishes that the assessment of environmental impacts should be undertaken in accordance with national requirements [1].

RADIOLOGICAL ENVIRONMENTAL IMPACT ASSESSMENT

2.14. The requirement to assess radiological environmental impacts is identified in the BSS, but the term 'radiological environmental impact assessment' is not formally defined. For the purpose of this Safety Guide, radiological environmental impact assessment is taken to be a form of prospective assessment that identifies the target(s), assesses the expected (e.g exposures due to normal releases) and conceivable for purposes of authorization (e.g. potential exposures due to postulated incident scenarios) radiological impacts, and compares the results with predefined criteria. Within this Safety Guide radiological impact is taken to mean the estimated effects of radiation dose that may be caused by releases from a proposed facility or activity on human health and, if deemed necessary, other elements in the environment, for example flora and fauna. A radiological environmental impact assessment may be seen as one component of an EIA in the context of planning for nuclear facilities. The numerical criteria presented in this safety guide are in the form of dose criteria or risk criteria related to a level of dose.

MEMBERS OF THE PUBLIC

2.15. The BSS [1] defines a member of the public as "in a general sense, any individual in the population except when subject to occupational exposure or medical exposure". The IAEA Safety Fundamentals, Principle 7, states that safety standards apply not only to local populations but also to populations remote from facilities and activities. In addition, where effects could span generations, subsequent generations have to be adequately protected without any need for them to take significant protective actions [2].

GRADED APPROACH

2.16. BSS [1] defines graded approach for a system of control, such as a regulatory system or a safety system, "a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control". In the context of this Safety Guide a graded approach means first, considering whether a radiological impact assessment is needed and second, that the level of details in the modelling and the input data necessary to characterize the level of protection of people and the environment should be commensurate with the risk resulting from the expected exposures (normal releases) and the potential exposures (releases that may occur as a result of an theoretical incident).

3. SAFETY REQUIREMENTS RELEVANT TO ASSESSMENT OF FACILITIES AND ACTIVITIES FOR PROTECTION OF THE PUBLIC AND PROTECTION OF THE ENVIRONMENT

3.1. The following paragraphs contain extracts from the IAEA Fundamental Safety Principles [2], the BSS [1] and other IAEA standards [28, 29] illustrating the relevant safety requirements to conduct an assessment of the protection of the public and protection of the environment for planned exposure situations. The requirements are addressed in more details in Section 4 and 5 of this Safety Guide.

LIMITATION OF DOSES AND RISK

3.2. The BSS [1] states that there is a need to control and minimize the radiological impact to members of the public and the environment.

3.3. The IAEA Fundamental Safety Principles [2] establish, among others, principles for ensuring the protection of the public and the environment, now and in the future, from harmful effects of ionizing radiation, and the need for "doses and radiation risks to be controlled within specified limits" (Principle 6). These principles apply to situations involving exposure to, or the potential for exposure to, ionizing radiation[5].

This is discussed in Section 5 which describes the methodology for an assessment of the level of protection of the public and the environment including the use of dose and risk criteria.

RESPONSIBILITIES

3.4. Requirement 7 of the BSS [1] (Paragraph 3.8) states that "any person or organization applying for authorization:

> (a) … shall, as required by the regulatory body, have an appropriate prospective assessment made for radiological environmental impacts, commensurate with the radiation risks associated with the facility or activity".

This is discussed in Section 4 which gives the context in which an assessment is done and Section 5 which describes the methodology for an assessment of the level of protection.

3.5. Requirement 9 of the BSS (paragraph 3.15) gives the responsibilities of registrants and licensees in planned exposure situations. It states that "registrants and licensees:

> (a) … shall, for the sources for which they are authorized and for which the regulatory body requires a prospective assessment to be made for radiological environmental impacts, conduct such an assessment and keep it up to date".
>
> (b) … shall assess the likelihood and magnitude of potential exposures, their likely consequences and the number of persons who may be affected by them.

[5] In contrast, dose and risk limitation is not applied to emergency exposures situations, where reference levels are used.

These requirements are covered in Section 5 which describes the methodology for an assessment of the level of protection.

3.6. Requirement 12 of the BSS states that "the government or the regulatory body shall establish dose limits for… public exposure, and registrants and licensees shall apply these limits". Section 5 addresses this requirement.

3.7. Requirement 29 of the BSS (paragraph 3.120), which relates to responsibilities specific to public exposure, states that "the government or regulatory body shall establish or approve constraints on dose and on risk to be used in the optimization of protection and safety for members of the public". Paragraph 3.123 states that "the regulatory body shall establish or approve operational limits and conditions relating to public exposure, including authorized limits for discharge. These operational limits and conditions:

> (a) … shall take into account the results of the assessment of the potential radiological environmental impacts undertaken in accordance with national requirements" .

The definitions of and use of constraints on dose and risk are discussed in Section 5.

ASSESSMENT FOR PROTECTION OF THE PUBLIC AND PROTECTION OF THE ENVIRONMENT

3.8. Principle 7 of the IAEA Fundamental Safety Principles [2] states that: "People and the environment, present and future, must be protected against radiation risks".

3.9. The consideration of the protection of the environment is contemplated in the IAEA safety standards [1, 2], in line with ICRP recommendations [3]. Where a specific link to the BSS cannot be made, this Safety Guide uses as a reference on environmental protection the IAEA Safety Guide on Radiation Protection of the Public and the Environment [5].

3.10. Requirement 31 of the BSS relates to radioactive waste and discharges[6]. Paragraph 3.132 of the BSS states that "registrants and licensees, in cooperation with suppliers, in applying for an authorization for discharges, as appropriate:

(a) Shall determine the characteristics and activity of the material to be discharged, and the possible points and methods of discharge;
(b) Shall determine by an appropriate pre-operational study all significant exposure pathways by which discharged radionuclides could give rise to exposure of members of the public;
(c) Shall assess the doses to the representative person due to the planned discharges;
(d) Shall consider the radiological environmental impacts in an integrated manner with features of the system of protection and safety, as required by the regulatory body".

[6] Some aspects of assessment of radiological impact to public and the environment in general are included in Requirement 31 in the BSS [1]. However, the main objective of Requirement 31 is to establish authorized discharge limits. The procedure for establishing authorized discharge limits is not specifically addressed in this Safety Guide and it is discussed more fully in an IAEA Safety Guide on control of discharges [7].

These elements are addressed in Section 5 which deals with the methodologies for assessing doses to members of the public and to the environment.

ASSESSMENT AND CONTROL OF POTENTIAL EXPOSURE

3.11. Paragraph 3.24 of the BSS establishes that "registrants and licensees shall ensure that all relevant factors are taken into account in a coherent way in the optimization of protection and safety to contribute to achieving the following objectives:

(a) To determine measures for protection and safety that are optimized for the prevailing circumstances, with account taken of the available options for protection and safety as well as the nature, likelihood and magnitude of exposures;

(b) To establish criteria, on the basis of the results of the optimization, for the restriction of the likelihood and magnitudes of exposures by means of measures for preventing accidents and for mitigating the consequences of those that do occur".

3.12. Paragraph 3.15 of the BSS establishes that "Registrants and licensees:

(e) … shall assess the likelihood and magnitude of potential exposures, their likely consequences and the number of persons who may be affected by them".

3.13. Requirement 6 of GSR Part 4 [29] states that "the possible radiation risks associated with the facility or activity shall be identified and assessed". These include "the level and likelihood of radiation exposure of […] the public, and of the possible release of radioactive material to the environment, that are associated with anticipated operational occurrences or with accidents that lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation".

3.14. Requirement 13 of the BSS states *inter alia* that "safety assessment shall:

(a) Identify the ways in which exposures could be incurred....

(b) Determine the expected magnitudes and likelihoods of exposures in normal operations and, to the extent reasonable and practicable, make an assessment of potential exposures".

The assessment and control of potential exposure is addressed in Section 5 and Appendix I of this Safety Guide.

GRADED APPROACH

3.15. Principle 5 of the Fundamental Safety Principles (paragraph 3.24 in the SF) [2] states that "the resources devoted to safety by the licensee and the scope and stringency of the regulations and their application, have to be commensurate with the magnitude of the possible radiation risks and their amenability to control".

3.16. Requirement 1 of GSR Part 4 (paragraph 3.1) [29] states that to apply Principle 5 "a graded approach needs to be taken in carrying out the safety assessments for the wide range of facilities and activities … owing to the very different levels of possible radiation risks associated with them".

3.17. Requirement 6 of the BSS states that the application of the requirements of these Standards shall be commensurate with the characteristics of the practice or the source within a practice, and with the magnitude and likelihood of the exposures.

3.18. Requirement 1 of GSR Part 4 [29] (para. 3.4) states that "other relevant factors, such as the maturity or complexity of the facility or activity, are also to be taken into account in a graded approach to safety assessment". It also states (para. 3.6) that "the application of the graded approach needs to be reassessed as the safety assessment progresses and a better understanding is obtained of the radiation risks arising from the facility or activity. The scope and level of detail of the safety assessment are then modified as necessary and the level of resources to be applied is adjusted accordingly".

The graded approach as applied to an assessment is discussed further in Section 4.

TRANSBOUNDARY IMPACTS

3.19. Requirement 29 of the BSS addresses the issue of exposure outside the territory under the jurisdiction or control of the State in which the source is located[7]. Paragraph 3.124 requires that "when a source within a practice could cause public exposure, the government or the regulatory body shall:

> (a)…ensure that the assessment of the radiological impacts includes those impacts outside the territory or other area under the jurisdiction or control of the State.
>
> (b)…arrange with the affected State the means for exchange of information and consultations, as appropriate".

This is discussed in Section 5.

[7] The consideration of the protection of the environment at the transboundary level and the obligations for assessing the impacts and sharing information between States should also be included within the broader context of relevant international agreements and conventions (e.g. UNCLOS 1982 [21], Espoo 1991 [20], Aarhus 1998 [22]) and Article 37 of the EURATOM Treaty [30]).

4. FRAMEWORK OF ASSESSMENT OF FACILITIES AND ACTIVITIES FOR PROTECTION OF THE PUBLIC AND PROTECTION OF THE ENVIRONMENT

4.1. As discussed in Section 3, a number of different formal processes, such as a decision process and authorization process, may require an assessment of the facility or activity for protection of the public and protection of the environment. The need of a radiological environmental impact assessment and the level of complexity required for a decision or an authorization process may vary depending on the type of facility, the framework of the process, and its stage in the process.

4.2. The need of a radiological impact assessment should be defined by the government or the regulatory body, considering the characteristics of the activity or facility, based on the consideration of the risk due to the expected and potential exposures. Activities and facilities which can be exempted from regulatory control should not require a radiological environmental impact assessment[8].

4.3. The following section discusses the factors which should be considered once the need of a radiological environmental impact assessment was defined and when deciding upon the required level of complexity and how the complexity may vary during the process.

ASSESSMENT FOR THE AUTHORIZATION PROCESS

4.4. The approaches used for an assessment (assumptions, models and input data) may vary with the complexity of the exposure scenario. For the sake of clarity, assessments discussed in this Safety Guide are categorized as either simple or complex. However, it is recognized that these terms are the two ends of the range of possible assessments and there are a large number of activities, and facilities that require an assessment falling between these two categories.

4.5. The national regulatory body should establish the general requirements and criteria for the assessment taking into account the likelihood and expected magnitude of exposures, the characteristics of the facility and a number of additional factors. Examples of these factors and different elements are given in Table 1. Factors which are important to define the complexity of the assessment are: the source term[9], the level of doses, the safety characteristics of the activity or facility and the characteristics of the location. The scope and level of detail of the assessment may also vary depending on the national regulations for each type of activity and facility and the stage in the authorization process. The applicant should define the level of detail of the assessment for a specific facility or activity considering the requirements and criteria established and present a proposal to the regulatory body for review and agreement. States may consider that, for certain facilities or activities, the level of detail of the assessment could be defined a priori by the regulatory body.

[8] The concept of exemption and the radiological criteria for exemption of practices from the need of regulatory control is established in BSS.

[9] The amount and isotopic composition of material released (or postulated to be released) from a facility or during an activity involving radioactive materials, together with its physical and chemical properties relevant for environmental dispersion.

4.6. The list provided in Table 1 is not exhaustive, and judgement on the significance of these factors when selecting the type of assessment should be made by experts in nuclear and radiation safety and by national regulatory bodies.

TABLE 1. EXAMPLES OF FACTORS AFFECTING THE REQUIRED LEVEL OF COMPLEXITY OF AN ASSESSMENT

Factor	**Element**
Source term	Radionuclides
	Quantity (both activity and mass/volume)
	Form (chemical/physical make up)
	Geometry (size, shape, height of release)
	Potential for release: source term varies significantly between normal operation and incidents or accidents
Level of expected dose from normal operations or projected doses for potential exposures	Preliminary assessments or previous assessments for similar facilities
Safety characteristics of the activity or facility	Types of safety barriers and engineering features present in the design
	Potential for severe accident scenarios
Location characteristics	Characteristics of environment around the facility (geology, hydrology, meteorology, morphology, biophysical)
	Presence of receptor (people, flora and fauna)
	Exposure pathways
	Land use (agriculture)
	Characteristics of possible natural and man-made external events (for examples, earthquakes, industrial accidents)
	Existence of other nuclear installations in the vicinity of the facilities or activities in question
Characteristics of authorization process for the particular activity or facility	Requirement of regulations (licensing requirements)
	Stage of the authorization process

4.7. Factors and elements in Table 1 are not ranked in order of importance and should be used as general guidance as to whether a simple or complex assessment might be appropriate. In principle an assessment for the authorization of a nuclear power plant requires a high degree of complexity, while for a hospital operating a small nuclear medicine department a very detailed analysis may be not justified.

