IAEA Safety Standards

for protecting people and the environment

Arrangements for the Termination of a Nuclear or Radiological Emergency

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General Safety Guide

No. GSG-11

International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

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

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

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 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 email to Official.Mail@iaea.org.

RELATED PUBLICATIONS

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

Reports on safety in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Emergency Preparedness and Response** publications, **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

ARRANGEMENTS FOR THE TERMINATION OF A NUCLEAR OR RADIOLOGICAL EMERGENCY

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. GSG-11

ARRANGEMENTS FOR THE TERMINATION OF A NUCLEAR OR RADIOLOGICAL EMERGENCY

GENERAL SAFETY GUIDE

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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to "establish or adopt… standards of safety for protection of health and minimization of danger to life and property" — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For 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 regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

PREFACE

In March 2015, the IAEA's Board of Governors approved a Safety Requirements publication, IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency, which was jointly sponsored by 13 international organizations. GSR Part 7 establishes requirements for an adequate level of preparedness for and response to a nuclear or radiological emergency, irrespective of the initiator of the emergency. The IAEA General Conference, in resolution GC(60)/RES/9, encouraged Member States "to consider the recently published IAEA Safety Standards Series No. GSR Part 7 on Preparedness and Response for a Nuclear or Radiological Emergency in the context of their nuclear or radiological emergency arrangements". At the International Conference on Global Emergency Preparedness and Response that took place in October 2015, the challenges and issues associated with the "lack of guidance for the termination of a nuclear or radiological emergency and the transitioning to recovery" were recognized, and it was recommended that the IAEA "continue to develop guidance on the termination of a nuclear or radiological emergency and the transition to recovery, which should include guidance for adapting and lifting of protective actions."

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 Assistance Convention'), IAEA Legal Series No. 14, adopted in 1986, place specific obligations on the States Parties and on the IAEA. Under Article 5a(ii) of the Assistance Convention, one function of the IAEA is to "collect and disseminate to States Parties and Member States information concerning: … methodologies, techniques and available results of research relating to response to nuclear accidents or radiological emergencies".

This Safety Guide is intended to assist Member States in the application of GSR Part 7 and of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, and to help in the fulfilment of the IAEA's obligations under the Assistance Convention. This Safety Guide provides guidance and recommendations on the emergency arrangements to be made for the termination of a nuclear or radiological emergency and the subsequent transition from the emergency exposure situation to either an existing exposure situation or a planned exposure situation. This Safety Guide includes detailed prerequisites that are expected to be met so that the authorities can formally declare an emergency ended, as well as guidance on adapting and lifting protective actions.

The Food and Agriculture Organization of the United Nations (FAO), the IAEA, the International Civil Aviation Organization (ICAO), the International Labour Office (ILO), the International Maritime Organization (IMO), INTERPOL, the OECD Nuclear Energy Agency (OECD/NEA), the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), the World Health Organization (WHO) and the World Meteorological Organization (WMO) are joint sponsors of this Safety Guide.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures[1] have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

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[1] See also publications issued in the IAEA Nuclear Security Series.

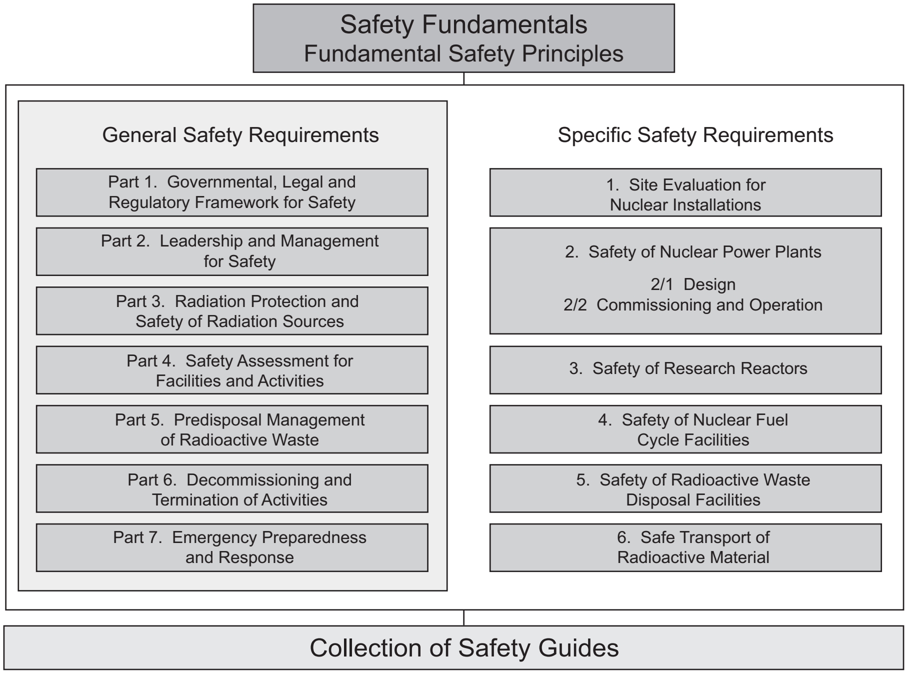

FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (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. The recommendations provided in Safety Guides are expressed as 'should' statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five safety standards committees, for emergency preparedness and response (EPReSC) (as of 2016), 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 IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of

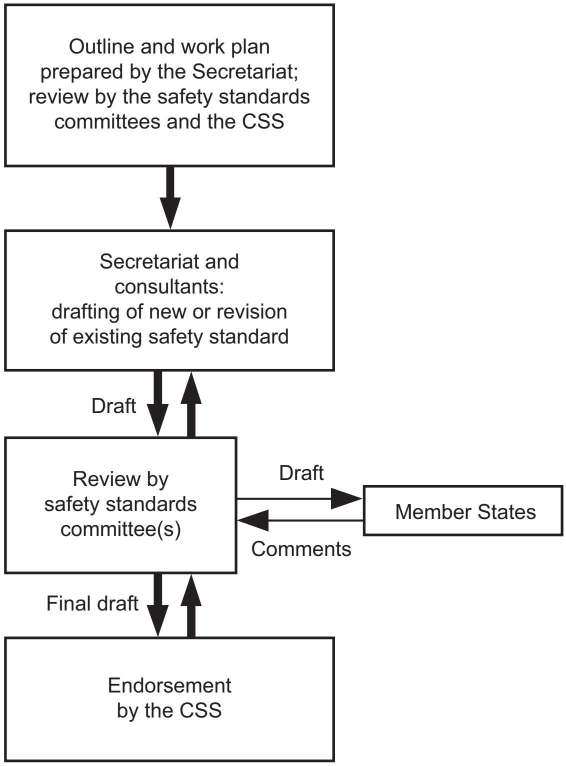

FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

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 IAEA safety standards. Some safety 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 United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see 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 in the IAEA 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 body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, 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 safety standard. Material in an appendix has the same status as the body 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. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. Under Article 5(a)(ii) of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [1], one function of the IAEA is to "collect and disseminate to States Parties and Member States information concerning: …methodologies, techniques and available results of research relating to response to nuclear accidents or radiological emergencies".

1.2. In March 2015, the IAEA's Board of Governors approved a Safety Requirements publication, IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [2], which was jointly sponsored by 13 international organizations. GSR Part 7 [2] establishes requirements for an adequate level of preparedness for and response to a nuclear or radiological emergency, irrespective of the initiator of the emergency; GSR Part 7 [2] is a revised and updated version of IAEA Safety Standards Series No. GS-R-2[1].

1.3. Requirement 18 of GSR Part 7 [2] requires the government to ensure that arrangements are made for "**the termination of a nuclear or radiological emergency, with account taken of the need for the resumption of social and economic activity.**" Most States have paid particular attention to ensuring adequate preparedness to respond effectively to a nuclear or radiological emergency in order to protect human life, health, property and the environment early in the response. However, less attention has been devoted, at the preparedness stage, to practical arrangements for dealing with the challenges associated with the termination of an emergency and the transition to the 'new normality'[2]. Past experience has demonstrated the importance of being prepared to address these

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[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).

[2] The 'new normality' is the situation compared with the situation before the emergency. In the context of this Safety Guide, the new normality represents either an existing exposure situation or a planned exposure situation.

challenges. To assist Member States in addressing these challenges, this Safety Guide provides guidance and recommendations on emergency arrangements for the termination of a nuclear or radiological emergency and the subsequent transition to either a planned exposure situation or an existing exposure situation to meet the relevant safety requirements established in GSR Part 7 [2].

1.4. The terms 'nuclear or radiological emergency', 'planned exposure situation', 'emergency exposure situation' and 'existing exposure situation' are defined in GSR Part 7 [2] and in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [3]. The definitions from GSR Part 7 [2] are as follows:

> "**emergency**. A non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human life, health, property or the environment.
>
> ⓘ This includes nuclear and radiological emergencies and conventional emergencies such as fires, releases of hazardous chemicals, storms or earthquakes.
>
> ⓘ This includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.
>
> ***nuclear or radiological emergency*** [3]. An emergency in which there is, or is perceived to be, a hazard due to:
>
> (a) The energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction;
> (b) Radiation exposure.
>
> …….

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[3] Notwithstanding the definitions of these terms, for reasons of brevity, in this Safety Guide the term 'emergency' is intended to mean a nuclear or radiological emergency, unless otherwise specified.

“**emergency exposure situation**[4]. A situation of exposure that arises as a result of an accident, a malicious act or other unexpected event, and requires prompt action in order to avoid or reduce adverse consequences.

…….

“**existing exposure situation.** …a situation of exposure that already exists when a decision on the need for control needs to be taken.

ⓘ Existing exposure situations include exposure to natural background radiation that is amenable to control; exposure due to residual radioactive material that derives from past practices that were never subject to regulatory control; and exposure due to residual radioactive material deriving from a nuclear or radiological emergency after an emergency has been declared to be ended.

…….

“**planned exposure situation.** …a situation of exposure that arises from the planned operation of a source or from a planned activity that results in an exposure due to a source.”

1.5. Requirement 46 of GSR Part 3 [3] addresses the arrangements to be in place, as part of overall emergency preparedness, and to be implemented as appropriate for the transition from an emergency exposure situation to an existing exposure situation. This Safety Guide provides guidance and recommendations on arrangements to be made at the preparedness stage for such a transition, in the context of a broader discussion of the arrangements necessary for the termination of a nuclear or radiological emergency.

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[4] From the definitions, it is obvious that each emergency exposure situation takes place within a nuclear or radiological emergency; however, in a nuclear or radiological emergency, an emergency exposure situation might not apply to every individual. There might be situations in which conditions indicative of a nuclear or radiological emergency have been identified at a site and the appropriate emergency class has been declared (i.e. an adequate level of emergency response has been activated) before any exposures occur as a result of these conditions.

OBJECTIVE

1.6. The objective of this Safety Guide is to provide guidance and recommendations to States on developing arrangements at the preparedness stage, as part of overall emergency preparedness efforts, for response to a nuclear or radiological emergency during the transition to either an existing exposure situation or a planned exposure situation, as appropriate, and the termination of the emergency. This Safety Guide also provides guidance and recommendations on the primary objective and on the general and specific prerequisites that are to be met in order to enable the termination of an emergency.

1.7. This Safety Guide should be used in conjunction with GSR Part 7 [2], with due account to be taken of the recommendations provided in IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [4] and IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [5]. This Safety Guide provides guidance for meeting Requirement 18 of GSR Part 7 [2] on the termination of a nuclear or radiological emergency, and Requirement 46 of GSR Part 3 [3] on the transition from an emergency exposure situation to an existing exposure situation.

1.8. The guidance and recommendations in this Safety Guide form the basis for achieving the goals of emergency response outlined in para. 3.2 of GSR Part 7 [2], particularly the goal of preparing for the resumption of normal social and economic activity.

SCOPE

1.9. The guidance and recommendations in this Safety Guide are applicable to any nuclear or radiological emergency, irrespective of its cause, in relation to the transition to either a planned exposure situation or an existing exposure situation and the termination of the emergency. Considering the range of potential nuclear or radiological emergencies[5], these recommendations necessitate the application of a graded approach[6] in their implementation.

1.10. The guidance and recommendations in this Safety Guide have been developed on the basis of objective considerations of radiation protection, including factors such as the health risks associated with exposure levels and the relevant attributes of various characteristics of the exposure situation. In addition, this Safety Guide also recognizes the influence of, and addresses, social, economic and political attributes, as well as national, local and site specific characteristics. Such attributes and characteristics are generally unrelated to radiation protection; however, these attributes and characteristics usually influence the final decision on the termination of a nuclear or radiological emergency.

1.11. This Safety Guide is intended to help in decision making that is based on scientific considerations regarding radiation protection, established best practices and lessons learned from experience. This Safety Guide is also intended to serve as an input into a comprehensive decision making process concerning the termination of a nuclear or radiological emergency. As a nuclear or radiological emergency may lead to long term exposures owing to residual radioactivity in the human habitat and in the overall environment, it is anticipated in this Safety Guide that the decision making process will not only include emergency planners, decision makers at various governmental levels and radiation protection specialists but will also involve consultation with the public and other interested parties[7].

1.12. The guidance and recommendations provided in this Safety Guide take into account lessons learned from past experience, including the Fukushima Daiichi

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[5] Examples of such emergencies include a general emergency at a nuclear power plant, an emergency involving a lost dangerous source, an emergency arising from an accidental overexposure of patients, an emergency involving a release (irrespective of whether intentional or not) of radioactive material to the environment and an emergency arising from a transport accident involving nuclear or radioactive material.

[6] "(1) For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control.

(2) An application of safety requirements that is commensurate with the characteristics of the facilities and activities or the source and with the magnitude and likelihood of the exposures" (GSR Part 7 [2]).

[7] An interested party is a "person, company, etc. with a concern or interest in the activities and performance of an organization, business, system, etc." (GSR Part 7 [2]).

accident (2011) [6, 7], the radiological accident in Nueva Aldea (2005) [8], the fuel damage incident at the Paks nuclear power plant (2003) [9], the radiological accident in Lia (2001) [10], the radiotherapy accident in Panama (2000–2001) [11], the radiological accident in Goiânia (1987) [12], the accident at the Chernobyl nuclear power plant (1986) [13, 14] and the accident at the Three Mile Island nuclear power plant (1979) [15]. Annex I to this Safety Guide provides case studies for several past emergencies.

1.13. As the full range of potential nuclear or radiological emergencies is considered in this Safety Guide, the following distinctions have to be made in relation to the way in which the emergency will be terminated and the situation to which the emergency will transition:

(a) An emergency that does not involve a significant release of radioactive material to the environment, and thus does not result in exposures of the public in the longer term due to residual radioactive material (e.g. the fuel damage incident at Paks nuclear power plant, the accidental overexposures in Panama and the radiological accident in Nueva Aldea), might not necessarily result in an emergency exposure situation. Such emergencies can be terminated in a way in which the facility, the activity and the source can ultimately be managed as a planned exposure situation. The planned exposure situation may be associated with normal operation, with cleanup and decommissioning, or with the ending of the operational life of the source. In terms of public exposure, such emergencies are not expected to result in an exposure situation that is different from the one that existed before the emergency. The decision to terminate an emergency of this type also delineates the beginning of a planned exposure situation. In such cases, within the context of this Safety Guide, the phrase 'transition to a planned exposure situation' is used.
(b) An emergency involving a significant release of radioactive material to the environment (e.g. the Chernobyl nuclear power plant accident, the Fukushima Daiichi accident, the Goiânia radiological accident) will result in an emergency exposure situation. In such emergencies, the public may be exposed in the longer term because of the presence of residual radioactive material in the environment. Such situations are eventually managed as existing exposure situations. The termination of such emergencies is possible after a period of time that allows for the transition to an existing exposure situation to take place. The decision to terminate an emergency of this type also means entering into an existing exposure situation. In such cases, within the context of this Safety Guide, the phrase 'transition to an existing exposure situation' is used.

1.14. The guidance and recommendations in this Safety Guide are not to be applied to:

(a) The termination of an exposure situation in which contamination has occurred due to a human activity but which is not an emergency exposure situation. This scenario would include, for example, situations arising from legacy sites or planned discharges of radioactive material to the environment.
(b) Arrangements for managing existing exposure situations and long term remediation, as well as arrangements for the decommissioning of accident damaged facilities at which permanent shutdown is warranted; guidance relevant to such situations can be found in Refs [16–19]. However, the basic concepts and approaches contained in this Safety Guide will support, within the context of overall emergency preparedness, planning for the management of the existing exposure situation after the termination of the nuclear or radiological emergency.

1.15. This Safety Guide does not provide guidance or recommendations on meeting the requirements established in GSR Part 7 [2] in relation to ensuring that arrangements are made for taking urgent protective actions, early protective actions and other response actions during the emergency response phase; guidance relevant to the implementation of these emergency response actions can be found in GS-G-2.1 [4] and GSG-2 [5]. However, this Safety Guide provides guidance for the integration and coordination of activities from the declaration of the emergency until its termination.

1.16. This Safety Guide does not provide recommendations on communication with the public in preparedness and response for a nuclear or radiological emergency in relation to the termination of the emergency, including the transition phase.[8]

1.17. This Safety Guide does not provide guidance on nuclear security considerations in relation to the termination of a nuclear or radiological emergency, irrespective of whether the emergency was initiated by a nuclear security event. However, relevant authorities may need to give considerations to nuclear security implications, as appropriate, before the termination of the

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[8] A Safety Guide on arrangements for public communication in preparedness and response for a nuclear or radiological emergency is in preparation. Further practical guidance on public communication in emergency preparedness and response can also be found in Refs [20, 21].

emergency. Relevant information relating to nuclear security can be found in the IAEA Nuclear Security Series Nos 13–15 [22–24].

1.18. Terms are used in this Safety Guide as defined in GSR Part 7 [2] and the IAEA Safety Glossary [25]. The terminology for the various phases of a nuclear or radiological emergency in the context of this Safety Guide is clarified in Section 2.

STRUCTURE

1.19. Section 2 describes the various phases of a nuclear or radiological emergency. The section focuses on the concept of the 'transition phase' and the meaning of the termination of a nuclear or radiological emergency and the beginning of either a planned exposure situation or an existing exposure situation. Section 3 states the primary objective of terminating a nuclear or radiological emergency and elaborates on the general and specific prerequisites that need to be met to terminate an emergency. Section 3 also provides generic guidance on the time frames in which a nuclear or radiological emergency is to be terminated. Section 4 describes the arrangements to be made at the preparedness stage, as part of the overall emergency preparedness, to facilitate the implementation of activities in the transition phase that will enable the termination of the emergency. The Appendix provides considerations for adapting or lifting protective actions and other response actions during the transition phase. Annex I provides case studies of several past nuclear or radiological emergencies that support the guidance and recommendations provided in this Safety Guide. Annex II presents factors that need to be considered when justifying and optimizing the protection strategy at the national level.

2. PHASES OF A NUCLEAR OR RADIOLOGICAL EMERGENCY

GENERAL

2.1. This section describes the various phases of a nuclear or radiological emergency and explains the concept of the 'transition phase'. This concept refers to the process and the time period during which there is a progression to the point at which an emergency can be terminated. During this period, the relevant prerequisites (set out in Section 3) that should be fulfilled before the termination of the emergency can be declared are gradually addressed. In this context it is generally assumed that the transition phase commences as early as possible once the source has been brought under control and the situation is stable[9]; the transition phase ends when all the necessary prerequisites for terminating the emergency have been met. The termination of a nuclear or radiological emergency marks the end of the emergency, and therefore the emergency exposure situation, and the beginning of either an existing exposure situation or a planned exposure situation.

2.2. The various phases of a nuclear or radiological emergency are distinguished on the basis of the different timescales in which specific protective actions and other response actions are to be undertaken in order to achieve the goals of emergency response (see para. 3.2 of GSR Part 7 [2]) and to fulfil the prerequisites that would allow the declaration of the end of the emergency. The transition phase may last from a day to a few weeks for a small scale emergency (e.g. a lost or stolen dangerous source) but could last months to a year for a large scale emergency (e.g. an emergency at a nuclear installation resulting in significant off-site contamination).

2.3. In this Safety Guide, the distinction between the various phases of a nuclear or radiological emergency is intended to support the planning efforts for each phase at the preparedness stage as well as to facilitate communication and a common understanding among those involved in the planning. These efforts depend on the characteristics of each phase, including the information available and the specific activities to be carried out.

