IAEA Safety Standards

for protecting people and the environment

Categorization of Radioactive Sources

Safety Guide

No. RS-G-1.9

IAEA

International Atomic Energy Agency

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals, Safety Requirements** and **Safety Guides**.

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

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

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

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

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

OTHER SAFETY RELATED PUBLICATIONS

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

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

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

CATEGORIZATION OF RADIOACTIVE SOURCES

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

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

IAEA SAFETY STANDARDS SERIES No. RS-G-1.9

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FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

IAEA SAFETY STANDARDS

SAFETY THROUGH INTERNATIONAL STANDARDS

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

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

THE IAEA STANDARDS

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

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

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

Safety Fundamentals

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

Safety Requirements

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

Safety Guides

— Providing recommendations and guidance on how to comply with the Safety Requirements. Recommendations in the Safety Guides are expressed as 'should' statements. It is recommended to take the measures stated or equivalent alternative measures. The Safety Guides present international good practices and increasingly they reflect best practices to help users striving to achieve high levels of safety. Each Safety Requirements publication is supplemented by a number of Safety Guides, which can be used in developing national regulatory guides.

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

MAIN USERS OF THE STANDARDS

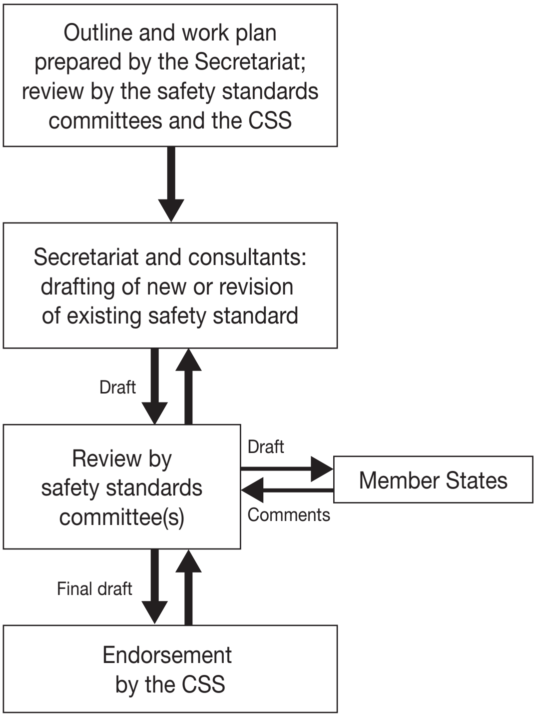
As well as by regulatory bodies and governmental departments, authorities and agencies, the standards are used by authorities and operating organizations in the nuclear industry; by organizations that design, manufacture and apply nuclear and radiation related technologies, including operating organizations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

DEVELOPMENT PROCESS FOR THE STANDARDS

The preparation and review of safety standards involves the IAEA Secretariat and four safety standards committees for safety in the areas of nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS), which oversees the entire safety standards programme. All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the CSS is appointed by the Director General and includes senior government officials having responsibility for establishing national standards.

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

Through this process the standards come to represent a consensus view of the IAEA's Member States. The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the standards. Some standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the International



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

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

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

APPLICATION AND SCOPE OF THE STANDARDS

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

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

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

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

INTERPRETATION OF THE TEXT

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

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

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Radioactive sources are used throughout the world in medicine, industry, agriculture, research and education; they are also used in some military applications. Many are in the form of sealed sources with the radioactive materials firmly contained or bound within a suitable capsule or housing. The risks posed by these sources vary widely, depending on such factors as the radionuclides used, the physical and chemical form and the activity.

1.2. Sealed sources, unless they have been breached or are leaking, present a risk of external radiation exposure only. However, breached or leaking sealed sources, as well as unsealed radioactive materials, may give rise to contamination of the environment and the intake of radioactive materials into the human body. Until the 1950s, only radionuclides of natural origin, particularly ^{226}Ra, were generally available for use. Since then, radionuclides produced artificially in nuclear facilities and accelerators, including ^{60}Co, ^{90}Sr, ^{137}Cs and ^{192}Ir, have become widely used.

1.3. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [1] provide an internationally harmonized basis for ensuring the safe and secure use of sources of ionizing radiation, and the Safety Requirements for Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety [2] set out the essential elements of a regulatory control system.

1.4. Sealed and unsealed radioactive sources are used for a variety of purposes and they incorporate a wide range of radionuclides and amounts of radioactive material. High activity sources, if not managed safely and securely, can cause severe deterministic effects to individuals in a short period of time [3–16], whereas low activity sources are unlikely to cause exposures with harmful consequences.

1.5. This Safety Guide provides a risk based ranking of radioactive sources and practices in five categories. The categorization system is based on a logical and transparent method that provides the flexibility for it to be applied in a wide range of circumstances. On the basis of this categorization, risk informed decisions can be made, in a graded approach to the regulatory control of radioactive sources for the purposes of safety and security.

1.6. Following an assessment of the major findings of the International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials, held in Dijon, France, from 14 to 18 September 1998 [17], the IAEA undertook a number of tasks designed to improve the safety and security of radioactive sources around the world. An ensuing 'Action Plan for the Safety of Radiation Sources and the Security of Radioactive Materials', approved by the IAEA Board of Governors in September 1999, identified the need for a categorization of radiation sources. A publication dealing with categorization was prepared in 2000, which was subsequently improved upon and superseded by the Categorization of Radioactive Sources [18], issued in 2003.

1.7. This Safety Guide provides guidance on categorizing radioactive sources and on how this categorization can be used to meet the requirements for regulatory control set out in IAEA Safety Standards Series No. GS-R-1 [2] and the BSS [1]. The categorization system is based on that of IAEA-TECDOC-1344 [18], and was developed by considering a variety of circumstances of use and misuse of radioactive sources. An explanation of the rationale is given in Annex I.

OBJECTIVE

1.8. The objective of this Safety Guide is to provide a simple, logical system for ranking radioactive sources in terms of their potential to cause harm to human health, and for grouping sources and the practices in which they are used into discrete categories. This categorization can assist regulatory bodies in establishing regulatory requirements that ensure an appropriate level of control for each authorized source.

1.9. The purpose of categorizing radioactive sources is to provide an internationally harmonized basis for risk informed decision making. It is envisaged that the categorization system will be used by national authorities[1] in

[1] Where the term 'national authorities' is used in this Safety Guide, it is intended to apply to all types of regulatory infrastructure, including systems having a single authority or multiple authorities at the national level only and federal systems in which authority is distributed among the relevant regional, provincial or state jurisdictions.

establishing the appropriate degree of regulatory control for many activities relating to the safety and security of radioactive sources. Applications of the categorization include:

— Developing or refining national regulatory infrastructures;
— Developing national strategies for improving control over radioactive sources;
— Optimizing decisions about the priorities for regulation within resource constraints;
— Optimizing security measures for radioactive sources, including measures directed against their possible malicious misuse;
— Emergency planning and response.

1.10. This Safety Guide also provides support for the international harmonization of measures for the control of radiation sources and their security, in particular for the implementation of the Code of Conduct on the Safety and Security of Radioactive Sources (Code of Conduct) [19, 20]. The same categorization system is used in the Code of Conduct for sources in Categories 1–3, and this Safety Guide provides further details of the system and of its application to sources in all categories.

SCOPE

1.11. This Safety Guide provides a categorization system for radioactive sources, particularly those used in industry, medicine, agriculture, research and education. The principles of the categorization can also be applied, where appropriate in the national context, to sources within military or defence programmes.

1.12. The categorization is not relevant to radiation generating devices such as X ray machines and particle accelerators, although it may be applied to radioactive sources produced by, or used as target material in, such devices. Nuclear material, as defined in the Convention on the Physical Protection of Nuclear Material [21] (revised in 2005), is excluded from the scope of this Safety Guide. In addition, in situations where factors other than those considered here are dominant, this categorization may not be appropriate. One example is in waste management and the consideration of disposal options for disused sources, where factors such as the specific activity, chemical properties and half-life take on different emphases [22]. This Safety Guide does not apply to packages of radioactive material in transport, for which the IAEA Transport Regulations apply [23].

1.13. The categorization is concerned with sealed sources; however, the method can also be used to categorize unsealed radioactive sources, and some examples are included in Appendix I.

STRUCTURE

1.14. The categorization system is set out in Section 2 and its implementation is discussed in Section 3. Further details on the recommended categories are given in Appendix I and plain language descriptions of the categories are given in Appendix II. Annexes I and II provide supporting material explaining the methods used to establish the categorization system and to categorize radioactive sources and the practices in which they are used.