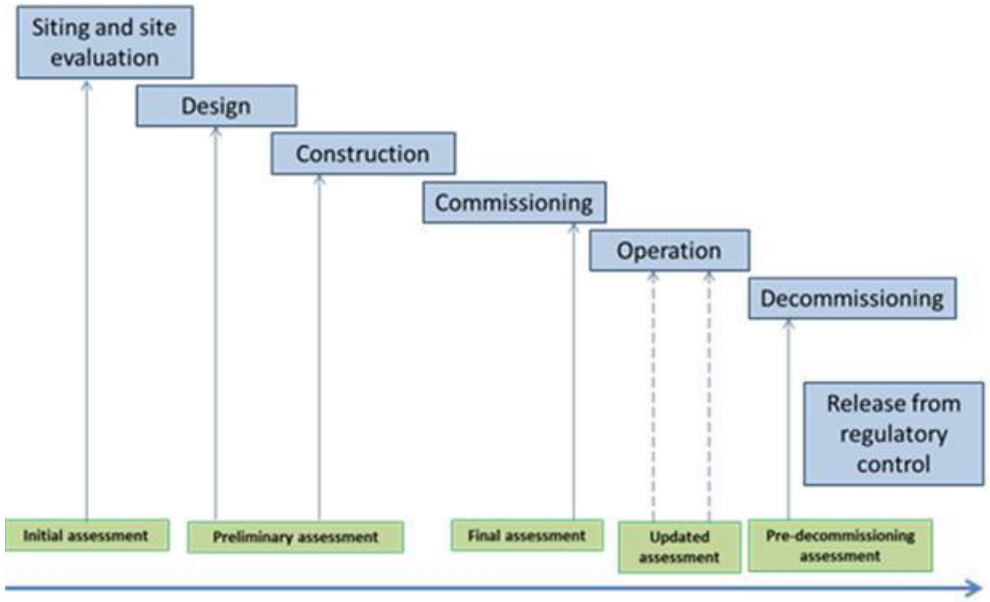
4.8. For some types of facilities, for example small laboratories using small sealed sources like radioimmunoassay kits, there may be no requirement for a radiological assessment because, due to the characteristic of the sources in use, a significant impact to the public and the environment is not expected, even following an accident. In some cases a radiological assessment based on relatively simple models using some generic data and cautious assumptions may be sufficient for the authorization process. The regulatory body should define the types of facilities not needing an environmental assessment. For some installation, the regulatory body may define a simple generic methodology. The IAEA includes generic guidance for different types activities and facilities in [ad ref: IAEA-TECDOC Guidance on Generic Radiological Environmental Impact Assessment (in preparation)].

4.9. For facilities like nuclear power plants and reprocessing facilities, there are likely to be a number of stages in the authorization process. During those stages the assessment should normally be updated when more specific data is obtained.

4.10. For authorization, the organizations responsible for the nuclear facility should ensure that an assessment for the protection of public and environment is adequately provided at the different stages. Figure 1 (adapted from [31]) presents schematically the stages in the lifetime

of a nuclear facility; as an example, it shows where an assessment might be carried out at different stages in the authorization process. All the assessments conducted in the stages previous to and during the operation of a nuclear facility are basically the same, incorporating more details and information to reduce the level of uncertainty and reviewing the models and assumptions when this is deemed necessary. The vertical arrows in full indicate the stage at which the assessment may be discussed with the regulatory body and, finally at the time of the authorization previous to operation when the final assessment is ready, submitted for approval. The vertical dashed lines indicate where an assessment may be submitted if significant changes have occurred during the operational stage. The horizontal arrow indicates the evolution of time .

FIG. 1. Stages in the lifetime of a nuclear installation where a prospective assessment for the protection of public and protection of the environment might be input into the authorization process.



4.11. An initial assessment using regional or generic data could be conducted during the stages of siting and site evaluation for identification of potential regions or potential sites for the facility or activity. During this stage, different technologies could also be under scrutiny.

4.12. Once a site or a reduced number of sites are selected and the technology is more specified (e.g. the type of nuclear power plant is defined) a preliminary assessment for that particular locations is (or those particular locations are) normally done using the available information. In general, during the construction period more information relevant for the assessment is collected, including the results of surveys for obtaining site specific data, where deemed necessary. The data and the models used for the assessments should evolve in order to be able to produce a final assessment at some point in the commissioning stage, before any release is authorized.

4.13. Before starting the operation of a facility or conducting an activity an assessment is normally performed to determine, for instance, the authorized discharge limits. Guidance on establishment of discharge limits is presented in [7].

4.14. Once the authorization or license has been granted or for facilities already in operation, a periodic safety assessment review will be required [29]; this should include the review of the radiological impact assessment for protection of public and protection of the environment. The assessment should also be re-evaluated if there are significant changes in the source term, including in the total amount and the spectrum of radionuclides and in the location characteristics (see Table 1).

4.15. At the end of a decommissioning stage or before release of a site from regulatory control a radiological environmental impact assessment is also expected. However, for most of the activities and facilities, typically no releases or potential exposures are involved after decommission and the methods for exposure estimation and criteria could be different (for example, the estimation of the doses should be based mainly on environmental monitoring data and the dose criteria could be below dose limits and constraints used for the operational stage). A particular situation could be that of some activities and facilities involving large areas, like uranium mining and milling after decommissioning, where source terms and impacts to the environment could still be foreseen. These situations should be analysed on a case by case basis and, for some of them, the methods for assessment and criteria described in this safety guide could be applied.

ASSESSMENT AS PART OF A DECISION PROCESS

4.16. An assessment of the level of radiation protection to the public and to the environment may be required as part of a decision process, for example within an EIA, for certain types of nuclear facilities, for example nuclear reactors, installations for reprocessing spent fuel or certain installations for waste treatment prior to disposal activities. This assessment will have elements in common and should be consistent with the assessment done as part of the authorization process discussed in the previous section.

4.17. Though a radiological assessment as part of a decision process typically has a lower level of details than an assessment for an authorization process, the level of complexity required in an assessment for a decision process should be consistent with that of the authorization process and determined by the factors in Table 1. In general, the level of complexity should be defined by the nuclear regulatory body(s) in the country in discussion with other governmental authorities or agencies. For some types of facilities, for example hospitals or small laboratories, there may be no requirement for a detailed radiological assessment for a decision process, because significant impact to the environment is not expected either for normal releases or accident scenarios. However, national competent authority may establish their own requirements for activities or facilities which need an assessment.

4.18. Subject to national requirements, an assessment during a decision process could have a single or multiple phase(s). The initial assessment may be relatively descriptive in nature and based on generic data and conservative assumptions, whilst further assessment may include more realistic and site-specific information. However, an assessment for a decision process is normally conducted at early stages when considering a proposed activity or facility and the information at that stage would be of a more general character. Generic assessments for similar facilities already in operation in equivalent sites can provide useful information. This is discussed further in Section 5.

ASSESSMENTS FOR OTHER PURPOSES

4.19. Operators outside a decision or an authorization processes can conduct a radiological environmental impact assessment for an activity or a facility. For example, as part of a process to evaluate the safety performance of and activity or facility, an operator can evaluate the the systems to reduce radioactive releases to the environment (i.e. normal operation filters or decay tanks) or systems to mitigate releases during accidental conditions (i.e. emergency filters). This is normally done during the operation of facilities with the objective of introducing improvements in the safety systems. When performing such assessments, the same approaches as described in this safety guide should be applied to ensure that all the aspects of public and environmental protection are considered, including the expected exposures and the potential exposures.

COMMUNICATION OF RESULTS

4.20. Requirement 36 of GSR Part 1 [28] requires that the regulatory body, either directly or through the applicant of a facility or activity, shall establish mechanism of communication to interested parties about the possible radiation risks and the processes and decisions of the regulatory body, in accordance with a graded approach. The factors in Table 1 of this Safety Guide should be considered when establishing the contents and the level of detail in the reports for information provision to the relevant interested parties. Depending on the importance of the enterprise, the regulatory body should involve governmental authorities when such communication is considered necessary for effectively performing the public informational functions of the regulatory body.

4.21. The radiological environmental impact assessment for protection of the public and protection of the environment results in technical documents which are generally intended for people with expertise in radiation safety and protection. Normally these are experts from regulatory bodies, radiation protection or technical support organizations, public health agencies or environment agencies. The assessment should be well documented and transparent for a broad audience, which may not have a highly specialized expertise, for example, the public, government departments and ministries not directly involved in radiation protection issues and others. Information on the assessment should be made available in appropriate technical language — for example, including a non-technical summary that summarizes the relevant chapters of the more technical reports and outlines the key findings from the assessment could be useful for some of the interested parties.

4.22. The communication of the results of the assessments of the level of protection of the public and the environment against routine discharges and potential releases is equally as important and challenging as the completion of technically sound environmental assessments. Essential information on radiation effects and the safety aspects related to design, operation, maintenance and surveillance of activities and facilities should be included together with the results the in the reports produced.

4.23. Despite the objective of the radiological impact assessment in order to grant an authorization is to demonstrate that the radiological effects on public and the environment are evaluated and controlled, e.g. that the radiation risk is acceptable, where the results of an assessment indicate that the information is relevant across national boundaries, this information should be shared with the States concerned. The State where the activity or

facility is located should arrange with the affected States the means for exchange of information and consultations, as appropriate.

4.24. The information used as basis for an assessment as described in this Safety Guide could have commercial and security implications (for example, plans for the facility layout, and information on plant accident sequences). This information should be available only to the regulatory authorities and other governmental agencies and should be treated confidentially. Normally the government in consultation with the national regulatory body and other relevant national organizations should establish which information should be made available publicly. The responsibility to ensure the soundness of the restricted information should remain with the governmental agencies with functions related to safety and security. The restriction of access to certain sensitive information should be clearly explained so that it is not perceived by the interested parties as concealing information that is relevant for estimating and understanding the radiation risks to people and to the environment.

5. METHODOLOGY FOR ASSESSMENT OF FACILITIES AND ACTIVITIES FOR PROTECTION OF THE PUBLIC AND PROTECTION OF THE ENVIRONMENT

GENERAL CONSIDERATIONS

5.1. The system of protection and safety aims to assess, manage and control exposure to radiation. The protection of the public is based on the principles of justification, dose limitation and optimization, which are incorporated in the IAEA safety standards as safety principles [2]. Practical advice, in the form of requirements to governments, regulatory bodies and operators, are described in the BSS, and frameworks of application and methods in IAEA technical safety guidance. Amongst the requirements in the BSS, in order to control the radiological impact due to radioactive releases during planned exposure situations, there is a need to conduct assessments that include the prospective estimation of the possible dose to members of the public and the likelihood and magnitude of potential exposures.

5.2. The assessment of the level of protection of members of the public is, in many instances, sufficient to provide for an adequate protection of the ecosystems in environment. For international frameworks which additionally require the explicit consideration of the protection of flora and fauna[10], or when national regulations consider the inclusion of this type of more explicit assessment, this Safety Guide includes a methodology to apply ICRP approach based on the concept of 'reference animals and plants' for protection of different ecosystems in the environment [32, 33]. This methodology is consistent with similar methods developed and used by Sates for various purposes, including evaluation of impacts to the environment and decision making. [64, 65, 66]. 'Reference animals and plants' is discussed below in the section on assessment of flora and fauna for normal operation.

5.3. Since an assessment for protection of the public and protection of the environment within this Safety Guide is prospective in nature, reliance will have to be placed on mathematical modelling for evaluating, for example, the dispersion of radionuclides in the environment, transfer through environmental compartments, transfer to humans and to the human food chain and, if being considered, to flora and fauna, and finally the radiation doses resulting from the associated external radiation or from the uptake of radionuclides by living organisms. The models should be appropriate for the situation in which they are being applied, ensuring that the assessment methodologies provide reasonable accuracy. Model assumptions and parameter choices should be sufficiently described and referenced to be transparent and allow independent verification.

5.4. Where possible, the selected models should be supported through comparison of their results with data resulting from measurements at similar exposure scenarios or, at least, by means of benchmarking procedures against other appropriate models. Section 1 also mentions the need for establishing environmental monitoring programmes for the operational phase of an activity or facility, not only to verify compliance with discharge and dose limits but to ensure that the assumptions used in the prospective assessment were accurate or conservative (i.e. over-protective) in nature.

[10] For example, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (see: http://www.imo.org/OurWork/Environment/LCLP/Pages/default.aspx.

5.5. Different methodologies, including calculation tools and input data, can be used to carry out an assessment for demonstrating protection [8, 9]. The national regulatory body needs to be satisfied that the methodology adopted is adequate for the purposes of national practice and should decide — possibly in discussion with the applicants of the facility or activity and other interested parties — which methodology is best suited to carry out a particular assessment.

5.6. One consideration when deciding on the methodology is the balance between the amount of effort and the level of detail required. For example, for an installation with low levels of discharges and/or low potential for accidents with consequences to the public and the environment, the use of a complex methodology would not be necessary. For these types of installations, regulatory bodies may develop generic guidance on simple and cautious assessments that can be used. In addition the uses of additional resources to gather more information for complex methodologies may not be justified by the improvement in the calculated results.

5.7. For facilities needing complex assessments, the level of detail in the models and the data used for the assessment may evolve during the decision process and authorization process. The evolution in the models and data requirements for an assessment during decision and authorization processes is further discussed in the following paragraphs. The following sections describe the characteristics of the assessments for protection of the public and protection of flora and fauna (as an option) in normal operations, and for protection of the public against potential exposure.

ASSESSMENT FOR PROTECTION OF THE PUBLIC FOR NORMAL OPERATION

5.8. Facilities and activities that use or process radioactive sources or materials, are designed, constructed, commissioned operated or conducted, maintained and decommissioned —and regulated throughout all these stages, in order to prevent or minimise releases of radioactive materials to the environment. However, radionuclides can be found in some of the gaseous or liquid effluents resulting from the normal operations and, in accordance with the safety principles in [2] and the safety requirements in the BSS discussed in Section 3, there is a need to conduct assessments that include prospective estimations of the possible dose to members of the public and compare the results to defined criteria.

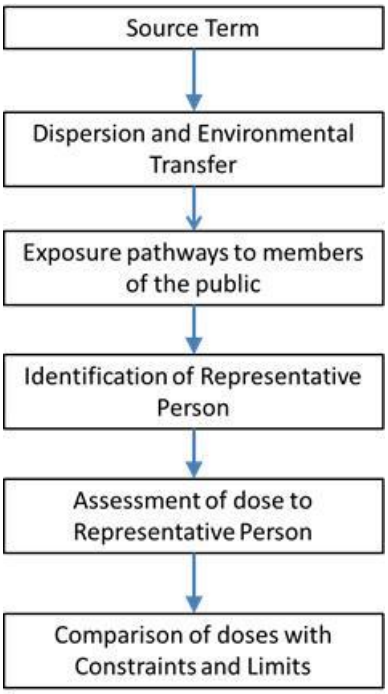
Procedure for the assessment

5.9. The assessment of facilities and activities for protection of the public for normal operation uses estimations of the dose to the public. Figure 2 gives schematically[11] the components of such assessment. In general terms, the first stage of the assessment is to characterize the source of radiation related to the exposures; in the second stage dispersion in the environment and the transfer in the environmental compartments relevant for the identified exposure pathways are considered. The activity concentrations estimated in a

[11] The Safety Guide is intended to provide a general framework for radiological impact assessment. This and other figures in this Safety Guide are conceived to illustrate the elements of such assessments, facilitate their discussions and are not proposed to be used as detailed procedure. Important steps which are not discussed but should be considered when performing the assessments are, i.e., selection of computer codes, uncertainty analysis, verification and QA/QC control.

number of environmental media are then combined with relevant habit data and occupation factors to calculate intakes of radionuclides (internal exposure) or external radiation (external exposure) to a representative person. Intakes and external radiation are combined with dosimetric data to calculate doses to the representative person for comparison with relevant criteria, for example dose constraints.

FIG. 2. Components of an assessment for protection of the members of the public for normal operations.



The different components of the assessment presented in Figure 2 are discussed in the following paragraphs.