2.4. The response to a nuclear or radiological emergency is a continuous effort; therefore, during the response it is not intended that a distinction be made between the various phases of the emergency (see para. 2.13).

2.5. The period covering the management of an existing exposure situation and the long term recovery operations after the emergency has been declared to have ended is excluded from the scope of this Safety Guide and is covered in IAEA Safety Standards Series No. WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents [16] and IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment [17].

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[9] A situation is considered stable when the source has been brought under control, no further significant accidental releases or exposures resulting from the event are expected and the future development of the situation is well understood.

EMERGENCY RESPONSE PHASE

2.6. If conditions are detected in relation to a facility, an activity or a source indicating an actual or potential nuclear or radiological emergency warranting protective actions and other response actions, the emergency class is required to be declared and the preplanned response actions that correspond to the emergency class and the level of emergency response that is warranted are required to be initiated on the site and, as necessary, off the site (see Requirement 7 of GSR Part 7 [2]).

2.7. Early in the emergency, the response organizations focus their response actions on mitigating the potential consequences of the emergency so that undesirable conditions are prevented from developing, or their development is delayed, making it possible to take effective protective actions on the site and, as necessary, off the site. Such mitigatory actions are accompanied by protective actions and other response actions that are aimed at the potentially or actually affected individuals. Most of these actions are taken as a matter of urgency (i.e. precautionary urgent protective actions, urgent protective actions and other response actions); however, some actions involve more detailed assessments, primarily based on monitoring, and can be taken within days or weeks and still be effective (i.e. early protective actions and other response actions).

2.8. Protective actions and other response actions are defined in GSR Part 7 [2], as follows:

> "**protective action.** An action for the purposes of avoiding or reducing doses that might otherwise be received in an emergency exposure situation or an existing exposure situation.
>
> ***early protective action***. A protective action in the event of a nuclear or radiological emergency that can be implemented within days to weeks and still be effective.
>
> ⓘ The most common early protective actions are relocation and longer term restriction of the consumption of food potentially affected by contamination.
>
> ***mitigatory action***. Immediate action by the operator or other party:
>
> (a) To reduce the potential for conditions to develop that would result in exposure or a release of radioactive material requiring emergency response actions on the site or off the site; or

(b) To mitigate source conditions that may result in exposure or a release of radioactive material requiring emergency response actions on the site or off the site.

urgent protective action. A protective action in the event of a nuclear or radiological emergency which must be taken promptly (usually within hours to a day) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed.

ⓘ Urgent protective actions include iodine thyroid blocking, evacuation, short term sheltering, actions to reduce inadvertent ingestion, decontamination of individuals and prevention of ingestion of food, milk or drinking water possibly with contamination.

ⓘ A precautionary urgent protective action is an urgent protective action taken before or shortly after a release of radioactive material, or an exposure, on the basis of the prevailing conditions to avoid or to minimize severe deterministic effects."

"***other response action***. An emergency response action other than a protective action.

ⓘ The most common other response actions are: medical examination, consultation and treatment; registration and longer term medical follow-up; providing psychological counselling; and public information and other actions for mitigating non-radiological consequences and for public reassurance."

2.9. The safety requirements established in GSR Part 7 [2] and its supporting guidance and recommendations (GS-G-2.1 [4] and GSG-2 [5]) address emergency arrangements[10] to be established and implemented in the period after the identification of the conditions leading to the declaration of a nuclear or radiological emergency, until the time the situation is brought under control and radiological conditions are characterized sufficiently well. This period is called the 'emergency response phase' and is defined as the period of time from the

[10] These emergency arrangements include arrangements for the implementation of urgent protective actions, early protective actions and other response actions.

detection of conditions warranting an emergency response until the completion of all the actions taken in anticipation of or in response to the radiological conditions expected in the first few months of the emergency. The emergency response phase typically ends when the situation is under control, the off-site radiological conditions have been characterized sufficiently well to identify whether and where food restrictions and temporary relocation are required, and all required food restrictions and temporary relocations have been put into effect (see Ref. [26]).

2.10. For the purposes of this Safety Guide, the emergency response phase is divided into an urgent response phase and an early response phase (see Fig. 1) as follows:

(a) Urgent response phase: The period of time, within the emergency response phase, from the detection of conditions warranting emergency response actions that must be taken promptly in order to be effective until the completion of all such actions. Such emergency response actions include mitigatory actions by the operator and urgent protective actions on the site and off the site. The urgent response phase may last from hours to days depending on the nature and scale of the nuclear or radiological emergency.[11]
(b) Early response phase: The period of time, within the emergency response phase, from which a radiological situation is already characterized sufficiently well that a need for taking early protective actions and other response actions can be identified, until the completion of all such actions. The early response phase may last from days to weeks depending on the nature and scale of the nuclear or radiological emergency.[12]

[11] For example, the urgent response phase may last just hours in the case of a small scale emergency, such as a radiological emergency during transport or a radiological emergency involving a sealed dangerous source.

[12] For example, the early response phase may last hours to a day in the case of a small scale emergency, such as a radiological emergency during transport or a radiological emergency involving a sealed dangerous source.

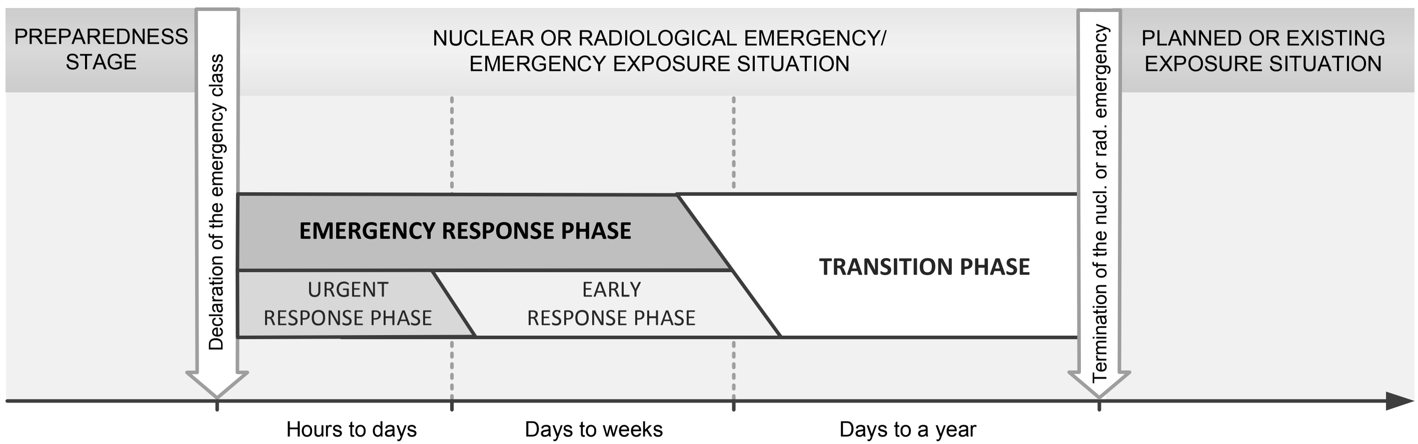

FIG. 1. Temporal sequence of the various phases and exposure situations for a nuclear or radiological emergency within a single geographical area or a single site.

TRANSITION PHASE

2.11. For the purposes of this Safety Guide, the transition phase is the period of time after the emergency response phase[13] when (a) the situation is under control (see footnote 9), (b) detailed characterization of the radiological situation has been carried out and (c) activities are planned and implemented to enable the emergency to be declared terminated. The activities carried out during the transition phase aim to achieve the primary objective and the prerequisites elaborated in Section 3. The transition phase may last from days to months, notwithstanding that for a small scale emergency (e.g. a radiological emergency during transport or a radiological emergency involving a sealed dangerous source) the transition phase may last not more than a day. The termination of the nuclear or radiological emergency marks the end of the transition phase for a particular area or a site and the beginning of either an existing exposure situation or a planned exposure situation (see Fig. 1).

2.12. Compared to the urgent response phase and, to some extent, the early response phase, the transition phase is not driven by urgency and allows for adapting, justifying and optimizing protection strategies as the emergency evolves and for interested parties to be consulted. Depending on the nature of the nuclear or radiological emergency, these processes may continue in the longer term after the emergency has been declared terminated. In the transition phase and in the longer term, the implementation of remedial actions might be more efficient than carrying out further disruptive public protective actions.

2.13. While the distinction between various phases of a nuclear or radiological emergency may be helpful for planning purposes, it can be difficult to clearly define a line between the various phases of an emergency during the emergency response (see paras 2.3 and 2.4) as the emergency response actions are implemented on a continuous basis (see Fig. 2). This lack of clear distinction is particularly true for the early response phase and the transition phase, when the activities that are carried out may support the implementation of specific actions and activities associated with both phases. For example, a monitoring strategy implemented during the early response phase may support both the decision making on early protective actions and the assessment of the radiological situation, which may in turn help to determine how protection strategies are to be further adapted.

[13] The exposure situation in the transition phase is still an emergency exposure situation even though the emergency response phase is over, as presented in Figs 1 and 2.

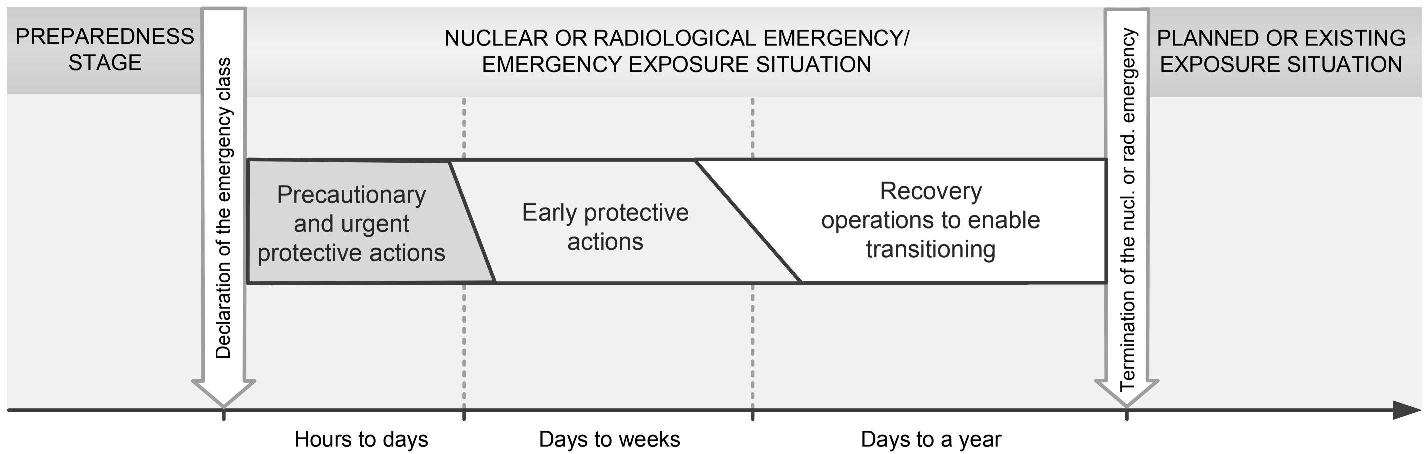

FIG. 2. Temporal sequence of various types of protective actions and recovery operations for a nuclear or radiological emergency within a single geographical area or a single site.

2.14. In a large scale emergency, the complexity of the radiological situation may vary greatly within an affected area and may be transient in nature. It is therefore likely that different phases and different exposure situations will coexist geographically and temporally. This coexistence challenges both the management of the situation and the communication with interested parties. The transition from the emergency exposure situation will occur gradually in specific areas within the whole affected area. In this case, the transition phase will end when the final area that was in an emergency exposure situation has transitioned to an existing exposure situation.[14] The transition of this final area to an existing exposure situation will also denote the overall termination of the emergency.

3. PRIMARY OBJECTIVE OF AND PREREQUISITES FOR TERMINATING THE EMERGENCY

GENERAL

3.1. This section elaborates on the primary objective and the prerequisites to be considered in planning and decision making regarding the termination of a nuclear or radiological emergency. This section provides general guidance on a broad spectrum of aspects that authorities should consider in relation to the termination of the emergency in accordance with an all-hazards approach,[15] notwithstanding the need to use a graded approach when applying the prerequisites for each postulated nuclear or radiological emergency and the need to consider national, local and site specific circumstances.

3.2. The primary objective and the prerequisites stated in this section should guide the development and implementation of the protection strategy for the transition phase. The primary objective and the prerequisites should, therefore, also guide the arrangements that need to be put in place during the preparedness stage to ensure that the protection strategy is implemented in an efficient and

[14] See also paras 3.20, 3.22 and 4.98, particularly with regard to the delineation of areas.

[15] States usually have arrangements in place for returning to normal social and economic activity after any type of emergency. Such arrangements would also be expected to support the preparations for the transition to either an existing exposure situation or a planned exposure situation after a nuclear or radiological emergency. To this end, all the arrangements necessary to be put in place in accordance with this Safety Guide need to be integrated with one another in accordance with an all-hazards approach.

coordinated manner in the transition phase. The primary objective and the prerequisites should also serve as intermediate steps for any objectives that need to be attained in the longer term for an existing exposure situation, as applicable.

3.3. The emergency should be terminated if the relevant prerequisites set forth in this section and selected on the basis of a graded approach (see para. 3.1) have been fulfilled; the decision to terminate the emergency should be a formal decision and should be made public. The new exposure situation should then be managed as either a planned exposure situation or an existing exposure situation (see Fig. 1), as appropriate, in line with the national legal and regulatory framework as required in GSR Part 7 [2], GSR Part 3 [3] and IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [27].

3.4. It should be recognized that:

(a) The transition from the emergency exposure situation will likely take place at different geographical areas or at different parts of the site at different points in time. The situation in some geographical areas or some parts of the site might therefore continue to be managed as a nuclear or radiological emergency, while the situation in other areas might be managed as a planned exposure situation or an existing exposure situation, as appropriate.
(b) Some of the prerequisites set out in this section are to be fulfilled by the operating organization in addition to responsible off-site response organizations. To a great extent, the transition from the emergency exposure situation in areas off the site will be subject to confirmation by the operating organization that the respective prerequisites[16] have been fulfilled on the site.

PRIMARY OBJECTIVE

3.5. The primary objective of the termination of the emergency is to facilitate the timely resumption of social and economic activity.

[16] Such prerequisites may include, as appropriate, those stated in paras 3.6, 3.7, 3.9–3.12, 3.19 and para. 3.20 (e)–(g).

3.6. A nuclear or radiological emergency should not be terminated until the necessary urgent protective actions and early protective actions have been implemented.[17]

3.7. Before the termination of the emergency, the exposure situation should be well understood and confirmed to be stable, meaning that the source has been brought under control, no further significant accidental releases or exposures resulting from the event are expected and the likely future development of the situation is well understood.

3.8. Before the termination of the emergency, the radiological situation should be well characterized, exposure pathways should be identified and doses[18] should be assessed for affected populations[19] (including those population groups most vulnerable to radiation exposure, such as children and pregnant women). This characterization should consider the impact of lifting and adapting the protective actions implemented earlier in the emergency response and, where applicable, possible options for the future use of land and water bodies (e.g. imposing restrictions or identifying alternative ways in which the land and water bodies can be exploited).

3.9. Before any decision to terminate the emergency is made, a thorough hazard assessment should be performed in respect of the situation and its future development, consistent with Requirement 4 of GSR Part 7 [2]. The hazard assessment should provide a basis for preparedness and response for any new emergency that may occur.

3.10. On the basis of the hazard assessment, those events and associated areas that may warrant protective actions and other response actions — including

[17] When deciding on the termination of a nuclear or radiological emergency, some of the urgent protective actions and early protective actions (e.g. evacuation) might be already under consideration to be adapted or lifted. Other actions (e.g. restrictions on food, milk and drinking water) might remain in place in the longer term after the termination of the emergency, and some actions, such as iodine thyroid blocking, might already have been implemented and require no further consideration in the transition phase. For details see paras 4.70–4.101.

[18] Effective dose, equivalent dose to a tissue or organ, or relative biological effectiveness weighted absorbed dose to a tissue or organ, as appropriate. See GSG-2 [5] for details.

[19] Including the public, workers (including emergency workers), helpers and patients, as appropriate.

those that may mitigate the consequences of a future emergency — should be identified, and the existing emergency arrangements should be reviewed. The review should determine whether there is a need to revise the existing emergency arrangements and/or to establish new arrangements.[20]

3.11. The emergency should not be terminated until revised or new emergency arrangements have been formulated and have been coordinated among the relevant response organizations. However, in some cases, the formal establishment of revised or new emergency arrangements might be a lengthy process. Therefore, the establishment of an interim response capability[21] in the transition phase should be considered to prevent unnecessary delay in the termination of the emergency.

3.12. Before the termination of the emergency, it should be confirmed that the requirements for occupational exposure in planned exposure situations[22] established in Section 3 of GSR Part 3 [3] can be applied for all workers who will be engaged in recovery operations (see para. 5.101 of GSR Part 7 [2]) and that the source is secured in a manner that is consistent with Refs [22–24].

3.13. The radiological situation should be assessed, as appropriate, against reference levels, generic criteria, operational criteria and dose limits, to determine whether the relevant prerequisites for the transition to either an existing exposure situation or a planned exposure situation, as appropriate, have been achieved (see paras 3.19–3.22).

3.14. Non-radiological consequences (e.g. psychosocial and economic consequences) and other factors (e.g. technology, land use options, availability of resources, community resilience[23], the availability of social services) relevant

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[20] For example, the hazards associated with a nuclear power plant in normal operation and its associated emergency arrangements will differ from the hazards associated with an accident damaged nuclear power plant and its associated emergency arrangements.

[21] The purpose of such an interim response capability is to provide an improved response to any future emergency, postulated on the basis of the hazard assessment, before the full emergency arrangements are put in place. This interim capability might not be optimal and would need to make use of all available means and resources with only minimal additional arrangements (e.g. training, a few revised procedures).

[22] Paragraph 5.26 of GSR Part 3 [3] requires that employers "ensure that the exposure of workers undertaking remedial actions is controlled in accordance with the relevant requirements on occupational exposure in planned exposure situations."

[23] Community resilience is the capacity of a community to be able to recover quickly and easily from the consequences of a nuclear or radiological emergency.

to the termination of the emergency should be identified, and actions to address them should be considered.

3.15. A registry of those individuals[24] who, by the time the emergency is to be terminated, have been identified as requiring longer term medical follow-up (see GSR Part 7 [2] and GSG-2 [5]) should be established before the termination of the emergency.

3.16. Consideration should be given to the management of any radioactive waste arising from the emergency, as appropriate, before the termination of the emergency.

3.17. Consultation with interested parties is required before the termination of the emergency [2]. This process should not unduly impede timely and effective decision making by the responsible authority with respect to the termination of the emergency; however, this process is intended to help increase the public trust in and the public acceptance of the decision to terminate the emergency.

3.18. Before the termination of the emergency, the following should be discussed with and communicated to the public and other interested parties, as appropriate:

(a) The basis and rationale for the termination of the emergency and an overview of the actions taken and the restrictions imposed;
(b) The need to adjust imposed restrictions, to continue protective actions or to introduce new protective actions, as well as the expected duration of these actions and restrictions;
(c) Any necessary modifications to people's personal behaviours and habits;
(d) Options for the implementation of self-help actions[25], as appropriate;
(e) The need for continued environmental monitoring and source monitoring after the termination of the emergency;
(f) The need for continued efforts to restore services and workplaces;
(g) Radiological health hazards associated with the new exposure situation.

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[24] Including the public, workers (including emergency workers), helpers and patients, as appropriate.

[25] Examples of self-help actions include, but are not limited to, avoiding prolonged visits to certain areas, changing farming practices and land use, and reducing the consumption of certain foods.

SPECIFIC PREREQUISITES

Transition to a planned exposure situation

3.19. In addition to the general prerequisites (see paras 3.6–3.18), the following specific prerequisites should be met in order to be able to declare the termination of an emergency and to move to a planned exposure situation:

(a) The circumstances that led to the emergency have been analysed, corrective actions have been identified and an action plan has been developed for the implementation of corrective actions by the respective authorities, as applicable, in relation to the facility, activity or source involved in the emergency. However, in some cases, the formal analysis and development of the action plan might be a lengthy process. Therefore, consideration should be given to establishing administrative procedures that limit or prevent the use or handling of the source until the circumstances that led to the emergency have been better understood, with the aim of preventing unnecessary delays in the termination of the emergency.
(b) Conditions have been assessed to ensure compliance with the safe and secure handling of the source[26] involved in the emergency in accordance with the national requirements set forth for the respective planned exposure situation[27].
(c) Compliance has been confirmed with the dose limits for public exposures in planned exposure situations and with the requirements for medical exposure established in Section 3 of GSR Part 3 [3].

