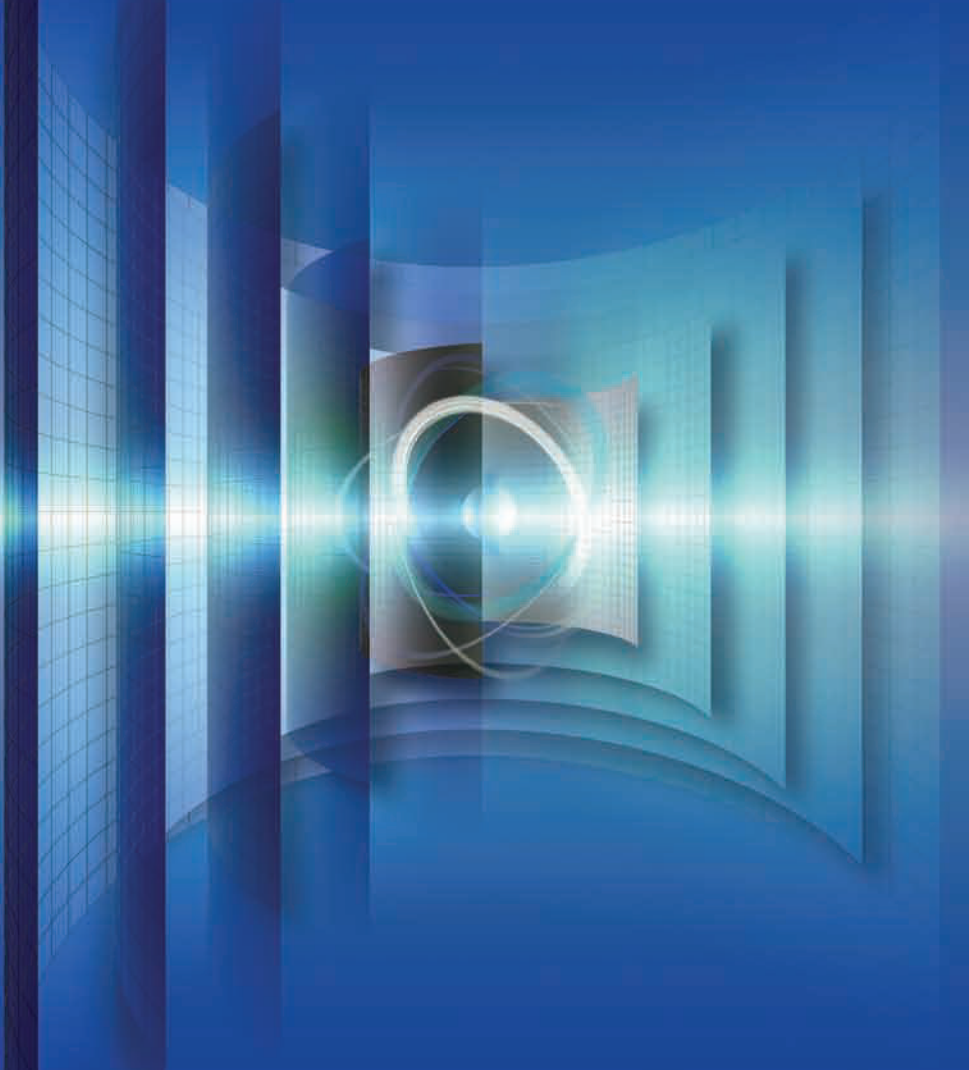
IAEA Nuclear Security Series No. 9

Implementing Guide

Security in the Transport of Radioactive Material



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SECURITY IN THE TRANSPORT OF RADIOACTIVE MATERIAL

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

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IMPLEMENTING GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2008

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International Atomic Energy Agency
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1400 Vienna, Austria
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tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
September 2008
STI/PUB/1348

IAEA Library Cataloguing in Publication Data

Security in the transport of radioactive material. — Vienna : International Atomic Energy Agency, 2008.
p. ; 24 cm. — (IAEA nuclear security series, ISSN 1816–9317 ; no. 9)
STI/PUB/1348
ISBN 978–92–0–107908–4
Includes bibliographical references.

1. Radioactive Substances — Transportation — Security measures. I. International Atomic Energy Agency. II. Series.

IAEAL 08–00539

FOREWORD

In response to a resolution by the IAEA General Conference in September 2002, the IAEA adopted an integrated approach to protection against nuclear terrorism. This approach coordinates IAEA activities concerned with the physical protection of nuclear material and nuclear installations, nuclear material accountancy, detection of, and response to, trafficking in nuclear and other radioactive material, the security of radioactive sources, security in the transport of nuclear and other radioactive material, emergency response and emergency preparedness in Member States and at the IAEA, and promotion of adherence by States to relevant international instruments. The IAEA also helps to identify threats and vulnerability related to the security of nuclear and other radioactive material. However, it is the responsibility of the States to provide for the physical protection of nuclear and other radioactive material and the associated facilities, to ensure the security of such material in transport, and to combat illicit trafficking and the inadvertent movement of radioactive material.

The IAEA's nuclear security plan of activities 2006–2009, approved by its Board of Governors in September 2005, clearly states the need for a comprehensive approach to security in the transport of radioactive material.

The potential destruction resulting from an improvised nuclear device or the potential economic and social disruption resulting from a radiological dispersal device could be enormous. Since 11 September 2001, a new realization has emerged regarding the potential for malicious acts involving nuclear material. Recent evaluations of the potential consequences of the use of a radiological dispersal device have identified the need to improve the security of radioactive material.

Examination of the supply chain for large radioactive sources (those capable of having serious consequences if used maliciously) shows that in certain circumstances these sources may be vulnerable to sabotage or diversion, such as when they are: (a) in use at inadequately protected fixed facilities and (b) being transported in import, domestic transport, in-use (in mobile applications) and export.

While considerable attention and resources have been directed towards improving the security of sources in facilities, there has been a less focused effort directed at the security of radioactive material, other than nuclear material, during transport; radioactive material is most vulnerable during transport. Transport of large radioactive sources is often an international activity involving movement through the public domain with minimal physical protection. The vulnerability of a package during transport highlights the absolute need for adequate security in transport. Additionally, perception of the risk involved in transporting radioactive material has changed. Historically, the emphasis has been on safety in transport, but now there is a recognized need to address security as a priority. The current concern about transport security may be due to the fact that the safety record for the transport of radioactive material has been very good but the threat of malicious acts, including sabotage, is now more widely recognized.

This guide can be used by regulatory bodies in Member States as a source of guidance when setting up national regulations for security in the transport of radioactive material. It includes contributions from the participants in meetings and individual contributions. Relevant national and international standards were taken into account. The work undertaken by the participants in meetings and other contributors is gratefully acknowledged.

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1. INTRODUCTION

1.1. BACKGROUND

Historically, the focus of IAEA publications on the transport of radioactive material has been on safety. The IAEA Safety Standards Series include the Regulations for the Safe Transport of Radioactive Material, TS-R-1 (henceforth referred to as the Transport Regulations), the latest version of which was published in 2005 [1], The Fundamental Safety Principles, which were published in 2006 [2] and the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [3], all of which are relevant to transport safety and, additionally, include limited coverage of security[1].

Efforts were initiated in 2002 by the IAEA to provide additional guidance for security in the transport of radioactive material, based upon the new security requirements in the Recommendations on the Transport of Dangerous Goods — Model Regulations [4]. These model regulations were developed by the United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. The United Nations Model Regulations (henceforth referred to as the Model Regulations) recommend a basic security level with commensurate provisions for the transport of all dangerous goods, and an enhanced security level with additional provisions for those quantities of dangerous goods defined as 'high consequence' dangerous goods. These provisions became part of the Model Regulations in late 2003.

To that end, the IAEA convened a series of meetings to develop a defensible technical basis for establishing security levels for the protection of radioactive material in transport and appropriate security measures commensurate with the potential radiological consequences that could result from malicious use of radioactive material. This guide is the result of these efforts.