Source term

5.10. The source term selected for an assessment should be appropriate for the type of facility or activity being considered. All relevant radionuclides, from a radiological point of view, should be identified along with the discharge route and the physical and chemical properties relevant for environmental transfers of these radionuclides. Releases to the atmosphere and to the aquatic environment should be considered, as appropriate.

5.11. In some cases, for instance at the initial stages of an authorization or decision process, generic source terms for the postulated facility could be used, based on preliminary estimations, published data or on the experience from similar installations. Information on generic source terms for normal operation of nuclear reactors can be found in [34, 35]. Later, when the type of facility has been selected (e.g. the design and detailed characteristics of the nuclear power plant are known) and the possible sites have been identified or decided upon, the source term should be more accurately characterized by means of an appropriate engineering analysis.

5.12. The total estimated releases should be provided over the period required by the regulatory body — this is generally given in terms of activity released per year of operation. An assessment will typically assume that the discharges are continuous and constant over a

year. Where this is not the case and there is a significant variation in the discharges over a short time period, e.g. during special maintenance or refuelling of reactors or for typical iodine-131 discharges to sewer from thyroid treatment departments at a hospital, then short term releases will need to be assessed.

Dispersion and transfer in the environment

5.13. A variety of models and data are required to predict the dispersion and transfer of radionuclides through the environmental media and to the representative person. The processes more relevant to dose estimations should be identified and a conceptual model[12] should be elaborated. Activity concentrations in environmental media, resulting from the postulated releases of radioactive materials, such as in air, in sediments, in soil, in water, and in biota will need to be estimated through the use of mathematical models. Environmental models to assess dispersion and transfers of varying levels of complexity have been developed by several authors and were compiled and adapted by the IAEA [8, 36]. The regulatory body should decide if models and data presented by the applicant are appropriate for the assessment under consideration, taking into account the characteristics of the installations and the factors discussed in Section 4.

5.14. Two possible approaches of models and data for the assessment are: (i) a generic methodology which takes account of dilution and dispersion of releases into the environment; or (ii) a detailed methodology —using, for example, site-specific data— to estimate activity concentrations in different environmental media. In both cases, models should be able to estimate spatial distribution and temporal variation of activity concentrations in the environment. The complexity of the model used should be commensurate with the possible level of environmental impact of the installation and should be defined by the regulatory body considering the factors discussed in Section 4.

5.15. For assessment of exposures to members of the public the models should be able to simulate the dispersion, dilution, transfer and decay (or other removal mechanism), as necessary. This includes the following processes:

(a) Atmospheric dispersion;
(b) Deposition of radionuclides on the ground or other surfaces;
(c) Dispersion of radionuclides in surface water (freshwater, brackish or marine) and ground water; and
(d) Transfer of radionuclides to plants and animals in the food chain.

5.16. For nuclear installations requiring complex assessments, the models used to estimate activity concentrations in environmental media (e.g., in the air, in the aquatic media, on the ground and through the soil) should take account of the physicochemical properties of the radionuclides being released necessary to assess, for example, the effective release height, the effects on the dispersion of effluents by nearby buildings and removal mechanisms like wet and dry deposition.

5.17. For installations needing simple assessments the meteorological and hydrological conditions could be of a generic character based on bibliography or national records. The

[12] A conceptual model is a representation that captures the key elements or components of a complex system, like the relationship between the released radionuclides and the environment.

meteorological and hydrological conditions used for the complex assessments should be appropriate and specific for the site in question and should preferably be averaged from several years of data. Such data may be available for the site itself or from nearby meteorological or hydrological stations.

5.18. Gaussian type atmospheric dispersion models can be used in general [8], particularly where the geographical characteristics of the sites under consideration leads to simple dispersion scenarios (e.g. relatively flat terrains) and the representative person is located in the first 1-20 km from the release point. However, for more complex dispersion conditions, for example for installations located close to mountainous regions or places where complex local atmospheric circulations are expected, or in cases where greatest distances need to be considered, more complex dispersion models may be necessary. In any case, predictions of the dispersion models should be based on realistic assumptions as far as possible and pessimistic assumptions when uncertainties or variability in the data prevent those realistic assumptions to be considered. If the location of the facility is known at the time of the assessment, these assumptions should take account of site-specific conditions. If not, generic information at a regional level should be used until more details on the project are known.

5.19. Radionuclides may be discharged to a freshwater, estuarine or marine environment. There may also be discharges of radionuclides to the sewerage system. Radionuclides discharged to water bodies are dispersed by general water movements and sedimentation processes. Much depends on the local characteristics of the receiving environment, and it is not possible to have a totally generic model for these releases. For example, information for rivers requires at least the size of the river and its flow rate [SRS 19]. Models should be able to estimate the activity concentrations in water and in sediment. From these data activity concentrations in aquatic food, such as fish and crustaceans and aquatic flora and fauna, as relevant, can be estimated together with external radiation doses from exposure to sediments.

5.20. For some activities and facilities, discharges of radioactive liquids to sewerage systems may occur with the waste water being carried to sewage treatment works. When assessing discharges to sewers, the models should be able to estimate the transfer of the radionuclides to the sewerage works and their subsequent release into the environment. Radionuclides could be discharged from the sewerage works with the treated effluent, to rivers or coastal waters, where the models discussed in the paragraph above would be required. In addition, radionuclides may be associated with the sewage sludge which is managed in various ways including its reuse as a soil conditioner and fertilizer on agricultural land treatment or disposal by incineration or to a municipal waste landfill site. Appropriate models should be available for the transfer of radionuclides through terrestrial food chains and for atmospheric releases.

5.21. When radionuclides are continuously discharged they accumulate in the environment up to the point where equilibrium conditions are or can be assumed to have been reached. The activity concentrations in the environmental media used to estimate doses should be representative of the conditions when accumulation can be assumed to have reached equilibrium. Dose estimates should be calculated for the time period at which the highest radiological exposure is expected**.** For example, when a facility is expected to be operational for 30 or 40 years and the equilibrium can be assumed at the end of the operational life, the dose should be assessed at the 30th or 40th year to take this accumulation into account.

5.22. Decay chains may need to be taken into account. In some cases, the decay products may be more radiologically significant than the parent and so it is important to consider the

ingrowth. Examples of this are the uranium decay series and plutonium-241 which decays into americium-241. The assumptions and approaches to deal with progeny, including the exclusion of progeny if applicable, should be justified.

5.23. The transfer of radionuclides from environmental media to the plants and animals in the human food chain should be estimated using generic recommended transfer factors like those in IAEA publications [8, 10, 11, 37]. Those publications provide transfer factors for food in the terrestrial, marine and freshwater ecosystems. If there is a need to refine the assessment, for instance when the initial estimated doses using generic transfer factors are above or close to the dose criteria, transfer factors based on site specific measurements could be necessary. However, this could be difficult in the framework of prospective assessments. The regulatory body should decide when site specific data based on measurements should be used in an assessment. The uncertainties due to lack of site specific data on transfer parameters can be compensated by the use of generic data with conservative assumptions, whilst noting the need not to be grossly pessimistic in these assumptions.

5.24. For installations requiring complex assessment, when at the initial stages of an authorization process, a preliminary estimation of the dispersion and transfer to the environment can be done using simple cautious models and meteorological/hydrological data generic to the region (e.g. from published data or from records from the closest meteorological/hydrological stations, which may sometimes be located at tens to hundreds of kilometres from the sites). At later stages of the authorization process, meteorological and hydrological data from measurements conducted on-site or very close to the plant location should be used, as it become available. These measurements are the regular practice during site survey and construction stages. Information on the type and detail of data which should be available at the later stages of licensing process can be found in IAEA publications [38-40].

Exposure pathways

5.25. Doses should be calculated resulting from a number of exposure pathways which are considered relevant for releases to the environment in particular scenarios. An indicative list of exposure pathways for both internal and external exposures is given below:

For releases to atmosphere and surface waters during normal operation (typically, for nuclear power plants):

(a) Inhalation of radionuclides in an atmospheric plume;
(b) Ingestion of crops;
(c) Ingestion of animal food products (milk, meat, eggs);
(d) Ingestion of drinking water;
(e) Ingestion of aquatic food (freshwater or seawater fish, crustaceans, molluscs);
(f) Ingestion of forest food (wild mushroom, wild berries).
(g) Ingestion of breast milk or locally elaborated baby food.
(h) External exposure from radionuclides in an atmospheric plume;
(i) External exposure from radionuclides deposited on ground;
(j) External exposure from radionuclides in water and sediments (e.g. from activities on shores, swimming, fishing etc.); and
(k) Inadvertent ingestion of soil and sediments.

For releases to the sewerage system during normal operation (typically for laboratories and hospitals):

(m) Inhalation of resuspended sewage sludge; and
(n) External exposure from radionuclides in sewage sludge.

In some facilities or activities, radiation sources could contribute to doses to the member of the public living in the close vicinity of the installations or working on site. Additional pathways to be considered are:

(o) Direct irradiation from sources stored in the facility (i. e. from spent fuel or radioactive waste storages);
(p) Direct irradiation from sources used in the facility (i.e. from industrial irradiators); and
(q) Direct irradiation from the facility (i.e. from components of the facility like nuclear reactors or coolant systems).

5.26. Depending on the exposure scenarios, not all the exposure pathways listed in the paragraphs above may need to be included in the assessment; the contribution of an exposure pathway to the overall dose depends on the radionuclides involved, the habit data, the occupation factors and other characteristics of the population being considered. Therefore some exposure pathways may be excluded from the assessment on the grounds that the doses associated with certain pathway are negligible.

5.27. In some circumstances, it may only be possible to calculate doses for very general categories of food using generic values. For example doses can only be calculated for ingestion of crops, without being able to specify which types of crops are likely to be consumed. However, if surveys have been made close to the site then it may be appropriate to use site specific values of the actual crops in the region as long as the site-specific values are representative.

5.28. It should also be noted that other exposure pathways may contribute to the dose received by individuals in particular circumstances, for example consumption of seasonal or atypical foods.

Identification of representative person for normal operations

5.29. Dose should be calculated to a representative person[13] using characteristics selected from a group of individuals representative of those more highly exposed in the population. Ref. [41] gives guidance on the characteristics of the representative person.

5.30. The characteristics of the representative person should be defined according to the national regulations and through a systematic process involving the regulator. For example, the regulatory body may require the use of more detailed and site specific habit data for assessments carried out for certain types of facilities or at later stages in the authorization process.

[13] BSS define representative person as: An individual receiving a dose that is representative of the doses to the more highly exposed individuals in the population. The dose to the representative person is the equivalent of, and replaces, the mean dose in the 'critical group'. The concept of critical group remains valid.

5.31. Habit data of the representative person should be habits typical of the population living in the region where the facility is located or of the country at large. Habit data used in an assessment can be obtained from statistics collected at national, regional or international level or, where possible, from surveys carried out at or near the location where the facility will operate. Habit data include, for example, consumption rates of food and drinking water and inhalation rates. Important characteristics when assessing doses to the representative person is the assumed location (e.g. distance and direction from the point of release), where they obtain their food, and the fraction of the food consumed that is of local origin, occupancy times (time spent at different locations) and time spent outdoors and indoors.

5.32. Account should be taken of where people live and factors reducing the level of exposure, such as the degree of shielding or filtering offered by the buildings assumed to be inhabited. The location of the representative person can be based on actual or hypothetical person or group of persons in a conservative location from the point of view of the exposure (e.g. close to the fence or in the regions where the highest deposition of radionuclides can be expected).

Assessment of dose to representative person

5.33. The assessment of radiation doses to the public should be estimated using individual effective dose, which is the sum of the committed effective dose from intakes of radionuclides (by ingestion and inhalation) and effective dose from external irradiation [1, 3]. Doses from internal irradiation are calculated using dose coefficients from intakes of radionuclides by ingestion and inhalation, which provide committed effective doses per unit activity of intake, expressed in units of Sv Bq^{-1}. Tabulated values of dose coefficients applicable for members of the public are available in a number of publications [1, 42]. For calculating effective dose from external irradiation, standard models exist as well as compilations of dose coefficients [1, 43].

5.34. Dose coefficients for internal irradiation are provided for different age groups [1, 42]. If there are factors that may result in a particular age group being the most highly exposed then this age group should be considered. The application of dose coefficients for age groups should be weighed in relation to the ability to predict concentrations in the environment from a source and the ability to account for uncertainties in habit data for individuals exposed. Uncertainties in estimates of dose, particularly for prospective calculations, are generally not reduced significantly by increasing the number of age categories for which dose coefficients have been provided [41].

Comparison of doses with constraint and limits

5.35. For the purpose of comparison with the dose estimations resulting from the assessment, the government or the regulatory body should define a dose constraint below the dose limits for members of the public, taking into accounts the requirements in the BSS [1]. [5] provide guidance for the definition and use of dose constraint for protection of members of the public in planned exposures situations.

5.36. The BSS [1] defines an annual effective dose limit of 1 mSv for members of the public. Dose constraints should fall within the range of 0.1 – 1 mSv [5]. The government or the regulatory body could define a generic upper value for dose constraint for different

activities or facilities [7]. The effective dose estimated using the sum of the doses from external exposure in the specified period and the relevant committed[14] doses from intakes in the same period should be used to compare with the constraint; the period for calculating the committed dose should be defined considering life expectancies, for example 50 years may be taken for intakes by adults and up to age 70 years for intakes by children.

5.37. Because dose constraints refer to a single source, the regulatory body should take account of the possible contribution to the individual doses of other sources, for example another installation located close by or in the same site.

5.38. At an early stage of a decision or an authorization process, a generic upper value of a dose constraint for different types of activities and facilities (i.e. for fuel cycle facilities), which is to be defined by the national authorities, could be used for comparison with the results of the initial assessment. Later the results of the assessment should be compared with the specific constraint for the activity or facility under consideration, as defined by the regulatory body. After the process of optimization of protection of the public is conducted, in accordance with the requirements in the BSS, a dose corresponding to and optimized level of discharge could be used for comparison to the results of the assessment. The process of optimization of the protection[15] is discussed further in [41], [7], [44], [5 and 7]

5.39. When considering transboundary impacts the criteria used for the assessment of the level of protection in other States should be in line with the criteria discussed in this safety guide and, in principle, may be the same used in the State where the facility or activity is located.

ASSESSMENT FOR PROTECTION OF FLORA AND FAUNA FOR NORMAL OPERATION

5.40. The aim of protection of the environment is set at a high level, for instance: to provide for the maintenance of biological diversity, to ensure the conservation of species and the health of natural habitats, communities and ecosystems [32]. Within this Safety Guide, the general intent of the measures taken for the purposes of environmental protection is to protect ecosystems against radiation exposure that would have adverse consequences for populations of a species (as distinct from individual organisms) [2].

Considerations for assessment of facilities and activities for protection of the environment may vary between States and are subject to the regulations and guidelines of the national competent authorities, including regulatory bodies.

5.41. States may consider that the assessment of the protection to members of the public is sufficient to demonstrate protection of the environment as well. This position is based on the assumption that the system of protection and safety, which aims to assess, manage and control the exposure to radiation to humans, provides for appropriate protection of the environment from harmful effects of radiation. In that case the assessment may not need to include explicit consideration of the radiation exposures to flora and fauna as described below in this section.