Transition to an existing exposure situation

3.20. In addition to the general prerequisites (see paras 3.6–3.18), the following specific prerequisites should be met in order to be able to declare the termination of an emergency and to move to an existing exposure situation:

(a) Justified and optimized actions have been taken to meet the national generic criteria established to enable the transition to an existing exposure

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[26] A source is "Anything that may cause radiation exposure — such as by emitting ionizing radiation or by releasing radioactive substances or radioactive material — and can be treated as a single entity for purposes of protection and safety" (GSR Part 3 [3]).

[27] Depending on the type of emergency, the planned exposure situation can be associated with the normal operation of the facility or activity, with cleanup and decommissioning, or with the ending of the operational life of the source involved in the emergency.

situation, with account taken of the generic criteria provided in appendix II to GSR Part 7 [2], and it has been verified that the assessed residual doses[28] approach the lower bound of the reference level for an emergency exposure situation (see paras 4.52–4.69).

(b) Areas have been delineated that are not permitted to be inhabited and where it is not feasible to carry out social and economic activity. This delineation relates to areas that, earlier in the emergency response, were subject to evacuation and/or relocation, and/or where specific restrictions were imposed that will continue to be implemented after the termination of the emergency.

(c) For these delineated areas, administrative and other provisions have been established to monitor compliance with any restrictions imposed.

(d) Before the termination of the emergency, a strategy has been developed for the restoration of infrastructure, workplaces and public services (e.g. public transportation, shops and markets, schools, kindergartens, health care facilities, and police and firefighting services) necessary to support normal living conditions in the affected areas, such as those areas in which evacuations or relocations were carried out.

(e) A mechanism and the means for continued communication and consultation with all interested parties, including local communities, have been put in place.

(f) Before the termination of the emergency, any change or transfer of authority and responsibilities from the emergency response organization to organizations responsible for the long term recovery operations has been completed.

(g) The sharing of any information and data that were gathered during the emergency exposure situation and that are relevant for long term planning has been organized among the relevant organizations and authorities.

(h) Development of a long term monitoring strategy in relation to residual contamination has been initiated.

(i) A programme for longer term medical follow-up for the registered individuals (see para. 3.15) has been developed.

(j) A strategy for mental health and psychosocial support for the affected population has been developed.

(k) Consideration has been given to the compensation of victims for damage due to the emergency so as to provide for public reassurance,

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[28] The residual dose is the “dose expected to be incurred after protective actions have been terminated (or after a decision has been taken not to take protective actions)” (GSR Part 7 [2]).

notwithstanding the fact that the processes for compensation will extend after the emergency is terminated.

(l) Administrative arrangements, legal provisions and regulatory provisions have been put in place or are being put in place for the management of the existing exposure situation, including provisions for the allocation of the necessary financial, technical and human resources.

3.21. After the termination of the emergency, individual monitoring[29] of members of the public should in general no longer be necessary for radiation protection purposes. However, the doses received by individuals can differ considerably depending on their individual habits; therefore, the doses received by such individuals will need to be assessed, and the protection of these individuals may still need to be addressed in the long term protection strategy.

3.22. There might be exceptional circumstances in which it has not been feasible, within a reasonable time, to meet the national generic criteria for enabling a transition to an existing exposure situation (see para. 3.20(a)). In such cases, a decision to terminate the emergency may still be taken, as long as it has been determined that no further justified and optimized actions are feasible and the generic criteria for taking early protective actions and other response actions provided in appendix II to GSR Part 7 [2] are not exceeded.

TIME FRAMES FOR THE TERMINATION OF AN EMERGENCY

3.23. At the preparedness stage, the time frames in which it is anticipated that an emergency will be terminated should be assessed for a range of postulated nuclear or radiological emergencies on the basis of a hazard assessment. There may be unforeseen circumstances that would be difficult to factor in to determine the time frame for the termination of a specific nuclear or radiological emergency. However, a strategy should nevertheless be determined for coping with specific aspects of the termination within a reasonable time frame.

3.24. Experience suggests that a time frame in the range of several weeks to one year can be proposed for terminating a large scale emergency (e.g. an emergency at a nuclear installation resulting in significant off-site contamination); however,

[29] Individual monitoring is “Monitoring using measurements by equipment worn by individuals, or measurements of quantities of radioactive substances in or on, or taken into, the bodies of individuals, or measurements of quantities of radioactive substances excreted from the body by individuals” (GSR Part 3 [3]).

a time frame in the range of a day to a few weeks may be adequate for terminating a small scale emergency (e.g. a radiological emergency during transport or a radiological emergency involving a sealed dangerous source).

4. ARRANGEMENTS FOR THE TRANSITION PHASE

GENERAL

4.1. This section provides detailed guidance on various aspects to be considered at the preparedness stage (see Fig. 1) when establishing arrangements for the transition phase of a nuclear or radiological emergency. The implementation of this guidance is intended to provide support in terms of meeting the prerequisites for terminating the emergency stated in Section 3.

AUTHORITY, RESPONSIBILITIES AND MANAGEMENT

4.2. GSR Part 7 [2] states that:

— "The government shall make adequate preparations to anticipate, prepare for, respond to and recover from a nuclear or radiological emergency at the operating organization, local, regional and national levels, and also, as appropriate, at the international level. These preparations shall include adopting legislation and establishing regulations for effectively governing the preparedness and response for a nuclear or radiological emergency at all levels" (para. 4.5 of GSR Part 7 [2]).
— "The emergency arrangements shall include clear assignment of responsibilities and authorities, and shall provide for coordination…in all phases of the response" (para 6.5 of GSR Part 7 [2]).
— "The government shall ensure that all roles and responsibilities for preparedness and response for a nuclear or radiological emergency are clearly allocated in advance among operating organizations, the regulatory body and response organizations" (para. 4.7 of GSR Part 7 [2]).
— "The government shall ensure that response organizations, operating organizations and the regulatory body have the necessary human, financial and other resources, in view of their expected roles and responsibilities and the assessed hazards, to prepare for and to deal with both radiological and non-radiological consequences of a nuclear or radiological emergency,

whether the emergency occurs within or beyond national borders" (para. 4.8 of GSR Part 7 [2]).

— "**The government shall ensure that arrangements are in place for operations in response to a nuclear or radiological emergency to be appropriately managed**" (Requirement 6 of GSR Part 7 [2]).
— "The arrangements for delegation and/or transfer of authority shall be specified in the relevant emergency plans, together with arrangements for notifying all appropriate parties of the transfer" (para. 6.6 of GSR Part 7 [2]).

4.3. In consideration of the prerequisites stated in Section 3, the government should review and revise at the preparedness stage, as appropriate:

(a) The legal and regulatory framework governing preparedness and response in respect of the transition phase of a nuclear or radiological emergency;
(b) The framework for radiation protection and safety relating to longer term issues associated with an existing exposure situation, to ensure a smooth transition and to avoid unnecessary delays due to legal and regulatory issues.

4.4. As part of the review referred to in para. 4.3, the need for the following should be identified:

(a) The positions to be staffed to implement the necessary activities in the transition phase and, over the longer term, in a planned exposure situation or an existing exposure situation, as appropriate;
(b) The provision of 'just in time' training to emergency workers and helpers;
(c) The mobilization of resources among relevant organizations.

Arrangements should be established to ensure that such positions, training and resources will be in place when they are needed.

Authority, role and responsibilities

4.5. In the urgent response phase, the discharge of authority and the assumption of responsibilities in the emergency response have to be, to the extent possible, straightforward and based on planned arrangements to enable the effective implementation of precautionary urgent protective actions and urgent protective actions. Thus, the input from other organizations into the decision making process regarding the emergency response actions warranted during the urgent response phase is expected to be limited.

4.6. As the emergency evolves, the focus of the emergency response will shift from bringing the situation under control and taking public protective actions, to allowing the timely resumption of social and economic activity. At this time, radiological considerations will be only one of the many factors to be evaluated in the decision making processes. Decision making at this time will require the involvement of additional organizations, with relevant responsibilities at different levels, that might not necessarily have been directly engaged during the urgent response phase. These organizations should gradually be involved, when appropriate, in the emergency response in order to discharge their allocated roles and responsibilities. This involvement should be arranged in a way that enables ongoing response efforts to continue without interruption on a routine basis in the longer term, after the emergency response organization has been relieved of its duties.

4.7. The authority, roles and responsibilities of all organizations with regard to preparation, response and recovery in the transition phase — including oversight of the implementation of provisions within the legal and regulatory framework, as well as ensuring the necessary resources (human, technical and financial) — should be identified at the preparedness stage. The identification of these elements should be based on the activities that are expected to be carried out during the transition phase to fulfil the prerequisites set out in Section 3. As part of these arrangements, the authority and responsibility for making a formal decision on the termination of a nuclear or radiological emergency should be clearly allocated, well understood and documented in the respective emergency plans and procedures. Consideration should be given to the fact that the organization with the authority and responsibility for deciding on the transition from an emergency exposure situation to an existing exposure situation or a planned exposure situation may differ between the on-site areas and off-site areas (see also para. 3.4).

4.8. A mechanism should be put in place at the preparedness stage that would allow for the mobilization and coordination of different organizations at different levels, provide for any necessary change in authority and discharge of responsibilities during the transition phase, and enable the prompt resolution of any conflicting responsibilities. This mechanism should take into account that, in the transition phase, there will be a need for multidisciplinary contributions, including those from the operating organization, which will need to be channelled efficiently and effectively.

4.9. In the transition phase, the necessary transfer of responsibilities to different jurisdictions or different authorities (or to different units within an organization) should be carried out in a formal, coordinated and fully transparent manner and should be communicated to all interested parties.

Management

4.10. The differences in management necessary for the various phases of a nuclear or radiological emergency should be identified at the preparedness stage. During the transition phase, the emergency response organization that was established in the emergency response phase should gradually return to routine (non-emergency) duties, so that the organizations with the relevant authority, roles and responsibilities can take over the activities on a routine basis within the planned exposure situation or existing exposure situation.

4.11. With the formal termination of the emergency, the structure of the emergency response organization should be deactivated. At that stage, the management structure of the various response organizations should revert to what it had been prior to the emergency to allow for an effective response to any emergency that might occur in the future; however, some of these organizations may need to assume additional responsibilities. There may also be a need for new coordination and consultation mechanisms for those organizations dealing with the consequences of the emergency in the longer term as an existing exposure situation or a planned exposure situation.

4.12. Consideration should be given to the need for the simultaneous existence of different management structures in different geographical areas owing to the gradual change in management during the transition phase.

4.13. The organizations assuming responsibility for the activities in the transition phase, and in the longer term within an existing exposure situation, as appropriate, should quickly develop an understanding of the situation. Arrangements should be established that would allow for the relevant information and data on the nuclear or radiological emergency to be made available to these organizations, including, for example, the protection strategy implemented in the emergency response phase and the rationale supporting the decisions made in the emergency response phase.

4.14. As part of the arrangements referred to in para. 4.13:

(a) The types of information and data from the emergency response phase that may be of relevance to the transition phase as well as in the longer term should be clearly identified.

(b) Relevant organizations that will need access to such information and data should be identified.
(c) A mechanism should be established to record such information and data during the emergency response phase and to exchange this information and data efficiently between the relevant organizations, taking into account the need for continued data collection and sharing in the transition phase as well as in the longer term.

4.15. Consideration should be given to ensuring an overlap, for an agreed period, of management and technical personnel involved in the emergency response phase and those to be involved in the transition phase to ensure continuity between the two phases.

HAZARD ASSESSMENT

4.16. Requirement 4 of GSR Part 7 [2] requires the government to ensure that a hazard assessment is performed to provide a basis for a graded approach in preparedness and response for a nuclear or radiological emergency. Five emergency preparedness categories are used to group the assessed hazards in relation to facilities, activities and sources (and their potential consequences) and to establish a basis for developing generically justified and optimized arrangements for emergency preparedness and response. Paragraph 5.14 of GSR Part 7 [2] requires that, on the basis of the hazard assessment, a system be established for promptly classifying a nuclear or radiological emergency warranting protective actions and other response actions. Declaration of an emergency class initiates a coordinated and preplanned level of emergency response on the site and, where appropriate, off the site, in accordance with the protection strategy. GS-G-2.1 [4] provides further guidance in this regard.

4.17. With account taken of the uncertainties in, and the limitations of, the information available at the preparedness stage, the hazard assessment identifies facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency might warrant the implementation of protective actions and other response actions. Facilities and activities, on-site areas, off-site areas and locations for which actions aimed at enabling the termination of the emergency may also be warranted should be identified as well.

4.18. The government, the response organizations and the operating organization should use the hazard assessment and the postulated nuclear or radiological emergencies within each emergency class to anticipate what the transition phase might encompass; the government, the response organizations and the operating organization should also aim to foresee the level of response warranted in relation to the transition phase for a range of postulated nuclear or radiological emergencies and thus provide a basis for applying a graded approach as follows:

(a) For a *general emergency* at a facility in emergency preparedness category I or II, leading to a significant release of radioactive material to the environment (e.g. the Fukushima Daiichi accident in 2011, for which a case study is given in Annex I), termination of the emergency will take place through transition to an existing exposure situation.
(b) For a *site area emergency* at a facility in emergency preparedness category I or II and for a *facility emergency* at a facility in emergency preparedness category I, II or III, termination of the emergency will take place through transition to a planned exposure situation (e.g. the Paks fuel damage incident in 2003, for which a case study is given in Annex I). In this context, the planned exposure situation may be associated with a continuation of normal operation, or with cleanup and decommissioning, or with the ending of the operational life of the source involved in the emergency, as applicable. However, postulated nuclear or radiological emergencies within these classes are not expected to result in a different exposure situation for the public compared with the situation that existed before the emergency.
(c) An *alert* at a facility in emergency preparedness category I, II or III will be followed by the resumption of normal operations in a planned exposure situation.
(d) *Other nuclear or radiological emergency* covers a broad spectrum of emergencies involving activities or acts in emergency preparedness category IV and may occur at any location (see para. 4.19 of GSR Part 7 [2]). In this class, depending on the type of emergency, termination of the emergency is envisaged by transition to either an existing exposure situation or a planned exposure situation. For example:
    (i) An emergency without a release of radioactive material to the environment is to be terminated by transition to the same exposure situation for the affected public that existed before the emergency (e.g. the radiological incident in Hueypoxtla, Mexico, in 2013, for which a case study is given in Annex I). The recovered source may be brought back to normal operation or its operational life may be ended. In the latter case, the source may be managed as radioactive waste under the requirements for a planned exposure situation.
    (ii) An emergency with a release of radioactive material to the environment resulting in significant residual radioactivity in the environment is to be terminated by transition to an existing exposure situation (e.g. the

Goiânia accident of 1987 [12], for which a case study is given in Annex I).

4.19. The insights gained through the hazard assessment should be used for the identification of options and limitations of specific emergency arrangements to be made for the transition phase, including for the estimation of the time frames in which the prerequisites in Section 3 might be fulfilled, with account taken of:

(a) The likely inability to predict accurately when, where and what the actual impact of the nuclear or radiological emergency might be;
(b) The complexity of potential recovery efforts;
(c) The potential impact of non-radiological factors, such as public concerns and the political situation, on decision making at the time of the emergency.[30]

4.20. An emergency may result in changes in the hazards applicable to the State compared with the hazards applicable before the emergency. Such a change may necessitate adjustment of the emergency arrangements (i.e. the revision of existing emergency arrangements and/or the introduction of new arrangements to manage the new hazards) in line with paras 4.26 and 4.27 of GSR Part 7 [2]. As a result, before a decision to terminate the emergency can be made, a thorough hazard assessment of the situation and its future development should be performed in accordance with Requirement 4 of GSR Part 7 [2]. The implications of this hazard assessment on the existing emergency arrangements should also be identified and addressed (see paras 3.9–3.11 of Section 3).

[30] For example, more detailed planning can be made for a general emergency at a facility in emergency preparedness category I (e.g. a nuclear power plant), particularly for the urgent response phase and the early response phase. In this case, aspects such as the potentially affected areas, the habits and customs of the potentially affected population and land use can be identified at the preparedness stage as part of the hazard assessment. A radiological emergency involving a dangerous source can occur at any location, and therefore a more generic approach towards preparedness would need to be adopted.

PROTECTION OF THE PUBLIC

Protection strategy

General

4.21. A protection strategy, as the concept is used in this Safety Guide, describes in a comprehensive manner what needs to be achieved in response to a nuclear or radiological emergency in all its phases and how this strategy will be achieved through the implementation of a justified and optimized set of protective actions and other response actions. In this Safety Guide, particular emphasis is placed on the protection strategy in the transition phase.

4.22. The guidance in this subsection focuses on considerations concerning the protection of the public and society in general; the protection of emergency workers and helpers is addressed in paras 4.102–4.141.

Development of protection strategies at the preparedness stage

4.23. GSR Part 7 [2] states that:

> "4.27. The government shall ensure that, on the basis of the hazards identified and the potential consequences of a nuclear or radiological emergency, protection strategies are developed, justified and optimized at the preparedness stage for taking protective actions and other response actions effectively in a nuclear or radiological emergency.
>
> …….
>
> "4.30. The government shall ensure that interested parties are involved and are consulted, as appropriate, in the development of the protection strategy.
>
> "4.31. The government shall ensure that the protection strategy is implemented safely and effectively in an emergency response through the implementation of emergency arrangements".

4.24. The protection strategy should cover, at least, the period from the declaration of the emergency until the termination of the emergency to support the achievement of all the goals of emergency response stated in para. 3.2 of GSR Part 7 [2]. The primary objective and the prerequisites for the termination of the emergency stated in Section 3 of this Safety Guide should be the main drivers for the development of the protection strategy for the transition phase.

4.25. For a large scale emergency, the implementation of a protection strategy could extend in the longer term within the framework of an existing exposure situation (see WS-G-3.1 [16] and GSG-8 [17]). The comprehensive protection strategy developed at the preparedness stage should extend beyond the termination of the emergency to support all the activities necessary for achieving any long term objectives.

4.26. The protection strategy for the transition phase developed at the preparedness stage might not be as detailed as the protection strategy for the emergency response phase. This lack of detail is often due to large uncertainties in the prediction of the long term development of the radiological situation for postulated nuclear or radiological emergencies. Other uncertainties are related to social, economic, political and other aspects prevailing at the time of the emergency and the increasing importance of these non-radiological factors later in the response. Thus, the protection strategy for the transition phase should be further elaborated and adapted during the transition phase itself, as relevant information becomes increasingly available. The process for adapting the protection strategy during the emergency response should be agreed, at the preparedness stage, with all relevant authorities and interested parties and should be included in the protection strategy.

4.27. As part of the protection strategy, the processes of justification and optimization to cope with the prevailing conditions as the emergency evolves should be agreed on. In general, this agreement should include the following elements:

(a) The processes and methods to be used in the transition phase, including the designation of any necessary decision aiding tools;
(b) The parties that will need to be consulted on the inputs necessary for the justification and optimization processes;
(c) Clearly defined roles and responsibilities for the justification and optimization processes.

4.28. As part of the processes of justification and optimization, the protection strategy should take into account the impact that emergency response actions taken during the emergency response phase may have on the actions warranted in the transition phase and in the longer term. The impact that emergency response actions may have on meeting the prerequisites for the termination of the emergency should also be examined and considered.[31] However, such considerations should not compromise the effectiveness of the protection strategy for the emergency response phase.

4.29. Each protection strategy should include (a) a national reference level, expressed in terms of residual dose from all exposure pathways, to be used as a benchmark for the optimization of protection and safety; (b) generic criteria for taking protective actions and other response actions; and (c) pre-established national operational criteria for initiating the different emergency response actions in line with Requirement 5 of GSR Part 7 [2], with account taken of the recommendations provided in this Safety Guide and in GSG-2 [5].

4.30. Public self-help actions aimed at supporting the implementation of the protection strategy should be an integral element of each protection strategy, particularly for the transition phase of a large scale emergency involving a substantial release of radioactive material to the environment.