The security regime for the transport of radioactive material defined in this guide addresses the radiological concerns and hazards associated with the unauthorized removal, sabotage and other malicious acts involving radioactive material (as opposed to the hazards posed by weapon usable nuclear material). It is intended to complement the security regime established under the

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[1] (Nuclear) security means the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.

Convention on the Physical Protection of Nuclear Material (CPPNM) [5], which addresses international transport of nuclear material and the Amendment relating thereto which extends, inter alia, to domestic transport.

1.2. RELATIONSHIP WITH OTHER PUBLICATIONS

The Model Regulations provide the basis for security requirements for the transport of dangerous goods implemented by States and international modal organizations. The security requirements for the transport of dangerous goods are found in Sections 1.4 and 7.2 of the Model Regulations.

Existing international instruments, recommendations and guidance for physical protection of nuclear material and security of radioactive sources, including during transport, can be found in:

- The CPPNM and Amendment of 8 July 2005 [5, 6] and The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225 Rev.4(Corrected) [7];
- The Code of Conduct on the Safety and Security of Radioactive Sources (henceforth referred to as the Code of Conduct) [8], Categorization of Radioactive Sources [9] and other guidance.

Other United Nations specialized agencies and programmes, e.g. the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO) and the United Nations Economic Commission for Europe (UNECE), and other intergovernmental organizations such as the Intergovernmental Organization for International Carriage by Rail have taken similar steps to provide improved security in the transport of all dangerous goods. The IMO, ICAO and UNECE have also amended their respective international instruments — the International Maritime Dangerous Goods Code, Technical Instructions for the Safe Transport of Dangerous Goods by Air, European Agreement Covering International Carriage of Dangerous Goods by Road, Regulations concerning the International Carriage of Dangerous Goods by Rail, European Agreement Covering International Carriage of Dangerous Goods by Inland Waterway — to reflect the security provisions of the Model Regulations, which became mandatory in international transport in 2005.

This guide builds on the obligations and guidance set forth in the previously noted security related publications [5–8] and in Physical Protection Objectives and Fundamental Principles [10] established by the IAEA for the physical protection of nuclear material and nuclear facilities.

The transport of nuclear material is governed by the CPPNM and subject to the recommended security measures specified in INFCIRC/225/ Rev.4(Corrected) [7]. INFCIRC/225/Rev.4(Corrected) discusses transport security with respect to the categorization of nuclear material, including specifics about thresholds for mass, enrichment, nuclides covered and non-proliferation aspects. The transport security measures in this guide are without prejudice to the provisions in INFCIRC/225/Rev.4(Corrected), in particular Section VIII thereof. However, for some category III nuclear material there may be cases where the potential radiological consequences of the material warrant higher security measures than those specified in INFCIRC/225/ Rev.4(Corrected). For example, because of their radioactivity, some category III nuclear material packages may require the enhanced security measures called for in this guide, which are more stringent than those in INFCIRC/225/ Rev.4(Corrected). In respect of these particular cases, this guide provides measures additional to those contained in INFCIRC/225/Rev.4(Corrected) [7].

The security measures specified in this guide also complement the provisions of the Code of Conduct [8] and its supplementary publication Guidance on the Import and Export of Radioactive Sources [11]. Related drafts on the security of radioactive sources and the security of radioactive waste are in preparation for publication in the Nuclear Security Series.

1.3. OBJECTIVE

Since transport occurs in the public domain and frequently involves intermodal transfers, it is a potentially vulnerable phase of domestic and international commerce. This guide is intended to facilitate a uniform and consistent approach to security.

The objective of this guide is to provide States with guidance in implementing, maintaining or enhancing a nuclear security regime to protect radioactive material (including nuclear material) while in transport against theft, sabotage or other malicious acts that could, if successful, have unacceptable radiological consequences. From a security point of view, a threshold is defined for determining which packages or types of radioactive material need to be protected beyond prudent management practice. Minimizing the likelihood of theft or sabotage of radioactive material during transport is accomplished by a combination of measures to deter, detect, delay and respond to such acts. These measures are complemented by other measures to recover stolen material and mitigate possible consequences, to further reduce the risks.

1.4. SCOPE

This guidance applies to the security of the international and domestic transport of all packages containing nuclear material as defined in the CPPNM and associated publications, and radioactive material that may pose a significant radiological hazard to individuals, society and the environment as a consequence of a malicious act.

1.5. STRUCTURE

The guidance contained in Section 2 to be applied to the transport of radioactive material is intended to be used by a State to develop a nuclear security system.

Section 3 uses the radioactivity level of the contents of a single package as the basis for defining security levels:

- For small quantities of radioactive material transported in excepted packages, as defined in TS-R-1 [1], with an activity level not exceeding the level permitted for the radionuclide when it is not in special form, or for material of low activity concentration (LSA-I material) or low level contaminated objects (SCO-I material), no specific security measures beyond the control measures required by the safety regulations, Basic Safety Standards [3] and **prudent management practices** already implemented by consignors and carriers are suggested.
- For any package with contents exceeding the excepted package quantity for non-special form contents and material other than LSA-I and SCO-I, a **basic security level** should be applied that includes some specific security measures.
- For radioactive material packaged in significant quantities, such that it is deemed to be ‘high consequence’ (Model Regulations terminology) radioactive material, an **enhanced security level** should be applied that includes both the basic security measures and enhanced security measures.
- Where, as a result of a State threat assessment or risk assessment, **additional security measures** are considered necessary, they may be applied by that State.

Section 4 sets out baseline measures and guidance for those States that may not already have a well-defined and developed security system, including a regulatory infrastructure and a threat assessment process. States with a well-defined and developed regulatory infrastructure and threat assessment process may already have an adequate degree of security in place. However, even these States may also find this guidance useful.

The generic guidelines presented in this guide are broadly consistent with the Model Regulations with regard to the number of security levels and the security measures proposed, although the threshold values and some details of the security measures proposed here (in Sections 3 and 4) differ from those in the Model Regulations.

The threshold values outlined in this guide have been derived on the basis of the potential radiological consequences of malicious acts involving radioactive material. The activity thresholds have been calculated and compared with existing approaches used in the Transport Regulations and in the Code of Conduct.

While safety in the transport of radioactive material is addressed by separate IAEA publications, it is recognized that some of the measures designed to address safety can also complement security aims. For this reason, the safety measures and procedures already in place as a result of the broad and effective application of the Transport Regulations at the modal level internationally and at the State level may already meet some security needs. Care should be taken to ensure that safety measures do not compromise security and that security measures do not compromise safety.

2. DESIGN AND EVALUATION OF SECURITY MEASURES

In determining the security measures to be implemented for radioactive material in transport, a number of topics need to be considered to prevent the unauthorized access to, or theft of, or other malicious acts involving the material. For the nuclear security regime of a State to function well, the responsibilities of all parties involved must, as a first step, be clearly defined. The threat which the material should be protected against should be determined and well understood by all parties involved in designing the security measures to be applied during transport. Operators'[2] security plans, where required, are considered the appropriate way to guide the in-depth implementation of the security measures. Depending on potential consequences, some types and quantities of material could be more attractive targets for malicious acts than others. This should be effectively addressed by a graded system of security measures.

2.1. GENERAL APPROACH

The responsibility for establishing, implementing and maintaining a security regime within a State rests entirely with that State. States need to establish a legislative and regulatory framework covering the security of radioactive material[3] in transport that effectively interfaces with the security system applied to such material while in use and during storage.

Security measures taken during the transport of radioactive material to protect it against malicious acts[4] should be based on evaluating the threat[5] to the material and its potential to generate unacceptable consequences.

Development of a radiological model to evaluate the potential radiological consequences resulting from malicious acts provides a logical and transparent basis for developing a graded and consistent system for specifying adequate levels of protection.

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[2] The term 'operator' is used to describe an entity (person or organization) authorized to operate a nuclear or radiological facility or authorized to use, store or transport nuclear material and/or radioactive material. Such an entity would normally hold a licence or other document of authorization from a competent authority or be contractors of a holder of such an authorization. Definitions and explanations of terms are also provided in Section II of Ref. [1] and in the IAEA Safety Glossary [12].