[14] The lifetime dose expected to result from an intake.

[15] As defined in the BSS, the process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, as low as reasonably achievable, economic, societal and environmental factors being taken into account.

5.42. Other States may require the more explicit inclusion in the assessments of additional specific components of the environment, for instance, flora and fauna. However, the concept of graded approach should be considered, i.e. that the efforts should be commensurate to the expected level of risk.

5.43. Normally, for activities or facilities requiring a simple assessment, like hospitals and small laboratories, the explicit consideration of protection to flora and fauna is not necessary, on the basis that a significant radiological impact to the environment is not foreseeable owing to, for example, the limited radionuclides inventory in the sources of the facilities or its intrinsically safe characteristics.

5.44. The following paragraphs only apply to situations where the explicit assessment of the radiological impact to flora and fauna is deemed necessary by the regulatory body.

5.45. ICRP has defined an approach to assess and control the effects of radiation on flora and fauna using the concepts of 'reference animals and plants', representative organism' — consistent with the concepts of 'reference person' and 'representative person' — and dose criteria in the form of 'derived consideration reference levels' [32]. These concepts and criteria are discussed below.

5.46. This Safety Guide presents an assessment for protection of flora and fauna of generic character, consistent with the ICRP approach for protection of the environment [32, . A generic assessment, as described below, implies the use of the ICRP RAPs relevant for the specific ecological scenarios (e.g. Terrestrial, marine, freshwater) and the use of cautious assumptions when modelling the environmental dispersion and transfers and when defining the use of the criteria.

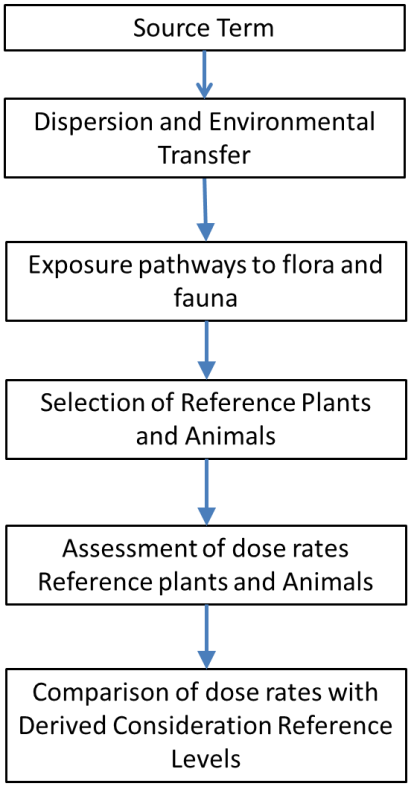
5.47. For most facilities and activities and environmental situations, a generic assessment would be sufficient to demonstrate protection of flora and fauna. However, a generic approach may not be appropriate for the assessment of the impact to flora and fauna in particular circumstances, for example when dealing with protected or endangered species or when very sensitive ecological niches are identified.

5.48. The regulatory body or other competent governmental agency could identify specific exposure scenarios that need special considerations different from those more of a generic character as presented in this Safety Guide. The assumptions and types of assessments for situations needing special consideration should be discussed amongst those responsible for conducting the assessment, the national regulatory body and the competent governmental agency. In any case, the methods described in this Safety Guide could be used as a screening tool for those particular circumstances.

Procedure for the generic assessment

5.49. The assessment of facilities and activities for protection of the environment against releases during normal operation uses estimations of the dose to flora and fauna. Figure 3 gives the components of such generic assessment. For this assessment, using the same source term provided for the assessment of the protection of humans, activity concentrations in a number of environmental media should be estimated and then combined with available dosimetric data as well as information on the times spent in different habitats (e.g. on or above soil, in the water or in aquatic sediments) to estimate dose rates from internal and external exposures to RAPs relevant for the ecosystems under consideration.

FIG. 3. Components of an assessment for protection of flora and fauna for normal operations.



5.50. The characteristics of the source term and the models to simulate the dispersion and environmental transfers for flora and fauna (the first 2 boxes in Figure 3) are the same to those used in the assessment of exposures to humans, ensuring that the environmental media considered are relevant to estimate exposures to flora and fauna. For example, the models should be able to predict the activity concentrations in the environmental media such as air, rivers, seawater, sediments and soil and the transfer parameters should be the relevant for flora and fauna. IAEA provides models and data applicable for flora and fauna [9, 10].

5.51. Differences between the assessments for humans and for flora and fauna in the latter components of the assessment are more significant and a description is given below.

Exposure pathways

5.52. The exposure pathways that should be considered when assessing doses to flora and fauna [32] are:

(a) External exposure due to radioactive material in the atmosphere, water, soil and sediments; and
(b) Internal exposure from incorporated radioactive material.

Selection of Representative Animals and Plants

5.53.].

5.54.

5.55. A generic assessment should use the types of animals and plants given for major ecosystems (terrestrial, freshwater and marine), representing the most significant exposure pathways, which are relevant to the location being assessed. These types of animals and plants for the different ecosystems are presented in Table 2 below.

TABLE 2. TYPES OF PLANTS AND ANIMALS FOR THREE MAJOR ECOSYSTEMS TO BE USED IN GENERIC ASSESSMENTS OF RADIOLOGICAL IMPACT TO FLORA AND FAUNA AND RELEVANT DERIVED CONSIDERATION REFERENCE LEVELS (DCRL)

Ecosystem of interest	**Types of animals and plants**	**ICRP reference animal and plant**	**DCRL [mGy d^{-1}]**
Terrestrial	Large plant	Reference Pine tree	0.1–1
	Small plant	Reference Wild grass	1–10
	Insect	Reference Bee	10–100
	Annelid	Reference Earthworm	0.1–1
	Large mammal	Reference Deer	0.1–1
	Small mammal	Reference Rat	0.1–1
Freshwater	Aquatic Bird	Reference Duck	0.1–1
	Amphibian	Reference Frog	1–10
	Fish	Reference Trout	1–10
Marine	Seaweed	Reference Brown seaweed	1–10
	Crustacean	Reference Crab	10–100
	Fish	Reference Flatfish	1–10

5.56. The types of animals and plants presented in Table 2 are related to reference animals and plants defined by ICRP [32]. The reference animals and plants are a set of hypothetical entities defined for the procedure of dose estimation and for considering the relation between doses and their effects for managing environmental situations from the radiation protection point of view.

5.57. The reference animals and plants indicated in Table 2 are representative of marine, terrestrial and freshwater ecosystems and have a wide geographical variation[16].

5.58. The aim of radiological protection of flora and fauna is at the level of populations and not individuals [2, 32]; i.e. the evaluation of radiological impacts to flora and fauna requires the consideration of the effects of radiation exposures at the level of population. ICRP approach for protection of flora and fauna considers effects at the individual level that may have impact in the structures of populations [32 and 33]. However, the dose used in the assessment, which should be compared with the criteria, should not be the dose of the most exposed individual, but that dose considered representative of the doses being received by a group of individuals located in an area where the highest exposures may occur.

5.59. In a generic assessment, for the estimation of exposures, the reference animals and plants should be located in a reference area around the source — normally around the release point — where the highest environmental activity concentrations will typically occur[17]. The

[16] With regard to the need for reference models to represent typical farm animals for the purpose of their protection - primarily large mammals that live essentially in a human environment — it was considered that the use of humans was probably sufficient for such managed environmental or ecological situations [32].

[17] This assumption is based on the intrinsic properties of atmospheric and aquatic dispersion. This is discussed in Annex I.

dose rates characteristic for this group should be estimated using, for example, the average activity concentrations within this area. Although ecological characteristics may vary, in general, areas surrounding the effluent release points in the order of 100–400 km^2 could be applied for most exposure scenarios relating to normal operation of activities or facilities. This is discussed further in Annex I.

Assessment of dose rates to Representative Animals and Plants

5.60. While for humans the dose quantity used for comparison with the dose criteria is the effective dose, for flora and fauna the relevant quantity to be used is the absorbed dose rate [18] [32]. Dose rates due to exposure via internal and external pathways should be calculated for the selected Representative Animals and Plants located in the reference area around the source described before. The absorbed dose rate could generally be estimated by using environmental transfer models based on concentration factors medium to biota and the corresponding dosimetric factors.

5.61. Ref. [11] and [46] provide environmental media to biota concentration ratios for different flora and fauna,. For the estimation of dose rates to the RAPs dosimetric factors presented in [32] should be used. [36] provides practical methods to estimate dose rates to representative animals and plants using generic dispersion scenarios.

Comparison of dose rates with reference levels

5.62. The derived consideration reference levels [32] is a set of dose rate bands within which there is some very low probability of deleterious effects of ionizing radiation to individuals of flora and fauna, which may have implications in the structures or populations. Derived consideration reference level bands span an order of magnitude; for dose rates below the lower level of the bands, no effects have been observed (or no information on effects were reported) [32, 33]. Derived consideration reference levels have been defined on the basis of radiation effects observed for species corresponding to reference animals and plants and should be used as criteria for comparison with the estimated dose rates. The derived consideration reference levels are presented in Table 2 above. Some member States have defined and use their own radiological criteria which are compatible with the DCRLs [64, 65, 66].

5.63. The derived consideration reference levels do not represent limits; they should be considered as points of reference to inform on the appropriate level of effort that should be expended on environmental protection, dependent on the overall management objectives, the actual fauna and flora present, and the numbers of individuals thus exposed [33].

5.64. In a generic assessment as presented in this Safety Guide, if the dose rates to the RAPs are below the lower boundary of the relevant derived consideration reference level band, impact on population of flora and fauna could be considered negligible and the level of protection of environment can be considered adequate. In the case where the estimated dose

[18] Radiation quality factors, like those used for the assessment of exposure to humans (resulting in effective doses expressed in Sv) are not applied to assess exposure to biota; the key quantity for the exposure assessment of biota is the absorbed dose, which is defined as the amount of energy that is absorbed by a unit mass of tissue of an organ or organism, given in units of Joules per kilogram or Gray (Gy) [8, 22]. Due to the consideration of different species of flora and fauna, with different life spans, it is convenient to express the criteria in terms of a dose rate, in Gy per day (or its adequate subunit, for instance mGy/d) [32, 47].

rates are within the bands the situation can still be acceptable, but the regulatory body could decide whether additional considerations (i.e. improvement in the level of details of the assessment) or practical mitigation measures would be needed, bearing in mind that derived consideration reference levels are reference points, not limits. If the resulting dose rates are above the upper boundary of the relevant derived consideration reference level band, the regulatory body should decide if this implies a stronger need to consider more control on the source or further protection efforts.

ASSESSMENT OF PROTECTION OF THE PUBLIC AGAINST POTENTIAL EXPOSURES

5.65. Facilities and activities are designed, constructed, operated or conducted, maintained and decommissioned in order to prevent and mitigate incidents and accidents that, in the vast majority of cases, result in no radiological consequences for the public [1, 2, 48, 49].

5.66. During the safety assessments carried out for activities and facilities in the authorization process, various types of accident analysis may be carried out to determine theoretical source terms and the frequencies or probabilities of these events. The types of accidents to be considered depend on the characteristics of the activities and facilities under consideration. In order to assess prospectively the potential exposures to members of the public, as required in the IAEA safety standards [1, 2, 48], those incidents and incidents, with their probabilities, should be considered.

5.67. The consideration of potential exposures in the assessment of facilities and activities for protection of the public may vary between States and should be subject to the regulations and guidelines of regulatory bodies. Annex III provides examples from different States of the consideration of potential exposures. The following sections provide guidance to conduct the assessments of the potential exposures to members of the public, once the type and characteristics of the incidents or accidents are defined as a result of a safety analysis. The regulatory body should define the characteristics of the events necessary for the assessments of potential exposures to members of the public to be used in an authorization of a decision processes. Guidance on definition and characteristics of the events which may be considered when assessing potential exposures to the public is found in [add IAEA references on Safety Assessment]

5.68. For the purposes of this Safety Guide, the expression ‘potential exposure scenarios’ is used to include the characteristics of all the incidents, events or sequences of events that may lead to an accident, including their source term characteristics —and when applicable their frequencies or probabilities—, combined with the selected environmental conditions which are taken into account to assess the potential exposures.

Procedure of the assessment

5.69. As it is explained in the section Scope, this Safety Guide covers only health effects due to radiation doses resulting from hypothetical accidents to members of the public at the individual level. Potential exposures to flora and fauna are not taken into account, since those are not amenable to regulatory control under accidental situations.

5.70. The assessment of potential exposures uses estimations of doses to members of the public or a measure of risk. The elements of such assessment are given in Figure 4. In general terms, the first step should be to consider the defined potential exposure scenarios. Next, the

related source terms, including quantities and relevant physical and chemical characteristics of the releases (i.e. those that determine behaviour in the environment), should be consider to make the input to environmental dispersion and transport. Environmental dispersion and transfer should then be estimated with relevant models, considering the defined environmental scenario (i.e. the meteorological and hydrological scenario). The relevant exposure pathways should then be identified. The exposed population group for consideration of potential exposures should then be selected. Finally, the dose, or a measure of the risk of health effects, should be assessed and compared with the applicable established criteria.

Potential exposure scenarios

5.71. The potential exposure scenarios for facilities and activities can be specified in different ways, such as (i) by selecting a single conservative scenario[19], (ii) by identifying a set of characteristic scenarios[20] or (iii) by identifying scenarios from a broad range of initiating events and environmental conditions by means of a methodological approach[21]. In the last two cases the frequency or likelihood of occurrence is taken into account.

5.72. The identification and selection of potential exposure scenarios for facilities and activities needing simple assessments is a straightforward process. It generally involves the consideration of typical industrial accidents or events leading to environmental releases —such as fires and spillage, and other inadvertent unexpected releases— combined with environmental conditions which tend to overestimate the exposures. For example, for hospitals and small research laboratories, a single or a reduced number of industrial accidents involving the sources and conservative dispersion scenarios should be selected.

5.73. For facilities necessitating complex assessments a greater number and more realistic set of potential exposure scenarios may need to be considered. Since the source terms could be higher and the facilities have more complex technological features, the identification and analysis of potential exposure scenarios may need to be carried out in greater detail. For these assessments, complex safety assessment techniques may be necessary, combining deterministic and probabilistic methods and, in some cases, expert judgement. The IAEA has developed extensive guidance to assist in identifying initiating events of various types for potential exposure scenarios for nuclear power plants [55], research reactors [57] and other types of nuclear facilities [63]. The environmental conditions which need to be included in the potential exposures scenarios for these facilities should be realistic, based in the actual conditions representative for the site.

[19] A single conservative scenario is assumed to be a bounding set of characteristics that may be recognized as representative of a worst case accidental scenario..