4.31. The development of the protection strategy should involve all response organizations at all levels, as well as relevant interested parties (see paras 4.197–4.207) to allow for a common understanding and to enhance the acceptability, feasibility and any associated practicalities of the proposed protection strategy.

4.32. When significant radiological consequences could extend beyond national borders, every effort should be made to develop the protection strategy in consultation with neighbouring States that may be directly impacted by the emergency to ensure consistent and coordinated responses.

4.33. The protection strategies should be used at the preparedness stage as a framework to guide the establishment of adequate emergency arrangements by all response organizations.

Implementation of the protection strategy in the transition phase

4.34. As soon as the emergency has been declared, the prompt implementation of the protection strategy is paramount to provide the best level of protection under

[31] For example, if two options within the protection strategy provide the same level of protection of the public during the emergency response phase, the one that is less disruptive to society would be the preferred option, as this option will better support later efforts associated with the termination of the emergency and the overall recovery.

the circumstances, even if very little information is available, as may be the case during the urgent response phase. As the emergency evolves, and particularly during the transition phase, more information on the circumstances that led to the emergency and its consequences will become available. The implementation of the protection strategy should be continually reassessed, and the protection strategy should be adapted on the basis of the prevailing conditions [5].

4.35. The effectiveness of the protection strategy in the transition phase should be assessed against the pre-established prerequisites for the termination of the emergency (see Section 3). This assessment should include a comparison of the residual doses among affected populations against the chosen reference level.

4.36. The process of reassessment and adaptation of the protection strategy during the transition phase should allow for iterative application of the processes of justification and optimization (see paras 4.39–4.51 and Fig. 3).

4.37. The rationale for adapting the protection strategy should be transparent with respect to the criteria and conditions considered (including radiological factors and other factors) and should be documented and communicated to relevant authorities and relevant interested parties.

4.38. In the transition phase there is likely to be a gradual increase in both the need to engage with interested parties (see paras 4.197–4.207) and their interest in the decision making processes. Although relevant interested parties are required to be engaged with and consulted, the process should be such that the responsibility for timely decision making clearly remains with the relevant authorities. In the transition phase, consideration should be given to the time allocated for such engagement and consultation and to the need for timely and effective implementation of the protection strategy.

Justification and optimization

General

4.39. Non-radiological factors become an increasingly important input into decision making in the transition phase as the doses tend to decrease with the effective implementation of the protection strategy. Notwithstanding the need to consider both radiological and non-radiological factors in the justification and optimization of the protection strategy, for situations involving higher doses (approaching or exceeding an effective dose of 100 mSv per year), protective

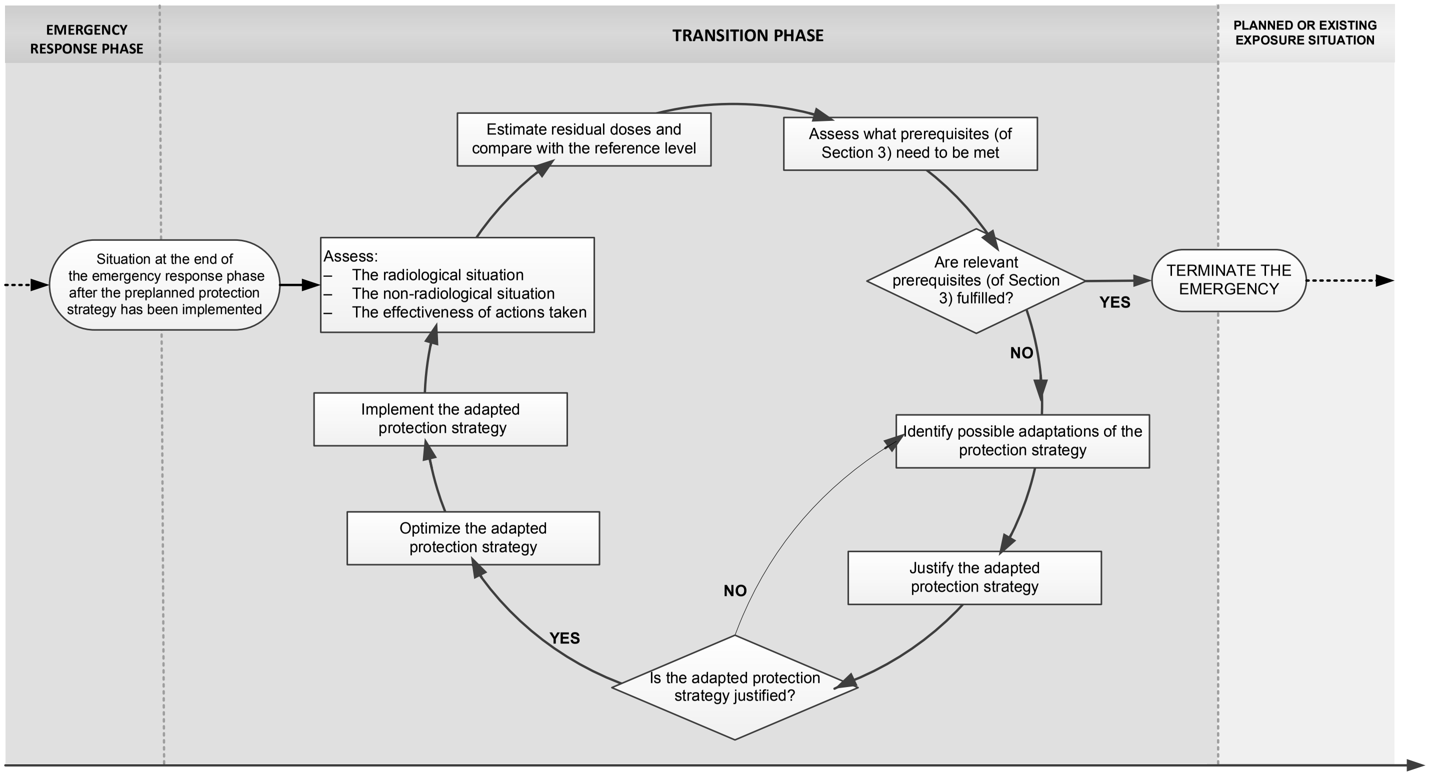

FIG. 3. *The iterative process of assessing the implementation and adaptation of the protection strategy in the transition phase.*

actions are almost always justified,[32] and the radiation protection considerations generally outweigh the non-radiological impacts.

4.40. The processes of justification and optimization should consider a variety of factors, examples of which are given in Table II–1 of Annex II. In order to take this range of factors into account, the processes for justification and optimization of the protection strategy should be such that input can be obtained from relevant authorities and relevant interested parties.

4.41. While some of the factors to be considered in the processes of justification and optimization can be known or estimated at the preparedness stage, some of them cannot be known or may be known without sufficient accuracy. Examples of such factors include seasonal and weather conditions, the occurrence of simultaneous or sequential events that may have caused a major loss of essential infrastructure (such as a conventional emergency), the actual radionuclides involved and the different lifestyles and dietary habits of the population. The processes of justification and optimization should recognize such uncertainties and limitations in terms of the information available at the preparedness stage and should ensure that these uncertainties are adequately reflected in the estimated impact of an emergency and are appropriately considered during the response.

4.42. In all phases of an emergency, and especially in the transition phase, the processes of justification and optimization of the protection strategy should be conducted to continually assess the impact of the protection strategy on the overall radiological situation, including the assessment of (a) the residual doses incurred by people compared with the reference levels, (b) the impact on society and (c) other non-radiological impacts. Such continual reassessment should demonstrate the progress made in achieving the prerequisites for terminating the emergency and should lead to an adaptation of the protection strategy, when necessary, to allow the relevant prerequisites stated in Section 3 to be met (see Fig. 3).

Justification

4.43. Paragraph 4.29 of GSR Part 7 [2] states that "Each protective action, in the context of the protection strategy, and the protection strategy itself shall be

[32] Examples of unjustified actions at this level of dose would include the unsafe evacuation of patients (e.g. the evacuation of seriously ill patients without ensuring the provision of continuous medical care) from hospitals in areas where evacuation has been ordered.

demonstrated to be justified". The application of the principle of justification allows the respective authorities to determine:

> "whether a proposed protective action or remedial action is likely, overall, to be beneficial; i.e. whether the expected benefits to individuals and to society (including the reduction in radiation detriment) from introducing or continuing the protective action or remedial action outweigh the cost of such action and any harm or damage caused by the action" (GSR Part 3 [3]).

4.44. In determining whether the proposed actions and the protection strategy are justified, the reduction in radiation detriment should be weighed against the impacts in other areas, such as public health, social and economic disruption, ethical considerations and the environment. Examples of such impacts include (a) possible reduced life expectancy owing to stress associated with resettlement, (b) costs associated with the loss of essential infrastructure, (c) loss of productivity of industrial facilities, (d) the need for compensation payments to those impacted, (e) societal impact owing to the loss of places of great cultural or historical importance and (f) the costs to society and its economy associated with the management of the radioactive waste generated.

4.45. A justified protection strategy and justified actions within the protection strategy should be developed during the preparedness stage, with account taken of the uncertainties in and limitations of the information available. Protective actions and other response actions implemented solely on the basis of political pressure or public concerns that do not have any scientific and technical merit should be avoided, as these actions may necessitate later remediation activities that are not justified in terms of the associated harm and costs, particularly in the longer term. In addition, taking such unjustified actions may give the impression to the public that the risk associated with the emergency is much greater than the actual risk and therefore may cause unnecessary anxiety and adverse psychological consequences.

4.46. The protective actions and the protection strategy should be periodically reassessed in the transition phase to ensure they continue to do more good than harm, with account taken of any new information that becomes available.

4.47. Paragraph 4.31(h) of GSR Part 7 [2] requires that protective actions and other response actions be discontinued when they are no longer justified.

Optimization

4.48. The optimization of protection and safety should be applied to the protective actions and the protection strategy that have been demonstrated to be justified in accordance with paras 4.39–4.47.

4.49. The optimization of protection and safety is defined in GSR Part 3 [3] as:

> "The process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being 'as low as reasonably achievable, economic and social factors being taken into account'".

The aim is to achieve the best level of protection under the prevailing circumstances; this will not necessarily be the option with the lowest dose.

4.50. The process for optimization should allow for all relevant factors (see Table II–1 of Annex II for examples) to be considered in the decision making process. Optimization of protection and safety should be a forward looking, iterative process that examines the available options for protection and adjusts the actions to be taken to obtain the best outcome.

4.51. Implementation of an optimized protection strategy should result in exposure levels below the reference level, and as low as reasonably achievable, as long as these reductions are justified, with account taken of the aspects indicated in para. 4.44. Optimization should be applied even if the initially projected doses are below the defined reference level, but only if actions that are justified are available to reduce exposures.

Reference levels

4.52. For emergency exposure situations, GSR Part 7 [2], GSR Part 3 [3] and Ref. [28] require that the typical reference level expressed in terms of residual dose be set, typically as an effective dose in the range 20 to 100 mSv, acute or annual, which includes dose contributions via all exposure pathways. Above this level, it is judged to be inappropriate to allow exposures to occur as a result of the exposure situation (i.e. an upper constraint on optimization). The residual dose expresses the accumulated exposure from the initiation of the event through a specified period of time, with account taken of the implementation of the protection strategy, if any.[33]

4.53. Reference levels are used as a tool in the optimization of the protection strategy so that any optimization of protection gives priority to reducing exposures that are above the reference level; the optimization of protection should continue to be applied below the reference level as long as this optimization is justified (i.e. it has been demonstrated that the strategy subject to optimization does more good than harm). Exposures above 100 mSv are justified under some circumstances, either because the exposure is unavoidable or because in exceptional situations the expected benefits clearly outweigh the health risks. Such a situation would apply, for example, to seriously ill patients when their evacuation would present a higher risk to their health than the dose they are likely to receive by remaining in place until their safe evacuation can be arranged.

4.54. The reference level should also serve as a benchmark for retrospective assessment of the effectiveness of the actions and the protection strategy applied in the response (see Refs [2, 26, 29]). This comparison should be used to identify the need to adapt the protection strategy to address the prevailing conditions. In this process, further protective actions should be determined and implemented so that they are focused, as a priority, on those groups or individuals whose doses exceed the reference level. The available resources should then be allocated accordingly.

4.55. The decision to select specific numerical values for the national reference level remains the responsibility of the relevant national authority. This selection will depend on a range of circumstances, including national and local conditions (e.g. the prevailing economic and societal circumstances, and the available national, regional and local resources and capabilities), the phase of the emergency under consideration, the practicality of reducing or preventing exposures and the availability of options to reduce or prevent exposures. The process of selecting specific numerical values for the national reference level should be based on

[33] For emergency exposure situations that may result in doses over a period of less than one year, the residual dose will be the total dose from all exposure pathways for the entire duration of the emergency. For a large scale emergency resulting in longer term exposures due to residual radioactive material in the environment, the residual dose will encompass the total dose from all exposure pathways over one year from the onset of the emergency. For residual doses to be used during the response, the total residual dose includes the doses received from all exposure pathways (received dose) and the doses expected to be received in future (projected residual dose), with account taken of the implementation of the protection strategy, if any.

the results of the hazard assessment and consideration of the urgent protective actions, early protective actions and other response actions implemented, as well as the projected long term development of the exposures. When selecting the values for reference levels, it should be considered that selecting a value close to the lower bound will not necessarily provide for better protection when other factors (see Annex II) are also considered in the overall processes of justification and optimization.

4.56. The following two examples aim to clarify the process of applying the concept of the reference level for residual dose during the transition phase of a large scale emergency and of a small scale emergency:

(a) An emergency involving large scale contamination resulting in exposures of the public due to long-lasting residual radioactive material in the environment will result in longer term exposures, which are expected to decrease with time. The time dependence of the reduction of the residual doses will depend on various circumstances, including the effectiveness and the efficiency of the implementation of the protection strategy. Successful implementation of the protective strategy will lead to residual doses approaching an effective dose of 20 mSv per year, which is expected to facilitate efforts aimed at enabling the transition to an existing exposure situation.
(b) An emergency involving a dangerous source that does not result in long-lasting residual radioactive material in the environment will not result in a need for the residual dose to be gradually reduced, as in the example in para. 4.56(a). As such, while the reference level for the emergency exposure situation may be selected from the range proposed (see para. 4.52) for the purpose of the response, once the source is recovered safely, the concept of the reference level will no longer apply, as the situation will return to a planned exposure situation.

4.57. In general, a reference level of the magnitude used in an emergency exposure situation will not be acceptable as a long term benchmark for an existing exposure situation (see paras 4.29 and 4.54). Termination of an emergency should not be considered if the annual effective dose (residual dose) to the affected population who remain living in an area that is under an emergency exposure situation would be close to the upper end of the range of the reference level for the emergency exposure situation.

4.58. In exceptional cases, however, when no justified and optimized actions can be taken to further minimize the residual doses, a value for the reference level exceeding the lower end of the range of the typical reference level for an emergency exposure situation (which is the upper bound for an existing exposure situation) can be selected for the termination of the emergency, after consultation with all parties concerned. In this case, efforts should be continued to investigate the possible options for reducing doses and to further assess and minimize, as far as practicable and reasonable, the exposures of the people affected. These efforts may include providing advice and support to individuals to help minimize their exposures (e.g. advising on self-help actions).

4.59. A residual dose that is approaching the lower end of the range for the reference level for an emergency exposure situation (on the order of 20 mSv effective dose in a year (see Table 1)) should be accepted for the termination of the emergency; continued efforts will likely be necessary to progressively reduce doses further in the longer term.

4.60. After termination of the emergency and transition to an existing exposure situation, the reference level for the residual dose in an existing exposure situation should be applied in the range of 1 to 20 mSv per year, as required by GSR Part 3 [3] (see Table 1). The International Commission on Radiological Protection recommends that the reference level for the optimization of the protection strategy is selected from the lower end of the 1–20 mSv per year range as a long term objective for existing exposure situations (see Ref. [29]). Further guidance can be found in WS-G-3.1 [16] and GSG-8 [17].

TABLE 1. OVERVIEW OF THE APPLICABILITY OF REFERENCE LEVELS FOR DIFFERENT EXPOSURE SITUATIONS

Range of the reference level for the residual dose	Applicability
20–100 mSv[a]	Emergency exposure situation
~20 mSv[b]	Transition from an emergency exposure situation to an existing exposure situation
1–20 mSv[b]	Existing exposure situation

[a] Acute or annual effective dose.
[b] Annual effective dose.

4.61. What is feasible to achieve in a given time frame may differ from area to area. It may be necessary to apply different reference levels as benchmarks for the optimization process and for enabling the transition to an existing exposure situation in different geographical areas at the same time. Interested parties, including the public from the areas affected, should be informed about the rationale for such differences.

Generic criteria and operational criteria

4.62. Generic criteria and operational criteria are concepts within the protection strategy that are required to be used to implement protective actions and other response actions in a nuclear or radiological emergency, as described in GSR Part 7 [2] and GSG-2 [5]. If the projected dose or the dose that has been received[34] in an emergency exceed the generic criteria, then protective actions and other response actions, either individually or in combination, are required to be implemented.

4.63. Paragraph 4.28(3) of GSR Part 7 [2] requires national generic criteria to be developed for the protective actions and other response actions to be taken in an emergency response. Appendix II to GSR Part 7 [2] provides a comprehensive set of generic criteria to be considered when developing a justified and optimized protection strategy at the national level, including when establishing the national generic criteria. The generic criteria given in appendix II to GSR Part 7 [2] are considered to be generically justified and optimized and are intended for application (a) when taking protective actions and other response actions to avoid or minimize severe deterministic effects, to reasonably reduce the risk of stochastic effects, and to mitigate the economic impact of an emergency by providing a basis for the resumption of international trade, and (b) when guiding actions aimed at enabling the transition to an existing exposure situation.

4.64. Appendix II to GSR Part 7 [2] establishes generic criteria for enabling the transition to an existing exposure situation at the following projected doses:

(a) An effective dose of 20 mSv per year;
(b) An equivalent dose to a fetus of 20 mSv for the full period of in utero development.

[34] For further details see GSG-2 [5].

4.65. If an emergency occurs, prompt decision making is essential to allow the necessary emergency response actions to be implemented effectively. To facilitate this implementation, operational criteria should be developed on the basis of the generic criteria to trigger specific emergency response actions, without the need for further assessments against the generic criteria and before substantial information on the situation is available. The operational criteria used in the emergency response phase include observable conditions on the site, emergency action levels (EALs) and operational intervention levels (OILs). Further guidance on the criteria to be implemented in emergency preparedness and response can be found in GSG-2 [5].

4.66. In the transition phase, OILs based on the generic criteria for taking specific protective actions and other response actions and OILs based on the generic criteria (see para. 4.64) for enabling the transition to an existing exposure situation (referred to as OIL_T in this Safety Guide) should be used as a tool to support:

(a) Decision making on lifting or adapting protective actions, including the determination of what protective actions may need to be lifted or adapted, when the protective actions may need to be lifted or adapted and to whom the decision may apply;
(b) Implementation of activities to enable the transition from an emergency exposure situation to an existing exposure situation by providing a basis to guide simple activities aimed at reducing the residual dose.

4.67. The Appendix to this Safety Guide provides OILs that should be taken into account when establishing the national OILs to be applied in accordance with para. 4.66. The Appendix also provides considerations as well as a methodology for deriving the OIL_T to support the implementation of generic criteria to enable the transition to an existing exposure situation.

4.68. As for other default OILs, default OIL_T values should be developed on the basis of conservative assumptions regarding the emergency, the affected population and the prevailing conditions. However, if the characteristics of the emergency differ from those assumed in the calculations of default OIL_T values, the OIL_T values should be recalculated using the same methodology but with the new available information. Paragraph 4.28(4) of GSR Part 7 [2] requires that arrangements be established to revise the default OILs in the course of an emergency, with account taken of the prevailing conditions as they evolve. A methodology and processes for the recalculation of the OIL_T values in the course of an emergency to address the prevailing conditions should be an integral part of the protection strategies.

4.69. In revising the default OILs during an emergency, it should be ensured that the situation is well understood and that there are compelling reasons for the revision. The public and other interested parties should be informed of the reasons for any change in the OILs applied in an actual emergency.