2. CATEGORIZATION SYSTEM

GENERAL

2.1. Table 2 in Appendix I shows examples of the wide range of radionuclides and activities in radioactive sources used for beneficial purposes around the world. In recognition of the fact that human health is of paramount importance, the categorization system is based primarily on the potential for radioactive sources to cause deterministic health effects. The categorization system is therefore based on the concept of 'dangerous sources' — which are quantified in terms of '*D* values'[2]. The *D* value is the radionuclide specific activity of a source which, if not under control, could cause severe deterministic effects for a range of scenarios that include both external exposure from an unshielded source and internal exposure following dispersal of the source material (see Annex II).

[2] *D* values were originally derived in the context of emergency preparedness [23] to establish a reference point corresponding to a 'dangerous source' [24, 25] on a scale of the risks that could arise from uncontrolled sources.

2.2. The activity A of the radioactive material in sources varies over many orders of magnitude (Appendix I); D values are therefore used to normalize the range of activities in order to provide a reference for comparing risks[3]. The A/D values for a range of commonly used sources are given in Appendix I[4]. The A/D values are used to provide an initial ranking of relative risk for sources, which are then categorized after consideration of other factors such as the physical and chemical forms, the type of shielding or containment employed, the circumstances of use and accident case histories. This consideration of other factors is necessarily subjective and is based largely on international consensus judgements, as are the boundaries between the categories.

2.3. The categorization system set out in this Safety Guide has five categories. This number is considered sufficient to enable the practical application of the scheme, without unwarranted precision. Within this categorization system, sources in Category 1 are considered to be the most 'dangerous' because they can pose a very high risk to human health if not managed safely and securely. An exposure of only a few minutes to an unshielded Category 1 source may be fatal. At the lower end of the categorization system, sources in Category 5 are the least dangerous; however, even these sources could give rise to doses in excess of the dose limits if not properly controlled, and therefore need to be kept under appropriate regulatory control. Categories should not be subdivided as this would imply a degree of precision that is not warranted and would lead to a loss of international harmonization. A plain language description of the categories is given in Appendix II.

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[3] 'Risk' is used here in the broad sense of a multiattribute 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. In ranking risks, D values have been used as the normalizing factor as they are based on deterministic health effects — and are therefore applicable for all States. In the interests of international harmonization, no account was taken of the possible cleanup costs following the dispersion of a source, since these will vary from State to State.

[4] The list of sources given in Appendix I includes examples of sources that have been or were (in 2004) in common use. The list is not exhaustive — there may be sources with higher or lower activities than those described, and the list may also change over time with technological developments.

RECOMMENDED CATEGORIES FOR SOURCES USED IN COMMON PRACTICES

2.4. The categorization method outlined here and described in more detail in Annex I has been used to assign sources used in common practices to one of five categories, as shown in Appendix I. Examples of commonly used sources are shown in Table 1.

TABLE 1. RECOMMENDED CATEGORIES FOR SOURCES USED IN COMMON PRACTICES

Category	Source[a] and practice	Activity ratio[b] (A/D)
1	Radioisotope thermoelectric generators (RTGs) Irradiators Teletherapy sources Fixed, multi-beam teletherapy (gamma knife) sources	$A/D \geq 1000$
2	Industrial gamma radiography sources High/medium dose rate brachytherapy sources	$1000 > A/D \geq 10$
3	Fixed industrial gauges that incorporate high activity sources[c] Well logging gauges	$10 > A/D \geq 1$
4	Low dose rate brachytherapy sources (except eye plaques and permanent implants) Industrial gauges that do not incorporate high activity sources[c] Bone densitometers Static eliminators	$1 > A/D \geq 0.01$
5	Low dose rate brachytherapy eye plaques and permanent implant sources X ray fluorescence (XRF) devices Electron capture devices Mossbauer spectrometry sources Positron emission tomography (PET) check sources	$0.01 > A/D$ and $A >$ exempt[d]

[a] Factors other than A/D alone have been taken into consideration in assigning the sources to a category (see Annex I).

[b] This column can be used to determine the category of a source purely on the basis of A/D. This may be appropriate, for example, if the practice is not known or is not listed, if sources have a short half-life and/or are unsealed, or if sources are aggregated (see para. 3.5).

[c] Examples are given in Appendix I.

[d] Exempt quantities are given in Schedule I of Ref. [1].

3. IMPLEMENTATION OF THE CATEGORIZATION SYSTEM

USE OF THE SYSTEM

3.1. The Safety Requirements publication No. GS-R-1 [2] and the BSS [1] place obligations on the parties involved in the use of radiation sources to ensure their safety and security. In particular, GS-R-1 requires that the regulatory body "shall define policies, safety principles and associated criteria as a basis for its regulatory actions" (para. 3.1). It also specifies that legislation "shall establish authorization and other processes (such as notification and exemption), with account taken of the potential magnitude and nature of the hazard associated with the facility or activity…" (para. 2.4 (3)); and that the extent of the control applied by the regulatory body "shall be commensurate with the potential magnitude and nature of the hazard presented" (para. 5.3). Similarly, the BSS state that: "The application of the requirements of the Standards to any practice or any source within a practice … shall be commensurate with the characteristics of the practice or source and with the magnitude and likelihood of the exposures." (para. 2.8).

3.2. The regulatory body should use the categorization system described in this Safety Guide to provide a consistent basis for implementing these requirements in different areas, including the following:

- *Regulatory measures*: To provide one of the factors to be taken into account in developing a graded system for notification, registration, licensing and inspections [1, 2, 26, 27]. The categorization system also assists in ensuring that the allocation of human and financial resources to protection measures is commensurate with the degree of risk associated with the source.
- *Security measures*: To provide a graded basis for assisting in the choice of security measures, while it is recognized that other factors are also important [20] (see also Ref. [28]);
- *National register of sources*: To optimize decisions regarding which sources should be included and what level of detail should be used in a national register of sources, as recommended in the Code of Conduct [19] (see para. 3.7 below);
- *Import/export controls*: To optimize decisions regarding which sources should be subject to import and export controls, in meeting national

obligations relating to the Code of Conduct [19] and guidance on import/export controls for Category 1 and 2 sources [29] (see para. 3.9);

— *Labelling of high activity sources*: To guide decisions regarding which sources should be marked with an appropriate label (in addition to the radiation trefoil) warning of the radiation hazard, as recommended in the Code of Conduct [19];
— *Emergency preparedness and response*: To ensure that emergency preparedness plans and response to accidents are commensurate with the hazards posed by the source [25];
— *Prioritization for regaining control over orphan sources*: To inform decisions relating to how efforts should be focused to regain control over orphan sources [27];
— *Communication with the public*: To provide a basis for explaining the relative hazards associated with events involving radioactive sources (see also Ref. [30]).

CATEGORIZATION OF SOURCES

3.3. The regulatory body should use the data in Table 1 and Appendix I to categorize sources. If a particular type of source is not listed in Table 1 or Appendix I, the activity ratio *A*/*D* should be calculated and compared with those given in Appendix I for similar types of source. This should be done by taking the activity *A* of the source (in TBq) and dividing it by the *D* value for the relevant radionuclide given in Annex II. The resulting ratio *A*/*D* should then be compared with the values tabulated in the right hand column of Table 1. In some situations it may be appropriate to categorize a source on the basis of *A*/*D* alone — for example, when the practice for which the source may be used is unknown or not confirmed, as may happen at the time of import or export of the source. However, when the circumstances of use of the source are known, the regulatory body may make a judgement to modify this initial categorization using other information about the source or its use. In some circumstances it may be convenient to assign a category on the basis of the practice in which the source is used.

Short half-life radionuclides and unsealed sources

3.4. In some practices, such as nuclear medicine, radionuclides with a short half-life are used in a source form that is unsealed. Examples of such applications include ^{99m}Tc in radiodiagnosis and ^{131}I in radiotherapy. In such situations, the principles of the categorization system may be applied to determine a category for the source, but a judgement should be made in choosing the activity on the basis of which to calculate the ratio A/D. These situations should be considered on a case by case basis.

Aggregation of sources

3.5. There will be situations in which radioactive sources are in close proximity to each other, such as in manufacturing processes (e.g. in the same room or building) or in storage facilities (e.g. in the same enclosure). In such circumstances, the regulatory body may wish to aggregate the activity in the sources to determine a situation specific categorization for the purposes of implementing regulatory control measures. In such situations, the summed activity of the radionuclide should be divided by the appropriate D value and the calculated ratio A/D compared with the ratios A/D given in Table 1, thus allowing the set of sources to be categorized on the basis of activity. If sources with various radionuclides are aggregated, then the sum of the ratios A/D should be used in determining the category, in accordance with the formula:

$$\text{Aggregate } A/D = \sum_n \frac{\sum_i A_{i,n}}{D_n}$$

where

$A_{i,n}$ = activity of each individual source i of radionuclide n;

D_n = D value for radionuclide n.