[20] Characteristic scenarios are those that can be considered to be a comprehensive representation of the characteristics of the specific facility or activity and the specific location. The scenarios identified as characteristics can be divided into different categories in accordance with their annual frequency or likelihood of occurrence and their consequences. Characteristic scenarios do not necessarily include the worst case scenario which tends to be an over-conservative assumption leading to estimations of unrealistic potential consequences. (For further information see Annex II).

[21] A methodological approach to identifying potential exposures scenarios resulting from a broad range of initiating events and that include a systematic determination of accident frequencies, source terms and environmental characteristics relevant to estimate potential consequences is based on techniques known as probabilistic safety analysis (PSA). Probabilistic safety analysis is normally applied to facilities necessitating complex assessments, such as nuclear power plants, but they could also be applied to simple facilities. More information is provided in [52, 54].

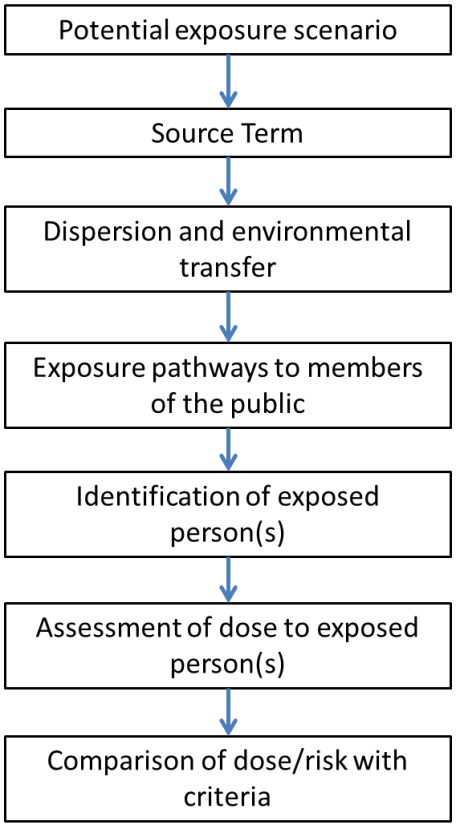


FIG. 4. Components of an assessment for potential exposures.

Source term

5.74. Different options for assessing potential exposures are related to the definition of representative source terms[22]. The following characteristics of the source terms for the assessment of the potential exposures should be considered.

5.75. The types and amounts and the physical and chemical characteristics of radionuclides released during an accident may differ considerably from those for discharges in normal operation. Source terms should be estimated by considering the range of possible releases and by using simple or complex techniques as dictated by the technological complexity of the facility or activity.

5.76. For simple assessments for small facilities, as an initial step, it could be assumed that the entire inventory of radioactive material is released, and the radiological impacts of such a release analysed. In general, this approach is reasonable if the related facilities or activities have relatively small inventories, such as hospitals or research facilities. If the source term for this maximized potential exposure scenario leads to estimated doses that are below the criteria

[22] The details of the process for the identification and selection of potential exposure scenarios and their associated source terms and, when applicable, the associated probabilities are not covered in this Safety Guide. Only general characteristics of the processes for selecting source terms that are relevant for the assessment and for comparison with the criteria are discussed here. For applying this Safety Guide for the purpose of conducting an assessment, it is assumed that adequate information on the source term is already available.

established by the regulatory body, then no further assessment may be needed. If the criteria are exceeded, a more realistic release fraction should be used. However, in this case, the assumptions made should be justified, for example by means of simple engineering assessments to demonstrate that the source terms are more realistic than that obtained with the simple conservative assumptions and that they are not underestimates.

5.77. Some installations may have large radioactive sources but with physical properties that impede releases of large fractions of the inventory to the environment, even under accident conditions. Conservative assumptions should be used where necessary, and engineering analysis should be used where possible to determine the source term for the assessment. If with this conservative source term the predefined criteria are exceeded, a more realistic estimate should be obtained on the basis of detailed safety analysis techniques.

5.78. For facilities, such as nuclear power plants, large research reactors or laboratories, waste management facilities and nuclear fuel reprocessing plants, which have large inventories and where the physical, chemical or nuclear characteristics may facilitate large releases in accident scenarios, detailed safety analysis techniques should always be applied to estimate more realistic potential source terms. Further guidance on accident source term estimations could be found in [57] and [58].

5.79. In estimating more realistic source terms, consideration should be given to the physical and chemical processes occurring during the accident sequence, the behaviour of any safety systems or the effects of any mitigation measures, and the behaviour and movement of any radioactive material in the facility before it is released off site. A time profile for the release should be provided. For example, in accidents at a nuclear power plant, initially noble gas radionuclides may be released to atmosphere followed then by volatile radioactive material and subsequently by other radioactive material in aerosol or particulate form. This time profile to the release may be taken into account by separating the source term into different phases.

5.80. As an indication, the source term should include the composition and amounts of radionuclides, the physical (e.g. gas or aerosol) and chemical form, the release point, the height (for an aerial release) or depth (for an aquatic release). The flow speed and the thermal energy associated with the release may be also necessary to assess the effective height the radioactive plume could reach.

5.81. For the initial assessments, for instance at early stages in a decision or an authorization process (e.g. in an EIA or during siting studies for a nuclear power plant), a reduced number of generic accident source terms may be used, as well as a reduced list of the most radiologically significant and representative radionuclides (e.g. iodine-131, caesium-137, radioactive noble gases, strontium-90). This source term could be based on published data or on experience from safety assessments of similar facilities [55, 58]. Later in the authorization process, the complete set of relevant accident source terms should be more accurately characterized by mean of safety analysis techniques.

Dispersion and environmental transfer

5.82. For simple assessments, conservative assumptions for the meteorological and hydrological data may be made. For example, a uniform wind direction for atmospheric dispersion and little environmental dispersion or dilution conditions at the time of the postulated accident may be assumed. Such assumptions would give conservative results and

avoid the need to obtain site specific data. However, conservative assumptions are not straightforward, e.g. assumptions conservative for inhalation (i.e. that all the releases go to the atmosphere instead of to a river) may be not conservative for ingestion of food produced with irrigation. When different pathways are involved, it might be not so easy to identify the most conservative assumption and a careful compromise should be evaluated.

5.83. If, because of the conservative assumptions which tend to overestimate the doses, the results are above the selected criteria, more realistic representative values for the applicable meteorological and hydrological parameters at the location should be considered. This also applies for more complex assessments. The meteorological and hydrological data are discussed in more detail in paragraphs 5.13 to 5.24 (Note: correct paragr, number at the end) in the considerations of the dispersion and environmental transfer for normal operation.

5.84. For facilities like nuclear power plants, meteorological and hydrological data collected over at least a year should be used to specify characteristic accident dispersion conditions [39, 40]. Site specific meteorological and hydrological data for nuclear facilities is generally collected during the programme for site evaluation; detailed guidance on the type and characteristics of this data is presented in [40]. If the data used for the assessment of normal operation are not sufficiently comprehensive for accident analysis (for instance, if data on the long-range transport of radioactive material parameters in the atmosphere or in aquatic media are missing or if there is only monthly data) more detailed data (including hourly data if necessary) should be obtained from relevant records. Data could also be derived from the analysis of numerical atmospheric or aquatic models.

5.85. An event leading to a potential exposure scenario could occur at any time of day and any day of year. This may influence the characteristics of the dispersion (i.e. due to different hydrological regimes or atmospheric dispersion conditions) and transfer in the environment. For a facilities needing complex assessment, in order to reduce the calculation efforts, the hours of occurrence of the accident could be selected by means of statistical sampling techniques (such as cyclic or stratified sampling). Alternatively, an assessment could be performed by using the full set of annual hourly meteorological data (in all cases, the resulting selected dispersion conditions have to be associated with a frequency of occurrence or a probability). For facilities needing simpler assessments, a single time or a small set of times for the occurrence of the release should be selected, and it should be ensured that the meteorological data for that time are either conservative or characteristic for the site under consideration.

5.86. The season of the year at the time of occurrence of a release can have a significant influence on the estimated concentrations of radionuclides in environmental media and the vegetables. It should be possible to take account of this in the models for the transfer of radionuclides through the environment. For example, the period of growth of a plant, the time of harvest, and water levels and snow levels could have significant influences on the dose estimations.

5.87. Transfer models should be able to predict non-equilibrium conditions. In addition, there can also be significant short-term variations in the source term and meteorological conditions. If there is potential for a large release, models to estimate the transfer and the dispersion of radionuclides in the environment at longer distances (for instance, up to 100 km) should be available. Applicable dispersion models for short term releases and long range transport of radionuclides should be used when necessary to estimate the dispersion and distribution in the environment of radionuclides [8].

5.88. As is the case for discharges in normal operation, for complex assessments conducted at an early stage of a decision or authorization process, the dispersion and transfer to the environment during accidental releases can be estimated using simple conservative models and meteorological and hydrological data generic to the region (from published data or from records from the closest meteorological and hydrological stations). Subsequently, data from measurements conducted on or very close to the site considered or data from numerical meteorological and hydrological models would normally be available, as the acquisition of such data is normally required during the site evaluation and construction stages [40]. Site specific data should be used to characterize the environmental dispersion conditions for the selected location [39, 40].

Exposure pathways to members of the public

5.89. The exposure pathways that are major contributors to the dose from accidental releases may be very different from those for normal operation. For example, consumption of fresh milk or vegetables immediately following an accident at a nuclear power plant could be an important pathway for exposures due to short lived iodine radionuclides. Care should therefore be taken in the adequate identification of the exposure pathways and in their modelling.

5.90. An indicative list of exposure pathways relevant for potential exposure scenarios which should be considered in the assessment is given below:

(a) External irradiation due to deposition on skin;
(b) External irradiation from the source;
(c) External irradiation from the plume;
(d) Inhalation from the plume;
(e) Inhalation of resuspended material;
(f) External irradiation due to deposition on the ground or other surfaces;
(g) Intakes of radionuclides due to the inadvertent ingestion of radioactive material deposited on ground or other surfaces; and
(h) Intakes of radionuclides due to the consumption of fresh and processed food and water.

5.91. Depending on the assumptions defined for the assessment, the exposure due to ingestion of contaminated food may be reduced or avoided due to the immediate implementation of protective actions. Other exposure pathways, such as inhalation, external irradiation, may also be significantly reduced if countermeasures are considered as hypothesis for the assessment. The exposure pathways and the assumptions of countermeasures should be clearly indicated when reporting the results of the assessment.

5.92. In an initial assessment, for example during a decision process or at the early stages of an authorization process, the exposure pathways that are known to typically dominate accident scenarios can be selected (i.e. external irradiation from the plume and exposure due to deposition on surfaces, deposition on skin, inhalation, milk consumption, etc.) and the data on habits can be conservatively estimated using national or regional statistics. Subsequently, exposure pathways and habit data should be based on site surveys.

Identification of exposed persons

5.93. The actual or hypothetical persons likely to be exposed in accident conditions should be identified for the consideration of potential exposures [59]; these may be different from those identified as representative persons for normal operation.

5.94. Different exposed population groups may be identified, depending on the characteristics of the accident or event and the time of day or year of the postulated release, in accordance, for instance, with the prevailing meteorological or hydrological conditions, possible temporary occupation factors (i.e. different occupation during day and night, existence of summer campsites and schools, presence of workers near the facility) and seasonal effects in the habits and food products.

5.95. For simple assessments or in the initial phase of complex assessments, the potential exposures could be assessed for a representative person or a population group in the area identified as most potentially affected. Later, for complex assessments, the exposed persons for consideration of potential exposures should be identified by using site specific information where available. Care should be taken when defining the population group to be considered for comparison with the criteria, since the potential exposures can be influenced by the possible implementation of protective actions and countermeasures. The assumption to include or not countermeasures into the hypothesis for the assessment should be defined in conjunction with the definition of criteria. . These assumptions should be clearly indicated and considered when comparing the results of the assessment with criteria.

5.96. The endpoints of the assessment of the potential exposures could change, depending on the type of the assessment and the criteria defined to consider potential exposures. For instance, instead of the concept of the most exposed persons, a specific location (for example the nearest town in the region), fixed distances (for example, 1 km, 5 km or 10 km) or a distance where certain projected dose is exceeded (for example, 10 mSv or 50 mSv) can be used for the consideration of potential exposures. In some States specific individual persons or groups of persons are selected while in others the distribution of doses or risks among larger affected population is taken into account. Though there could be flexibility on the ways to consider potential exposures, and different States can adopt different options, the endpoints and the criteria should be clearly defined and justified to avoid misunderstanding and misinterpretation of the results.

Assessment of dose to the exposed persons

5.97. In an assessment for potential exposures, mean absorbed doses to the organ or tissue, weighted by an appropriate relative biological effectiveness (RBE) for the biological endpoint of concern (for doses in the range for deterministic effects) and the effective dose (resulting from the sum of the committed effective dose from internal exposure pathways and the effective dose from external exposure, for doses in the range of stochastic effects) should be calculated. Equivalent dose to certain organs (e.g. thyroids) can also be used for consideration of potential exposures.

5.98. If the probabilities determined in the specification of the source term and in the meteorological distribution are analysed, the dose can be converted into an indication of the risk of health effects by means of risk coefficients provided, for example, by ICRP [60] (see Annex II for more details). The use of an indication of risk should be applied on the basis of national practices and regulations.

5.99. Different age groups should be given due consideration when assessing for protection of the public from potential exposures owing to the differences in the exposure conditions and in the associated radiation effects. The consideration of age groups should be carefully examined during the assessment. Experience has shown that infants are more exposed via some pathways, such as irradiation of the thyroid gland due to the incorporation

of radioactive iodine isotopes, which could potentially be released in a nuclear reactor accident.

5.100. The relevant time periods over which exposures could occur and the relevant exposure pathways should be defined. For example, doses due to inhalation in the first 24 hours (mainly due to passage of the plume) or doses due to the ingestion of green vegetables over a three month period could be used as indicators of the main potential radiological impacts. In other cases, doses over longer periods could be estimated; for instance, from the time of an accident to one year afterwards. When comparing these with criteria, the time periods and exposure pathways under consideration should be indicated in the results.

Comparison of dose/risk with criteria

5.101. The BSS require that the likelihood and magnitude of potential exposures be considered and that restrictions be established by the regulatory body[23]. For consideration of potential exposures—that uses as endpoints a 'dose' or a 'measure of the risk' of health effects— the restrictions established by the regulatory body should be in terms of a dose or risk criterion, as relevant.

5.102. For activities or facilities needing a simple assessment and using a conservative exposure scenario for consideration of potential exposures (i.e. installations with small inventories and sources with low potential for releases), a dose due to the defined conservative scenario is normally estimated and doses of 1 to a few mSv should be used as the decision criteria. For example doses in the range of 1-5 mSv could be adopted as the range for establishing the criterion.