Adaptation and lifting of the protective actions

General

4.70. The most commonly considered urgent protective actions within a protection strategy are (a) evacuation; (b) sheltering; (c) iodine thyroid blocking; (d) restrictions on local produce, milk from grazing animals, rainwater or other open sources of drinking water; (e) restrictions on the use of commodities that have the potential to result in significant exposures; (f) decontamination of individuals when appropriate; and (g) actions to prevent inadvertent ingestion. Many of these urgent protective actions may be implemented as a precaution on the basis of observable conditions or plant conditions before the release of radioactive material or before the occurrence of radiation exposures (precautionary urgent protective actions). A decision on taking urgent protective actions is often based on limited information about the emergency and is guided by conservative assumptions about the potential development and impacts of the exposure situation.

4.71. The most commonly considered early protective actions within a protection strategy are (a) relocation; (b) long term restrictions on the consumption of food, milk and drinking water; (c) restrictions on the use of commodities that have the potential to result in significant exposures; (d) actions to prevent inadvertent ingestion and to control the spread of contamination (including access control for areas where evacuation or relocation is implemented); and (e) decontamination of areas or commodities to further reduce the individual doses. Decisions on the adaptation of urgent protective actions and the implementation of early protective actions are taken on the basis of increasingly more detailed information and better knowledge of the exposure situation.

4.72. The transition phase is characterized by a change in approach, from a strategy predominantly driven by urgency to a strategy based on more comprehensive assessments aimed both at reducing longer term exposures and improving living conditions. The protection strategy already in place will probably need to be adjusted to identify where and for whom new protective actions are necessary; those protective actions that are no longer necessary are then lifted or adapted. For example, some of the urgent protective actions implemented as a precaution might be lifted if further assessment indicates that these actions are no longer justified. A decision that certain protective actions are no longer justified might be based on the positive evolution of the situation and the return to safe conditions or it might be based on evidence that the protective action was not necessary because the impact of the emergency was limited.

4.73. Adaptation or lifting of protective actions in the transition phase should be justified and optimized on the basis of the prevailing conditions, with account taken of the results of the detailed characterization of the exposure situation and exposure pathways (see paras 4.142–4.157) and a range of radiological and non-radiological considerations.

4.74. Decisions on the adaptation and/or lifting of protective actions (e.g. lifting orders for evacuation, relocation or restrictions on certain foods for consumption) should be made after the impact on the residual doses among the affected population has been assessed.

4.75. To initiate discussions and enable decisions to be made on the adaptation or lifting of protective actions in the transition phase, OILs should be established at the preparedness stage, with account taken of the default OILs provided in the Appendix to this Safety Guide. The pre-established OILs should be used to consider which specific protective actions may need to be lifted or adapted, when those protective actions may need to be lifted or adapted and for whom the protective actions many need to be lifted or adapted. After this preliminary screening, the final decision on the adaptation or lifting of protective actions should be based on an assessment of the residual dose (see para. 4.74) from all exposure pathways against the pre-set reference level for enabling the transition (see para. 4.57).

4.76. As the prevailing conditions may vary within an affected area, consideration should be given to the fact that the adaptation or lifting of protective actions may take place at different times in different locations. Overly frequent changes in the protective actions applied should be avoided, unless such changes would provide significant benefits, as frequent changes could result in a loss of public trust in the decisions of the authorities.

4.77. Before the adaptation or lifting of protective actions, the public and other interested parties should be informed about the protective actions that are to be adapted or lifted; the public and other interested parties should be told why, when and where the protective actions will be adapted or lifted and should be advised on how this adaptation or lifting will affect them.

Considerations for the adaptation or lifting of specific protective actions

Iodine thyroid blocking

4.78. Iodine thyroid blocking is a short term urgent protective action that provides protection for the thyroid against radioactive iodine (see Refs [2, 4, 5, 30]). Iodine thyroid blocking may be implemented as a precaution, although it is not usually a stand-alone action but rather is combined with other protective actions such as sheltering. Iodine thyroid blocking is not a protective action to be implemented for prolonged periods, although under some circumstances repeated administration of stable iodine might be considered. Whenever there is a need to implement iodine thyroid blocking for a longer duration (e.g. for several days), consideration should be given to implementing evacuation or relocation. Iodine thyroid blocking is suitable for use in the urgent response phase and is not appropriate for implementation in the transition phase. Iodine thyroid blocking is adapted or lifted in the emergency response phase.

Sheltering

4.79. Sheltering is also an urgent protective action that is relatively easy to implement in an emergency, either as a precaution or as an urgent protective action to be taken for a short time until more effective but more disruptive actions (e.g. evacuation) can be safely implemented. Sheltering should not be carried out for long periods (more than approximately two days). Sheltering is not appropriate for implementation in the transition phase but may be lifted or adapted during this phase.

4.80. Aspects to be considered in the decision to adapt or lift sheltering imposed during the emergency response phase should include:

(a) The level of protection offered by the types of buildings used for sheltering (shielding factor and tightness against diffusion of outside atmosphere);
(b) The need for continued simultaneous implementation of iodine thyroid blocking when appropriate;
(c) The medical care and other needs of those sheltered (e.g. the availability of medicines, food supplies, clean clothing and sanitation);

(d) Any necessity to gradually increase the time recommended for members of the public to spend outdoors until sheltering is fully lifted, with account taken of the need for any instructions to be given on areas to be avoided while outdoors;
(e) The need for further protective actions based on generic criteria and OILs to replace sheltering (e.g. evacuation or relocation).

Evacuation

4.81. Evacuation may be taken as a precautionary action on the basis of observable conditions or plant conditions (i.e. EALs) or as an urgent protective action based on OILs. Because of the temporary nature of evacuation, priority should be given to lifting this protective action, with consideration given to the following (see the Appendix):

(a) In an evacuated area where the monitoring results indicate that the projected doses may exceed the generic criteria for relocation (i.e. the measurement results exceed OIL2 of GSG-2 [5]), evacuation should be substituted by relocation to provide better living conditions for evacuees.
(b) In an evacuated area where the monitoring results indicate that the projected doses do not exceed the generic criteria for relocation (i.e. the measurement results do not exceed OIL2 of GSG-2 [5]), evacuation should be lifted if no or only limited restrictions (e.g. restrictions on locally produced food or limited access to certain recreational areas) would continue to be necessary for those people living normally in the area and if the preconditions in para. 4.101 are fulfilled.
(c) In an evacuated area where the monitoring results indicate that the projected doses do not exceed the generic criteria for relocation (i.e. the measurement results do not exceed OIL2 of GSG-2 [5]), but limited restrictions are not sufficient for the protection of the people returning to live normally in the area, or the preconditions in para. 4.101 are not fulfilled, evacuation should not be lifted until this area can be managed as an existing exposure situation, after fulfilment of the prerequisites in Section 3 and of the preconditions in para. 4.101.[35]

[35] If the responsible authorities cannot fulfil some of the relevant prerequisites in Section 3 or the preconditions in para. 4.101 for evacuated areas, such areas should be delineated, and relocation can be considered instead of evacuation for these areas to enable the timely termination of the emergency.

4.82. In areas with circumstances such as those referred to in para. 4.81(c), OIL_T (as provided in the Appendix) should be applied to guide remedial actions for preparing these areas so that people may live normally with limited restrictions. In deciding whether to allow people to return to these areas, the residual doses from all exposure pathways — based on the actual circumstances — should be considered, with account taken of the limited restrictions continuing to be in place.

4.83. When substituting evacuation with relocation, the people evacuated should be granted access to the evacuated areas for short periods of time and in a controlled manner to allow them to prepare for longer term relocation.

Relocation

4.84. Relocation is an early protective action intended for longer duration (months). The adaptation or lifting of relocation is less urgent than for evacuation; therefore, more time is available for planning. Relocation should be lifted under the same conditions as those applicable for lifting evacuation outlined in paras 4.81(b) and (c) and 4.82.

Restrictions on food, milk and drinking water

4.85. Restrictions that were imposed on food, milk and drinking water as a precaution in the emergency response phase on the basis of estimates (e.g. on the basis of EALs or OIL3 of GSG-2 [5] and thereafter adjusted on the basis of OIL5 and OIL6 of GSG-2 [5] or OIL7 of Ref. [31]) should be characterized in detail in the transition phase. The purpose is to identify food production areas and foodstuffs that need to remain under restriction even in the longer term and to identify those restrictions that need to be lifted. OILs for restrictions of food, milk and drinking water derived on the basis of sampling and analysis (i.e. OIL6 in GSG-2 [5]) should be used when considering whether to adapt or lift this protective action.

4.86. OIL6 in GSG-2 [5] has been derived on the basis of the generic criterion of a projected effective dose of 10 mSv per year and uses extremely conservative assumptions (see GSG-2 [5] for more details). In the transition phase, the actual doses received from the ingestion pathway and their contribution to the residual dose should be estimated on the basis of actual conditions to aid in decision making on the adaptation or lifting of this protective action. Under actual conditions, the contribution of actual doses from the ingestion pathway to the total residual dose is expected to be significantly less than 10 mSv effective dose per year.

4.87. For existing exposure situations, Requirement 51 of GSR Part 3 [3] requires that specific reference levels be established for exposure due to radionuclides in commodities including food and drinking water, each of which is typically required to be expressed as, or based on, an annual effective dose to the representative person that does not generally exceed a value of about 1 mSv. In addition, the World Health Organization has issued guidelines for drinking water quality [32] that provide guidance levels for radionuclides in drinking water for prolonged situations of exposure resulting from past emergencies. Thus, further restrictions on food, milk and drinking water extending into the longer term in an existing exposure situation might be implemented in order to eventually achieve these levels. However, this discussion goes beyond considerations concerning the termination of the emergency and is therefore beyond the scope of this Safety Guide.[36]

4.88. The implementation, adaptation or lifting of restrictions on the international trade of food, milk and drinking water should take into account established national criteria (that, in turn, take account of the guideline levels contained in Ref. [34]), while ensuring consistency with GSR Part 7 [2] and GSR Part 3 [3].

4.89. To reassure the public of the radiation safety of food, milk and drinking water in the transition phase, the relevant authorities should provide evidence for compliance with applicable national regulations. Such evidence should include publishing of monitoring results, including information that places the radiological health hazards in perspective and, where appropriate, certification.

Restriction on non-food commodities

4.90. Decisions on the adaptation or lifting of restrictions on non-food commodities implemented during the emergency response phase as a precaution or based on estimates (e.g. on the basis of EALs or OIL3 of GSG-2 [5]) should be based on comprehensive information and actual monitoring results. The purpose is to identify non-food commodities that are justified to remain under restriction even in the longer term and to identify those restrictions that need to be lifted. OILs for non-food commodities derived on the basis of sampling and

[36] Further information can be found in Ref. [33].

analysis (referred to in this publication as OIL_C) should be used for this purpose. A methodology to derive default OIL_C values is given in the Appendix.

4.91. In the transition phase, the actual doses received from the use of non-food commodities and the contribution of these doses to the residual dose should be estimated on the basis of the actual circumstances. These estimates should be used to inform decision making on the adaptation or lifting of restrictions on the use of non-food commodities.

4.92. Requirement 51 of GSR Part 3 [3] establishes the specific reference level for commodities in the longer term in an existing exposure situation as an annual effective dose of about 1 mSv. Further restrictions on non-food commodities extending to the longer term in an existing exposure situation might be implemented to achieve this reference level. However, this discussion goes beyond considerations concerning the termination of the emergency and is thus beyond the scope of this Safety Guide.

4.93. The implementation, adaptation or lifting of restrictions on the international trade of non-food commodities should be determined on the basis of OILs derived from the respective generic criteria given in appendix II to GSR Part 7 [2]. The methodology given in the Appendix to this Safety Guide can also be used to derive OIL_C values.

4.94. To reassure the public of the radiation safety of non-food commodities in the transition phase, the relevant authorities should provide evidence for compliance with applicable national regulations. Such evidence should include publishing of monitoring results, including information that places the radiological health hazards in perspective, and, where appropriate, certification.

Dose reduction considerations in the transition phase

Prevention of inadvertent ingestion and inhalation

4.95. Actions to prevent inadvertent ingestion and inhalation (e.g. washing hands and limitations on playing on the ground or on working in gardens) could be advised during the urgent response phase. However, as a protective action, advice on preventing inadvertent ingestion and the inhalation of resuspended material should also be implemented in the transition phase, on the basis of actual conditions, to reduce the residual dose among those returning to live in an affected area once evacuation or relocation is lifted.

Decontamination, control of access and other actions

4.96. Long term remediation may be needed after a large scale emergency with significant releases of radioactive material to the environment (further guidance on remediation is provided in WS-G-3.1 [16]). However, control of access, decontamination of the area or commodities and other simple dose reduction techniques should be used in the transition phase to enable the progressive lifting of protective actions such as evacuation and relocation. These actions should be considered for implementation beyond the areas where evacuation and relocation were implemented during the emergency response phase and should include areas to which people are returning.

4.97. OIL_T provided in the Appendix should be used as a benchmark for screening where the actions in para. 4.96 may be warranted. Any decision on the implementation of such actions should give consideration to the actual residual doses against the pre-set reference level in line with the protection strategy.

Delineation of areas

4.98. Those areas identified in the transition phase that cannot be inhabited, and where social and economic activity cannot be resumed, should be delineated. Such areas should normally not be opened for people to return to live in, and administrative measures should be put in place to control access (see para. 3.20(b) and (c)). Subject to these measures for access control, the delineation of an area as unsuitable for inhabitation should not constitute an obstacle to terminating the emergency.

4.99. Information about delineated areas and measures put in place to control access should be clearly communicated to all interested parties.

4.100. The decision to delineate areas as unsuitable for inhabitation should involve consideration of radiological aspects along with the other prerequisites mentioned in Section 3; in addition, social factors, such as public acceptance of returning to the area, should also be taken into account. Existing geographic or jurisdictional boundaries may also be considered when deciding on the delineation.

Additional preconditions for allowing people to return to an area

4.101. If people are allowed to return to an area, their well-being should not be endangered and it should be possible for them to carry out their routine social and economic activities. However, limited restrictions on normal living habits may still need to be observed and might possibly extend into the longer term. The following preconditions should be fulfilled before allowing people to return to an area from which people were evacuated or relocated:

(a) Infrastructure and public services are in place (e.g. public transportation, shops and markets, schools, nurseries, health care facilities, police and firefighting services, water services, sanitation, energy supplies, telecommunication networks).
(b) Clear instructions and advice on the restrictions still in place and the recommended changes to behaviours and habits, including land use, have been provided to those returning.
(c) Public support centre(s) and informational material (e.g. leaflets, posters) for public reassurance and psychosocial support are available to those returning.
(d) A strategy has been established for the restoration of workplaces and for the provision of social support.
(e) Information on the likely evolution of the exposure situation and the associated health hazards has been provided to those returning.

PROTECTION OF EMERGENCY WORKERS AND HELPERS

General

4.102. GSR Part 7 [2] and GSR Part 3 [3] define an emergency worker as "A person having specified duties as a worker in response to an emergency." Thus, any person engaged as a worker in response to a nuclear or radiological emergency at any time between the onset of the emergency and its termination is referred to as an 'emergency worker' in the IAEA safety standards.

4.103. Emergency workers may include:

(a) Relevant employees of operating organizations (those employed directly by the operating organization and those engaged indirectly through a contractor) engaged in an emergency response on the site, including in the activities aimed at enabling the termination of the emergency;
(b) Relevant personnel from other response organizations and services, such as response managers, rescuers, firefighters, drivers and crews of evacuation vehicles, medical personnel, law enforcement personnel, members of monitoring teams, members of decontamination teams, and

workers engaged in various activities on the site and off the site, including the restoration of essential infrastructure and the management of waste generated in the emergency;

(c) Relevant personnel engaged in providing support and care to the affected population (e.g. in reception centres).

4.104. Paragraph 5.49 of GSR Part 7 [2] requires that emergency workers be, to the extent practicable, designated in advance, and para. 5.50 of GSR Part 7 [2] requires that arrangements be made to register and integrate into operations those emergency workers who were not designated as such in advance of the emergency. Emergency workers designated in advance are required to be assessed for their fitness for the intended duties before their engagement in an emergency response and on a regular basis thereafter.

4.105. GSR Part 7 [2] defines a helper in an emergency as a "Member of the public who willingly and voluntarily helps in the response to a nuclear or radiological emergency" even though such helpers are aware that they can be exposed to radiation while doing so. While the engagement of helpers in the urgent response phase of an emergency is less expected, helpers can be increasingly engaged as the emergency evolves, particularly in the transition phase.[37]

4.106. GSR Part 7 [2], GSR Part 3 [3], GSG-2 [5] and IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [35] establish the safety requirements for, and provide further recommendations and guidance on, the protection of emergency workers. GSR Part 7 [2] establishes the safety requirements for the protection of helpers in an emergency. The guidance provided in this Safety Guide addresses the specifics of the protection of emergency workers and helpers in the transition phase and complements these standards.

4.107. Paragraph 5.101 of GSR Part 7 [2] states that "Once the emergency is terminated, all workers undertaking relevant work shall be subject to the relevant requirements for occupational exposure in planned exposure situations" established in Section 3 of GSR Part 3 [3]. This requirement draws on past experience, showing that the long term aspects can be subject to detailed planning that will allow for workers undertaking relevant work to be protected

[37] Helpers in an emergency are members of the public and thus do not have the status of workers (for an employer) as defined in GSR Part 3 [3]. However, once registered and integrated into the emergency response operations, helpers are required to be protected in accordance with Requirement 11 of GSR Part 7 [2].

in accordance with the requirements for occupational exposure in planned exposure situations. GSG-7 [35] provides further recommendations and guidance on occupational radiation protection in planned exposure situations and existing exposure situations.

4.108. Any decision to terminate a nuclear or radiological emergency and to move to a planned exposure situation or an existing exposure situation should consider the feasibility of compliance with the requirements for occupational exposure in planned exposure situations for all workers engaged in recovery operations (see Section 3).

Identification and designation

Emergency workers

4.109. Emergency workers that will be engaged in the transition phase should be identified, to the extent possible, and designated as emergency workers at the preparedness stage by all relevant organizations. The relevant organizations, in this context, include response organizations, as well as other organizations[38] at the national, regional and local levels. These organizations might not necessarily be recognized as emergency response organizations, but during the transition phase they may gradually take over a role and assume responsibilities for long term recovery, when applicable.

4.110. Relevant organizations should use the process of designating emergency workers who will be engaged in the transition phase to:

(a) Inform emergency workers of their rights, duties and responsibilities with regard to occupational radiation protection;
(b) Recognize the organizations' responsibilities, commitments and duties as employers in occupational radiation protection, so that those responsibilities, commitments and duties can be effectively discharged at the preparedness stage and in the transition phase.

4.111. The relevant organizations that may take over a role and assume responsibilities in the transition phase might not have the necessary expertise and capabilities to provide for radiation protection of their employees (i.e. emergency

[38] Such organizations may come from either the public sector or the private sector and may provide different services.

workers). Examples of such organizations include organizations carrying out the restoration of infrastructure or dealing with conventional waste within an affected area. Thus, such organizations may need to call on a relevant institution[39] to provide such services and should make the necessary arrangements.

4.112. Irrespective of the arrangements referred to in para. 4.111, the responsibilities, commitments and duties in occupational radiation protection should remain with the relevant organization and cannot be transferred to the institution providing the services.

Helpers

4.113. Paragraph 5.50 of GSR Part 7 [2] requires that the response organization(s) responsible for the registration and integration of helpers into the overall response in an emergency be designated at the preparedness stage. The designated response organization should be assigned the same responsibilities, commitments and duties in occupational radiation protection for helpers as for emergency workers.

4.114. As part of the emergency arrangements, such designated response organizations should determine:

(a) What type of work helpers are permitted to be engaged in during the transition phase and the type of training the helpers will need to safely and effectively carry out this work;
(b) A mechanism for the helpers' engagement (e.g. where and how volunteers from the public may express their interest and willingness to help, how the willingness to help will be documented, what information and instructions the helpers will be provided with, and which organization(s) or tasks they will be assigned to);
(c) The process for informing helpers about and training them in their rights, duties and responsibilities.