3.6. In each case it should be recognized that other factors may need to be taken into consideration in assigning a category. For example, the aggregation of sources during their manufacture and their aggregation in use may have different safety implications.

NATIONAL REGISTER OF RADIOACTIVE SOURCES

3.7. As recommended in the Safety Guide on Regulatory Control of Radiation Sources [26], the regulatory body should maintain a national register of radioactive sources. Furthermore, it is stated in para. 11 of the Code of Conduct [19] that the register "should, as a minimum, include Category 1 and 2 radioactive sources" and that "[f]or the purpose of introducing efficiency in the exchange of radioactive source information between States, States should endeavour to harmonize the formats of their registers."

3.8. In view of the fact that Category 3 sources have the potential to cause severe deterministic effects, the regulatory body may also consider including them in a national register together with the Category 1 and 2 sources. Although sources in Categories 4 and 5 are unlikely to be dangerous to a person, such sources could give rise to detrimental consequences if misused, for example, through undue exposure of persons or contamination of the local environment. National authorities should, therefore, determine whether there is a need to include sources of Categories 4 and 5 in a national register.

IMPORT AND EXPORT OF RADIOACTIVE SOURCES

3.9. The Code of Conduct [19] provides guidance on the import and export of radioactive sources in Categories 1 and 2. Paragraphs 23–25 of the Code of Conduct recommend that:

> "23. Every State involved in the import or export of radioactive sources should take appropriate steps to ensure that transfers are undertaken in a manner consistent with the provisions of the Code and that transfers of radioactive sources in Categories 1 and 2 of Annex 1 of this Code take place only with the prior notification by the exporting State and, as appropriate, consent by the importing State in accordance with their respective laws and regulations.
>
> "24. Every State intending to authorize the import of radioactive sources in Categories 1 and 2 of Annex 1 to this Code should consent to their import only if the recipient is authorized to receive and possess the source under its national law and the State has the appropriate technical and administrative capability, resources and regulatory structure needed to ensure that the source will be managed in a manner consistent with the provisions of this Code.
>
> "25. Every State intending to authorize the export of radioactive sources in Categories 1 and 2 of Annex 1 to this Code should consent to its export only if it can satisfy itself, insofar as practicable, that the receiving State has authorized the recipient to receive and possess the source and has the appropriate technical and administrative capability, resources and regulatory structure needed to ensure that the source will be managed in a manner consistent with the provisions of this Code."

Paragraphs 26–29 of the Code of Conduct provide further guidance on import/export — including an 'exceptional circumstances' clause for cases where paras 24–25 reproduced above cannot be satisfied.

3.10. Detailed advice for States that import and/or export radioactive sources can be found in the IAEA ‘Guidance for the Import and Export of Radioactive Sources’ [29].

Appendix I

CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES

I.1. Table 2 gives examples of sources that have been or were in 2004 in common use (column I). The list is not exhaustive — there may be sources with a higher or lower activity than those described, and this may also change over time with technological developments. Column II identifies the radionuclide(s) typically used. Columns III–V give examples of maximum, minimum and typical activity. The D values are given in column VI and activity ratios A/D in column VII. The categorization is shown in columns VIII and IX. Column VIII shows the initial categorization based on A/D and column IX shows the recommended categorization with account taken of additional factors generally known to be associated with particular types of source. The regulatory body may modify this categorization on the basis of specific knowledge of relevant factors, such as method of construction, physical or chemical form of the source, use in remote or harsh environments, history of accidents and portability. Note that Table 2 lists only single sources; where sources are aggregated, the recommendations in para. 3.5 should be followed.