5.103. The International Nuclear Safety Group (INSAG) [51] and the ICRP [60] discussed possible risk criteria for potential exposure of members of the public which could be used by the regulatory body as the basis to define the national criteria. Ref. [51] states that for members of the public it seems to be appropriate that a risk for potential exposure, expressed as the annual probability of death attributable to a single installation[24], should not exceed 10^{-5}. Ref. [60] recommends that for the treatment of potential exposure, the risk constraint should be of the same order of magnitude as the health risk implied by the dose limits for normal releases exposures. Ref. [60] illustrates with a range of probabilities in a year which may be used to define risk constraints; for severe accidents with some deterministic consequences or when severe health effects are likely, the maximum probabilities should range from 10^{-6} to 10^{-5} per year. More detailed information on criteria for consideration of potential exposures is provided in Appendix I and discussed in Annex III.

5.104. The regulatory body should establish a risk constraint [1, 5]; this could be based on INSAG [51] or ICRP [60] guidance. Some examples or risk criteria used by States can be found in Annex III. The definition and use of risk constraints are more discussed in [5].

[23] Requirement 9 of the BSS (paragraph 3.15) indicates that the number of affected people shall be assessed but this safety guide limit the scope to individual effects.

[24] Some sites could have multiple units and even multiple operators which, in some cases, could involve the same exposed persons and this would be considered when establishing the criteria.

5.105. When for a nuclear facility characteristic exposure scenarios are used to consider potential exposures, a dose corresponding to a potential exposure scenario or a reduced set of scenarios is normally estimated. In that case, the criteria should be defined in terms of dose. For example a dose in the range 10-50 mSv could be used. Different values for the dose criteria could be defined within that range considering the different annual frequencies of those characteristics scenarios; i.e., for accidents with higher frequencies the dose criteria should be lower than for the accidents with very low frequency. Although the endpoint and the criteria of this type of assessment are in term of doses, owing to the fact that some frequencies are involved, there is an implicit notion of risk and the results can be related to the criteria discussed in Appendix I. This is more discussed in Annex III.

5.106. Another option may be to express the criteria qualitatively, in terms of 'a consequence to the public that would be unacceptable'. For instance, a criterion should be that very disruptive countermeasures —like large evacuation or relocation— as a result of the potential accident scenarios specified for the facility or activity would not be acceptable. Although this is in principle a qualitative criterion, the need of these countermeasures should be determined using estimations of projected doses (or related operational magnitudes) and comparing these estimations against emergency response decision numerical criteria. If this approach is used, the regulatory body should define the decision criteria for countermeasures to be used for the assessment of the potential exposures in line with the requirements in [14]. Examples of use of those decision criteria for countermeasures are available in [6].

5.107. Different criteria may be set for facilities and activities with varying levels of inventory and technological complexity. The criteria should also reflect the level of conservatism required for the analysis based on the severity of the potential exposures. For instance, the regulatory body may specify one set of criteria for the nuclear fuel cycle and another set of criteria for hospitals or small laboratories.

5.108. When considering transboundary impacts the criteria used for the consideration of potential exposures in other States should be in line with the criteria discussed in this safety guide and, in principle, may be the same used in the State where the facility or activity is located.

VARIABILITY AND UNCERTAINTY IN THE ASSESSMENTS

5.109. Uncertainty reflects the state of knowledge about the system being investigated and relates to how accurately the doses or the risk can be estimated. The main sources of uncertainty arise from the incomplete knowledge of the exposure condition of the representative person and on the variability of model parameters. Variability includes both, variations in the transfer of radionuclides in the different environments and for the case of humans, variations in living habits among individuals within a group as e.g. the food intake and the time spent indoors and outdoors. When defining the methodology, including the criteria, the regulatory body or the applicants of the facility or activity, as appropriate, should consider the aspects related to variability and uncertainty (some aspects are discussed in the following paragraphs).

5.110. Sensitivity analyses techniques can be useful for identifying important parameters for determining the overall impacts and should be applied when possible.

5.111. In general, an assessment provides a single result for each endpoint — for example, the dose to the representative person. This type of analysis is called deterministic analysis and

is generally being based on reasonable conservative assumptions. For instance the assessment could use conservative assumption with regard to the exposure scenario and mean value for the model parameters. The distribution of the resulting doses can be estimated e.g. by means of statistical methods, as Monte Carlo calculations, using the frequency distributions of the model parameters as input for the dose assessment. Model uncertainties should be addressed properly to facilitate the decisions by the governmental agencies and the regulators and the communication with other stakeholders, like the public.

5.112. The assessments as described in this Safety Guide tend to be conservative by nature, in order to avoid underestimating the impact to the public and the environment. If the doses calculated are small fractions of the dose constraints, simple conservative methodologies could be considered sufficient. When the doses estimated conservatively are closer to the criteria or the decisions to be made with respect to the technology could have a high impact on the level of investment, the regulatory body should decide whether more detailed methodologies, including, for instance, the use of site specific data, are necessary to increase the realism in the assessment.

5.113. The level of uncertainty in the assessments of facilities and activities for protection of the public and the environment should still ensure that the actual doses to members of the public do not exceed the dose limits set by the national regulatory body. Ref. [41] suggests that statistical methods and models could be used when assessing doses, noting that the parameter values and other data (habit data and dose coefficients) used in environmental models are usually represented by distributions, and provides examples on how these distributions can be chosen, as well as information on how to carry out calculations using these distributions and also on how to interpret the results. In general, for environmental parameters single recommended values in bibliography [10, 11, 46] or average measured values, when available, should be used.

5.114. For assessments using single values of habit data, high percentiles in some of the habit data distribution could be used (for instance, in particular food consumption rates); for assessments considering the distribution of the habit data, the resulting dose in the 95% percentile should be used to be compared with the established criteria.

5.115. The establishment of environmental monitoring programmes, once the installation is operating, would provide confidence that the predicted doses are reasonable and do not underestimated real doses.

5.116. If insufficient information or data is available then a conservative estimate should be used but sensitivity studies should be carried out to determine how important an individual assumption is in determining the overall risk. It should be avoided to combine many conservative assumptions and arrive at a result for the impact that is grossly pessimistic.

5.117. In addition to environmental dispersion and transfer uncertainties, unknown and/or complex interactions between individual organisms and populations of species in an ecosystem may affect flora and fauna in uncertain ways. However, if the increments of exposures are within the variations of the natural background doses and the exposed group of plants and animals is a small fraction to the total population, this source of uncertainty is of minor importance. In most situations related to normal operation of facilities or activities, the resulting dose rates would be significantly low when compared to dose rate levels where radiological effects on biota are expected and the increment of the level of exposures only affect a small number of individuals locally.

5.118. Addressing variability and uncertainty during the assessment of potential exposures is more complex. Reasons for this complexity include:

(a) Selection of potential exposures scenarios: The scenarios selected may not be representative of what might actually happen and the list might not be complete, e.g. some types of scenario may have been overlooked.
(b) The probability or frequency of the scenarios: Conservative analysis seeks to avoid the issue by assuming certain bounding representative initiating events and system failures occur. If, for example, probabilistic safety analysis techniques are used to estimate accident frequencies, these frequencies are determined by combining many other frequencies and failure probabilities all with their own uncertainties and so are usually subject to quite large uncertainties.
(c) Unlike exposures resulting from normal releases, which usually occur more or less continuously and can be averaged over a year smoothing out fluctuations, exposures due to potential releases will usually be short and the impact will be dependent on actual conditions as e.g. the weather and the location of members of the public.
(d) Unlike the estimations of exposures resulting from normal releases, which can be validated retrospectively by means of the environmental monitoring programmes established during the operational stage, this is not possible for potential exposures.

5.119. Sensitivity studies could be carried out to determine how sensitive the overall result is to any source of uncertainty. The overall result could be sensitive to one or several parameters and assumptions on the underlying exposure scenario. Further research, modelling, or experimental data collection may need to be carried out, if the reduction of the level of uncertainty is deemed to be necessary.

APPENDIX I.
CRITERIA FOR CONSIDERATION IN THE ASSESSMENT FOR PROTECTION OF THE PUBLIC AGAINST POTENTIAL EXPOSURE

I.1. Appendix I presents criteria, as discussed by relevant international organizations, which could be used as guidance for national regulatory bodies. The criteria discussed in this Appendix are for health effects to individual members of the public. Other types of effects related to accidental situations with large releases to the environment, like social, economic and environmental implications, are out of the scope of this Safety Guide (as it was explained in Section 5)

I.2. Risks of health effects to members of the public may arise from potential exposures related to accidental releases of radioactivity. Annex III presents definitions of measures of risk which can be used in the potential exposures assessment. National authorities should be responsible for setting criteria for potential exposure since the appropriate value may vary according to the prevailing legal, economic and social conditions [61]. International schemes which could be used to define national approaches for criteria for potential exposures are summarized and discussed below.

INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP

I.3. The International Nuclear Safety Advisory Group (INSAG) considered safety goals for potential exposure (INSAG 9) [51] making the following statements for individual risk to a member of the public:

> "It seems appropriate that for members of the public a risk for potential exposure, expressed as the annual probability of death attributable to a single installation, should not exceed 10^{-5}."
>
> "…it seems reasonable to expect that accidents that require simple, local countermeasures" [dose to most exposed member of the public of 10–100 mSv] "should have an annual probability of not more than about 10^{-4}."
>
> "An annual probability of such an accident" [more severe accidents with a dose to most exposed member of the public of 1 Sv] "of 10^{-5} is likely to be required because of the societal consequences."

I.4. The annual probabilities for the last two criteria — accidents leading to effective doses of 10-100 mSv and 1 Sv — are lower than would be implied by the first criterion of the annual probability of death of 10^{-5}, given the currently accepted value of approximately 0.05 for the probability of death per Sv for members of the general population; this accounts for the fact that for accidents giving rise to larger doses, there will be consequences additional to those of the radiation exposure such as those due to the implementation of countermeasures.

I.5. Risk targets from INSAG 3 [62] are quoted: a severe core damage frequency of less than 10^{-4} events per year for existing nuclear power plants which with the application of all safety principles should be not more than 10^{-5} events per year for new nuclear power plants. Severe accident management and mitigation measures should reduce by a factor of at least ten the probability of major external radioactive releases requiring off-site response in the short term. It states that this would correspond to an individual risk of death for a member of the public of much less than 10^{-5} per plant operating year for existing and 10^{-6} for new plant.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

I.6. The International Commission on Radiological Protection (ICRP) has recommended that for the treatment of potential exposure, the risk limits should be of the same order of magnitude as the health risk implied by the dose limits for exposures [60]. It adds:

> "One procedure for applying source-related constraints is to express the probability of an event sequence as a function of the dose that will be delivered should the sequence actually occur. Such a constraint would express the maximum probability that can be permitted from sequences exceeding a given magnitude of dose."

I.7. Such a scheme is proposed and is reproduced in Table 3. For complex systems, similar sequences should be grouped adding their probabilities and taking the worst consequence from any individual sequence to represent the group as a whole. ICRP states that the values in Table 3 are intended to illustrate the types of constraint that might be imposed based on experience taking into account the benefits derived from the particular practice. It adds that the values might also be imposed as tentative constraints in the absence of operating experience, subject to revision as experience is gained and in such cases the constraints may be regarded as upper bounds. ICRP emphasizes that these constraints refer to potential exposure of an individual.

TABLE 3. RANGE OF PROBABILITIES IN A YEAR FROM WHICH CONSTRAINT MAY BE SELECTED [60]

Impact	**Probability Range**
Sequences of events leading to doses treated as part of normal exposures	10^{-1} to 10^{-2}
Sequences of events leading to stochastic effects only but above dose limits	10^{-2} to 10^{-5}
Sequences of events leading to doses where some radiation effects are deterministic	10^{-5} to 10^{-6}
Sequences of events leading to doses where death is likely to result	$< 10^{-6}$

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ANNEX I.
CONSIDERATIONS ON ASSESSMENTS FOR PROTECTION OF THE ENVIRONMENT

I-1. IAEA has established fundamental principles that include a principle for protection of the environment [I-1]. In accordance with ICRP [I-2, I-3, I-4], the aims of environmental protection are to prevent or reduce the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities, and ecosystems. IAEA [I-1] establishes a safety principle requiring the protection of ecosystems against radiation exposure that would have adverse consequences for populations of a species (as distinct from individual organisms).

I-2. Due to the complexity in the interaction of different species, radiological effects on ecosystems exposed to very low increments of the levels of radiation are very difficult to be modelled and predicted. In most of the cases related to the operation of facilities and the conduct of activities, and particularly during normal operations, the increment in the radiation levels in the environment to which populations are exposed, is comparable with the variations on the natural radiation background.

I-3. Conclusions on the radiological impacts on populations of species and ecosystems, which can be applied prospectively to manage radioactive sources in planned exposures situations, could be extrapolated from the assessment of the exposures of a reduced number of individual organisms of a species, used as a reference.

I-4. ICRP selected species that can be considered to be representative of particular ecosystems (marine, terrestrial, freshwater) and have a wide geographical variation as well as considering their potential use in a pragmatic manner [I-3]. In the selection of this set, consideration was taken on which species would be more affected due to the exposure of internal and external radiation owing to the presence of activity concentration in the environmental media.

THE REFERENCE APPROACH FOR RADIOLOGICAL PROTECTION OF FLORA AND FAUNA

I-5. A pragmatic approach to assess the effects of radiation on flora and fauna is to model the exposures of reference animals and plants and consider the existing information on radiation effects. This approach [I-3, I-4] is consistent with the approach used for humans [I-2].

I-6. In the system of radiological protection for humans a model called ‘the reference person’ [I-2] and the methods to calculate its doses, is used in the assessment of the radiological impact to members of the public. In a similar manner, for protection of the environment, a small set of reference animals and plants (which similarly to the reference person are models) and methods for their dosimetry can be used to assess the impact to flora and fauna. A reference animal or plant is a hypothetical entity, with the assumed basic biological characteristics of a particular type of animal or plant, as described to the generality of the taxonomic level of family, with defined anatomical, physiological, and life history properties that can be used for the purposes of relating exposures to dose, and dose to effects, for that type of living organism [I-3, I-4].

I-7. Dosimetric models of the reference person are applied to the calculation of doses for a representative person and compared to a reference criterion. The habits used to characterize the representative person, including its location, are typical habits of a number of individuals representative of those most highly exposed, and not the extreme habits of a single member of the population [I-2]. Recently ICRP has defined the concept of 'representative organisms'. Consistently with the concept of representative person, the representative organisms should represent those animals and plants with habitats at and near the area that are most affected by the releases from the facility or activity. The representative organism is a particular species or group of organisms selected during a site specific assessment, taking account of their assumed location with respect to the source [I-4]. For the case of a generic assessment, as described in this Safety Guide, the IAEA indicates that the representative organism should be the ICRP reference animals and plants, located at or near the area where the exposure conditions lead to the highest doses.

AREA WHERE MOST HIGHLY EXPOSURES TO FLORA AND FAUNA ARE OBSERVED

I-8. To define the most highly exposed flora and fauna for generic assessments of radiological impact, the typical spatial distribution of radionuclides in the environment under planned exposures situation should be considered. In general, activities and facilities in normal operation can be considered as point sources with steady-state or semi steady-state releases and, in most cases, the highest activity concentrations in air, soil, water and biota, averaged along the year, are normally found within the first 10 km from the sources. The activity concentrations in the environment decrease significantly with the distance from such highest concentrations. This typical behaviour of materials released from a point source to the environment is illustrated in Figure I-1, for atmospheric and aquatic dispersion.