Specific considerations for the transition phase

4.115. For an emergency involving significant long-lasting contamination of the environment that would require transition to an existing exposure situation,

[39] Depending on the national legal and regulatory framework, technical service providers as specified in GSG-7 [35], for example, may be identified as relevant institutions.

the protection of emergency workers and helpers in the transition phase will be challenged by:

(a) Large variations in the radiological conditions expected within the affected area in an emergency exposure situation, warranting the simultaneous application of different measures for the protection of emergency workers and helpers;
(b) Severe radiological conditions having been present at the site for a longer period and, thus, challenging the on-site response efforts;
(c) Different exposure situations existing simultaneously in different areas, warranting workers undertaking the same work to be subject to different dose restrictions;
(d) Large numbers of emergency workers involved from different organizations and services with diverse backgrounds, knowledge and expertise, some of whom might not have been identified and designated as emergency workers in advance of the emergency;
(e) Numerous members of the public volunteering to help.

4.116. The arrangements to protect emergency workers and helpers should take into account the need to implement simultaneously different schemes for the protection of emergency workers and helpers. However, a consistent approach should be applied for the protection of emergency workers and helpers, to the extent possible, with account taken of the requirements established and the guidance provided for this purpose in GSR Part 7 [2], GSR Part 3 [3], GSG-2 [5] and GSG-7 [35].

4.117. The application of different measures and dose restrictions to protect emergency workers and helpers in the transition phase could be a source of confusion among all concerned parties. Thus, any inconsistency in dose restrictions and measures to be applied for the protection of emergency workers and helpers, and the reason for this inconsistency, should be clearly communicated to all concerned parties.

Justification and optimization

4.118. The detriment associated with doses received during the implementation of the protection strategy by emergency workers and helpers should be taken into account when justifying the protection strategy and the specific protective actions within the strategy. This consideration should be undertaken at the preparedness stage, as well as in the transition phase, when justifying and optimizing the protection strategy to meet the actual circumstances.

4.119. At the preparedness stage, the process of optimization should be applied to the protection of emergency workers and helpers and should be driven by pre-set dose restrictions (see paras 4.120–4.129). When implementing the protection strategy in the transition phase, the optimization process should be applied for the protection of emergency workers and helpers in the same way as for workers in planned exposure situations.

Dose restrictions for emergency workers and helpers

4.120. Paragraphs 5.54 and 5.55 of GSR Part 7 [2] stipulate that the relevant requirements for occupational exposure in planned exposure situations established in GSR Part 3 [3] are required to be applied, on the basis of a graded approach, for emergency workers, except if their tasks involve: (a) actions to save human life or prevent serious injury; (b) actions to prevent severe deterministic effects or prevent the development of catastrophic conditions that could significantly affect people and the environment; or (c) actions to avert a large collective dose. For such tasks, national guidance values are required to be established for restricting the exposures of emergency workers, with account taken of the guidance values given in appendix I to GSR Part 7 [2].

4.121. Actions to save lives, prevent severe deterministic effects or avert the development of catastrophic conditions that could significantly affect people and the environment are typical during the urgent response phase of a nuclear or radiological emergency. Although the implementation of these actions should be preplanned, it is expected that the actions would be driven by the prevailing conditions as the emergency evolves. Such actions would likely be carried out early in the emergency response when there is a scarcity of information about the radiological situation where the action is to be performed. Because of the urgency associated with implementing these actions and their importance, detailed planning of the work of emergency workers might not be possible; thus, exposures exceeding the dose limits for occupational radiation protection in planned exposure situations are justified to ensure the net benefit of the overall response efforts.

4.122. Actions to avert a large collective dose may extend through the early response phase and into the transition phase of an emergency because of the range of activities that are warranted to allow the timely resumption of social and economic activity. During the transition phase, knowledge and understanding of the situation where the work needs to be carried out increases, and there is no need to take urgent decisions on the deployment of workers. Thus, any work in the transition phase should be undertaken only after detailed planning. As a result, the protection of emergency workers in the transition phase should be applied stringently, in accordance with the requirements for occupational radiation protection for planned exposure situations, including the application of dose limits for occupational exposure in line with GSR Part 7 [2] and GSR Part 3 [3].

4.123. Paragraph 5.57 of GSR Part 7 [2] limits the exposure of helpers in an emergency to an effective dose of 50 mSv for the full duration of the emergency work.

4.124. The protection and safety of emergency workers and helpers in the transition phase should be optimized, with account taken of the characteristics and necessity of the work to be carried out. The dose restrictions described in paras 4.120–4.123 are summarized in Table 2.

Dose restrictions for female emergency workers who are or who might be pregnant

4.125. GSR Part 7 [2], GSG-2 [5] and GSG-7 [35] do not limit the involvement of female emergency workers in an emergency response. However, these standards establish requirements and provide guidance for protecting the fetus in case of a possible pregnancy of a female emergency worker.

4.126. In the circumstance of para. 4.125, GSR Part 7 [2] states that female workers "who are aware that they are pregnant or who might be pregnant" are required to be informed of the risk of severe deterministic effects to a fetus arising from an exposure of greater than 100 mSv equivalent dose to the fetus. Therefore, any pregnant female worker is required to be excluded from taking actions to avert a large collective dose if these actions could result in an equivalent dose to the embryo or fetus exceeding 50 mSv for the full period of in utero development. Situations in which a worker may receive doses at these levels are primarily expected early in the emergency response (i.e. during the urgent response phase).

4.127. For those activities to be carried out in accordance with the requirements established in Section 3 of GSR Part 3 [3] for occupational radiation protection during a planned exposure situation, the working conditions for female workers who are pregnant or suspect that they are pregnant or who are breast-feeding need to afford the same broad level of protection to the embryo or fetus or the breastfed infant as that required for members of the public in a planned exposure situation.

TABLE 2. DOSE RESTRICTIONS FOR EMERGENCY WORKERS AND HELPERS IN THE TRANSITION PHASE

Task	Guidance value *		
	$H_p(10)$ **	E ***	AD_T +
Emergency workers			
Actions to avert a large collective dose, such as: — Actions to keep the affected facility or source stable — Monitoring (environmental, source, individual)	<100 mSv	<100 mSv	$< \frac{1}{10} AD_{T,\ \text{Table II.1}}$ ++
Other activities, such as: — Remedial actions, including decontamination on the site and off the site — Repair of the affected facility and restoration of the relevant essential infrastructure — Management of radioactive waste and conventional waste — Environmental, source and individual monitoring — Medical management of contaminated patients — Implementation of corrective actions	Dose limits for occupational exposure in planned exposure situations established in schedule III of GSR Part 3 [3]		
Helpers			
	E ***		
Specified activities in the national arrangements, such as: — Restoring essential infrastructure (e.g. roads, public transportation networks) — Management of conventional waste	≤50 mSv		

* These values apply to:

(a) The dose from external exposure to strongly penetrating radiation for $H_p(10)$. Doses from external exposure to weakly penetrating radiation and from intake or skin contamination need to be prevented by all possible means. If prevention is not feasible, the effective dose and the RBE (relative biological effectiveness) weighted absorbed dose to a tissue or organ have to be limited to minimize the health risk to the individual in line with the risk associated with the guidance values given here.

(b) The total effective dose (E) and the RBE weighted absorbed dose to a tissue or organ (AD_T) via all exposure pathways (i.e. dose from external exposure and committed dose from intakes), which are to be estimated as early as possible to enable any further exposure to be restricted as appropriate.

** Personal dose equivalent $H_p(d)$, where d = 10 mm.

*** Effective dose.

\+ RBE weighted absorbed dose to a tissue or organ.

++ Value of RBE weighted absorbed dose to a tissue or organ given in table II.1 of appendix II to GSR Part 7 [2].

4.128. To ensure adequate protection of the fetus, female emergency workers who are aware that they are, or who might be, pregnant should notify their employers before undertaking relevant work. After being notified, the employer has the responsibility to inform the emergency worker of the associated health risks to the fetus and to provide adequate working conditions and protective measures to ensure compliance with the dose restrictions described in paras 4.126 and 4.127.

4.129. In order to protect the embryo or fetus, all relevant organizations should make adequate arrangements to:

(a) Encourage female workers to notify their employer of an actual or suspected pregnancy;
(b) Inform female workers who are or who might be pregnant of the associated health risks before they undertake the assigned work;
(c) Assess and monitor the conditions in which female emergency workers who are or who might be pregnant may need to work;
(d) Ensure that adequate protective equipment is provided to female emergency workers who are or who might be pregnant, and ensure that they are trained in its use;
(e) Assess the equivalent dose to the embryo or fetus after the emergency work as a basis for determining whether the further involvement of the female emergency worker needs to be restricted and whether medical consultation is warranted.

Dose management and measures to protect emergency workers and helpers

4.130. The adequate management of doses to emergency workers and helpers warrants the establishment of a comprehensive system for monitoring and controlling doses, including the use of individual dosimeters or other appropriate methods. GSG-7 [35] provides guidance on monitoring for the assessment of internal and external exposures relevant to occupational radiation protection.

4.131. To ensure that doses to emergency workers and helpers are adequately managed in the transition phase, all relevant organizations should make arrangements to:

(a) Register the emergency workers and helpers engaged in the emergency response;
(b) Continuously monitor hazardous conditions in which emergency workers and helpers are to perform their duties;

(c) Comprehensively plan the expected work in an emergency response, while accounting for the hazardous conditions present and the time needed to complete the work;
(d) Assess the total effective dose and the relative biological effectiveness (RBE) weighted absorbed doses to a tissue or organ for emergency workers and helpers via all exposure pathways, as appropriate;
(e) Record the doses received;
(f) Communicate to emergency workers and helpers in plain and understandable language the doses they receive, and place the associated health hazards in perspective.

4.132. Response organizations and other relevant organizations should optimize the protection and safety of emergency workers and helpers in recognition of the limited information available at the preparedness stage, taking into account the anticipated hazardous conditions and expected duties in an emergency response. In this context, these organizations should identify:

(a) The needs for training and for personal protective and monitoring equipment;
(b) The need to implement iodine thyroid blocking and/or provide adequate personal protective equipment to emergency workers against the inhalation of radioactive iodine and other radionuclides in cases of prolonged working activities in the transition phase;
(c) Tasks during which emergency workers may be subject to exposures exceeding occupational dose limits;
(d) To whom employers need to provide comprehensive information on the risk involved as a basis for obtaining informed consent;
(e) The need for regular health surveillance to assess the initial and continued fitness of emergency workers for their intended duties.

4.133. The implementation of the arrangements set out in paras 4.131 and 4.132 for emergency workers not designated in advance and for helpers may encounter the following challenges:

(a) Emergency workers not designated in advance and helpers might not have had any recognized rights and duties in relation to occupational radiation protection before their involvement and thus might not have received any training in radiation protection.
(b) The employers of emergency workers not designated in advance might not have the capacity to discharge their responsibilities, duties and commitments in the occupational radiation protection of these workers.

(c) Helpers will not have an employer who would provide for their protection.
(d) No assessment of the health condition (i.e. fitness for duty) of emergency workers not designated in advance and of helpers may be possible before they undertake emergency work.

4.134. In the circumstances described in para. 4.133, designated response organization(s) are required by para. 5.50 of GSR Part 7 [2] to register and to integrate into emergency response operations those emergency workers not designated in advance and helpers and, thus, provide for their protection. Such designated response organization(s) should be given the responsibility to implement, as appropriate, the arrangements set out in paras 4.131 and 4.132 for emergency workers not designated in advance and for helpers.

4.135. Such dedicated response organizations should also be responsible for the provision of 'just in time' training to emergency workers not designated in advance and to helpers before they carry out their specified duties. Such training should include:

(a) Instructions on the duties assigned and how to carry out those duties under the assessed conditions;
(b) Information on the health risks associated with performing these duties;
(c) The protective measures available and how they should be implemented effectively.

4.136. These arrangements should also provide the organization with an opportunity to obtain informed consent from emergency workers assigned to perform the tasks listed in Table 2, for which the dose limits for occupational radiation protection in a planned exposure situation might be exceeded.

Provision of medical support

4.137. GSR Part 7 [2] provides a basis for a common approach in providing medical support to emergency workers and helpers. This approach includes a generic criterion, in terms of received dose, consistent with the criterion for members of the public (an effective dose of 100 mSv in a month) at which longer term medical actions need to be taken. Such medical actions may include, as necessary, health screening, longer term medical follow-up and counselling aimed at detecting radiation induced health effects early and treating them effectively.

4.138. In the transition phase, it is not expected that emergency workers and helpers will receive doses exceeding 100 mSv effective dose in a month or approaching the thresholds for severe deterministic effects. If doses of this magnitude are received accidentally, the circumstances that have led to this should be investigated and the emergency worker or helper should be provided with adequate medical treatment in accordance with the requirements of GSR Part 7 [2].

4.139. Irrespective of the doses received, emergency workers and helpers need to have the right to psychological counselling and continuous medical care during the emergency response, including in the transition phase. Thus, the emergency arrangements should be such that both psychological counselling and continuous medical care can be provided, and the organizations and facilities responsible for providing these services should be identified.

Consideration for other workers

4.140. In the transition phase, other categories of workers may carry out work within an affected area. Examples include teachers and the medical staff of hospitals working in an affected area to prepare that area for the return of the population.

4.141. The workers referred to in para. 4.140 should be protected by their employers at the same level as members of the public within the area, and thus those workers should be subject to the reference levels agreed to be applied for members of the public to allow for the transition to take place (see paras 4.52–4.61). The application of the reference level for the residual dose for such workers should take into account that some of these workers may also reside in the affected area (and thus spend their entire time within the affected area as workers and as members of the public).

CHARACTERIZATION OF THE EXPOSURE SITUATION

4.142. As noted in para. 3.8, among the prerequisites to be met before the termination of the emergency are the detailed characterization of the radiological situation, the identification of exposure pathways and the assessment of the doses to the affected populations. The characterization of the exposure situation should be performed in the transition phase to support, as appropriate:

(a) Adjusting the implementation of the protection strategy on the basis of actual circumstances, including the adaptation or lifting of specific protective actions;

(b) Identifying measures necessary for protecting emergency workers and helpers;
(c) Identifying those individuals to be registered and needing longer term medical follow-up;
(d) Decision making on the termination of the emergency;
(e) Planning for long term recovery within the new exposure situation.

4.143. An emergency resulting in long term exposures due to residual radioactive material in the environment warrants continued monitoring in the longer term within an existing exposure situation. In accordance with the guidance provided in this Safety Guide, the development of a long term monitoring strategy should be initiated in the transition phase to enable the prerequisite in para. 3.20(h) to be met.

4.144. IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection [36], provides recommendations and guidance on environmental and source monitoring for the purposes of radiation protection in various circumstances, including in emergency exposure situations, and outlines some considerations relating to dose assessment and the interpretation of monitoring results.

Preparedness stage

4.145. To characterize the exposure situation in detail, monitoring (environmental, source and individual monitoring, as appropriate) should be carried out. A monitoring strategy should be developed at the preparedness stage on the basis of the hazards identified and the potential consequences assessed at the preparedness stage, with account taken of the available resources. The monitoring strategy should stipulate priorities for the different phases of the emergency in accordance with the protection strategy.

4.146. The monitoring strategy should provide for assessing doses to the affected population and should focus primarily on the following exposure pathways:

(a) External exposure from radionuclides deposited on the ground;
(b) Internal exposure due to ingestion of radionuclides incorporated in food, milk and drinking water;
(c) Internal exposure due to inhalation of resuspended radionuclides.

4.147. As part of the monitoring strategy, the available resources for monitoring should be identified and should include, but not be limited to:

(a) The organizations, expert bodies, local and national laboratories, private institutes, universities and research centres responsible for implementing the monitoring strategy;
(b) The availability of human resources and technical capabilities (including monitoring equipment and dose assessment tools) in each of these entities for implementing the monitoring strategy;
(c) Mechanisms for ensuring the comparability and consistency of measurements and for their interpretation, including training, quality management and intercomparison exercises;
(d) An organization designated as responsible for the validation, recording and retention of monitoring results and assessments;
(e) A mechanism for incorporating monitoring results and assessments into the decision making processes.

4.148. Monitoring data are an important basis for decision making in all phases of the emergency. The monitoring strategy may be supported by decision aiding tools and models[40] in assessing and adjusting the priorities for monitoring in order to allow for the effective and efficient use of available (but usually limited) resources and capabilities. However, monitoring should ultimately be conducted in all geographical areas and not just in those areas indicated by modelling tools. The objective of using such tools and their limitations should be clearly communicated to all concerned parties and documented in the monitoring strategy.

4.149. The uncertainties associated with the results of the monitoring will, in turn, contribute to the overall uncertainty associated with the estimated impact of an emergency; consequently, these uncertainties might affect the quality of the decision making process. These uncertainties may be of technical origin (variability of procedures for sampling, processing and measurement; spatial and temporal variability of the measured quantity; variability of calibration procedures) due to the non-representativeness of samples and/or measurements and/or human error (e.g. from a lack of training). Therefore, appropriate quality assurance requirements should be agreed on at the preparedness stage to reduce such technical uncertainties as much as possible, and these quality assurance requirements should be observed by all parties providing measurements during the emergency response. To reduce human errors, the individuals involved in

[40] Such tools and models include the tools and models for reanalysis of historical data and for meteorological modelling.

radiation monitoring should be periodically trained and human interference in monitoring procedures should be minimized when appropriate.

Transition phase

4.150. In an emergency involving a radioactive release to the environment, depending on the severity of the emergency, characterization of the radiological conditions may involve atmospheric modelling, wide area environmental monitoring and direct measurements, or a combination of these (see RS-G-1.8 [36]). In the transition phase, reliable data from monitoring should be obtained by direct measurements to accurately characterize the nature of radioactivity in the environment.

4.151. The radionuclide composition of the release has a major impact on the doses that will be received and on the contribution of each exposure pathway. Therefore, the radionuclide composition of the release or of any contamination should be identified as early as possible.

4.152. Evaluation of the external dose, dose rate and deposition measurements should be carried out. Therefore, detailed radionuclide specific deposition maps and external gamma dose rate maps should be established as soon as possible and should be periodically updated, with account taken of the fact that the deposition of the radionuclides will be subjected to redistribution due to weathering effects (such as resuspension) or natural radioactive decay processes over time.

4.153. Particular attention should be given to the possibility of heterogeneity in the deposition patterns due to the variation in the spectrum of released radionuclides and the weather conditions prevailing during the emergency response phase. Meteorological analyses and forecasts, especially of rainfall, wind and atmospheric stability data, as well as atmospheric transport modelling, may help to identify areas of potentially higher deposition.

4.154. Maps of deposition patterns and of external gamma dose rate should be prepared in the transition phase. Such maps should be shared with interested parties, and the maps should be accompanied by plain language explanations of the associated health hazards and the need for protective actions.

4.155. Exposure due to the ingestion of contaminated food, milk and drinking water may result from occasional or continual intakes. A comprehensive sampling and monitoring programme should be carried out to allow for continual analysis and assessment of the levels of radionuclides in food, milk and drinking water; of the doses received from the ingestion pathway; and of the need for any adaptation of the restrictions imposed on food, milk and drinking water. The monitoring programme should take into account local diets and food preferences as well as food production patterns. The monitoring results should be made publicly available to provide reassurance of the safety of the food, milk and drinking water intended for consumption.

4.156. In the transition phase, internal exposure due to the inhalation of resuspended material can be expected. While the contribution of this pathway to the total effective dose is usually small, particular circumstances (e.g. carrying out activities in an arid, windy environment or in a dusty environment) may lead to this exposure pathway contributing significantly to total doses. The potential for internal exposure due to inhalation should be taken into consideration, and monitoring for resuspended particles should be included in the monitoring programme as appropriate.

4.157. Doses should be reassessed by incorporating the monitoring results into the dose assessment tools and models selected as part of the monitoring strategy developed at the preparedness stage. Estimations should be carried out as realistically as possible and should focus on the doses to the representative person or groups, with account taken of realistic habits; the actual patterns of contamination; and the food, milk and drinking water that are used by people in the contaminated areas. Assessed doses (projected, received or residual doses) should be compared with the generic criteria and reference levels pre-set in the protection strategy or with the dose restrictions applicable to emergency workers and helpers.

MEDICAL FOLLOW-UP AND PROVISION OF MENTAL HEALTH AND PSYCHOSOCIAL SUPPORT

General

4.158. This subsection describes the emergency arrangements to be made to implement longer term medical follow-up and to provide mental health and psychosocial support following a nuclear or radiological emergency, in light of its public perception and the impact on the termination of the emergency.[41]

4.159. GSR Part 7 [2] states that:

> "5.67. Arrangements shall be made to identify individuals with possible contamination and individuals who have possibly been sufficiently exposed for radiation induced health effects to result, and to provide them with appropriate medical attention, including longer term medical follow-up.
>
> "5.68. Arrangements shall be made for the identification of individuals who are in those population groups that are at risk of sustaining increases in the incidence of cancers as a result of radiation exposure in a nuclear or radiological emergency. Arrangements shall be made to take longer term medical actions to detect radiation induced health effects among such population groups in time to allow for their effective treatment."

