

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

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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

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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.

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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

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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

CATEGORIZATION OF RADIOACTIVE SOURCES

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2005

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Sales and Promotion Unit, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Austria
fax: +43 1 2600 29302
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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.

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IAEA SAFETY STANDARDS

SAFETY THROUGH INTERNATIONAL STANDARDS

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

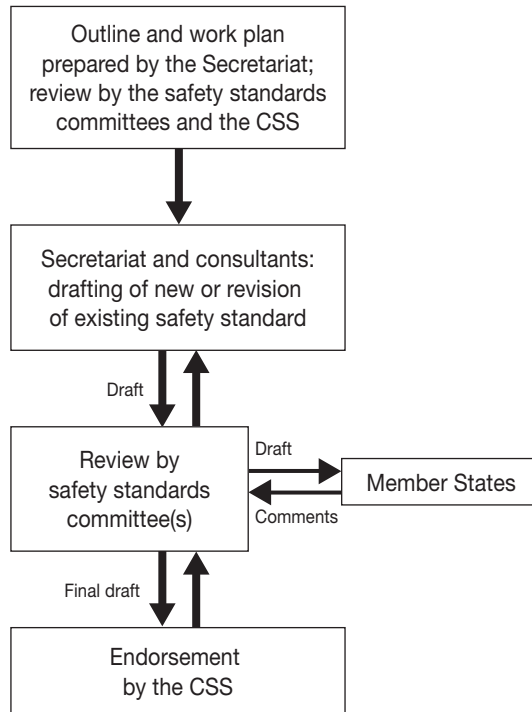
As well as by regulatory bodies and governmental departments, authorities and agencies, the standards are used by authorities and operating organizations in the nuclear industry; by organizations that design, manufacture and apply nuclear and radiation related technologies, including operating organizations 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.

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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 authorities¹ 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 risks³. The A/D values for a range of commonly used sources are given in Appendix I⁴. 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.

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 $A > \text{exempt}^d$

^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