[3] Radioactive material is material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.

[4] A malicious act is a deliberate act to remove radioactive material from authorized control (theft) or an act directed against radioactive material (e.g. sabotage) that could endanger workers, the public and the environment by exposure to radiation or the release or dispersal of radioactive material, including the deliberate dispersion of radioactive material to cause economic and social disruption.

[5] A threat is a characterization of an adversary capable of causing undesirable consequences, including the objectives, motivation and capabilities, e.g. number of potential attackers, equipment, training and attack plan.

Consideration should be given to the impact on human health and to the potential for economic, environmental or social harm and disruption resulting from malicious acts.

2.2. BASIC SECURITY CONSIDERATIONS

The security considerations embodied in this guide have been adapted from those in the Code of Conduct [8] and those for nuclear material[6] presented in Physical Protection Objectives and Fundamental Principles [10] and in the Amendment to the CPPNM [5].

For the transport of radioactive material, the considerations for security are:

- The responsibility of the State;
- Legislative and regulatory frameworks;
- The need to establish or designate a competent authority[7];
- Responsibilities of those involved in transport (e.g. consignors, carriers and consignees);
- Security culture;
- Threat evaluation;
- Use of a graded approach;
- The concept of defence in depth;
- Management systems;
- Contingency/emergency plans;
- Confidentiality.

2.3. SECURITY CONSIDERATIONS FOR TRANSPORT

The transport of radioactive material is usually an interim phase between production, use, storage and disposal of the material. The potential radiological

[6] Nuclear material means an plutonium, except that with isotopic concentration exceeding 80% in ^{238}Pu; ^{233}U; uranium enriched in the isotope ^{235}U or ^{233}U; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue; any material containing one or more of the foregoing.

[7] A competent authority is any national authority or authorities designated or otherwise recognized as such for any purpose relevant to this guide (adapted from Ref. [12]).

consequences of the loss of control due to theft of radioactive material during use, storage or transport do not differ in principle, although the potential consequences of an act of sabotage[8] might differ very much depending on the location of the radioactive material.

In view of the potential vulnerability of radioactive material in transport, the design of an adequate transport security system incorporates the concept of defence in depth[9] and uses a graded approach[10] to achieve the objective of preventing the material from becoming susceptible to malicious acts.

The transport security system should be designed to take into account:

- The quantity and the physical and chemical form of the radioactive material.
- The mode(s) of transport.
- The package(s) being used.
- Measures that are required:
  - To deter, detect and delay unauthorized access to the radioactive material while in transport and during storage in transit to defeat any attempted malicious acts;
  - To identify the actual possible malicious acts involving any consignment while in transport or during storage incidental to transport to enable an appropriate response and to allow recovery or mitigation efforts to start as soon as possible;

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[8] Sabotage is deliberate damage; sabotage in this context means deliberate damage to nuclear material or radioactive material in use, storage or transport or to an associated facility. A deliberate act directed against a nuclear facility or radioactive material in use, storage or transport could directly or indirectly endanger the health and safety of personnel, the public or the environment by exposure to radiation or release of radioactive material (adapted from Ref. [7]).

[9] The concept of defence in depth is used in designing security systems to require an adversary to overcome or circumvent multiple obstacles, either similar or diverse, to achieve an objective. The approach consists of implementing several layers of defence, including both administrative aspects (procedures, instructions, sanctions, access control rules, confidentiality rules) and technical aspects (multiple layers of protection together with measures for detection and delay) that adversaries would have to overcome or circumvent to achieve their objectives.

[10] A graded approach is an approach or process by which the scope, depth and rigour of the management and engineering control measures (such as a physical protection system) are commensurate with the evaluation of the threat and the magnitude of any hazard involved with the failure of the item or process concerned.

- — To provide rapid response to any attempts directed towards, or actual, unauthorized access to radioactive material, or to other malicious acts involving radioactive material while in transport or storage incidental to such transport.
- Capabilities for:
  - — Recovering any damaged, stolen or lost radioactive material and bringing it under secure regulatory control;
  - — Minimizing and mitigating the radiological consequences of any theft, sabotage or other malicious act.

The achievement of effective security in transport can be assisted by considering transport schedules, routing, security of passage, information security and procedures. In particular, and as far as is operationally practicable, general recommendations to be regarded as best practice are as follows:

- Regular movement schedules are to be avoided to the extent practicable.
- Routes are planned in such a way as to avoid areas of natural disaster, civil disorder or known threats; in the case of shipments of Category 1 and 2 sources, alternative routes are identified in advance of such shipments in case they are required under circumstances such that the primary route is not available.
- The total time that radioactive material is in transport, the number of intermodal transfers and the waiting times associated with the intermodal transfer are kept to the minimum necessary.
- Advance knowledge of transport information and the security measures applied to the transport are restricted to the minimum number of persons necessary.
- Packages or conveyances containing radioactive material are not left unattended for any longer than is absolutely necessary.
- Radioactive material in transport and in temporary storage incidental to transport are subject to security measures consistent with those to be applied to the material in use and storage.

2.4. ROLES

2.4.1. Role of States

The establishment of an adequate security regime for the transport of radioactive material is the responsibility of each State. The State establishes the basic requirements for legal and governmental infrastructure for transport security, including:

- Designation of an independent competent authority responsible for the implementation, application, inspection and enforcement of the legislative and regulatory framework, including effective sanctions;
- Setting objectives for protecting individuals, society and the environment from radiation hazards, including those that might result from a malicious act involving radioactive material in transport;
- Development and integration of formal objectives and standards in security regulations;
- Identification of the State's domestic threat and the prescription of requirements for the design and evaluation of the security system in transport;
- Review of the security system on a regular basis in order to take account of advances in technology and potential changes in the threat;
- Procedure for submission by the operator and, where appropriate, approval by the competent authority of a security plan prior to transport of radioactive material;
- Development of a programme for verifying continued compliance with the security regulations through periodic inspections and by ensuring that corrective actions are taken when needed;
- Development of a policy to identify, classify and control sensitive information, the unauthorized disclosure of which could compromise the security of radioactive material in transport;
- Determination of security clearance procedures, including a positive identification programme (with an officially issued photographic identification or biometric record that positively identifies the individual), for persons engaged in the transport of radioactive material, commensurate with their responsibilities;
- Reporting of security related events, including losses;
- Establishment of criminal penalties for non-compliance with the requirements for security in transport.

The competent authority should be provided with adequate authority, competence, and financial and human resources to discharge its assigned responsibilities in relation to the security of radioactive material in transport and should have the capability to enforce the applicable requirements.

In addition, the State takes appropriate measures to ensure the promotion of a security culture [13] for all involved in the transport of radioactive material.

States establish appropriate mechanisms to cooperate, consult and exchange information on security techniques and practices for transport, within the constraints of confidentiality. States aid each other in recovering stolen or missing radioactive material when requested. Appropriate arrangements may be established between receiving and transit States and relevant intergovernmental organizations, to promote cooperation, harmonization and information exchange, and to ensure that material under their jurisdiction is adequately protected. The designated competent authority should be identified to other States and to the IAEA.

2.4.2. Roles of the operator

All operators (e.g. consignors, carriers, consignees) and other persons engaged in the transport of radioactive material should have the responsibility for implementing and maintaining security measures for the transport of radioactive material in accordance with national requirements.

All operators should have contingency plans in place to respond to malicious acts involving radioactive material in transport, including plans for the recovery of lost or stolen material and for mitigating consequences.

For international transport, operators should ensure in advance that any State by State variations in security measures are applied as the radioactive material package progresses on its journey and also should clearly determine the point at which the responsibility for security is transferred.