4.160. The arrangements in para. 4.159 are required to include (see Requirement 12 of GSR Part 7 [2]):

(a) Guidelines for effective diagnosis and treatment;
(b) Designation of medical personnel trained in clinical management of radiation injuries;
(c) Designation of institutions for evaluating radiation exposure (external and internal), for providing specialized medical treatment and for longer term medical actions;
(d) Criteria for identifying the individuals referred to in para. 4.159 and for their registration (see appendix II to GSR Part 7 [2] and GSG-2 [5]).

4.161. Before deciding on the termination of the emergency, the following prerequisites (see Section 3) should be met with regard to longer term medical follow-up and to mental health and psychosocial support:

(a) A registry has been established of those individuals who have been identified, by the time the emergency is to be terminated, as requiring longer

[41] Generic procedures for medical response in a nuclear or radiological emergency, including for longer term medical follow-up and psychological counselling, are provided in Ref. [37]. Guidelines on mental health and psychosocial support in emergencies are provided in Refs [38–40].

term medical follow-up, on the basis of criteria established in table II.1 and table II.2 of GSR Part 7 [2] (see also GSG-2 [5] for further details).
(b) A programme for longer term medical follow-up for registered individuals has been established.
(c) For the transition to an existing exposure situation, a strategy for mental health and psychosocial support of the affected population has been developed.

4.162. The medical follow-up referred to in para. 4.161 should have the following objectives:

(a) To provide for the long term medical care of individuals who have suffered deterministic effects and of individuals incurring doses that exceed the threshold dose for deterministic effects;
(b) To provide for the early detection and diagnosis of stochastic effects (e.g. thyroid cancer) among the exposed population in order to allow for effective treatment.

4.163. The mental health and psychosocial support referred to in para. 4.161 should have the objective of reducing adverse psychological and societal consequences for the wider affected population, such as evacuees and people relocated after a decision has been made to lift evacuation and/or relocation, even if radiation induced health effects are not expected to be observed among that population.

4.164. The objectives of medical follow-up and mental health and psychosocial support should be clearly explained to those involved to ensure that the expectations of all relevant parties are appropriate.

Coordinating mechanism

4.165. The mechanism for coordinating the necessary arrangements to implement the medical follow-up and to provide mental health and psychosocial support following a nuclear or radiological emergency should be identified at the preparedness stage. The coordinating mechanism may involve an existing organization that is designated to act as a coordinating authority in this area or a newly established body consisting of representatives from authorities in public health, radiation protection, emergency management and epidemiology, and other relevant authorities.

4.166. The coordinating mechanism established in accordance with para. 4.165 should coordinate arrangements to be put in place at the preparedness stage by the relevant organizations with responsibilities for medical follow-up and for the provision of mental health and psychosocial support. The coordinating mechanism should coordinate the actions of the relevant organizations during an emergency response within a unified emergency response organization.

4.167. The responsible authority within the coordinating mechanism should, at the preparedness stage, establish criteria for identifying and registering those individuals requiring longer term medical follow-up and mental health and psychosocial support. These criteria should take into account the relevant criteria set out in GSR Part 7 [2] and GSG-2 [5] and should be subject to agreement by all relevant authorities.

Registering individuals for longer term medical follow-up

4.168. If a nuclear or radiological emergency occurs, registration of those individuals who may require longer term medical follow-up on the basis of predetermined criteria (see para. 4.160) should be an important response action in the protection strategy. National response organization(s) should be designated to maintain the registry.

4.169. The data and information to be gathered in the registry should be determined at the preparedness stage and may include basic contact details (e.g. name, date of birth, gender, address, telephone number); information on the circumstances under which exposures occurred during the emergency (e.g. location at the time of the event, duration of exposure, activities carried out); and any relevant medical history (e.g. previous illnesses, co-morbidities, family history, workplace history, habits).

4.170. An initial registration should be carried out by employers or first responders that would allow for completion of the registry later on. Arrangements should be made for transferring information to the organization designated for the maintenance of the registry.

4.171. Registered individuals should be provided with the necessary information, including the reason for their selection for longer term medical follow-up; the assessed doses and associated health risks; a contact point at the institution responsible for the medical follow-up; a record of the procedures and laboratory tests performed, if appropriate (e.g. radiological and clinical assessments, blood tests); a description of the symptoms that may eventually present and whom to consult in the case of the presentation of symptoms. Such individuals should also be given the opportunity to ask questions and should be offered psychological support.

4.172. The information on the doses received by patients, as well as their medical histories and associated records, should be handled in accordance with the usual conditions of doctor–patient confidentiality and should be securely stored in accordance with conditions established by the health authorities.

Medical follow-up

4.173. As part of the arrangements for the medical follow-up, the following should be considered:

(a) The initial duration of the medical follow-up;
(b) The management of the information and the reporting and sharing of results;
(c) The identification of medical specialists to be involved in the medical follow-up;
(d) The management of biological and non-biological samples;
(e) The management of mental health and psychosocial consequences;
(f) Ethical and cost–benefit aspects.

4.174. Arrangements for longer term medical follow-up should ensure that individuals are provided with access to information about the results of their medical evaluations and to adequate sources of information, such as health care providers.

4.175. Decisions on the medical follow-up of individuals in relation to deterministic effects should be made by medical specialists on the basis of established clinical criteria, with consideration of the assessed doses (see GSR Part 7 [2] and GSR Part 3 [3]) and individual health risk assessment. Consideration should be given to including these individuals in screening and monitoring programmes for stochastic effects as well.

4.176. Screening and monitoring programmes for stochastic effects should be based on criteria that are supported by scientific evidence for observing an increase in the incidence of cancer among the exposed population (see GSR Part 7 [2] and GSR Part 3 [3]). The inclusion of non-cancer health effects in the monitoring programme should be carefully considered. If limited resources are available, the most vulnerable population groups, such as children and pregnant women, should be prioritized for longer term medical follow-up.

Mental health and psychosocial support

4.177. Arrangements should be made to provide mental health and psychosocial support for people being evacuated, relocated or returning to live normally in the affected area and to support their well-being. In these arrangements, people's lifestyles and people's need for reassurance following a nuclear or radiological emergency should be taken into account. Such arrangements should facilitate two-way communication between the authorities and concerned parties.

4.178. As part of the arrangements set forth in para. 4.177, the establishment of a public support centre for affected populations should be considered. Local doctors, nurses, pharmacists, psychologists, respective experts from public universities and associations, and others who are in positions of trust and who have the respect of the community should be considered for participation in the work of the public support centres. Information that places the health hazards in perspective and training on effective approaches to risk communication, tailored to various population groups, should also be given to local doctors, nurses, pharmacists, psychologists and other health care specialists to enable them to provide advice to the public within the settings of their health care practices.

WASTE MANAGEMENT

General

4.179. A nuclear or radiological emergency may generate radioactive waste as well as conventional waste. In particular, nuclear or radiological emergencies resulting in significant contamination of the environment (e.g. the Chernobyl accident, the Goiânia radiological accident, the Fukushima Daiichi accident) can be expected to generate radioactive waste with various radiological, chemical, physical, mechanical and biological properties and of a volume that can overwhelm national capabilities and resources for radioactive waste management. Thus, the generation of radioactive waste in a nuclear or radiological emergency may pose a challenge for the implementation of the national policy and strategy for radioactive waste management, as well as for overall efforts to enable the termination of the emergency and to achieve the long term recovery objectives.

4.180. The management of radioactive waste will not be of primary importance early in the response (especially during the urgent response phase), when the focus will be on the effective implementation of the protection strategy and on bringing the situation under control. However, the generation of radioactive waste and its management is one of many factors that should be considered in the processes of justification and optimization of the protection strategy at the preparedness stage.

4.181. As the emergency evolves, and particularly during the transition phase, radioactive waste management activities will become an important and integral part of the overall emergency response effort. Therefore, adequate consideration should be given at the preparedness stage to waste management issues and challenges to be faced in the transition phase, in order to facilitate the safe and effective management of radioactive waste following the emergency in a manner that does not compromise the protection strategy, as required by Requirement 15 of GSR Part 7 [2].

4.182. While each emergency will be specific, and detailed planning for all aspects of waste management might not be possible, arrangements should be made as part of overall emergency preparedness to address these expected issues and challenges in radioactive waste management following the emergency. As part of these arrangements:

(a) Responsibilities for radioactive waste management during and after an emergency should be allocated clearly and consistently, to the extent possible, within the national policy and strategy for radioactive waste management.
(b) Responsibilities for the management of conventional waste and conditions under which conventional waste arising from the emergency and from emergency response actions will be managed should be agreed on (see paras 4.186–4.189).
(c) A mechanism should be established to coordinate the development of various arrangements by responsible organizations at the preparedness stage as well as to coordinate, under the unified command and control system (see para. 5.7 of GSR Part 7 [2]), the management of radioactive waste and conventional waste during the emergency response.
(d) The characteristics and volume of the radioactive waste to be generated in postulated nuclear or radiological emergencies should be identified, to the extent possible, on the basis of the hazard assessment, with account taken of past experience.

(e) Guidance should be prepared for the characterization and classification of radioactive waste. The guidance should take into account the diversity of radiological, chemical, physical, mechanical and biological properties of the waste likely to be generated in a range of postulated emergencies, in accordance with the applicable regulations and guidance on radioactive waste management. This guidance should comply with the applicable regulations and guidance on radioactive waste management.
(f) Guidance should be prepared for the handling of conventional waste and radioactive waste during an emergency. The guidance should describe the acceptance criteria of existing storage or disposal facilities to be applied to waste generated in the emergency. Guidance should also be given on measures for the management of waste that deviates from the acceptance criteria of existing facilities. This guidance should comply with the applicable regulations and guidance on the management of conventional waste and of radioactive waste.
(g) Methodologies should be developed for the initiation of predisposal management activities for radioactive waste (e.g. segregation, packaging, transport, storage) in a timely and appropriate manner following the emergency. As part of these methodologies:
    (i) Feasible options for the minimization of radioactive waste (e.g. clearance, reuse, recycling) should be identified.
    (ii) Necessary tools, equipment, procedures, training, drills and exercises to support effective waste management should be identified and put in place.
    (iii) Consideration should be given to the interdependencies among various steps in the predisposal management of radioactive waste as well as to the impact of waste management decisions on future disposal options [41].
(h) Limitations of available options and resources should be identified and well understood by all interested parties, and mechanisms for requesting and obtaining international assistance should be determined.

4.183. The guidance on the characterization and classification of radioactive waste in para. 4.182(e) should take into account the complexity of the characteristics, including the volume, of radioactive waste generated during the emergency, compared with radioactive waste arising from normal operations. Thus, it may be necessary to identify specific techniques and methods that may be needed to characterize the waste to complement those techniques and methods used for waste arising from normal operations. The general requirements and guidance on waste characterization and classification are provided in Refs [42–46].

Review of the national legal and regulatory framework

4.184. The establishment of the emergency arrangements described in para. 4.182 should be accompanied by a review of the national legal and regulatory framework for the management of radioactive waste established in accordance with IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [41]. The aim of this review is to identify whether there is a need to revise the national framework to accommodate radioactive waste generated in a nuclear or radiological emergency. Considerations should include, but not be limited to, (a) the applicability of existing provisions for exemption and clearance and of existing classification schemes for such waste, if available; (b) the robustness of safety demonstrations and licensing processes; and (c) the impact of the licensing processes on the management of radioactive waste in a timely manner following the emergency.

4.185. The national framework should be revised, as appropriate, to facilitate the safe management of radioactive waste following a nuclear or radiological emergency in a timely manner, with account taken that, for a small scale emergency, the management of radioactive waste may easily fit within the available waste management options and respective licensing framework established in accordance with GSR Part 5 [41] and IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [46].

Radioactive waste versus conventional waste generated during the emergency

4.186. As seen in past emergencies, authorities may be under public and political pressure to consider all waste resulting from the emergency as radioactive waste. The justification of such decisions should be carefully considered, as the management of waste and its impact on the economy and society can be further complicated by introducing criteria for the clearance of material from regulatory control that are more stringent than criteria derived directly from radiation protection considerations.

4.187. Radioactive waste is defined [3] as follows: “For legal and regulatory purposes, material for which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels as established by the regulatory body.” This is a ‘regulatory’ definition that recognizes that material with activity concentrations equal to, or less than, the established clearance levels is radioactive from a ‘scientific’ point of view, but the associated radiological hazards are considered to be negligible.

4.188. The specification and classification of radioactive waste generated in an emergency should consider the exemption and clearance levels established in schedule I of GSR Part 3 [3] or relevant national criteria established for the same purpose, in accordance with the national policy and strategy for radioactive waste management. For material that is below these levels, arrangements should be made to manage it within conventional waste management practices, where possible, and thus to minimize the amount of material declared unduly as radioactive waste. When exemption and clearance levels and concepts or relevant national criteria established for the same purpose are applied, conventional measures taken by workers for their protection while dealing with such waste (e.g. gloves, masks) should be assessed in terms of their adequacy in providing for radiation protection.

4.189. Further to para. 4.188, authorities and organizations with responsibilities for conventional waste management should also be engaged at the preparedness stage in the development of arrangements regarding radioactive waste management following an emergency.

Predisposal management

4.190. The radioactive waste should be properly segregated and characterized as early as possible in the transition phase, with account taken of both radiological and non-radiological aspects of waste (see Refs [42–46]). Emergency arrangements should also consider that, to support the emergency response actions, radioactive waste may need to be managed during the urgent response phase and early response phase, before its characteristics are fully understood (e.g. to allow mitigatory actions to be taken while protecting emergency workers). In all circumstances, the mixing of waste from different origins and/or of different compositions should be carefully considered for compliance with national regulations and guidance for radioactive waste management.

4.191. The predisposal management of radioactive waste should take account of the characteristics of the radioactive waste generated in the nuclear or radiological emergency. The general requirements for the predisposal management of radioactive waste established in GSR Part 5 [41] apply.

4.192. Arrangements made in advance for the predisposal management (e.g. pretreatment, treatment, conditioning, transport, storage) of radioactive waste arising from a nuclear or radiological emergency should include consideration of:

(a) National experience in radioactive waste management;
(b) Acceptable waste collection points and their characteristics;
(c) The characteristics of acceptable storage sites, such as geographical, physical and demographic aspects, as well as the proximity to the affected site or area and the availability of the necessary public infrastructure;
(d) The need for the transport of radioactive waste, adherence to transport regulations [47] and any deviation from established practices, as necessary.

Disposal

4.193. Considerations for disposal options that depend on both the nature of the emergency and the national policy and strategy on radioactive waste management may be less urgent than other aspects of predisposal management. Thus, the identification of disposal options should not delay the timely decision to terminate a nuclear or radiological emergency and the subsequent transition to either a planned exposure situation or an existing exposure situation.

Managing human remains and animal remains

4.194. Paragraph 5.88 of GSR Part 7 [2] states that consideration is required to be given to "the management of human remains and animal remains with contamination as a result of a nuclear or radiological emergency, with due account taken of religious practices and cultural practices."

4.195. Arrangements to prepare for the management of human remains and animal remains with contamination as a result of a nuclear or radiological emergency should include:

(a) Identification of common religious practices and cultural practices within the State;
(b) Identification of possible management options applicable to the identified practices and the type of contamination (internal or on the surface of the remains);
(c) Consultation on what management options may be acceptable with the relevant interested parties, including representatives of different religious groups;
(d) Training of workers assigned to handle the remains in accordance with basic radiation protection principles, including ways of preventing the spread of radionuclides and their inadvertent ingestion.

4.196. Conventional measures taken by workers for their general protection while handling remains (e.g. gloves, masks) should be assessed in terms of their adequacy in providing for radiation protection.

CONSULTATION WITH THE PUBLIC AND OTHER INTERESTED PARTIES

General

4.197. A successful transition from an emergency exposure situation to an existing exposure situation will also facilitate the recovery of individuals and communities in a manner that sustains their physical, emotional, social and economic well-being. Therefore, emergency management should enable the active participation and involvement of the affected local communities and other relevant interested parties in the transition phase (see prerequisite in para. 3.17). The active involvement of interested parties will not only increase public trust in, the credibility of and public acceptance of the arrangements planned at the preparedness stage, including the prerequisites to be met for terminating the emergency, but will also enhance community resilience to nuclear or radiological emergencies.

4.198. GSR Part 7 [2] states that:

- "The termination of a nuclear or radiological emergency…shall include prior consultation with interested parties, as appropriate" (para. 5.97 of GSR 7 Part [2]).
- "The government shall ensure that, as part of its emergency preparedness, arrangements are in place for the termination of a nuclear or radiological emergency.… The planning process shall include as appropriate: …Arrangements for consultation of interested parties" (para. 5.100 of GSR 7 Part [2]).
- "Adjustment of protective actions and other response actions and of other arrangements that are aimed at enabling the termination of an emergency shall be made by a formal process that includes consultation of interested parties" (para. 5.95 of GSR 7 Part [2]).

4.199. The involvement of, and consultation with, relevant interested parties should start as early as possible in the preparedness stage and should develop with an aim to continue, as appropriate, throughout the transition phase and after the termination of the emergency.

4.200. As shown in Fig. 4, the consultation process should vary in form and extent throughout the various phases of an emergency, allowing for an effective response during the emergency response phase with limited consultation or no consultation at all. In the transition phase, as the situation stabilizes and more information becomes available, consultation with relevant interested parties should start and gradually increase to enable the progressive engagement of interested parties and to make use of their contributions to implementing an effective protection strategy.

4.201. During the emergency response, particularly in the period when decisions about the termination of the emergency are to be made, public opinion and media response are required to be closely monitored to ensure that any concerns or rumours are addressed promptly [2].

4.202. Consultation with relevant interested parties should be based on effective communication mechanisms that are founded on transparency, inclusiveness, shared accountability and measures of effectiveness and should allow for feedback to be accommodated in a timely fashion.

4.203. The responsibility for ensuring that the public and other relevant interested parties have been consulted should lie with the relevant organizations, at all levels, in line with the predetermined consultation mechanism and responsibilities.

Preparedness stage

4.204. Interested parties who are to be involved in and consulted on nuclear or radiological emergency preparedness and response should be identified at the preparedness stage. Special attention should be given to achieving a diverse and balanced representation among the recognized interested parties, including individuals with special needs and different backgrounds.

4.205. Mechanisms for involving and consulting with relevant interested parties should be developed to enhance the understanding of the complexity of the community, the recognition of the community’s capabilities and needs, the fostering of relationships with community leaders, the building and maintaining of partnerships and the empowerment of the local community. The involvement of particular interested parties will depend on the actual situation (the type of emergency, the source involved and the actual consequences), the scale of the emergency and the phase of the emergency.

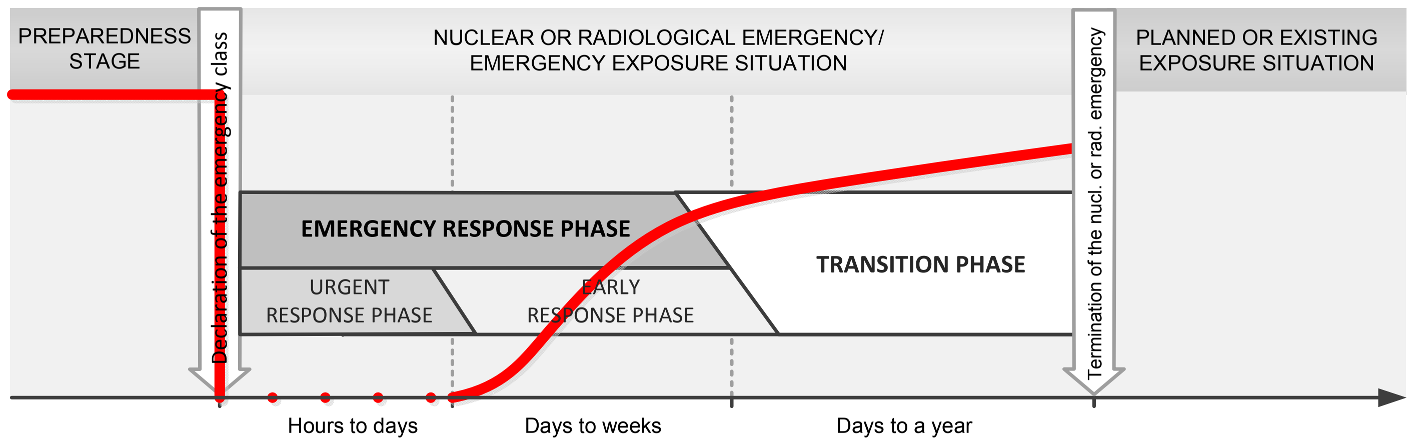

FIG. 4. Involvement of, and consultation with, interested parties in the different phases of a nuclear or radiological emergency.