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
RTGs					**Category 1**			
	Sr-90	Max	6.8E+05	2.5E+04	1.0E+00	2.5E+04	1	
	Sr-90	Min	9.0E+03	3.3E+02	1.0E+00	3.3E+02	2	1
	Sr-90	Typ	2.0E+04	7.4E+02	1.0E+00	7.4E+02	2	
	Pu-238	Max	2.8E+02	1.0E+01	6.E-02	1.7E+02	2	
	Pu-238	Min	2.8E+01	1.0E+00	6.E-02	1.7E+01	2	1
	Pu-238	Typ	2.8E+02	1.0E+01	6.E-02	1.7E+02	2	
Irradiators used in sterilization and food preservation	Co-60	Max	1.5E+07	5.6E+05	3.E-02	1.9E+07	1	
	Co-60	Min	5.0E+03	1.9E+02	3.E-02	6.2E+03	1	1
	Co-60	Typ	4.0E+06	1.5E+05	3.E-02	4.9E+06	1	
	Cs-137	Max	5.0E+06	1.9E+05	1.E-01	1.9E+06	1	
	Cs-137	Min	5.0E+03	1.9E+02	1.E-01	1.9E+03	1	1
	Cs-137	Typ	3.0E+06	1.1E+05	1.E-01	1.1E+06	1	
Self-shielded irradiators	Cs-137	Max	4.2E+04	1.6E+03	1.E-01	1.6E+04	1	
	Cs-137	Min	2.5E+03	9.3E+01	1.E-01	9.3E+02	2	1
	Cs-137	Typ	1.5E+04	5.6E+02	1.E-01	5.6E+03	1	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Co-60	Max	5.0E+04	1.9E+03	3.E-02	6.2E+04	1	
	Co-60	Min	1.5E+03	5.6E+01	3.E-02	1.9E+03	1	1
	Co-60	Typ	2.5E+04	9.3E+02	3.E-02	3.1E+04	1	
Blood/tissue irradiators	Cs-137	Max	1.2E+04	4.4E+02	1.E-01	4.4E+03	1	
	Cs-137	Min	1.0E+03	3.7E+01	1.E-01	3.7E+02	2	1
	Cs-137	Typ	7.0E+03	2.6E+02	1.E-01	2.6E+03	1	
	Co-60	Max	3.0E+03	1.1E+02	3.E-02	3.7E+03	1	
	Co-60	Min	1.5E+03	5.6E+01	3.E-02	1.9E+03	1	1
	Co-60	Typ	2.4E+03	8.9E+01	3.E-02	3.0E+03	1	
Multi-beam teletherapy (gamma knife) sources	Co-60	Max	1.0E+04	3.7E+02	3.E-02	1.2E+04	1	
	Co-60	Min	4.0E+03	1.5E+02	3.E-02	4.9E+03	1	1
	Co-60	Typ	7.0E+03	2.6E+02	3.E-02	8.6E+03	1	
Teletherapy sources	Co-60	Max	1.5E+04	5.6E+02	3.E-02	1.9E+04	1	
	Co-60	Min	1.0E+03	3.7E+01	3.E-02	1.2E+03	1	1
	Co-60	Typ	4.0E+03	1.5E+02	3.E-02	4.9E+03	1	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Cs-137	Max	1.5E+03	5.6E+01	1.E-01	5.6E+02	2	
	Cs-137	Min	5.0E+02	1.9E+01	1.E-01	1.9E+02	2	1
	Cs-137	Typ	5.0E+02	1.9E+01	1.E-01	1.9E+02	2	
				Category 2				
Industrial radiography sources	Co-60	Max	2.0E+02	7.4E+00	3.E-02	2.5E+02	2	
	Co-60	Min	1.1E+01	4.1E-01	3.E-02	1.4E+01	2	2
	Co-60	Typ	6.0E+01	2.2E+00	3.E-02	7.4E+01	2	
	Ir-192	Max	2.0E+02	7.4E+00	8.E-02	9.3E+01	2	
	Ir-192	Min	5.0E+00	1.9E-01	8.E-02	2.3E+00	3	2
	Ir-192	Typ	1.0E+02	3.7E+00	8.E-02	4.6E+01	2	
	Se-75	Max	8.0E+01	3.0E+00	2.E-01	1.5E+01	2	
	Se-75	Min	8.0E+01	3.0E+00	2.E-01	1.5E+01	2	2
	Se-75	Typ	8.0E+01	3.0E+00	2.E-01	1.5E+01	2	
	Yb-169	Max	1.0E+01	3.7E-01	3.E-01	1.2E+00	3	
	Yb-169	Min	2.5E+00	9.3E-02	3.E-01	3.1E-01	4	2
	Yb-169	Typ	5.0E+00	1.9E-01	3.E-01	6.2E-01	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Tm-170	Max	2.0E+02	7.4E+00	2.E+01	3.7E-01	4	
	Tm-170	Min	2.0E+01	7.4E-01	2.E+01	3.7E-02	4	2
	Tm-170	Typ	1.5E+02	5.6E+00	2.E+01	2.8E-01	4	
Brachytherapy sources — high/medium dose rate	Co-60	Max	2.0E+01	7.4E-01	3.E-02	2.5E+01	2	
	Co-60	Min	5.0E+00	1.9E-01	3.E-02	6.2E+00	3	2
	Co-60	Typ	1.0E+01	3.7E-01	3.E-02	1.2E+01	2	
	Cs-137	Max	8.0E+00	3.0E-01	1.E-01	3.0E+00	3	
	Cs-137	Min	3.0E+00	1.1E-01	1.E-01	1.1E+00	3	2
	Cs-137	Typ	3.0E+00	1.1E-01	1.E-01	1.1E+00	3	
	Ir-192	Max	1.2E+01	4.4E-01	8.E-02	5.6E+00	3	
	Ir-192	Min	3.0E+00	1.1E-01	8.E-02	1.4E+00	3	2
	Ir-192	Typ	6.0E+00	2.2E-01	8.E-02	2.8E+00	3	
Calibration sources	Co-60	Max	3.3E+01	1.2E+00	3.E-02	4.1E+01	2	
	Co-60	Min	5.5E-01	2.0E-02	3.E-02	6.8E-01	4	[a]
	Co-60	Typ	2.0E+01	7.4E-01	3.E-02	2.5E+01	2	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Cs-137	Max	3.0E+03	1.1E+02	1.E-01	1.1E+03	1	
	Cs-137	Min	1.5E+00	5.6E-02	1.E-01	5.6E-01	4	a
	Cs-137	Typ	6.0E+01	2.2E+00	1.E-01	2.2E+01	2	
				Category 3				
Level gauges	Cs-137	Max	5.0E+00	1.9E-01	1.E-01	1.9E+00	3	
	Cs-137	Min	1.0E+00	3.7E-02	1.E-01	3.7E-01	4	3
	Cs-137	Typ	5.0E+00	1.9E-01	1.E-01	1.9E+00	3	
	Co-60	Max	1.0E+01	3.7E-01	3.E-02	1.2E+01	2	
	Co-60	Min	1.0E-01	3.7E-03	3.E-02	1.2E-01	4	3
	Co-60	Typ	5.0E+00	1.9E-01	3.E-02	6.2E+00	3	
Calibration sources	Am-241	Max	2.0E+01	7.4E-01	6.E-02	1.2E+01	2	
	Am-241	Min	5.0E+00	1.9E-01	6.E-02	3.1E+00	3	[a]
	Am-241	Typ	1.0E+01	3.7E-01	6.E-02	6.2E+00	3	
Conveyor gauges	Cs-137	Max	4.0E+01	1.5E+00	1.E-01	1.5E+01	2	
	Cs-137	Min	3.0E-03	1.1E-04	1.E-01	1.1E-03	5	3
	Cs-137	Typ	3.0E+00	1.1E-01	1.E-01	1.1E+00	3	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Cf-252	Max	3.7E-02	1.4E-03	2.E-02	6.8E-02	4	
	Cf-252	Min	3.7E-02	1.4E-03	2.E-02	6.8E-02	4	3
	Cf-252	Typ	3.7E-02	1.4E-03	2.E-02	6.8E-02	4	
Blast furnace gauges	Co-60	Max	2.0E+00	7.4E-02	3.E-02	2.5E+00	3	
	Co-60	Min	1.0E+00	3.7E-02	3.E-02	1.2E+00	3	3
	Co-60	Typ	1.0E+00	3.7E-02	3.E-02	1.2E+00	3	
Dredger gauges	Co-60	Max	2.6E+00	9.6E-02	3.E-02	3.2E+00	3	
	Co-60	Min	2.5E-01	9.3E-03	3.E-02	3.1E-01	4	3
	Co-60	Typ	7.5E-01	2.8E-02	3.E-02	9.3E-01	4	
	Cs-137	Max	1.0E+01	3.7E-01	1.E-01	3.7E+00	3	
	Cs-137	Min	2.0E-01	7.4E-03	1.E-01	7.4E-02	4	3
	Cs-137	Typ	2.0E+00	7.4E-02	1.E-01	7.4E-01	4	
Spinning pipe gauges	Cs-137	Max	5.0E+00	1.9E-01	1.E-01	1.9E+00	3	
	Cs-137	Min	2.0E+00	7.4E-02	1.E-01	7.4E-01	4	3
	Cs-137	Typ	2.0E+00	7.4E-02	1.E-01	7.4E-01	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
Research reactor startup sources	Am-241/Be	Max	5.0E+00	1.9E-01	6.E-02	3.1E+00	3	
	Am-241/Be	Min	2.0E+00	7.4E-02	6.E-02	1.2E+00	3	3
	Am-241/Be	Typ	2.0E+00	7.4E-02	6.E-02	1.2E+00	3	
Well logging sources	Am-241/Be	Max	2.3E+01	8.5E-01	6.E-02	1.4E+01	2	
	Am-241/Be	Min	5.0E-01	1.9E-02	6.E-02	3.1E-01	4	3
	Am-241/Be	Typ	2.0E+01	7.4E-01	6.E-02	1.2E+01	2	
	Cs-137	Max	2.0E+00	7.4E-02	1.E-01	7.4E-01	4	
	Cs-137	Min	1.0E+00	3.7E-02	1.E-01	3.7E-01	4	3
	Cs-137	Typ	2.0E+00	7.4E-02	1.E-01	7.4E-01	4	
	Cf-252	Max	1.1E-01	4.1E-03	2.E-02	2.0E-01	4	
	Cf-252	Min	2.7E-02	1.0E-03	2.E-02	5.0E-02	4	3
	Cf-252	Typ	3.0E-02	1.1E-03	2.E-02	5.6E-02	4	
Pacemakers	Pu-238	Max	8.0E+00	3.0E-01	6.E-02	4.9E+00	3	
	Pu-238	Min	2.9E+00	1.1E-01	6.E-02	1.8E+00	3	[b]
	Pu-238	Typ	3.0E+00	1.1E-01	6.E-02	1.9E+00	3	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
Calibration sources	Pu-239/Be	Max	1.0E+01	3.7E-01	6.E-02	6.2E+00	3	
	Pu-239/Be	Min	2.0E+00	7.4E-02	6.E-02	1.2E+00	3	[a]
	Pu-239/Be	Typ	3.0E+00	1.1E-01	6.E-02	1.9E+00	3	
				Category 4				
Brachytherapy sources — low dose rate	Cs-137	Max	7.0E-01	2.6E-02	1.E-01	2.6E-01	4	
	Cs-137	Min	1.0E-02	3.7E-04	1.E-01	3.7E-03	5	4
	Cs-137	Typ	5.0E-01	1.9E-02	1.E-01	1.9E-01	4	
	Ra-226	Max	5.0E-02	1.9E-03	4.E-02	4.6E-02	4	
	Ra-226	Min	5.0E-03	1.9E-04	4.E-02	4.6E-03	5	4
	Ra-226	Typ	1.5E-02	5.6E-04	4.E-02	1.4E-02	4	
	I-125	Max	4.0E-02	1.5E-03	2.E-01	7.4E-03	5	