2.5. DETERMINATION OF SECURITY MEASURES

A State may use a prescriptive or performance based approach, or a combination, for defining objectives to be met or the security measures to be applied in the transport of radioactive material. In using the prescriptive approach, the State could employ the transport security levels discussed in Section 3 of this guide. Whichever approach is adopted, the security measures to be applied should comply with the administrative and technical requirements prescribed by national regulation (prescriptive based) or should be evaluated against the prevailing threat or the design basis threat[11] (performance based) to the State.

The prevailing threat or the design basis threat to the State may vary widely according to the State or to the location concerned.

It is necessary for States to review continuously the threats associated with radioactive material in transport and to evaluate the implications of any changes in those threats for the specification of security measures. States should share this information with carriers, as appropriate.

The basic steps required for specifying security measures are:

- At the State level:
  - Evaluating the potential consequences of malicious acts involving radioactive material;
  - Performing a threat assessment within the State, based on information from security and intelligence experts;
  - Establishing the security levels to be applied to radioactive material packages or conveyances;
  - Defining security objectives for each security level;
  - Specifying administrative and technical requirements or specific security measures necessary to meet the security objectives.
- At the operator level:
  - Identifying the radionuclides and their activities in each radioactive material package and the mode(s) of transport to be used;
  - Assigning security levels to the packages;
  - Determining appropriate security measures to meet regulatory requirements or to protect against the design basis threat, on the basis of the objectives set by national regulations.

The overall effectiveness of the security measures may be ensured either by complementing existing safety measures with additional security measures identified through a specific assessment of vulnerability based on the domestic threat or by applying measures that are already required and that are capable of coping with the domestic threat.

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[11] A design basis threat is a description of the attributes and characteristics of potential insider/external adversaries who might attempt unauthorized removal of nuclear material or radioactive material or sabotage, against which a physical protection system is designed and evaluated [14].

It is recognized that the information and resources required for the application of a comprehensive methodology for threat assessment[12] and vulnerability assessment may not always be available or may be deemed unnecessary in view of the potential radiological consequences of malicious acts involving the material being transported. Under these circumstances, security measures may be established using only a prescriptive approach. This approach involves specifying security levels and default security measures commensurate with the assumed level of threat and risk acceptance based solely on the potential (radiological or non-radiological) consequences of the malicious acts involving the radioactive material.

In such cases, the assignment of generic transport security levels based on the activity levels in each package as elaborated in Section 3 and the application of the guidance in Section 4 provide an acceptable generic method for defining security measures that a State and the operator could use for transport operations.

3. ESTABLISHING SECURITY LEVELS FOR RADIOACTIVE MATERIAL IN TRANSPORT

In order to specify the transport security levels in a manner that is easily understood and integrated into existing safety and security systems, it was essential to evaluate existing approaches being applied to radioactive material (including nuclear material) and sources. Two publications were used for this evaluation:

- The Code of Conduct [8] and the Categorization of Radioactive Sources [9]. Since these publications are being widely implemented to improve the safety and security of sources, the D-values that were developed to define a dangerous source are suitable for specifying the threshold activity for transport security levels.

[12] A threat assessment is an analysis that documents the credible motivations, intentions and capabilities of potential adversaries that could cause undesirable consequences with regard to radioactive material in use or storage and its associated facilities.

- Transport Regulations. These regulations use activity values A_1 and A_2 to specify the amount of radioactive material, above which the material must be transported in an accident resistant package. Since the A-values are well understood and used in the transport safety system, with appropriate numerical multipliers they are also suitable for specifying the activity thresholds.

The categorization of sealed sources contained in the Code of Conduct is based on the development of D-values for the Requirements in IAEA Safety Standards Series No. GS-R-2 [15], which specifies requirements for emergencies involving a dangerous source. These Safety Requirements define a dangerous source as one “that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects”. The Safety Requirements then go on to define a severe deterministic effect as one that “is fatal or life threatening or results in a permanent injury that decreases the quality of life”.

To apply the Safety Requirements, an operational definition of a dangerous source was needed. This operational definition of a dangerous source is known as the D-value. The D-value is that quantity of radioactive material, which, if uncontrolled, could result in the death of an exposed individual or a permanent injury that decreases that person’s quality of life.

Since there was a need for a categorization of radioactive sources[13] that was based upon the potential for sources to cause deterministic health effects, the D-values were also used as normalizing factors in generating the numerical relative ranking of sources and practices. Thus, the D-values were also used as the basis for the IAEA’s system for categorization of radioactive sources, parts of which became included in the Code of Conduct. The Code of Conduct lists D-values for 16 specific radioactive sources in the upper part of Table 1. However, according to the Code of Conduct, other radionuclides are very unlikely to be used in individual radioactive sources with an activity level that would place them within Categories 1, 2, or 3. For these radionuclides it was considered appropriate to use the Q system to determine enhanced threshold levels.

For transport, the Q system was developed as a methodology to evaluate a series of exposure routes, each of which might lead to radiation exposure, either external or internal, of persons in the vicinity of a Type A package

[13] A radioactive source is radioactive material that is permanently sealed in a capsule or closely bonded, is in a solid form and is not exempt from regulatory control (adapted from Ref. [8]).

involved in a severe accident in transport. In terms of the Basic Safety Standards [3], the Q system lies within the domain of potential exposures. A potential exposure is one that is not expected to be delivered with certainty but may result from an accident involving radioactive material or from an event or sequence of events of a probabilistic nature, including equipment failures and operating errors.

For potential exposures, a dose level of 50 mSv has been used on the grounds that, historically, actual accidents involving Type A packages have led to very low exposures. In choosing this reference dose, it is also important to take into account the probability of an individual being exposed as the result of a transport accident, since such exposures may, in general, be considered as ‘once in a lifetime’ exposures.

Neither of these approaches was entirely satisfactory from a security perspective. The Code of Conduct relates to sealed sources and considers deterministic health effects. The Q system uses the approach of considering stochastic health effects.

Since a malicious act involving radioactive material taken without authorization during transport may well involve the intentional dispersion of such material over a large area, a radiological dispersal device (RDD) scenario was considered. An RDD is a weapon of denial, i.e. it denies use of the affected area. Therefore, the dispersal of a radionuclide at levels that require the relocation or resettlement of people from the affected area is an appropriate measure of an effective RDD. Other types of malicious acts and consequences have also been taken into account in setting the thresholds in this section, such as the potential consequences of direct exposure to an unshielded radioactive source or plume, ingestion and inhalation.

A scoping model was used to calculate the amount of radioactive material required to cause resettlement of persons from an area contaminated by an RDD. ICRP 82, Protection of the Public in Situations of Prolonged Radiation Exposure [16], and an IAEA Safety Guide on emergency response [17] provide recommendations on action levels of dose in respect of actions to be taken following radiological incidents. Details of the scoping model, and its assumptions and parameters, are provided in the Appendix.

The results of the scoping model were compared with both the A-values and the D-values. This comparison sought to identify multipliers of those values that would approach but not exceed the model results. Given the uncertainties and conservative approaches inherent in the model, it was not necessary that a rigorous correlation be found, but only a reasonable one. It was found that a correlation could be made with either set of values. The Appendix provides the basis for the activity thresholds.

As a result, the following activity threshold values are used for the enhanced security level:

- For radioactive sources and other forms of radioactive material containing radionuclides covered by the Code of Conduct, 10 D (this includes Category 1 and Category 2 sources) per package; or
- For all other radionuclides, 3000 A_2 per package.

Some radioactive material poses a sufficiently low risk of radiological hazard that it does not present a security concern. Such material includes very small quantities (excepted packages with an activity level not exceeding the level permitted for the radionuclide when it is not in special form), material of low activity concentration and low level contaminated objects that can be transported (LSA-I and SCO-I). No specific security measures for these materials beyond the basic control measures stated in the Basic Safety Standards [3] and employed in normal commercial practices are suggested.

Radioactive material between these two threshold limits should be protected at the basic security level.

4. GUIDANCE FOR SECURITY MEASURES IN THE TRANSPORT OF RADIOACTIVE MATERIAL

This section discusses security measures that could be used to protect radioactive material against theft, sabotage, or other malicious acts during its transport by those States where the information and resources required for the application of a comprehensive methodology for threat assessment and vulnerability assessment are not available.