I-9. Due to the annual distribution of wind directions and, in some cases, the directions of the water flows in rivers, lakes and oceans, the highest activity concentrations could be detected in any direction within a radius of up to 10 km. Therefore, reference area of approximately 100–400 km^2 located around the release point is indicated by the IAEA for generic assessments, as described in this safety guide. The location of this area would ensure that highest environmental activity concentrations due to normal releases are found within that area used for the estimation of doses. Consequently, the plants and animals within that area would normally receive the highest radiation doses. The reference animals and plants located in that area around the release point, where the highest environmental activity concentrations are observed, can then be used for a generic assessment of the protection of the environment.

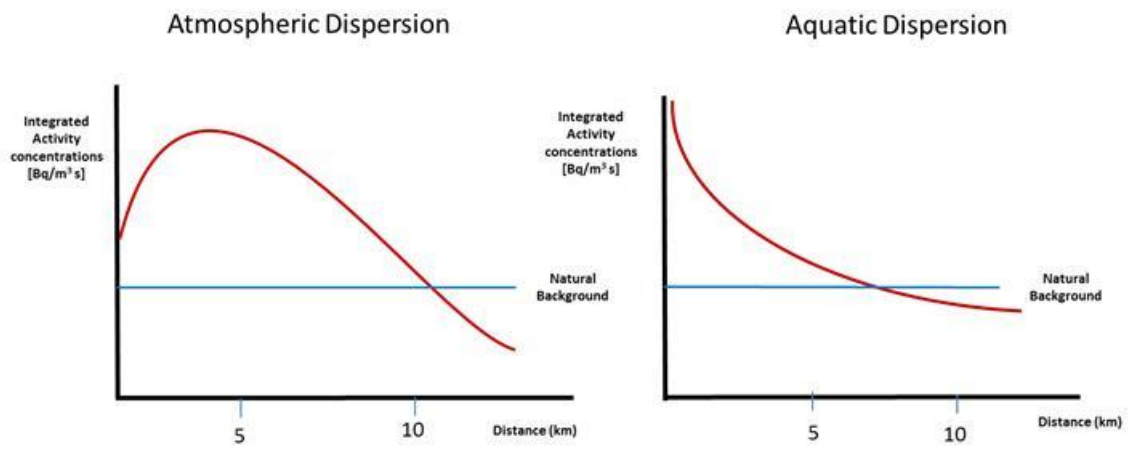

FIG. I-1. Typical patterns of environmental concentrations as a result of atmospheric and aquatic dispersion from a steady point source during normal releases from activities and facilities.

I-10. An area of 100-400 km^2 around the source[25], used to consider flora and fauna when performing radiological environmental impact assessments, is sufficiently large to ensure that mixing of the effluents with the environmental media occurs and that the number of individuals considered for the assessment is suitably large to ensure that the estimated doses and representative of those to the fraction of the population most highly exposed. The doses which are characteristic can be obtained using the average activity concentrations in that area, in the different environmental media which are relevant for the internal and external exposures pathways, for each reference animal and plant under consideration.

CRITERIA FOR FLORA AND FAUNA

I-11. For evaluating levels of radiological impact to populations of flora and fauna, ICRP introduced criteria in the form of derived consideration reference levels for the set of reference animals and plants [I-3]. Derived consideration reference levels are based on the existing database on effects of radiation. Derived consideration reference levels are presented as bands which span an order of magnitude.

I-12. Whereas for protection of humans radiological criteria are used to control stochastic effects for individuals, the derived consideration reference levels correspond to stochastic and deterministic effects observed for individual animals and plants (e.g. early mortality, some forms of morbidity, effects on reproduction, induction of chromosomal damage) which could have an impact in the structure of the population of a species.

I-13. Detectable effects in some single individuals of a population would not necessarily have consequences for the population as a whole [I-3]. For very low increments of doses at the local level (as that resulting during normal operation of activities and facilites), impacts at the level of population can hardly be observed [I-3]. Insofar, the use of reference animals and plants in combination with derived consideration reference levels as described in this safety

[25] This area could be either a circle of about 5–10 km radius or a box of 10–20 km side, both centred at the release point.

guide can be considered as a very cautious approach, based on the current level of information and knowledge. Therefore, a level of protection established by setting criteria below or equal to the lower band of the derived consideration reference levels is to be considered high level of protection for flora and fauna.

I-14. Because derived consideration reference levels are not defined as limits, the estimated doses could result within the band or even above the bands and the radiological situation can still be considered acceptable taking into account different factors. Factors which should be considered when making decisions based on impacts to flora and fauna and the estimated doses are above the bands are: the size of the area where the dose rates are assessed to occur, the time period predicted for such dose rates, the need to comply with a specific legislation, the type of managerial interest, the presence of additional environmental stressors, whether or not the assessment is related to actual species or generalized to plants and animals types, the degree of precaution considered necessary [I-3].

REFERENCES TO ANNEX I

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ANNEX II.
CONSIDERATIONS IN THE ASSESSMENT OF POTENTIAL EXPOSURE OF THE PUBLIC

INTRODUCTION

II-1. This annex refers to the assessment of facilities and activities to consider potential exposures for protection of the public. The Fundamental Safety Principles [II-1] states that "Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents"[26]. Since it also establishes that 'safety' means the protection of people and the environment against radiation risks, there is a clear requirement to assess and control the impact from potential exposures on people and the environment.

II-2. The estimation of radiation dose[27] to the public resulting from postulated incidents or accidents, in terms of the effective doses, combined with a health risk coefficient can be interpreted as the risk that detrimental health effects will materialize. A generic risk coefficient for stochastic effects on humans which can be used in this type of assessments is 5×10^{-2} Sv^{-1} [II-3].

II-3. The risk due to the unplanned or accidental releases of radionuclides to the environment from some facilities and activities[28] is an important factor to be considered when assessing potential exposures. The risk due to potential exposures is controlled starting from the design of facilities and activities, e.g. by adding a multilevel system of sequential, independent provisions for protection and safety (defence in depth) that is commensurate with the likelihood and the magnitude of the potential exposures [II-3].

II-4. Radiological risks (see definition in the next section in this Annex) due to installations which potentially may release radionuclides to the environment during accidents can be estimated. The BSS requires that the risk must be assessed and controlled (constraint). One option could be that, for consideration of potential exposure, the risk constraints should be of the same order of magnitude as the health risk implied by normal operations (see Appendix I and Ref. [II-4, II-5]. To put this into perspective, a typical risk due to normal operations of nuclear installations, based on generalizations about public exposures, can be estimated as an order of magnitude of 10^{-5} per year, assuming that annual doses to the public are in the order of 10^{-3} Sv.

II-5. The estimation of potential exposures requires the assessment and quantification of the impact of accidents or events that might happen with very low probability. Generally — and certainly in the case for facilities like nuclear power plants and reprocessing plants — there will be a whole spectrum of possible potential exposure scenarios, ranging from those with

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[26] Fundamental Safety Principles [II-1] states that: Incidents includes initiating events, accident precursors, near misses, accidents and unauthorized acts (including malicious and non-malicious acts), as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.

[27] IAEA Safety Glossary [II-2] defines effective dose equivalent as a measure of dose designed to reflect the risk associated with the dose, calculated as the weighted sum of the dose equivalents in the different tissues of the body. The definition of effective dose equivalent is superseded by effective dose.

[28] A large number of activities and facilities have potential of only minor or negligible radiological consequences even under accident scenarios owing to very limited inventories or the intrinsically safe characteristics of the sources.

little or no impact to those with a very high potential impact. Accident scenarios with a high radiological impact could be postulated by, for example, assuming that every single safety feature in the facility fails simultaneously. Since the likelihood of such extreme scenarios is very low, it seems clear that the probability or frequency of occurrence must be taken into account for the postulated accidents with large radiological impacts. Accident scenarios could result also from the interaction of safety failures and the impact of severe external events like tornadoes and earthquakes.

DEFINITION OF A MEASURE OF RISK

II-6. A term that is often introduced to express a combination of an impact of an event or scenario and the likelihood of that impact is 'risk'. Various schemes have been developed to quantify its combination and thus, allow the risk or risks of various events to be directly compared. Confusion can arise between this term with a defined meaning and mathematical definition, and the everyday meaning of the word 'risk' which can be synonymous of hazard.

II-7. The BSS [II-3] defines 'risk' as "multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual or potential exposures". It relates to quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences.

II-8. As explained in the main text of this safety guide, when using a methodological approach for assessing the impact of potential exposures, for each potential exposure scenario, a consequence (e.g. a dose to representative person) and the associated probability of that consequence has to be determined.

II-9. For radiation safety purposes it could be useful to define a single mathematical definition of a measure of individual health risk[29] [II-6]. Since the consequence of a radiation dose can be expressed as the increased probability of health effects (for example death from early cancer)[30], an indication of the risk can be evaluated by combining the probability of the scenario i occurring (p_i) and the probability of the health effects if it occurs (C_i).

$$R_i = p_i \times C_i \tag{II-1}$$

where R_i is the risk of health effect due to potential exposure scenario i.

II-10. If the events are mutually independent and the probabilities of the events are low, the risks of all the potential exposure scenarios could then be added to give the overall probability of health effect to the representative person:

$$R = \sum_i \; p_i \times C_i \tag{II-2}$$

[29] The definitions of 'risk' described in this Annex can only be interpreted as giving an indication of the risks, owing to the many uncertainties involved in a probabilistic safety analysis as it was described, in the estimation of the possible exposures and in the quantification of the associated radiological consequences.

[30] To be more precise, the probability of the health effect can be estimated using the dose response function, f(D), which changes with the level of dose. The risk of early health effects can also be calculated using hazard functions, taking into account the variation of risk with the rate at which dose is accumulated over a certain period (e.g. the first day or few days following the accident). The risk of late health effects can consider not only fatal but non-fatal cancers in different organs, leukaemia and heritable effects. The details of these considerations are out of the scope of this Annex which should be considered as introductory to the topic.

II-11. As discussed in the previous paragraphs, the risk estimated within an assessment as described in this safety guide apply to an individual (the exposed person or representative person for potential exposures). For large facilities such as nuclear power plants which may potentially affect many individuals and which could cause other impacts as e.g. evacuation and restriction of land use, possible societal risk could also need to be quantified and assessed against a criteria. However, the consideration of societal risk is not included in the present guidance and is subject to the national approaches.

II-12. Criteria which could be used for the consideration of potential exposures are presented in Appendix I of this Safety Guide based on [II-7] and [II-4].

PRACTICABLE APPLICATIONS TO CONSIDER POTENTIAL EXPOSURES

II-13. As discussed in the Section 5, this Safety Guide presents the generalities of three possible ways to assess potential exposures:

a) by selecting a conservative potential exposures scenario, including conservative assumptions for the source terms and environmental conditions (named here as a 'conservative approach'); or
b) by estimating a characteristic or a set of characteristic potential exposures scenarios, including characteristic source terms and environmental conditions considered representative of the safety characteristics of the facility and the environmental conditions of the site (named here as a 'characteristic approach'); or
c) by identifying potential exposures scenarios, using a methodological approach and estimating a set of potential source terms and environmental conditions both with their probabilities (named here as 'probabilistic approach').

In all three cases, the assessment of the potential exposures include the estimation of the associated doses to a representative person[31] defined for the above mentioned potential exposures scenarios.

II-14. In the first two cases — (a) and (b) — a single accident or a reduced set of accidents predefined accidents are used to estimate a dose. In the last case — (c) — a full set of accidents are selected with probabilistic techniques based on the analysis of the response of the safety systems and the environmental conditions are selected too considering the probabilities; combining the probabilities of the accidents, the probability of the environmental conditions and the probability of health effects as a function of the dose, the consequences are estimated in the form of a measure of risk.

II-15. In the conservative approach, a conservative source term is generally defined without considering or estimating the probability of occurrence and is associated with the assumption that the dispersion and transfer to the environment are also conservative. The resulting dose cannot be considered as basis to calculate an indication of the risk. Though, when the resulting dose is small (e.g. up to a few mSv), the analysis allows to conclude that the potential exposures are acceptable, irrespectively of the probability of occurrence. This type of analysis is typically applicable to activities and facilities with small total inventories (e.g.

[31] The representative person for potential exposures is typically different from the representative person for normal controlled releases.

hospitals and laboratories) or with sources intrinsically safe (e.g. sealed low-dispersible sources).

II-16. In the characteristic approach a dose is estimated for each source term, which is selected considering predefined accidents with certain annual frequencies, resulting from safety analysis, and then it is compared to a dose criterion. Usually, different dose criteria are considered for the different annual frequencies; i.e., for accidents with higher frequencies the resulting potential exposures must be lower than for the accidents with very low frequency. The assumptions in the environmental and transfer conditions are also selected as characteristic for the site under consideration, based on the analysis of meteorological and hydrological data. Although the endpoint of this assessment is also a dose, owing to the fact that some frequencies are involved in the selection of the characteristic accidents, there is an implicit notion of risk and the results can be related to the criteria discussed in Appendix I.

II-17. In the probabilistic approach, a larger set of source terms and their associated annual frequencies are combined with probabilities related to dispersion and transfer of radionuclides in the environment[32] for obtaining a distribution of doses with the associated probabilities. The result is normally expressed in terms of a measure of the risk of health effects and the criteria are also expressed as a reference risk. The following section discusses further the general features of the probabilistic approach.

BASIC ASPECTS OF THE PROBABILISTIC APPROACH

II-18. In this probabilistic approach, frequencies of initiating events are estimated and the possible fault sequences (or a representative sub-set) that encompass the responses of plant and safety systems, including human operators, are determined. The overall probability or frequency of the fault sequence or scenario is calculated by combining the frequency of the initiating events with probabilities of each failure of event in the sequence. The use of probabilities and frequencies implies a definition of a period of time which can be selected arbitrary in order to perform the analysis. A period of one year is usually selected.

II-19. Then, the source term for each sequence is calculated. In some cases a reduced number of source terms encompassing similar source terms may be used for a set of fault sequences to reduce the calculation required.

II-20. The dose to the most exposed individual or individuals are then calculated by using a set of meteorological conditions and other environmental transfer conditions along with the probabilities of these conditions applying along with factors that affect the dose and their probabilities. For a given source term and target, one would need to include: for example, the probability that the wind was blowing from the source to the target, the probability of other meteorological conditions such as stability, wind speed and rainfall, the probability that the person is outdoors or indoors, and so on. These probabilities are estimated based on the set of data for the location.

II-21. The doses obtained are combined with the probabilities of those doses being incurred (which results from combining the probabilities of the overall probability of the accident scenario and of the environmental conditions) to give an indication of risk which is then

[32] The environmental transfer probabilistic properties are determined, for example, by the wind rose frequencies and the frequency of atmospheric dispersion stability classes observed during the year.

compared with criteria[33].