	I-125	Min	4.0E-02	1.5E-03	2.E-01	7.4E-03	5	4
	I-125	Typ	4.0E-02	1.5E-03	2.E-01	7.4E-03	5	
	Ir-192	Max	7.5E-01	2.8E-02	8.E-02	3.5E-01	4	
	Ir-192	Min	2.0E-02	7.4E-04	8.E-02	9.3E-03	5	4
	Ir-192	Typ	5.0E-01	1.9E-02	8.E-02	2.3E-01	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (*A*)		*D* value (TBq)	Ratio of *A*/*D*	Category	
			Ci	TBq			*A*/*D* based	Recommended
	Au-198	Max	8.0E-02	3.0E-03	2.E-01	1.5E-02	4	
	Au-198	Min	8.0E-02	3.0E-03	2.E-01	1.5E-02	4	4
	Au-198	Typ	8.0E-02	3.0E-03	2.E-01	1.5E-02	4	
	Cf-252	Max	8.3E-02	3.1E-03	2.E-02	1.5E-01	4	
	Cf-252	Min	8.3E-02	3.1E-03	2.E-02	1.5E-01	4	4
	Cf-252	Typ	8.3E-02	3.1E-03	2.E-02	1.5E-01	4	
Thickness gauges	Kr-85	Max	1.0E+00	3.7E-02	3.E+01	1.2E-03	5	
	Kr-85	Min	5.0E-02	1.9E-03	3.E+01	6.2E-05	5	4
	Kr-85	Typ	1.0E+00	3.7E-02	3.E+01	1.2E-03	5	
	Sr-90	Max	2.0E-01	7.4E-03	1.E+00	7.4E-03	5	
	Sr-90	Min	1.0E-02	3.7E-04	1.E+00	3.7E-04	5	4
	Sr-90	Typ	1.0E-01	3.7E-03	1.E+00	3.7E-03	5	
	Am-241	Max	6.0E-01	2.2E-02	6.E-02	3.7E-01	4	
	Am-241	Min	3.0E-01	1.1E-02	6.E-02	1.9E-01	4	4
	Am-241	Typ	6.0E-01	2.2E-02	6.E-02	3.7E-01	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (*A*)		*D* value (TBq)	Ratio of *A*/*D*	Category	
			Ci	TBq			*A*/*D* based	Recommended
	Pm-147	Max	5.0E-02	1.9E-03	4.E+01	4.6E-05	5	
	Pm-147	Min	2.0E-03	7.4E-05	4.E+01	1.9E-06	5	4
	Pm-147	Typ	5.0E-02	1.9E-03	4.E+01	4.6E-05	5	
	Cm-244	Max	1.0E+00	3.7E-02	5.E-02	7.4E-01	4	
	Cm-244	Min	2.0E-01	7.4E-03	5.E-02	1.5E-01	4	4
	Cm-244	Typ	4.0E-01	1.5E-02	5.E-02	3.0E-01	4	
Fill level gauges	Am-241	Max	1.2E-01	4.4E-03	6.E-02	7.4E-02	4	
	Am-241	Min	1.2E-02	4.4E-04	6.E-02	7.4E-03	5	4
	Am-241	Typ	6.0E-02	2.2E-03	6.E-02	3.7E-02	4	
	Cs-137	Max	6.5E-02	2.4E-03	1.E-01	2.4E-02	4	
	Cs-137	Min	5.0E-02	1.9E-03	1.E-01	1.9E-02	4	4
	Cs-137	Typ	6.0E-02	2.2E-03	1.E-01	2.2E-02	4	
	Co-60	Max	5.0E-01	1.9E-02	3.E-02	6.2E-01	4	
	Co-60	Min	5.0E-03	1.9E-04	3.E-02	6.2E-03	5	4
	Co-60	Typ	2.4E-02	8.7E-04	3.E-02	2.9E-02	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
Calibration sources	Sr-90	Max	2.0E+00	7.4E-02	1.E+00	7.4E-02	4	
	Sr-90	Min	2.0E+00	7.4E-02	1.E+00	7.4E-02	4	[a]
	Sr-90	Typ	2.0E+00	7.4E-02	1.E+00	7.4E-02	4	
Moisture detectors	Am-241/Be	Max	1.0E-01	3.7E-03	6.E-02	6.2E-02	4	
	Am-241/Be	Min	5.0E-02	1.9E-03	6.E-02	3.1E-02	4	4
	Am-241/Be	Typ	5.0E-02	1.9E-03	6.E-02	3.1E-02	4	
Density gauges	Cs-137	Max	1.0E-02	3.7E-04	1.E-01	3.7E-03	5	
	Cs-137	Min	8.0E-03	3.0E-04	1.E-01	3.0E-03	5	4
	Cs-137	Typ	1.0E-02	3.7E-04	1.E-01	3.7E-03	5	
Moisture/ density gauges	Am-241/Be	Max	1.0E-01	3.7E-03	6.E-02	6.2E-02	4	
	Am-241/Be	Min	8.0E-03	3.0E-04	6.E-02	4.9E-03	5	4
	Am-241/Be	Typ	5.0E-02	1.9E-03	6.E-02	3.1E-02	4	
	Cs-137	Max	1.1E-02	4.1E-04	1.E-01	4.1E-03	5	
	Cs-137	Min	1.0E-03	3.7E-05	1.E-01	3.0E-04	5	4
	Cs-137	Typ	1.0E-02	3.7E-04	1.E-01	3.7E-03	5	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (*A*)		*D* value (TBq)	Ratio of *A*/*D*	Category	
			Ci	TBq			*A*/*D* based	Recommended
	Ra-226	Max	4.0E-03	1.5E-04	4.E-02	3.7E-03	5	
	Ra-226	Min	2.0E-03	7.4E-05	4.E-02	1.9E-03	5	4
	Ra-226	Typ	2.0E-03	7.4E-05	4.E-02	1.9E-03	5	
	Cf-252	Max	7.0E-05	2.6E-06	2.E-02	1.3E-04	5	
	Cf-252	Min	3.0E-05	1.1E-06	2.E-02	5.6E-05	5	4
	Cf-252	Typ	6.0E-05	2.2E-06	2.E-02	1.1E-04	5	
Bone densitometry sources	Cd-109	Max	2.0E-02	7.4E-04	2.E+01	3.7E-05	5	
	Cd-109	Min	2.0E-02	7.4E-04	2.E+01	3.7E-05	5	4
	Cd-109	Typ	2.0E-02	7.4E-04	2.E+01	3.7E-05	5	
	Gd-153	Max	1.5E+00	5.6E-02	1.E+00	5.6E-02	4	
	Gd-153	Min	2.0E-02	7.4E-04	1.E+00	7.4E-04	5	4
	Gd-153	Typ	1.0E+00	3.7E-02	1.E+00	3.7E-02	4	
	I-125	Max	8.0E-01	3.0E-02	2.E-01	1.5E-01	4	
	I-125	Min	4.0E-02	1.5E-03	2.E-01	7.4E-03	5	4
	I-125	Typ	5.0E-01	1.9E-02	2.E-01	9.3E-02	4	
	Am-241	Max	2.7E-01	1.0E-02	6.E-02	1.7E-01	4	
	Am-241	Min	2.7E-02	1.0E-03	6.E-02	1.7E-02	4	4
	Am-241	Typ	1.4E-01	5.0E-03	6.E-02	8.3E-02	4	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
Static eliminators	Am-241	Max	1.1E-01	4.1E-03	6.E-02	6.8E-02	4	
	Am-241	Min	3.0E-02	1.1E-03	6.E-02	1.9E-02	4	4
	Am-241	Typ	3.0E-02	1.1E-03	6.E-02	1.9E-02	4	
	Po-210	Max	1.1E-01	4.1E-03	6.E-02	6.8E-02	4	
	Po-210	Min	3.0E-02	1.1E-03	6.E-02	1.9E-02	4	4
	Po-210	Typ	3.0E-02	1.1E-03	6.E-02	1.9E-02	4	
Diagnostic isotope generators	Mo-99	Max	1.0E+01	3.7E-01	3.E-01	1.2E+00	3	
	Mo-99	Min	1.0E+00	3.7E-02	3.E-01	1.2E-01	4	4
	Mo-99	Typ	1.0E+00	3.7E-02	3.E-01	1.2E-01	4	
Medical unsealed sources	I-131	Max	2.0E-01	7.4E-03	2.E-01	3.7E-02	4	
	I-131	Min	1.0E-01	3.7E-03	2.E-01	1.9E-02	4	[c]
	I-131	Typ	1.0E-01	3.7E-03	2.E-01	1.9E-02	4	
				Category 5				
XRF analyser sources	Fe-55	Max	1.4E-01	5.0E-03	8.E+02	6.2E-06	5	
	Fe-55	Min	3.0E-03	1.1E-04	8.E+02	1.4E-07	5	5
	Fe-55	Typ	2.0E-02	7.4E-04	8.E+02	9.3E-07	5	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
	Cd-109	Max	1.5E-01	5.6E-03	2.E+01	2.8E-04	5	
	Cd-109	Min	3.0E-02	1.1E-03	2.E+01	5.6E-05	5	5
	Cd-109	Typ	3.0E-02	1.1E-03	2.E+01	5.6E-05	5	
	Co-57	Max	4.0E-02	1.5E-03	7.E-01	2.1E-03	5	
	Co-57	Min	1.5E-02	5.6E-04	7.E-01	7.9E-04	5	5
	Co-57	Typ	2.5E-02	9.3E-04	7.E-01	1.3E-03	5	
Electron capture detector sources	Ni-63	Max	2.0E-02	7.4E-04	6.E+01	1.2E-05	5	
	Ni-63	Min	5.0E-03	1.9E-04	6.E+01	3.1E-06	5	5
	Ni-63	Typ	1.0E-02	3.7E-04	6.E+01	6.2E-06	5	
	H-3	Max	3.0E-01	1.1E-02	2.E+03	5.6E-06	5	
	H-3	Min	5.0E-02	1.9E-03	2.E+03	9.3E-07	5	5
	H-3	Typ	2.5E-01	9.3E-03	2.E+03	4.6E-06	5	
Lightning preventers	Am-241	Max	1.3E-02	4.8E-04	6.E-02	8.0E-03	5	
	Am-241	Min	1.3E-03	4.8E-05	6.E-02	8.0E-04	5	5
	Am-241	Typ	1.3E-03	4.8E-05	6.E-02	8.0E-04	5	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (*A*)		*D* value (TBq)	Ratio of *A*/*D*	Category	
			Ci	TBq			*A*/*D* based	Recommended
	Ra-226	Max	8.0E-05	3.0E-06	4.E-02	7.4E-05	5	
	Ra-226	Min	7.0E-06	2.6E-07	4.E-02	6.5E-06	5	5
	Ra-226	Typ	3.0E-05	1.1E-06	4.E-02	2.8E-05	5	
	H-3	Max	2.0E-01	7.4E-03	2.E+03	3.7E-06	5	
	H-3	Min	2.0E-01	7.4E-03	2.E+03	3.7E-06	5	5
	H-3	Typ	2.0E-01	7.4E-03	2.E+03	3.7E-06	5	
Brachytherapy sources: low dose rate eye plaques and permanent implants	Sr-90	Max	4.0E-02	1.5E-03	1.E+00	1.5E-03	5	
	Sr-90	Min	2.0E-02	7.4E-04	1.E+00	7.4E-04	5	5
	Sr-90	Typ	2.5E-02	9.3E-04	1.E+00	9.3E-04	5	
	Ru/Rh-106	Max	6.0E-04	2.2E-05	3.E-01	7.4E-05	5	
	Ru/Rh-106	Min	2.2E-04	8.1E-06	3.E-01	2.7E-05	5	5
	Ru/Rh-106	Typ	6.0E-04	2.2E-05	3.E-01	7.4E-05	5	
	Pd-103	Max	3.0E-02	1.1E-03	9.E+01	1.2E-05	5	
	Pd-103	Min	3.0E-02	1.1E-03	9.E+01	1.2E-05	5	5
	Pd-103	Typ	3.0E-02	1.1E-03	9.E+01	1.2E-05	5	