Section 4.1 identifies prudent management practices for low levels of radioactive material. Section 4.2 provides guidance for the basic security level and Section 4.3 provides additional guidance for transport of radioactive material above the threshold level specified in Section 3. These are measures based on the Model Regulations and are to be considered by States and operators as representing a minimum set of measures. Section 4.4 provides additional guidance that States may wish to consider applying to the transport of particularly vulnerable radioactive material or at a time of increased threat.

4.1. PRUDENT MANAGEMENT PRACTICES

Packages of radioactive material for which no additional provisions are identified in Section 3 require no further security measures to be applied other than those basic control measures included in the Basic Safety Standards [3] and normal commercial practices.

4.2. BASIC SECURITY LEVEL

The guidance in this section applies to all packages of radioactive material defined in Section 3 as requiring at least basic security measures.

General security provisions

The competent authority should, at its discretion, provide information to operators regarding the potential change in the threat to radioactive material in transport. Operators should take all threat information into consideration when implementing security measures. For international transport, the threat information for each State involved in such transport should be considered.

All operators (consignors, carriers, consignees) and other persons engaged in the transport of radioactive material should apply security measures for the transport of radioactive material commensurate with their responsibilities and the level of threat.

Radioactive material should be transferred only to authorized operators. In normal circumstances, it is sufficient that there is an existing business relationship between a carrier and consignee/consignor. Where such a relationship does not already exist, a potential carrier's or consignee's suitability or capability to receive or transport radioactive material should be established by confirmation with relevant national regulatory authorities, or trade and industry associations, that the carrier's or consignee's interests are legitimate.

When radioactive material is temporarily stored in transit sites (such as warehouses, marshalling yards, etc.), appropriate security measures should be applied to the radioactive material consistent with the measures applied during use and storage.

The operator should have procedures in place that would initiate an inquiry about the status of packages that are not delivered to the intended recipient at the expected time. Through the course of the inquiry, if it is determined that the package has been lost or stolen or if it appears to have been tampered with, procedures should immediately be initiated to locate and recover the package.

Unless there are overriding safety or operational considerations, packages of radioactive material should be carried in secure and closed or sheeted conveyances. However, such packages individually weighing more than 2000 kg that are sealed and secured to the conveyances may be transported on an open conveyance. The integrity of locks and seals should be verified before dispatch and on arrival by staff who are specifically and previously authorized by their employer to undertake this verification.

In the event that packages need to be transported on open conveyances, it may be necessary for the State to consider — in view of the nature of the radioactive material or prevailing threat — whether additional security measures should be applied. Such measures may include providing guards, shielding the package to provide for external pre-detonation to prevent or mitigate damage to the package in the event of a stand-off attack using rocket propelled armour piercing weapons or similar devices that are not easily defended against, and enhancing route surveillance or response capability. Packages should be shielded on the basis of advice from safety specialists.

Basic security awareness training

Individuals engaged in the transport of radioactive material should receive training, including training in the elements of security awareness.

Security awareness training should address the nature of security related threats, with due recognition of security concerns, methods to address such concerns and actions to be undertaken in the event of a security incident. It should include awareness of security plans (as appropriate) commensurate with the responsibilities of individuals and their part in implementing security plans.

Such training should be provided or verified upon employment in a position involving the transport of radioactive material and should be periodically supplemented by retraining as deemed appropriate by the competent authority.

Records of all security training undertaken should be kept by the employer and should be made available to the employee if requested.

Personnel identity verification

Each crew member of any conveyance transporting radioactive material should carry means of positive identification during transport (an officially issued photographic identification or biometric record that uniquely identifies the individual). While biometric forms of identification are preferable, some States may not have the capability to confirm biometric details. Therefore, for international transport, a photographic identification issued by an officially approved company may be the most appropriate method of identification.

Security verification of conveyances

Carriers should perform security inspections of conveyances and should ensure that these security measures remain effective during transport. In normal circumstances, and as appropriate to the mode of transport, it will be sufficient for the carrier of the conveyance to carry out a visual inspection to ensure that nothing has been tampered with or that nothing has been affixed to the package or conveyance that might compromise the security of the consignment. Such an inspection will require no more than the carrier's own knowledge of the conveyance.

Written instructions

Operators should provide appropriate crew members with written instructions on any required security measures, including how to respond to a security incident during transport. At the basic security level, it is generally sufficient for these written instructions to contain no more than basic details of emergency contacts.

Exchange of security related information

Operators should cooperate with each other and with the appropriate authorities to exchange information on applying security measures and responding to security incidents, where the exchange of information does not conflict with requirements for security in respect of sensitive information.

Trustworthiness determination

Persons engaged in the transport of radioactive material may be subject to trustworthiness determination by the operator commensurate with their responsibilities. The trustworthiness determination[14] is a determination of the reliability of an individual, including characteristics and details that may be verified, where legally permitted and where necessary, by means of background checks and by checking criminal records. The trustworthiness determination should be based on background checks of previous activities to verify the character and reputation of the individual.

4.3. ENHANCED SECURITY LEVEL

For packages of radioactive material with contents meeting or exceeding the radioactivity threshold for the enhanced security level as specified in Section 3, the following security measures in this section should be applied over and above those for the basic security level.

Identification of carriers and consignors

In implementing national security provisions for shipments of radioactive material, the competent authority should establish a programme for identifying consignors or carriers engaged in the transport of radioactive material packages requiring the enhanced security level, for the purpose of communicating security related information.

Security plans

All operators (consignors, carriers, consignees) and other persons engaged in the transport of radioactive material packages requiring the enhanced security level should develop, adopt, implement, periodically review as necessary and comply with the provisions of a security plan. The security plan should include at least the following elements and should be modified as needed to reflect the threat level at the time of its application and any changes to the transport programme:

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[14] National laws may restrict the conduct of identity verification and trustworthiness determinations in a State. Implementation of trustworthiness determinations may require special efforts, and in particular public understanding and support, for their introduction into the legal system owing to the possible conflicts with privacy and human rights legislation. The trustworthiness measures may rely on general security legislation supported by more specific regulations covering nuclear security issues.

- Specific allocation of responsibilities for security to competent and qualified persons with appropriate authority to carry out their responsibilities.
- Provision for keeping records of radioactive material packages or types of radioactive material transported.
- Review of current operations and assessment of vulnerability, including intermodal transfer, storage in transit, handling and distribution as appropriate.
- Clear statements of measures, including: training, policies including response to conditions of a higher level threat, verification of new employees and employment, operating practices (e.g. choice and use of routes where known, use of guards, access to radioactive material packages requiring the enhanced security level in temporary storage, proximity to vulnerable infrastructure), equipment and resources that are to be used to reduce security related risks.
- Effective procedures and equipment for timely reporting and dealing with security related threats, breaches of security or security related incidents.
- Procedures for evaluating and testing security plans and procedures for periodic review and update of the plans.
- Measures to ensure the security of transport information contained in the security plan.
- Measures to ensure that the distribution of sensitive transport information is limited, to maintain security of the information. Such measures should not preclude the provision of transport documents and consignor's declaration as required by TS-R-1 [1].
- Measures to monitor the location of the shipment.
- Where appropriate, details concerning agreements on the point of transfer of responsibility for security.

It is necessary for States to establish clearly responsibility for, and ownership of, the security plan. This will normally be the operator having direct responsibility for the security of the radioactive material in any particular mode or phase of the transport. In the event that transports are subcontracted, it may be appropriate to ensure that contractual arrangements exist to develop and comply with a security plan.

Information required in a security plan under these provisions may be incorporated into plans developed for other purposes. However, security plans will, almost invariably, contain information that should be restricted to those who need to know it for the performance of their duties. Such information should not be included in plans that are developed for other purposes and that may be disseminated more widely.