[33] This methodology to consider potential exposures is known as probabilistic safety analysis Level 3.

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ANNEX III. EXAMPLES FROM STATES

EUROPEAN UTILITY REQUIREMENTS (LWR NUCLEAR POWER PLANTS ONLY) FOR NORMAL OPERATION AND ACCIDENT CONDITIONS

III-1. In 1991 the major European electricity producers formed an organization to develop the European Utility Requirement (EUR) document [III-1]. This document proposes a common set of utility requirements for the next generation of LWR nuclear power plants. Prior to these requirements, the development, design and licensing of existing LWR plants had been performed on a national basis with little interaction between countries.

III-2. The EUR document sets common safety targets which are consistent with the best European and international objectives. It states that these targets are values that are more restrictive than regulatory limits but are judged to be at a level that can be reasonably achieved by modern well-designed plants. Targets are set for normal operation, incident conditions, and accident conditions. For the preliminary design assessment, EUR has proposed criteria in terms of radionuclide releases rather than doses to members of the public. The targets are generally defined as linear combinations of the releases in each of the reference isotopic groups and depend on the category of the accident as determined by the estimated frequency of the initiating event. The detailed methodology can be found in [III-1].

APPROACH FOR POTENTIAL EXPOSURES IN THE UNITED KINGDOM

III-3. The United Kingdom nuclear safety regulator has issued Safety Assessment Principles which provides guidance to set numerical targets for potential exposures [III-2,III-3]. Table III-1 below summarizes the guidance on numerical targets applicable for off-site releases. These figures are termed basic safety levels which represent a level that it is considered a new facility should meet; basic safety objectives are set more stringent, for instance at lower levels (generally a factor of 100 lower) and mark the start of what is considered broadly acceptable. There are also targets for workers on-site.

TABLE III-1. NUMERICAL TARGETS FOR POTENTIAL EXPOSURES OFF-SITE IN THE UNITED KINGDOM

Target	**Applicability**	**Numerical values (Basic Safety Level)**	
Target 4	Design Basis fault sequences	1 mSv for initiating fault frequencies exceeding 1×10^{-3} pa 10 mSv for initiating fault frequencies between 1×10^{-3} and 1×10^{-4} pa 100 mSv for initiating fault frequencies less than 1×10^{-4} pa.	
Target 7	Individual risk of death from accidents	1×10^{-4} pa	
Target 8	Frequency-dose targets (all accidents)	Effective dose, mSv 0.1–1 1–10 10–100 100–1000 > 1000	Total predicted frequency pa 1 1×10^{-1} 1×10^{-2} 1×10^{-3} 1×10^{-4}
Target 9	Total risk of 100 or more fatalities (immediate or eventual)	1×10^{-5} pa	

APPROACH TO POTENTIAL EXPOSURES IN ARGENTINA

III-4. The Argentine Nuclear Regulatory Authority (ARN) has defined an Acceptability Criterion Curve (a function) against which the nuclear safety level of a nuclear power plant can be assessed [III-4, III-5, III-6] (see Figure III-1 below). The criterion is based on the individual radiological risk limitation quantified in terms of probability and it is related to the dose limitation system recommended by the International Commission on Radiological Protection for protection against exposures to ionizing radiation resulting from normal operation [III-7].

III-5. The objective of the Acceptability Criterion is to limit the individual risk to members of the public associated with potential exposures that could originate from living in the proximity of a nuclear facility to values not greater than the individual risk associated with exposures from normal operations.

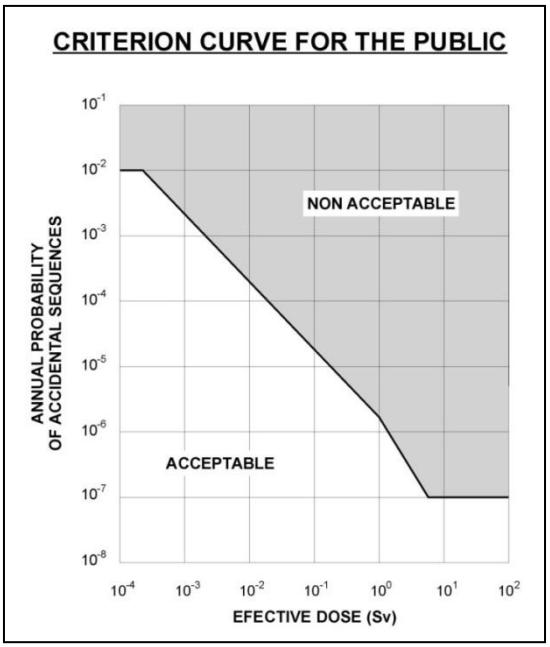

FIG. III-1. Argentine acceptability criterion curve for consideration of potential exposure of the public.

III-6. ICRP has suggested a risk coefficient for stochastic effects of 5×10^{-2} Sv^{-1} [III-7]. The ARN applies a dose constraint for exposure from a single source such as a nuclear power plant of 0.3 mSv per year and derive an annual limit value of the individual risk R, associated with exposures due to normal operation originating in a single practice or source of 1.5×10^{-5}.

III-7. For potential exposures the individual risk will be the sum of the risks associated with exposures from all possible accident sequences (a sequence is the series of events leading up to the radioactive release followed by a particular set of meteorological conditions or other exposure pathways that lead to exposure of an individual). The calculated risks do not take account of any counter-measures that might be implemented.

III-8. ARN recognizes that there are many uncertainties involved in probabilistic methods such as Probabilistic Safety Assessment (PSA) and to account for this a lower value (a factor of 15 lower) for the risk limit of 10^{-6} — in other words the individual risk of death from accidents at a nuclear facility for the most exposed individual must be less than 10^{-6} or 1 in a million.

III-9. Figure III-I (above) which is taken from the ARN Regulation [III-5] is a plot of the annual probability of accidental sequences against the effective dose resulting from all accidents with that annual probability showing the criterion curve.

APPROACH TO NORMAL AND ACCIDENT CONDITIONS IN THE USA

III-10. The United States Nuclear Regulatory Commission (NRC) is the Federal agency responsible for protecting the health and safety of the public and the environment by licensing and regulating civilian uses of source material, by product material, and special nuclear material in medical, academic, research, and industrial applications (including the generation of nuclear power). The primary safety consideration in the operation of any nuclear reactor is the control and containment of radioactive material, under both normal operation and accident conditions. Numerous controls and barriers are installed in nuclear plants to protect workers and the public from the effects of radiation

III-11. The US National Environmental Policy Act of 1969, as amended (NEPA) directs that an environmental impact statement be prepared for major Federal actions that significantly affect the quality of the human environment. This includes considering other past, present, and reasonably foreseeable future actions that could potentially affect the same resources for both radiological and non-radiological effects. The NRC has implemented its NEPA obligations through 10 CFR Part 51. When reviewing an application for a nuclear plant, the NRC evaluates the potential exposures to the public due to radiological releases. In order to perform this analysis, the exposure pathways and receptor locations are determined. Receptor locations include areas having populations such as schools, hospitals, or residences, or they may be locations at which plants or animals that become food for the public may be exposed to either direct radiation or radionuclides contamination. Parameters necessary to determine the exposure pathways to calculate the dose include the population of the affected area (assumed to be within an 80 kilometre [50 mile] radius), the distance from the reactor to the receptor location, and the time required for the plume to reach the receptor locations.

III-12. The NRC analyses radiological consequences under normal conditions against the requirements of 10 CFR Part 20, and affluent release limits (Part 20, Appendix B) as well as "Standards for Protection Against Radiation," under 10 CFR Part 50.

III-13. The NRC analyses design basis accident radiological consequences against the 10 CFR Part 100 and/or 10 CFR Part 50.67 dose criteria. The base guidance that the NRC provides for facilitating compliance with these criteria is contained in multiple NRC Regulatory Guides

SAFETY CRITERIA FOR EXPOSURES DUE TO NORMAL OPERATION AND POTENTIAL EXPOSURES IN SOUTH AFRICA

III-14. The elements of the Nuclear Regulatory Framework consists of legally binding requirements by International Safety Conventions, laws passed by Parliament that govern the regulation of South Africa's nuclear industry, regulations, authorizations, conditions of authorizations, requirements and guidance documents that the National Nuclear Regulator

(NNR) uses to regulate the industry. Requirements are developed in conjunction with the applicable authorized action and effectively cover all the relevant requirements on the holder, including those in legislation such as the Safety Standards and Regulatory Practices (SSRP). Guidance provides direction to the holder / applicant on how to meet the requirements set out in NNR's Regulations.

III-15. The NNR's policy for regulating radiation safety is in line with international consensus and requires that the risks to both the workforce involved in licensed activities and the public should not exceed prescribed limits for both normal operation and for potential accidents, and that both individual and population risks be maintained as low as reasonably achievable, social and environmental factors being taken into consideration. These fundamental principles lead to a system of radiation dose limitation for persons occupationally exposed to radiation and for members of the public.

III-16. Safety standards and regulatory practices adopted by NNR are in line with the IAEA and the International Commission on Radiation Protection as well as other international norms and standards such as INSAG, ASME etc. The suite of IAEA safety standards and the current IAEA basic safety standards in particular, were used as references in the development of the South African Regulations on Safety Standards and Regulatory Practices.

III-17. Increasing the level of safety culture within regulated entities is imperative towards achieving the high level of safety required by the NNR. In South Africa the SSRP regulation published under the National Nuclear Regulator Act, provides detailed technical rules to regulate the conduct of persons engaged in activities related to the use and exposure to fissionable materials, ionizing radiation and natural sources of radiation.

III-18. .

III-19. The SSRP regulation includes:

— Risk criteria which address the mortality risk from nuclear energy and radiation to the present and future generations;
— Acceptable radiation dose limits for exposure of people (individually and collectively) and the environment arising under normal operations and as a consequence of nuclear incidents;
— Fundamental safety principles to ensure that the activities relating to the construction, operation and decommissioning of facilities are conducted to achieve the highest standards of safety that can be reasonably achieved; and
— Emergency preparedness and response planning to mitigate the consequences of nuclear events and incidents.

III-20. The principal safety criteria refer to limits on the annual risk/dose to members of the public due to exposure to radioactive material as a result of accident conditions/normal operations.

III-21. In order to control the risk to members of the public due to accident conditions a limit of 10^{-7} fatalities per person per annum is established for all nuclear installations in South Africa. This figure is based on comparison with other risks imposed on society by industry and various natural disasters. Based on a projection of ten nuclear sites in South Africa during the operational lifetime of the existing nuclear installations, a factor of 0.1 is applied to this

figure to obtain the risk limit of 10^{-8} fatalities per person per annum for each site. The risk to the public is to be computed using projections on the relevant site-specific data (e.g. demographic, agricultural, farming practices, food consumption data).

III-22. A peak-to-average ratio of 50 is used to obtain an acceptable variation in risk in the country. This gives an upper risk limit for an individual of 5×10^{-6} fatalities per annum applicable cumulatively to all nuclear installations in the country.

III-23. Whereas for accident conditions the corresponding safety criteria relate directly to risk as determined using a probabilistic risk assessment methodology, the relevant criteria for normal operations refer directly to deterministic dose levels to the average representative of the critical group [III-8].

Table III-2 presents a summary of safety criteria related to normal operations and accident conditions.

TABLE III-2. SAFETY CRITERIA RELATED TO NORMAL OPERATIONS AND ACCIDENT CONDITIONS FOR PUBLIC

	Normal Operations	**Accident Conditions**
Assessment Type	**Deterministic**	**Probabilistic**
Average Annual Population Risk	Risk to be controlled to a trivial level by application of the ALARA principle.	10^{-8} fatalities person^{-1} year^{-1} site^{-1} (one fatality per person per one hundred million year per site) (1)
Maximum Annual Individual Risk	250 μSv year^{-1} site^{-1} individual dose limit for the average representative of the critical group.	5×10^{-6} fatalities year^{-1} (one fatality per two hundred thousand year).

(1) Subject to a maximum of 10 nuclear installation sites in South Africa.

CONSIDERATION OF POTENTIAL EXPOSURES FOR NUCLEAR FACILITIES IN FRANCE

(NOTE: It should be noted that there are ongoing discussion between the regulator (ASN) and licensee (EDF) with regard to dose for category 4 or DEC)

III-24. The article 3.7 of the 7th February 2012 decree on the General Rules for Nuclear Facilities prescribes that the nuclear safety demonstration should include radiological potential consequences of incidents and accidents. This assessment should include, for each scenario:

— The presentation of the assumptions considered for the calculation of the releases and for the exposure scenarios. The assumptions should be reasonably pessimistic for the calculation of the releases; the exposure scenarios should be based on realistic parameters, but should not take into account population protection countermeasures that authorities may implement.
— An assessment of effective doses received at short, intermediate and long terms, for several age classes as necessary; the equivalent dose to the thyroid should also be assessed for specific radioactive releases.

— An assessment of the potentially affected area.
— The kinetics of the consequences of the accident outside the nuclear site.

III-25. The dose assessments of an accidental release usually takes into account four pathways: external exposure to plume radiation, internal exposure due to inhalation of radioactive substances, ingestion of contaminated foodstuffs and external exposure to radiation from substances deposited on the ground. For nuclear power plants, the doses are assessed for adults, children and infants.

III-26. Typical dose assessments are carried out for short to long terms at several distances from the facility. For generic studies (no specific sites), following doses are assessed:

— Doses after 24h of exposure at 500 m (assumed to be typical distance of the fence from the facility);
— Doses after 7 days of exposure (2 km, 5 km, 10 km are typical distances); for power reactors, effective doses are assessed for example at 5 km and doses to the thyroid at 10 km;
— Doses after 1 year of exposure;
— Doses after 50 year of exposure (for adults only).

III-27. For specific site studies, the exact distance of the fence is used instead of 500 m and the exact distance of the first habitations instead of 2 km. In addition, areas where the contamination of foodstuff may exceed maximum permissible levels are assessed.

III-28. Neither countermeasures (for example, sheltering, soil decontamination) nor food restrictions are taken into account for all these assessments. The contamination of foodstuff is usually assessed with models based on dynamic processes involved in radionuclide transfers to vegetables and animal products. For specific site studies, site specific data are used for the dose assessment (e.g. local food consumption rates).

III-29. As a general rule for safety analysis, doses should be as low as reasonably achievable and should be less than appropriate national reference levels. For operating reactors, for the short term assessment (up to 7 days), operating conditions are specified by frequency of occurrence:

(a) for category 3 accidental conditions (10^{-2} to 10^{-4} y^{-1}), the effective doses are compared to 10 mSv (dose level for sheltering);

(b) for category 4 accidental conditions (10^{-4} to 10^{-6} y^{-1}), the effective doses are compared to 50 mSv (dose level for evacuation);

(c) for the operating conditions of the design extension condition, values for category 4 accidents are used.

III-30. In addition, short term doses to thyroid are compared to 50mSv (dose level for stable iodine administration).

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