TABLE 2. CATEGORIES FOR SOURCES USED IN SOME COMMON PRACTICES (cont.)

I	II	III	IV	V	VI	VII	VIII	IX
Source	Radionuclide		Quantity in use (A)		D value (TBq)	Ratio of A/D	Category	
			Ci	TBq			A/D based	Recommended
PET check sources	Ge-68	Max	1.0E-02	3.7E-04	7.E-01	5.3E-04	5	
	Ge-68	Min	1.0E-03	3.7E-05	7.E-01	5.3E-05	5	5
	Ge-68	Typ	3.0E-03	1.1E-04	7.E-01	1.6E-04	5	
Mossbauer spectrometry sources	Co-57	Max	1.0E-01	3.7E-03	7.E-01	5.3E-03	5	5
	Co-57	Min	5.0E-03	1.9E-04	7.E-01	2.6E-04	5	5
	Co-57	Typ	5.0E-02	1.9E-03	7.E-01	2.6E-03	5	5
Tritium targets	H-3	Max	3.0E+01	1.1E+00	2.E+03	5.6E-04	5	
	H-3	Min	3.0E+00	1.1E-01	2.E+03	5.6E-05	5	5
	H-3	Typ	7.0E+00	2.6E-01	2.E+03	1.3E-04	5	
Medical unsealed sources	P-32	Max	6.0E-01	2.2E-02	1.E+01	2.2E-03	5	
	P-32	Min	6.0E-02	2.2E-03	1.E+01	2.2E-04	5	[c]
	P-32	Typ	6.0E-01	2.2E-02	1.E+01	2.2E-03	5	

[a] Calibration sources are found in all categories except Category 1. They have been assigned to Table 2 in accordance with the radionuclide and activity. The regulatory body may modify the assignment on the basis of specific factors and circumstances.

[b] ^{238}Pu sources are no longer manufactured for use in pacemakers.

[c] Unsealed medical sources typically fall into Categories 4 and 5. The unsealed nature of these sources and their short half-life requires their case by case categorization.

Appendix II

PLAIN LANGUAGE DESCRIPTIONS OF THE CATEGORIES

(The following plain language description of the categorization of sources has been developed for purposes of public information.)

II.1. Radioactive sources are used throughout the world for a wide variety of beneficial purposes in industry, medicine, agriculture, research and education. When such sources are safely managed and securely protected, the risks to workers and the public are kept acceptably low and the benefits will outweigh any associated hazards.

II.2. If a radioactive source were to become separated from the system of control or the radioactive material from the source were to become dispersed as a result of an accident or a malevolent act, people could be exposed to radiation at dangerous levels. For the purposes of this Safety Guide, and in accordance with the Safety Requirements for emergency preparedness and response [25] and the Code of Conduct [19], a radioactive source is considered dangerous if its misuse could be life threatening or could cause a permanent injury that would reduce the quality of life of the person exposed. Possible permanent injuries include burns requiring surgery and debilitating injuries to the hands. Temporary injuries such as reddening and irritation of the skin or temporary changes to the composition of the blood are not considered dangerous. The extent of any such injuries will depend on many factors, including: the activity of the radioactive source; how close a person is to the source and for how long; whether the source is shielded; and whether or not its radioactive material has been dispersed, thus leading to contamination of the skin or inhalation or ingestion. For the purposes of categorization, any possible harm from delayed effects of radiation — such as radiation induced cancer developing later in life in any persons who are exposed — is treated as a secondary consideration to the paramount need to protect against the dangerous consequences described above.

II.3. The categorization shown in Table 3 provides a ranking of radioactive sources in terms of their potential to cause early harmful health effects if the source is not safely managed or securely protected. Sources are classified into five categories: Category 1 sources are potentially the most dangerous and Category 5 sources are the most unlikely to be dangerous. In Table 3, two types of risk are considered: the risk in handling or being close to a source, and the risk associated with radioactive material being dispersed from a source by fire or explosion. A third type of risk arises from the potential for a source to contaminate a public water supply. It would be highly unlikely for a Category 1 source to contaminate a public water supply to dangerous levels, even if the radioactive material were highly soluble in water. It would be virtually impossible for a source in Category 2, 3, 4 or 5 to contaminate a public water supply to dangerous levels.

TABLE 3. PLAIN LANGUAGE DESCRIPTIONS OF THE CATEGORIES

Category of source	Risk in being close to an individual source	Risk in the event that the radioactive material in the source is dispersed by fire or explosion
1	**Extremely dangerous to the person:** This source, if not safely managed or securely protected, would be likely to cause permanent injury to a person who handled it or who was otherwise in contact with it for more than a few minutes. It would probably be fatal to be close to this amount of unshielded radioactive material for a period in the range of a few minutes to an hour.	This amount of radioactive material, if dispersed, could possibly — although it would be unlikely — permanently injure or be life threatening to persons in the immediate vicinity. There would be little or no risk of immediate health effects to persons beyond a few hundred metres away, but contaminated areas would need to be cleaned up in accordance with international standards. For large sources the area to be cleaned up could be a square kilometre or more.[a]
2	**Very dangerous to the person:** This source, if not safely managed or securely protected, could cause permanent injury to a person who handled it or who was otherwise in contact with it for a short time (minutes to hours). It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of hours to days.	This amount of radioactive material, if dispersed, could possibly – although it would be very unlikely — permanently injure or be life threatening to persons in the immediate vicinity. There would be little or no risk of immediate health effects to persons beyond a hundred metres or so away, but contaminated areas would need to be cleaned up in accordance with international standards. The area to be cleaned up would probably not exceed a square kilometre.[a]
3	**Dangerous to the person:** This source, if not safely managed or securely protected, could cause permanent injury to a person who handled it or who was otherwise in contact with it for some hours. It could possibly — although it would be unlikely — be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks.	This amount of radioactive material, if dispersed, could possibly – although it would be extremely unlikely — permanently injure or be life threatening to persons in the immediate vicinity. There would be little or no risk of immediate health effects to persons beyond a few metres away, but contaminated areas would need to be cleaned up in accordance with international standards. The area to be cleaned up would probably not exceed a small fraction of a square kilometre.[a]

TABLE 3. PLAIN LANGUAGE DESCRIPTIONS OF THE CATEGORIES (cont.)

Category of source	Risk in being close to an individual source	Risk in the event that the radioactive material in the source is dispersed by fire or explosion
4	**Unlikely to be dangerous to the person:** It is very unlikely that anyone would be permanently injured by this source. However, this amount of unshielded radioactive material, if not safely managed or securely protected, could possibly — although it would be unlikely — temporarily injure someone who handled it or who was otherwise in contact with it for many hours, or who was close to it for a period of many weeks.	This amount of radioactive material, if dispersed, could not permanently injure persons.[b]
5	**Most unlikely to be dangerous to the person:** No one could be permanently injured by this source.[b]	This amount of radioactive material, if dispersed, could not permanently injure anyone.[b]

[a] The size of the area to be cleaned up would depend on many factors (including the activity, the radionuclide, how it was dispersed and the weather).