When developing security plans, operators are required to ensure that appropriate emergency response plans (as required by IAEA Safety Standards Series No. GS-R-2 [15] and supported by related Safety Guides such as IAEA Safety Standards Series No. TS-G-1.2 [17]) are incorporated.

Advance notification

The consignor should provide advance notification to the consignee of the planned shipment, mode of transport and expected delivery time.

The consignee should confirm capability and readiness to accept delivery at the expected time, prior to the commencement of transport, and should notify the consignor on receipt or non-receipt within the expected delivery time frame.

The consignor, if requested or required, should provide advance shipment notification to the competent authority of any receiving or transit State. At this level, notification that may be required for security purposes may be developed from advance notification already required for other purposes.

Tracking devices

When appropriate, tracking methods or devices may be used to monitor the movement of conveyances containing radioactive material. A simple tracking system will be able to track when a shipment has departed, whether the mode of transport has changed and if the material has been placed in interim storage or the consignment has been received. This information about status changes should be readily available to the appropriate parties (i.e. carriers, shippers and other operators). This tracking system may be as simple as a bar code system that provides information on the package location and status. The tracking system, in conjunction with a communications system and response procedures, will allow the operator and the competent authority to react in a timely manner to a malicious act, including theft of radioactive material.

Communications from the conveyance

During transport, the carrier should provide, in the conveyance, the capability for personnel to communicate with a designated contact point as specified in the security plan.

Additional security provisions for transport by road, rail and inland waterway

The carrier should ensure, for transport conveyances by road, rail and inland waterway, the application of devices, equipment or other arrangements to deter, detect, delay and respond to theft, sabotage or other malicious acts affecting the conveyance or its cargo and should ensure that these arrangements are operational and effective at all times.

The operator should maintain continuous attendance of the road conveyance during transport where possible. Where non-attendance is unavoidable, the road conveyance should be secured such that it complies with the criteria for protection, detection and response and preferably in a well illuminated area.

4.4. ADDITIONAL SECURITY MEASURES

In certain circumstances, States may consider enhancing the foregoing baseline security measures in view of the design basis threat, the assessment of the prevailing threat or the nature of the material being transported. In such cases, possibly relevant only to certain categories or quantities of radioactive material or to particularly sensitive transports, States may require some or all of the following measures to be applied. This list is not exhaustive.

Additional training, beyond basic security awareness, may be provided to persons engaged in the transport of radioactive material to ensure that they have the proper skills and knowledge for implementing specific security measures associated with their responsibilities.

Radioactive material carriers may be subject to a regime whereby their operations are licensed, their security procedures are subject to audit and their security plans are subject to formal approval and periodic review by the competent authority.

Automated and real time tracking methods or devices may be required, where feasible, to permit a transport control centre to monitor remotely the movement of radioactive material conveyances and packages and the status of the material.

Persons engaged in the transport of radioactive material may be subject to formal national security clearance commensurate with their responsibilities.

Guards may be required to accompany certain transports to provide for continuous effective surveillance of the package and/or conveyance. In such cases it will be important to ensure that guards are adequately trained (especially if they are armed), suitably equipped and fully aware of their responsibilities.

An evaluation of the potential for sabotage and associated radiological consequences for a package design with regard to its mode of transport may be required by the competent authority. This should be done in close consultation with safety specialists.

Prior to loading and shipment, appropriately trained personnel may be required to conduct a thorough search of the conveyance to ensure that it has not been tampered with in any way that could compromise security.

Special attention may be given to procedures that address points where responsibility for security is transferred and at intermodal transfer points.

Consideration may be given to using conveyances that are specially designed or modified to provide additional security features.

The response plan may be reviewed to ensure that there would be an adequate response to any attempts at theft, sabotage or other malicious acts. In particular, coordination with response forces should be reviewed to ensure an appropriate and timely response to an incident.

Appropriate exercises may be carried out in advance of a transport of radioactive material to ensure that contingency plans are adequately robust.

Personnel with specific security responsibilities may be provided with written instructions detailing their responsibilities.

Additional measures, consistent with national requirements, may be taken to protect the confidentiality of information relating to transport operations, including detailed information on schedules and routes. In addition, it may be appropriate to ensure that secure communications are used during the course of the transport and that such measures provide redundancy of systems.

4.5. INTERNATIONAL SHIPMENT

For air transport, shipment is required to be carried out in accordance with the applicable security provisions (Annexes 17 and 18 of the Convention on International Civil Aviation [18] and the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air) [19]. For maritime transport, shipment is required to be carried out in accordance with the applicable security provisions of the International Ship and Port Facility Security Code [20] and of the International Maritime Dangerous Goods Code [21] as required by the International Convention for the Safety of Life at Sea (SOLAS 74 amended) [22]. These provisions should be supplemented by the information provided by this guide.

Before an international shipment is undertaken, the originating State may make adequate provisions to confirm that the security requirements of the receiving State and any transit States will be met.

Appendix

DETAILED CONSIDERATIONS IN SETTING SECURITY LEVELS

This appendix outlines the detailed development of the model used to identify the quantity of radioactive material required to produce the baseline consequence. The model is not intended to predict the effects of an RDD but to define the quantity of a radionuclide that could result in the need for resettlement or relocation from an area. ICRP 82, Protection of the Public in Situations of Prolonged Radiation Exposure [16], and IAEA Safety Requirements on emergency preparedness and response [15] provide requirements and recommendations on dose levels for actions to be taken following radiological accidents and are used as the basis for the reference dose in the model. This is a conservative measure of the severity of an intentional dispersal incident since it identifies when an area might be denied for use.

A.1. MALICIOUS USE OF RADIOACTIVE MATERIAL

Potential malicious acts involving radioactive material cover a wide spectrum of possible scenarios. The following events represent some broad categories of possible malicious acts with the potential to give rise to significant radiological consequences:

- *Covert placement of unshielded material in working and/or living areas or street locations where the public might be externally irradiated.*
- *Sabotage of radioactive material packages or shipments with the subsequent release of radioactive material and its dispersal to the environment.*
- *Capture of a radioactive material package or shipment and the subsequent dispersal of the material by means of conventional explosives.* The main radiological consequences from such an event, i.e. an RDD scenario, include both near-field and far-field effects. In the vicinity of the explosion (near-field) there may be radioactive shrapnel and larger pieces of radioactive material dispersed in the area and injuring persons and damaging and contaminating buildings, etc., and also general contamination from vaporized or finely divided material. Persons in the area may inhale vaporized or finely divided material and their skin and clothes may become contaminated. There may also be a rising plume that disperses vaporized and finely divided material (to the far-field) resulting in

contamination of the area and of persons in the area, as well as exposure due to inhalation as the plume passes.

- *Capture of a radioactive material package or shipment and its subsequent processing (e.g. transformation into a more highly dispersible form) with subsequent dispersal of the radioactive material in the environment (RDD scenario).* The time and resources required for this action would increase the likelihood of successful intervention by security forces, so this scenario is considered less likely than others.

The radiological consequences arising from radiological attacks of these types are extremely variable depending on, for example, the type and nature of the event and the type and amount of radioactive material involved. Since the RDD scenario may be a very attractive means for adversaries to cause harm and can be undertaken with unsophisticated capabilities, it is considered a more likely scenario. The RDD scenario is also considered appropriate in respect of evaluating the potential radiological consequences of a malicious act involving different radionuclides.

A.2. ESTABLISHING SECURITY LEVELS

Since the transport of radioactive material occurs within the framework of the transport of other dangerous goods, it is desirable to be as consistent as possible with existing security requirements and guidelines, particularly the Model Regulations and the international modal regulations. Additionally, since some radioactive material is also covered by the Code of Conduct [8] with its supplementary guidance, the CPPNM [5] together with its Amendment [6] and INFCIRC/225/Rev.4(Corrected) [7], it is also desirable to be as consistent as possible with these documents. The security levels included in this guide have been developed with these considerations in mind.

Since transport operations vary widely in respect of how they are carried out (whether full load, consignments of individual packages, etc.), it is necessary to define clearly the basis for specifying security measures. There are two feasible bases for specifying what should be subject to enhanced transport security measures:

- Per package: Enhanced security provisions would be applied when any package in a consignment exceeds the threshold value. There are operational benefits to this approach, such as not requiring carriers to keep a tally of the total activity on the conveyance. However, this approach may not provide an accurate measure of the potential harm that a single diverted conveyance could be used to cause (since multiple packages could be present on a single conveyance).

- Per conveyance: Enhanced security provisions would be applied when the total activity on a conveyance exceeds the threshold. This approach ensures that the total activity on a single conveyance will not exceed the threshold without necessitating the enhanced security provisions. However, this would be difficult to implement operationally.

The per package approach is used in this guide.

There are some packages of radioactive material with such low levels of radioactivity that they present low radiological hazards and low security risks (e.g. consumer products, very small quantities of radionuclides, material with very low activity concentration). Because of the very limited potential consequences that could arise from their use in malicious acts, excepted packages (as defined in Ref. [1], para. 230) with contents not exceeding the activity allowed for non-special form material, and LSA-I (as defined in Ref. [1], para. 226) and SCO-I (as defined in Ref. [1], para. 241) need not be subjected to transport security provisions more stringent than those ordinarily applied to a commercial shipment. The normal commercial controls applied to these shipments are appropriate for their very low potential consequences if used in a malicious act.

For packages exceeding the radioactivity level allowed in excepted packages, the potential consequences of their use in a malicious act vary greatly (over many orders of magnitude). However, in order to specify appropriate transport security measures, packages may be grouped on the basis of their potential consequences. A small number of security levels are desirable for simplicity, but a larger number of security levels make it easier to 'tailor' the security measures more precisely to the potential radiological consequences of the material. After several meetings, it was agreed that two security levels would be sufficient for specifying transport security measures for packages containing more radioactive material than that allowed in excepted packages. The use of two levels allows the security measures to be specified as simply as possible while identifying packages that warrant either 'basic' or 'enhanced' security measures.

The use of two levels for security in transport means that some quantitative measure must be used to specify which level is assigned to a package (that is, the criterion). This can be done by defining an activity threshold, since the potential consequences of the contents of a package are based on the radionuclides and radioactivity levels in the package. The use of a single radioactivity level threshold is also consistent with the approach to the transport of dangerous goods of the Model Regulations. This threshold specifies the criterion for distinguishing between high consequence (Model Regulations terminology) radioactive material packages and other radioactive material packages (down to the level of excepted packages, LSA-I and SCO-I, which do not warrant security measures beyond prudent management practices).

This approach results in a total of three levels of security in transport for packages which, on the basis of their potential consequences, are subject to:

- Prudent management practices: Consists of excepted radioactive material packages with contents not exceeding the activity allowed for non-special form material and radioactive material specified as LSA-I and SCO-I. No additional provisions other than those control measures required by the Basic Safety Standards [3] and normal commercial practices are suggested.
- Basic security level: Comprises consignments of packages analogous to other dangerous goods subject to the 'general provisions' for dangerous goods security in the Model Regulations (packages that are below the specified radioactivity threshold).
- Enhanced security level: Comprises consignments that include at least one package analogous to high consequence dangerous goods as defined in the Model Regulations (a package that is above the radioactivity threshold).
- Additional security measures: These may be considered by a State in certain circumstances.

The transport security levels are illustrated in Fig. 1.

A.3. DEFINING THE RADIOACTIVITY THRESHOLD

To specify which packages should be transported under enhanced security measures, it is necessary to define the radioactivity level that would constitute high consequence radioactive material.

Considerable analysis and modelling have been done to define a dangerous source (see RS-G-1.9 [9]). This work identifies exposure scenarios and dose criteria used to define the quantity of a radionuclide that would constitute a danger to an individual (the D-value). These scenarios also include a dispersion scenario that may be relevant to a malicious act. The scenario included dispersal of a source, for example by fire, explosion (i.e. by means of an RDD) or human action, resulting in exposure of an individual due to inhalation, ingestion and/or skin contamination [9]. A dangerous source is defined as one that could, if not under control, give rise to a severe

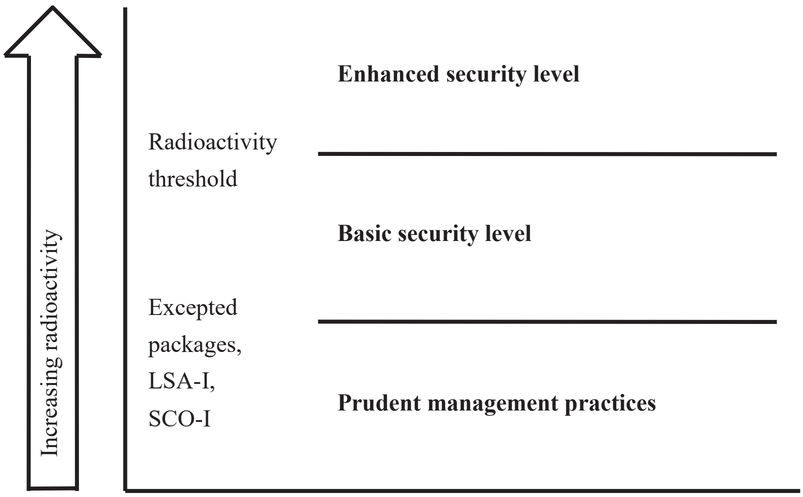

FIG. 1. Incremental transport security levels.

deterministic health effect. A deterministic health effect is a health effect of radiation exposure for which, generally, a threshold level of dose exists above which the severity of the effect is greater for a higher dose. A severe deterministic effect is one that is fatal, life threatening, or results in a permanent injury that decreases the quality of life of an individual. The doses required to produce severe deterministic effects are much higher than doses that cause stochastic effects (for which no threshold level of dose is assumed to exist and for which the severity of the effect, for example a cancer, does not increase for a higher dose).

Since the intentional dispersal of radioactive material to the environment has the greatest potential to cause long term and widespread health, social and economic consequences (by necessitating relocation, resettlement, cleanup, etc.), it was chosen as the basis for the model.

In order to apply the dispersal scenario quantitatively, a measure of the effects of such an event is needed. Since an RDD is not likely to cause massive immediate deaths or casualties by radiation exposure, this is not a good measure of consequences. Similarly, since the long term health effects of an RDD would be mitigated by protective actions and remedial actions that may vary greatly, this is also not a good measure. An RDD is basically a ‘weapon of denial’ since it may result in the evacuation, relocation and resettlement of persons from an area. A measure of the effectiveness of an RDD could be based on the amount of denial of use that such a device could necessitate. If the population must be relocated or resettled out of an area, especially if they must be resettled permanently or for long periods of time until cleanup is completed, then the device has been successful. Therefore, the model could be based on this measure of potential consequences.

A.4. PARAMETERS FOR AN RDD SCENARIO

Assessment and evaluation of the potential radiological consequences of the use of an RDD require consideration of a number of processes involved in the dispersion of the radioactive material. A key consideration is the amount of radioactive material dispersed in the environment. This parameter can be characterized by the airborne release fraction (amount of material dispersed) and the respirable release fraction. The respirable release fraction (RRF) is the fraction of material that is released in particles that are small enough to be inhaled (typically less than 50 μm). Particles in this size range are of particular interest since inhalation may be a significant exposure pathway for some radionuclides. These particles can be carried in a plume with resulting inhalation by persons from the plume, deposition onto the ground and other surfaces, and resuspension with subsequent inhalation at a later time.

An IAEA consultants meeting noted an RRF of around 10^{-5} for malicious incidents involving spent fuel casks subjected to attacks using devices of high energy density. This was taken as a reasonable approximation for stand-off attacks (using rocket propelled armour piercing weapons or similar devices which are not easily defended against) on heavily shielded Type B packages. While smaller and less robust packages would release more of their contents, the fraction of material released by an act of sabotage would be less than that resulting from a dispersal action on the radioactive material itself.