[b] Possible delayed health effects are not taken into account in this statement (see para. II.2).

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Annex I

RATIONALE AND METHOD FOR THE CATEGORIZATION OF RADIOACTIVE SOURCES

BASIS FOR THE CATEGORIZATION SYSTEM

I-1. When radioactive sources are managed in accordance with safety standards in a safe and secure manner, the radiation risks to workers and the public are kept acceptably low. However, if they are not managed appropriately, as in the case of accidents, malicious use or orphan sources, high activity sources may cause a range of deterministic health effects, including erythema, tissue burns, acute radiation sickness and death.

I-2. In recognition of the fact that human health is of paramount importance, therefore, the categorization system is based on the potential for radioactive sources to cause deterministic health effects. This potential is due partly to the physical properties of the source, especially its activity, and partly to the way in which the source is used. The practice in which the source is used, the provision of any inherent shielding provided by the device containing the source, the level of supervision and other factors need to be taken into consideration, as described in paras I-13–I-14.

I-3. Certain factors are specifically excluded from the categorization criteria:

— Socioeconomic consequences resulting from radiological accidents or malicious acts are excluded, as no methodology for quantifying and comparing these effects, especially on an international basis, has yet been developed;
— The intentional exposure of patients for medical reasons is excluded from the categorization criteria, although the radioactive sources used for these purposes are included in the categorization system as there have been accidents involving such sources [I-1–I-3].

The stochastic effects of radiation exposure (e.g. an increased risk of cancer) are not quantified in the derivation of the *D* values. However, given that the risk of stochastic effects increases with exposure, higher category sources will, in general, present a higher risk of stochastic effects. Furthermore, the deterministic effects resulting from an accident or malicious act are likely in the short term to overshadow any increased risk of stochastic effects. The deliberate ingestion of radioactive material by individuals was not taken into consideration.

METHODOLOGY AND DEVELOPMENT OF THE CATEGORIZATION SYSTEM

Collection of data

I-4. Data on the radionuclides and activities used for various sources and practices [I-4, I-5, I-6] are given in Appendix I. For each practice (e.g. industrial radiography) and each radionuclide used within the practice, three activity levels are given: the maximum, minimum and typical levels (there may be exceptions that have not been included). These data are given in Columns I–V of Table 2 in Appendix I.

Normalizing factor

I-5. In order to rank sources and practices numerically on a common basis, each source activity is divided by a normalizing factor — the *D* value, as described below. Initial consideration was given to using the A_1 and A_2 values from the IAEA Transport Regulations [I-7] as normalizing factors. However, although the A_1 and A_2 values are well established and could be used as a means of comparing risks arising from radionuclides in transport, other factors limit their application for other uses. Since A_1 and A_2 were derived for transport related purposes [I-8], whereas the categorization system is needed for general application, it was considered inappropriate to use A_1 and A_2 values as the normalizing factors.

I-6. The IAEA has developed a listing of radionuclide specific activity levels for the purposes of emergency planning and response [I-9]. These levels, referred to in this Safety Guide as *D* values, are given in terms of an activity above which a radioactive source is considered to be a 'dangerous source' as it has a significant potential for causing severe deterministic effects if it is not managed safely and securely. Since the categorization is also based on the potential for sources to cause deterministic health effects, the *D* values were considered to be compatible normalizing factors for the purpose of generating a numerical ranking of sources and practices. A comprehensive listing of radionuclide specific *D* values for both external (D_1 values) and internal (D_2 values) exposure is given in Ref. [I-9]. For the purposes of developing the categorization, the more restrictive of the D_1 and D_2 values was used as the radionuclide specific normalizing factor. The D values, for the radionuclides listed in Appendix I, are given in Table II-2 of Annex II. (Note that because Table II-2 shows only the more restrictive value of D_1 and D_2, it cannot be used in reverse to derive doses that may arise from sources with a known activity.)

Ranking of sources

I-7. For each source, its activity in TBq (column V, Table 2, Appendix I) was divided by the corresponding radionuclide specific D value in TBq (column VI) to give a dimensionless normalized ratio of A/D (column VII).

Number of categories

I-8. In order to fulfil the various needs of the categorization system, the relative ranking of sources needs to be divided into a number of discrete categories. The optimum number of categories and the A/D bounding values between them require a certain degree of judgement based on professional expertise. The following factors were taken into consideration:

— Setting too few categories might lead to categories being split at a later date to meet national or other needs. This could lead to a loss of transparency of the categorization system and a loss of international harmonization, resulting in the potential for inconsistent approaches to similar issues.
— Setting too many categories might imply a degree of precision that is not warranted and would be difficult to justify. Having too many categories might, furthermore, lead to difficulties in the application of the categorization system and discourage its use.

Category boundaries based on radionuclide and activity

I-9. Sources with an activity greater than D have the potential to cause severe deterministic effects. The activity ratio $A/D = 1$ was, therefore, considered to be a logical category bounding value, resulting in two categories. However, in order for the categorization system to accommodate the many and various uses, there clearly needed to be more than two categories.

I-10. In the development of the D values, it was recognized that a source activity ten times greater than D could give rise to a life threatening exposure in a relatively short period of time [I-10]. Hence a category bounding values was set at $A/D = 10$. This, however, left some very high activity sources (e.g.

RTGs) in the same category as sources with significantly lower activity (e.g. high dose rate (HDR) brachytherapy sources). It was therefore decided to use operational experience, professional judgement and lessons learned from radiological accidents to separate these practices, which resulted in a further bounding value at $A/D = 1000$.

I-11. As there was a wide range of practices and sources with activity below $A/D = 1$, a further category bounding value was needed. Operational experience, professional judgement and lessons learned from radiological accidents were again used to draw a bounding value at $A/D = 0.01$, with a lower cut-off for this category set at the activity of a radionuclide that is considered 'exempt' from regulatory control. Radionuclide specific exemption levels are given in Schedule I of the BSS [I-11].

I-12. Taking all the above factors into consideration resulted in a five category system, as shown in Appendix I. The assignment of sources to categories was then refined by considering, where appropriate, factors other than their activity A.

Refinement of the categorization system

I-13. Experience and judgement were used to review the categorization of each practice or source. The results indicated that, although the A/D ratios provided a robust and logical basis for the categorization, other risk factors may also be relevant. The categorization of each type of source and the practice in which it is used was reviewed, therefore, with consideration given to factors such as the nature of the work, the mobility of the source, experience from reported accidents, and typical and unique activities within an application. For example, some low activity RTGs could fall into Category 2 if the activity alone were considered. However, all RTGs were assigned to Category 1, since they are likely to be put to use in remote locations, unsupervised, and they may contain large amounts of plutonium or strontium. Likewise, although some ^{169}Yb sources used for industrial radiography fall into Category 3 by virtue of their activity alone, the practice was categorized as Category 2 in recognition of the relatively large number of accidental radiation exposures that have occurred with industrial radiography sources. The final categorization for some of the most common applications is given in Table 1, Section 2, and a comparison of categories based solely on A/D with those to which practices were finally assigned is shown in columns VIII and IX of Table 2 of Appendix I.

I-14. It was considered undesirable for a particular practice to span two categories, where it was practicable to avoid it. However, in some cases it was necessary to divide a generic practice in this way because of the wide range of activities within it (e.g. brachytherapy was divided into HDR, low dose rate (LDR) and permanent implants). In other cases, such as for calibration sources, it was not possible to assign sources to a single category since their activity may range from a low activity to over 100 TBq. In such situations, the categorization can be considered by national authorities case by case by calculating the A/D ratio and then considering other factors as appropriate.

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Annex II

THE *D* VALUE

II-1. This annex explains the concept of a 'dangerous source' and the origins of the *D* value that was used in the development of the categorization system. It is a brief summary only, and Refs [II-1, II-2] should be consulted for a more detailed explanation.

II-2. A dangerous source is defined as a source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. A deterministic effect is defined as a health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a severe deterministic effect if it is fatal or life threatening or results in a permanent injury that reduces the quality of life.

II-3. The concept of a dangerous source has been converted into operational parameters by calculating the quantity of radioactive material that could give rise to severe deterministic effects for given exposure scenarios and for given dose criteria [II-1]. In addition to typical accident situations, these scenarios include dispersion situations that may be relevant to malevolent acts. The following exposure scenarios (and pathways) were considered:

— An unshielded source being carried in the hand for one hour or in a pocket for 10 hours, or being in a room for days to weeks (the D_1 value);
— Dispersal of a source, for example by fire, explosion or human action, resulting in exposure due to inhalation, ingestion and/or skin contamination (the D_2 value).