Investigations (NUREG/CR-0743 [23], Lange et al. 1994 [24]) have shown that a wide range of RRFs (10^{-1}–10^{-3}) can result from the explosive fragmentation of radioactive material in solid form. Such an event can also result in the distribution of approximately 10^2–10^4 solid fragments over an area of approximately 1 km^2. In such cases, cleanup of the fragmented material may be less difficult and time consuming than for more finely divided particles.

Recognizing the range of possible airborne releases and RRFs, a release factor of 10% was chosen for use in a model of the potential effects of an RDD. This value represents a conservative estimation of the release fraction that would be widely dispersed, in view of the wide range in the type and nature of radioactive material being shipped in the public domain. For most material considered dispersible, an RRF of 10% would be a conservative estimate [25, 26]. All material that is released is assumed to be respirable so the RRF is the same as the release factor.

A.5. MODELLING APPROACH

There are several different ways that airborne dispersion of radioactive material can be modelled. The two most widely used methods and their advantages and disadvantages are:

- Planar uniform distribution model: With appropriate parameters this approach provides conservative results, is easy to understand and is reliable.
- Dispersion model: This approach more closely models the actual distribution of contamination following a release but is dependent on assumptions about conditions at the time of release (meteorology, topography, intensity of blast, etc.).

The planar uniform distribution model has been used in many applications to assist in emergency planning and decision making. Consequently, this approach was chosen for examining the possible effects of an RDD. Since the model assumes uniform distribution over a defined surface area, it is conservative in that it does not rely on predicting how the dispersion of material occurs. Comparisons of the results of the conservative planar uniform distribution model with those of contemporary airborne dispersion models (e.g. HOTSPOT and HPAC) confirm that the planar model is conservative (i.e. overestimates the consequences) yet provides acceptable results.

A.6. RADIOLOGICAL MODEL

A model was developed for assessing the effects of radioactive material that is dispersed over a wide area, resulting in radioactive material being uniformly distributed over that area.

Guidelines for the cleanup of land contamination establish criteria for identifying when intervention is warranted after a radiological incident. Emergency preparedness guidance such as that provided in Ref. [27], Generic Assessment Procedures for Determining Protective Actions During a Reactor Accident, identifies criteria regarding when the general public should be relocated or resettled from the area contaminated by an incident. These resettlement and relocation criteria are appropriate criteria for use in determining whether an area has been sufficiently contaminated by an RDD for people to be removed (i.e. for the area to be denied for use). The ICRP 82 dose criterion for resettlement of 1000 mSv/lifetime was selected since it is internationally accepted [28]. This value provides a reliable measure of the severity of an RDD incident since it is a measure of when an area might be denied for use.

The planar uniform dispersion model that was developed requires a number of parameters that must be specified. Several parameters were taken from Ref. [27], drawing on the previous applications developed by the IAEA to assess the conditions in emergencies following radiological accidents. These include an occupancy factor and a building shielding factor for time spent indoors. By using the CF_4 factors (Procedure F2, Table F5) from Ref. [27], the long term dose conversion factors for deposition, it is possible to derive the radioactivity levels that, owing to widespread dispersion, result in a dose that meets the resettlement dose criterion (i.e. the radioactivity thresholds).

For the size of the contaminated area, a value of 1 km^2 is used. This represents a typical urban area with a population of about 10 000. This reference area of 1 km^2 is a conservative estimate in comparison with the size of a contaminated area predicted from sophisticated airborne release and distribution models.

With these starting assumptions:

Area:	1 km^2
Release factor:	0.1
Shielding factor:	0.16
Occupancy factor:	0.6

The following equation was developed to model the activity necessitating the resettlement of the population from an area of 1 km^2:

$$A = \frac{D \times \text{area}}{CF_4 \times RF}\left[\frac{1}{(OF \times SF) + (1 - OF)}\right] \times \frac{1\ \text{TBq}}{10^9\ \text{kBq}} \tag{1}$$

where

A is the activity (TBq);
D is the ICRP lifetime dose value (1000 mSv);
CF_4 is the long term dose conversion factor for deposition $\left(\frac{\text{mSv}\cdot\text{m}^2}{\text{kBq}}\right)$;
Area is the surface area covered (10^6 m^2);
OF is the occupancy factor (0.6);

SF is the shielding factor (0.16);
RF is the release factor (0.1).

Parameters that are automatically taken into account by using the CF_4 factors from Ref. [27] include:

- Radioactive decay;
- Weathering;
- Surface roughness;
- Ground shine;
- Inhalation due to resuspension (with a resuspension factor of 10^{-6}).

A.7. RESULTS OF THE RADIOLOGICAL MODEL

Using a spreadsheet that incorporated Eq. (1) and the parameters described above, the activity required to meet the dose criteria was calculated for a number of radionuclides. These activity values were compared with the D-values and A-values described previously.

Recognizing that the Code of Conduct is being implemented by Member States, the approach embodied in the Code was examined to determine whether it could be used for setting the activity thresholds of the radionuclides included in the Code. Reasonable correlation was found with 1000 D for beta/gamma emitters and 10 D for alpha emitters. Since a radioactive source containing 10 D is 10 times more dangerous than the reference 'dangerous source' and is capable of producing severe deterministic effects, it was decided that a value of 10 D could be used to specify the enhanced transport security level for radionuclides included in the Code.

For radionuclides not included in the Code of Conduct another approach is needed for specifying the activity threshold. A strong desire has been expressed to specify the radioactivity threshold in terms of the traditional transport safety A-values. These values are calculated using the 'Q system' that has been incorporated in the Transport Regulations for over 30 years (see Ref. [28]).

The A_1-values are derived for special form (non-dispersible) radioactive material and the A_2-values are for 'other than special form' (dispersible) radioactive material. While the A-values are not based on exposure scenarios that are appropriate for representing the potential consequences of an RDD (they are derived from transport accident scenarios), the values are widely used in the transport of radioactive material. Consequently, a multiple of the A-values was considered to be the desired way to express the radioactivity threshold. When the radionuclides covered by the Code of Conduct are disregarded, the remaining radionuclides showed good correlation with a value of 3000 A_2 (since the A_2 value of a radionuclide never exceeds the A_1 value). Subsequently, for radionuclides not included in the Code of Conduct, a value of 3000 A_2 may be used to identify packages that are subject to the enhanced transport security measures. This does not mean that 3000 A_2 corresponds to the same risk of causing severe deterministic health effects as 10 D. For some radionuclides, 3000 A_2 is 1000 or more times the quantity of a radionuclide (D-value) that, if not under control, could result in severe deterministic health effects to an individual.

A.8. MIXTURES OF RADIONUCLIDES

For mixtures of radionuclides, the determination of whether or not the transport security radioactivity threshold has been met or exceeded can be calculated by summing the ratios of activity present for each radionuclide divided by the transport security threshold for that radionuclide. If the sum of the fractions is less than 1, then the radioactivity threshold for the mixture has not been exceeded (see Eq. (2)):

$$\sum_i \frac{A_i}{T_i} < 1 \qquad (2)$$

where

A_i is the activity of radionuclide i that is present in a package (TBq);
T_i is the transport security threshold for radionuclide i (TBq).

A.9. SPECIFICATION OF THE TRANSPORT SECURITY THRESHOLD

To facilitate the undertaking of the transport security measures, the following definition of ‘high consequence’ radioactive material is used; 3000 A_2 in a single package, except for the following radionuclides:

Radionuclide	Transport security threshold (TBq)
Am-241	0.6
Au-198	2
Cd-109	200
Cf-252	0.2
Cm-244	0.5
Co-57	7
Co-60	0.3
Cs-137	1
Fe-55	8000
Ge-68	7
Gd-153	10
Ir-192	0.8
Ni-63	600
Pd-103	900
Pm-147	400
Po-210	0.6
Pu-238	0.6
Pu-239	0.6
Ra-226	0.4
Ru-106	3
Se-75	2
Sr-90	10
Tl-204	200
Tm-170	200
Yb-169	3

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