The ingestion of food deliberately contaminated with radioactive material was not taken into consideration. For the purposes of the categorization, the lower value of D_1 and D_2 from Ref. [II-1] was used as the *D* value (see Table II-2).

II-4. The derivation of the dangerous source values relates to the following dose criteria (see Table II-1):

(1) *A dose of 1 Gy to the bone marrow or 6 Gy to the lung from low linear energy transfer (low LET) radiation, received by the organ in 2 d*. These are the dose levels from Table IV-I of Schedule IV of the BSS at which intervention is always justified to prevent early deaths [II-3–II-5]. It

should be noted that these are limiting criteria associated with the lowest dose rates that are considered to be life threatening [II-1].

(2) *A dose of 25 Gy to the lung from inhalation exposure to high LET radiation in 1 a.* This is the dose level at which fatalities are likely to be induced within 1.5 a owing to radiation pneumonitis and pulmonary fibrosis [II-6].

(3) *A dose of 5 Gy to the thyroid received by the organ in 2 d.* This is the dose level from Table IV-I of Schedule IV of the BSS at which intervention is always justified to prevent hypothyroidism. Hypothyroidism is assumed to reduce the quality of life.

(4) *For a source in contact with tissue, a dose of more than 25 Gy at a depth of: (a) 2 cm for most parts of the body (e.g. from a source in a pocket) or (b) 1 cm for the hand.* A dose of 25 Gy is the threshold for necrosis (death of tissue) [II-5, II-7]. Experience [II-8] indicates that tissue death in many parts of the body (e.g. in the thigh) from carrying a source in a pocket can be successfully treated without resulting in a reduction in the quality of life provided that the absorbed dose to tissue within about 2 cm of a source is kept below 25 Gy. However, for a source carried in the hand, the absorbed dose to tissue within about 1 cm must be kept below 25 Gy in order to prevent an injury that would reduce the quality of life.

(5) *For a source that is considered too big to be carried, a dose of 1 Gy to the bone marrow in 100 h from a source at a distance of 1 m.*

TABLE II-1. REFERENCE DOSES FOR *D* VALUES

Tissue	Dose criteria
Bone marrow	1 Gy in 2 d
Lung	6 Gy in 2 d from low LET radiation 25 Gy in 1 a from high LET radiation
Thyroid	5 Gy in 2 d
Skin/tissue (contact)	25 Gy at a depth of 2 cm for most parts of the body (e.g. from a source in a pocket) or 1 cm for the hand, for a period of 10 h
Bone marrow	1 Gy in 100 h for a source that is too big to be carried

TABLE II-2. ACTIVITY[a] CORRESPONDING TO A DANGEROUS SOURCE (*D* VALUE[b]) FOR SELECTED RADIONUCLIDES, AND MULTIPLES THEREOF

Radionuclide	1000 × *D*		10 × *D*		*D*		0.01 × *D*	
	TBq	Ci[c]	TBq	Ci[c]	TBq	Ci[c]	TBq	Ci[c]
Am-241	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00	6.E-04	2.E-02
Am-241/Be	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00	6.E-04	2.E-02
Au-198	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00	2.E-03	5.E-02
Cd-109	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02	2.E-01	5.E+00
Cf-252	2.E+01	5.E+02	2.E-01	5.E-00	2.E-02	5.E-01	2.E-04	5.E-03
Cm-244	5.E+01	1.E+03	5.E-01	1.E+01	5.E-02	1.E+00	5.E-04	1.E-02
Co-57	7.E+02	2.E+04	7.E+00	2.E+02	7.E-01	2.E+01	7.E-03	2.E-01
Co-60	3.E+01	8.E+02	3.E-01	8.E+00	3.E-02	8.E-01	3.E-04	8.E-03
Cs-137	1.E+02	3.E+03	1.E+00	3.E+01	1.E-01	3.E+00	1.E-03	3.E-02
Fe-55	8.E+05	2.E+07	8.E+03	2.E+05	8.E+02	2.E+04	8.E+00	2.E+02
Gd-153	1.E+03	3.E+04	1.E+01	3.E+02	1.E+00	3.E+01	1.E-02	3.E-01
Ge-68	7.E+01	2.E+03	7.E-01	2.E+01	7.E-02	2.E+00	7.E-04	2.E-02
H-3	2.E+06	5.E+07	2.E+04	5.E+05	2.E+03	5.E+04	2.E+01	5.E+02
I-125	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00	2.E-03	5.E-02
I-131	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00	2.E-03	5.E-02
Ir-192	8.E+01	2.E+03	8.E-01	2.E+01	8.E-02	2.E+00	8.E-04	2.E-02
Kr-85	3.E+04	8.E+05	3.E+02	8.E+03	3.E+01	8.E+02	3.E-01	8.E+00
Mo-99	3.E+02	8.E+03	3.E+00	8.E+01	3.E-01	8.E+00	3.E-03	8.E-02
Ni-63	6.E+04	2.E+06	6.E+02	2.E+04	6.E+01	2.E+03	6.E-01	2.E+01
P-32	1.E+04	3.E+05	1.E+02	3.E+03	1.E+01	3.E+02	1.E-01	3.E+00
Pd-103	9.E+04	2.E+06	9.E+02	2.E+04	9.E+01	2.E+03	9.E-01	2.E+01
Pm-147	4.E+04	1.E+06	4.E+02	1.E+04	4.E+01	1.E+03	4.E-01	1.E+01
Po-210	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00	6.E-04	2.E-02
Pu-238	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00	6.E-04	2.E-02
Pu-239[d]/Be	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00	6.E-04	2.E-02
Ra-226	4.E+01	1.E+03	4.E-01	1.E+01	4.E-02	1.E+00	4.E-04	1.E-02
Ru-106 (Rh-106)	3.E+02	8.E+03	3.E+00	8.E+01	3.E-01	8.E+00	3.E-03	8.E-02
Se-75	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00	2.E-03	5.E-02

TABLE II-2. ACTIVITY[a] CORRESPONDING TO A DANGEROUS SOURCE (*D* VALUE[b]) FOR SELECTED RADIONUCLIDES, AND MULTIPLES THEREOF (cont.)

Radionuclide	1000 × *D*		10 × *D*		*D*		0.01 × *D*	
	TBq	Ci[c]	TBq	Ci[c]	TBq	Ci[c]	TBq	Ci[c]
Sr-90 (Y-90)	1.E+03	3.E+04	1.E+01	3.E+02	1.E+00	3.E+01	1.E-02	3.E-01
Tc-99^{m}	7.E+02	2.E+04	7.E+00	2.E+02	7.E-01	2.E+01	7.E-03	2.E-01
Tl-204	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02	2.E-01	5.E+00
Tm-170	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02	2.E-01	5.E+00
Yb-169	3.E+02	8.E+03	3.E+00	8.E+01	3.E-01	8.E+00	3.E-03	8.E-02

[a] Since Table II-2 does not show which dose criteria were used, these *D* values should not be used in reverse to derive possible doses due to sources of known activity.

[b] Full details of the derivation of the *D* values and *D* values for additional radionuclides are provided in Ref. [II-1].

[c] The primary values to be used are given in TBq. Curie values are provided for practical usefulness and these are rounded after conversion.

[d] Criticality and safeguards issues will need to be considered for large multiples of *D*.

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GLOSSARY

accident. Any unintended event, including operating errors, equipment failures, or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

dangerous source. A source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. This categorization is used for determining the need for emergency response arrangements and is not to be confused with categorizations of sources for other purposes.

deterministic effect. A health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a 'severe deterministic effect' if it is fatal or life threatening or results in a permanent injury that reduces quality of life.

licence. A legal document issued by the regulatory body granting authorization to perform specified activities related to a facility or activity.

notification. A document submitted to the regulatory body by a legal person to notify an intention to carry out a practice or other use of a source.

orphan source. A radioactive source which is not under regulatory control, either because it has never been under regulatory control, or because it has been abandoned, lost, misplaced, stolen or otherwise transferred without proper authorization.

practice. Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

registration. A form of authorization for practices of low or moderate risks whereby the legal person responsible for the practice has, as appropriate, prepared and submitted a safety assessment of the facilities and equipment to the regulatory body. The practice or use is authorized with conditions or limitations as appropriate. The requirements for safety assessment and the conditions or limitations applied to the practice should be less severe than those for licensing.

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

sealed source. Radioactive material that is (a) permanently sealed in a capsule, or (b) closely bonded and in a solid form.

security of radioactive sources. Measures to prevent unauthorized access or damage to, and loss, theft or unauthorized transfer of, radioactive sources.

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