4.206. As part of the consultation mechanisms, the following should be determined:

(a) The objectives of the consultation;
(b) The targeted interested parties;
(c) Applicable legal and regulatory requirements;
(d) Time frames for effective consultation;
(e) Relevant documents to be published or otherwise made publicly available;
(f) Ways in which interested parties may comment, directly or through representative consultative bodies, on relevant documents;
(g) Possibilities for communicating with interested parties through public meetings, formal hearings and other appropriate means of consultation;
(h) Arrangements for reviewing and assessing the result of the consultation;
(i) Provisions to consider the result of the consultation in the decision making processes.

4.207. Interested parties should be made aware, at the preparedness stage, of the rationale for the options selected for the protection strategy, as well as of the consequences and limitations associated with the implementation of different protective actions and strategies. Interested parties should be made aware that, while many aspects can be considered in advance, emergencies can be dynamic, and the specific conditions that exist at the time of an emergency may require the protection strategy or management options to be adapted to cope with the actual situation.

COMPENSATION OF VICTIMS FOR DAMAGE

4.208. Many past nuclear or radiological emergencies resulted in loss of life, health consequences and loss of or damage to property and the environment. These consequences may have an adverse impact on industry, the economy, trade, tourism, agriculture and the quality of life of those affected. Ensuring an efficient return to normal social and economic activities following the emergency is likely to necessitate the payment of compensation for the damage caused either by the emergency or by the emergency response actions taken.

4.209. Paragraph 4.6 of GSR Part 7 [2] states that "The government shall ensure that arrangements are in place for effectively governing the provision of prompt and adequate compensation of victims for damage due to a nuclear or radiological emergency." The following paragraphs address the compensation based on the legal regime of civil liability. Other forms of compensation (i.e. those that are not based on the civil liability regime) are not covered.

4.210. Compensation for damage caused by radiological (i.e. non-nuclear) emergencies is exclusively governed by the national laws of each State, and no international treaty has been adopted to harmonize the various national laws. Compensation is usually based on national rules relating to civil liability, in particular those relating to third party (i.e. non-contractual) liability, which are also known in some legal systems as tort law rules. Under the general rules relating to third party liability, a person causing someone else a loss or harm has to pay compensation for the damage caused. In most legal systems, specific rules have also been adopted to govern third party liability for damage caused by dangerous activities, such as those involving a potential for radiation exposure.

4.211. In the case of nuclear emergencies, a number of treaties (see Refs [48–55][42]) have been adopted by States in order to harmonize national laws relating to third party liability for nuclear damage caused by emergencies at nuclear installations, as defined, and in the transport of nuclear material to and from such installations. Thus, compensation for nuclear damage in States is based either on these treaties or on national rules implementing them.

4.212. All of these treaties are based on the same basic principles of civil liability for nuclear damage. These principles are (a) exclusive liability of the operator of a nuclear installation, (b) strict (no fault) liability[43] of the operator, (c) minimum liability amount, (d) the operator's obligation to cover liability through insurance or other financial security, (e) limitation of liability in time, (f) equal treatment of victims (i.e. non-discrimination) and (g) exclusive jurisdictional competence of the courts of one contracting party. In addition, some of these treaties provide for supplementary compensation based on public funds in cases in which the financial amount available under the civil liability regime is insufficient to compensate for nuclear damage.

[42] Protocol to Amend the Paris Convention on Nuclear Third Party Liability (2004 Protocol to the Paris Convention) [54] and Protocol to Amend the Brussels Supplementary Convention on Third Party Liability in the Field of Nuclear Energy (2004 Protocol to the Brussels Supplementary Convention) [55] are not yet in force.

[43] Referred to in Refs [50, 53] as 'absolute liability'.

INFRASTRUCTURE

Plans and procedures

4.213. Requirement 23 of GSR Part 7 [2] requires that emergency plans, procedures and other arrangements be established at the preparedness stage for an effective response to a nuclear or radiological emergency. In order to ensure a timely and effective response from the onset of the emergency until the time the emergency is terminated, these arrangements should cover the transition phase in accordance with the guidance provided in this Safety Guide.

4.214. The emergency plans, procedures and other arrangements for the transition phase should be developed by all relevant organizations (with account taken of the results from the hazard assessment) in a manner that will allow for the effective implementation of the protection strategy, which includes considerations for meeting the prerequisites in Section 3.

4.215. As more organizations and parties become involved in the response during the transition phase, the national emergency plan developed in line with para. 6.17 of GSR Part 7 [2] should clearly describe the roles and responsibilities of all relevant actors during the transition phase and beyond. The national emergency plan should take into account any changes in the authority and discharge of responsibilities between different phases, the triggering mechanism for this change, the coordination arrangements, the decision making processes and criteria, the necessary human resources, the type of data and information that needs to be transferred or made accessible by relevant parties and the arrangements and mechanism for carrying out such actions.

Training, drills and exercises

4.216. GSR Part 7 [2] states that:

— "The operating organization and response organizations shall identify the knowledge, skills and abilities necessary to perform the functions [for emergency response]" (para. 6.28 of GSR Part 7 [2]).
— "**The government shall ensure that personnel relevant for emergency response shall take part in regular training, drills and exercises to ensure that they are able to perform their assigned response functions effectively in a nuclear or radiological emergency**" (Requirement 25 of GSR Part 7 [2]).

— “Exercise programmes shall be developed and implemented to ensure that all specified functions…for emergency response [and] all organizational interfaces…are tested at suitable intervals” (para. 6.30 of GSR Part 7 [2]).
— “The operating organization and response organizations shall make arrangements to review and evaluate responses in actual events and in exercises, in order to record the areas in which improvements are necessary and to ensure that the necessary improvements are made” (para 6.38 of GSR Part 7 [2]).

4.217. The knowledge, skills and abilities necessary to carry out activities in the transition phase may differ from and extend beyond the knowledge, skills and abilities necessary in the emergency response phase. Therefore, the selection of the requisite knowledge, skills and abilities for personnel who will be involved in the transition phase should consider the different aspects of the transition phase and should also be directed at those personnel who will actually be engaged.

4.218. The training programmes in emergency preparedness and response developed at different levels for the transition phase should consider the personnel who will participate in the training and retraining. These programmes should also consider the level of the training (e.g. its duration, frequency, type and format, and arrangements for performance review) warranted for different personnel carrying out different activities in the transition phase.

4.219. The exercise programmes developed and implemented to systematically test the overall adequacy and effectiveness of the emergency arrangements should include the objective of testing existing arrangements set up to facilitate the timely resumption of normal social and economic activity within an agreed time frame (e.g. within three to five years), including the participation of the relevant organizations. Small scale exercises (e.g. tabletop exercises) should also be designed and used frequently to test various aspects of the transition phase within an organization (e.g. coordination, information exchange, transfer of information and data, changes in authority and in discharge of responsibilities, decision making processes) at the facility, local, regional or national levels.

4.220. As part of the management system, training, drill and exercise programmes should be evaluated, and areas of improvement should be identified. The feedback from this evaluation should be used to review and, as necessary, revise the emergency arrangements for the transition phase.

Logistical support and facilities

4.221. Requirement 24 of GSR Part 7 [2] states that "**The government shall ensure that adequate logistical support and facilities are provided to enable emergency response functions to be performed effectively in a nuclear or radiological emergency.**" To enable the termination of the emergency, adequate logistical support and facilities should be made available, when and where necessary, for the transition phase.

4.222. The logistical support and facilities required should be identified and selected in consideration of the activities that need to be carried out in the transition phase in order to meet the prerequisites in Section 3. Arrangements for the acquisition, deployment and mobilization of logistical support should be established and communicated to the relevant parties at the preparedness stage.

Quality management system

4.223. Requirement 26 of GSR Part 7 [2] states that:

> "**The government shall ensure that a programme is established within an integrated management system to ensure the availability and reliability of all supplies, equipment, communication systems and facilities, plans, procedures and other arrangements necessary for an effective response in a nuclear or radiological emergency.**"

This programme includes periodic and independent appraisals, record keeping and arrangements for incorporating lessons from research, operating experience and exercises. The programme should cover all the arrangements for the transition phase.

Appendix

CONSIDERATIONS FOR ADAPTING OR LIFTING PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

A.1. This Appendix provides the generic criteria and OILs that should be considered for initiating the adaptation or lifting of protective actions and other response actions implemented in a nuclear or radiological emergency, with account taken of the generic criteria and OILs established in GSR Part 7 [2] and GSG-2 [5]. This Appendix also provides guidance on further considerations for adapting or lifting of specific protective actions and other response actions.

A.2. National generic criteria and OILs should be established at the preparedness stage to support the adapting or lifting of specific protective actions and other response actions, with account taken of the generic criteria and OILs contained in Table 3. These pre-established OILs for the transition phase should be used to initiate considerations for adapting or lifting specific protective actions (including what protective actions may need to be lifted, when this might happen and to whom the decision may apply) in accordance with para. 4.66.

A.3. Following the preliminary screening based on the pre-established OILs, the decision on adapting or lifting of protective actions should be taken on the basis of an assessment of the residual dose from all exposure pathways against the pre-set reference level (see paras 4.57 and 4.74).

A.4. The pre-established OILs for adapting or lifting protective actions and other response actions should consider the following:[44]

(a) The generic criteria established in GSR Part 7 [2] for enabling the transition to an existing exposure situation (see para. 4.64);
(b) A 'ground' exposure scenario in which it is assumed that, in the affected area, all members of the public, including those most vulnerable to radiation exposure, such as children and pregnant women, will be living normally[45]

[44] Details on the methodology for deriving OILs can be found in Ref. [56].

[45] Carrying out normal activities, such as children playing on the ground and people working outside.

and that the lifting of restrictions on food, milk or drinking water will be implemented through the use of OIL6 [5][46] (see Table 3);

(c) All individuals being exposed;
(d) The contribution from all relevant radionuclides and their progenies;
(e) The contribution from all relevant exposure pathways;
(f) Any behaviour of the radioactive material that will have a significant impact on the OIL value;
(g) The relevant effective dose (annual) and, as appropriate, calculations of the organ dose (annual or for the full period of in utero development);
(h) The response of monitoring instruments;
(i) Relevant operational requirements (e.g. usability of OILs under field conditions);
(j) The overall protection strategy.

A.5. A methodology that can be used to derive default OILs for enabling the transition to an existing exposure situation (i.e. the default OIL_T value; see paras A.6 and A.7) for a specific radionuclide mix is given below. The relative activity of the radionuclides in the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_T(t, \text{mix})$, given by:

$$\mathrm{OIL}_{\mathrm{T}}(t,\mathrm{mix}) = \left(\sum_i \left(\mathrm{RA}_i(t,\mathrm{mix}) \times \mathrm{IR}_{\mathrm{grd},i}\right)\right) \times \min.\left\{ \begin{array}{l} \left(\dfrac{\mathrm{GC}(\mathrm{transition}, E, 1a)}{\sum_i \left(E_{\mathrm{grd\text{-}scenario},i}(1a) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right), \\ \left(\dfrac{\mathrm{GC}(\mathrm{transition}, H_{\mathrm{fetus}}, 9\mathrm{mo})}{\sum_i \left(H_{\mathrm{fetus,grd\text{-}scenario},i}(9\mathrm{mo}) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right) \end{array} \right\} \times \mathrm{WF} \qquad (1)$$

where

$RA_i(t, \text{mix})$ [unitless]	is the relative activity of radionuclide i at time t for a specific radionuclide mix. It is determined by $RA_i(t, \text{mix}) = A_i(t, \text{mix}) / \Sigma_i[A_i(t, \text{mix})]$, where $A_i(t, \text{mix})$

[46] The simultaneous use of OIL_T and OIL6 will ensure that all relevant exposure pathways are considered, covering the ingestion of affected food, milk or drinking water (with OIL6), external exposure from radioactive material deposited on the ground (i.e. ground shine), external exposure from resuspended radioactive material (i.e. air shine), the inhalation of resuspended radioactive material and the inadvertent ingestion of soil (e.g. from dirt on the hands) (with OIL_T).

[Bq] is the activity of radionuclide i at time t, for a specific radionuclide mix;

$IR_{grd,i}$ [(Sv/s)/(Bq/m^2) or cps/(Bq/m^2)] is the instrument response per unit ground surface activity of radionuclide i;

GC(transition, E, 1a) = 0.02 Sv is the generic criterion used for transition to an existing exposure situation based on the total effective dose to the representative person over one year [2];

GC(transition, H_{fetus}, 9mo) = 0.02 Sv is the generic criterion used for transition to an existing exposure situation based on the total equivalent dose to the fetus for the full period of in utero development [2];

$E_{grd\text{-}scenario,i}$ (1a) [Sv/(Bq/m^2)] is the total effective dose to the representative person over 1 year for the 'ground' exposure scenario, per unit ground surface activity of radionuclide i [56];

$H_{fetus,grd\text{-}scenario,i}$ (9mo) [Sv/(Bq/m^2)] is the total equivalent dose to the fetus for the full period of in utero development for the 'ground' exposure scenario, per unit ground surface activity of radionuclide i [56];

and WF [unitless] is a weighting factor used to allow for the quantification of other considerations. For the example values given below, the weighting factor was set to 1 for simplicity.

A.6. For a single radionuclide, Eq. (1) in para. A.5 will result in a single time independent OIL_T value. For a single radionuclide mix, Eq. (1) will result in a time dependent $OIL_T(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (1) will result in a set of time dependent $OIL_T(t$, mix) curves on the basis of which a single time independent value should be chosen.

A.7. Examples of default OIL_T values[47] calculated using the method in para. A.5 for a light water reactor emergency and for an emergency involving a specific radionuclide (e.g. ^{137}Cs) are given below:

— $OIL_{T,LWR}$ is 4.8 μSv/h ambient dose equivalent rate above gamma background at 1 m above ground level.[48]
— $OIL_{T,Cs\text{-}137}$ is 4.8 μSv/h ambient dose equivalent rate above gamma background at 1 m above ground level.

A.8. A method for deriving a default OIL_C value for a specific radionuclide mix is given below. The relative activity of the radionuclides comprising the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_C(t, \text{mix})$, given by:

$$\mathrm{OIL_C}(t,\text{mix}) = \left(\sum_i \left(\mathrm{RA}_i(t,\text{mix}) \times \mathrm{IR}_{\text{comm},i}\right)\right) \times \min.\left\{ \begin{bmatrix} \left(\dfrac{\mathrm{GC}(\text{commodities}, E, 1a)}{\sum_i \left(E_{\text{comm-scenario},i}(1a) \times \mathrm{RA}_i(t,\text{mix})\right)}\right), \\ \left(\dfrac{\mathrm{GC}(\text{commodities}, H_{\text{fetus}}, 9\text{mo})}{\sum_i \left(H_{\text{fetus,comm-scenario},i}(9\text{mo}) \times \mathrm{RA}_i(t,\text{mix})\right)}\right) \end{bmatrix} \right\} \times \mathrm{WF} \quad (2)$$

where

$RA_i(t, \text{mix})$ [unitless]	is the relative activity of radionuclide i at time t for a specific radionuclide mix. It is determined by $RA_i(t, \text{mix}) = A_i(t, \text{mix}) / \Sigma_i[A_i(t, \text{mix})]$, where A_i(t, mix) [Bq] is the activity of radionuclide i at time t, for a specific radionuclide mix;

[47] For a nuclear or radiological emergency involving a large scale release of radioactive material to the environment. The default value was calculated in accordance with the assumptions outlined in Ref. [56]. The contributions from the progenies that are in equilibrium with the respective radionuclides were also considered.

[48] $OIL_{T,LWR}$ is OIL_T for a release of radioactive material resulting from a severe emergency at a light water reactor or its spent fuel, in accordance with the assumptions outlined in Ref. [56].

$IR_{comm,i}$ [(Sv/s)/(Bq/m^2) or cps/(Bq/m^2)] is the instrument response per unit activity of radionuclide *i* on the non-food commodity's surface;

GC(commodities,E,1a) = 0.01 Sv is the generic criterion for non-food commodities based on the total effective dose to the representative person over one year [2];

GC(commodities,H_{fetus},9mo) = 0.01 Sv is the generic criterion for non-food commodities based on the total equivalent dose to the fetus over the period of in utero development [2];

$E_{comm\text{-}scenario,i}(1a)$ [Sv/(Bq/m^2)] is the total effective dose to the representative person over 1 year for a 'non-food commodities' exposure scenario, per unit activity of radionuclide *i* on the non-food commodity's surface;

and $H_{fetus,comm\text{-}scenario,i}$ (9mo) [Sv/(Bq/m^2)] is the total equivalent dose to the fetus over the period of in utero development for the 'non-food commodities' exposure scenario, per unit activity of radionuclide *i* on the non-food commodity's surface.

A.9. For a single radionuclide, Eq. (2) in para. A.8 will result in a single time independent OIL_C value. For a single radionuclide mix, Eq. (2) will result in a time dependent $OIL_C(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (2) will result in a set of time dependent $OIL_{T,C}(t$, mix) curves, on the basis of which a single time independent value should be chosen.

A.10. The ambient dose equivalent rate should be the preferred quantity for ground monitoring and for monitoring commodities during a nuclear or radiological emergency. If the radionuclide or the radionuclide mix is such that the ambient dose equivalent rate is not usable (e.g. measured values are within the gamma background levels), the beta or alpha count rates should be monitored and used instead.

TABLE 3. GENERIC CRITERIA FOR THE PROJECTED DOSES AND OILs FOR INITIATING CONSIDERATIONS TO ADAPT OR LIFT SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

Protective action	Generic criteria for taking the action [2]		Generic criteria for considering to adapt/lift the action		OILs for considering to adapt/lift the action	Consideration
	E^{*}	H_{fetus}^{**}	E^{*}	H_{fetus}^{**} for the full period of in utero development		
Evacuation	≥100 mSv in the first 7 days	≥100 mSv in the first 7 days	≥100 mSv in the first year	≥100 mSv	≥OIL2 [5]	Substituting evacuation with relocation
			<100 mSv in the first year	<100 mSv	<OIL2 [5]	Lifting the evacuation only if limited restrictions are still necessary for people living normally in the area, with account taken of (a) the actual residual doses in comparison to the pre-set reference level and (b) the preconditions referred to in para. 4.101
			≤20 mSv per year	≤20 mSv	<OIL_T (see paras A.5 and A.6)	Lifting the evacuation along with the decision to terminate the emergency if the prerequisites specified in Section 3 and the preconditions referred to in para. 4.101 are fulfilled

TABLE 3. GENERIC CRITERIA FOR THE PROJECTED DOSES AND OILs FOR INITIATING CONSIDERATIONS TO ADAPT OR LIFT SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS (cont.)

Protective action	Generic criteria for taking the action [2]		Generic criteria for considering to adapt/lift the action		OILs for considering to adapt/lift the action	Consideration
	E^{*}	H_{fetus}^{**}	E^{*}	H_{fetus}^{**} for the full period of in utero development		
Relocation	≥100 mSv in the first year	≥100 mSv for the full period of in utero development	<100 mSv in the first year	<100 mSv	<OIL2 [5]	Lifting the relocation only if limited restrictions are still necessary for people living normally in the area, with account taken of (a) the actual residual doses in comparison to the pre-set reference level and (b) the preconditions referred to in para. 4.101
			≤20 mSv per year	≤20 mSv	$<\mathrm{OIL}_{\mathrm{T}}$ (derived on the basis of the method outlined in para. A.5)	Lifting the relocation along with the decision to transition to the emergency exposure situation if the prerequisites specified in Section 3 and the preconditions referred in para. 4.101 are fulfilled

TABLE 3. GENERIC CRITERIA FOR THE PROJECTED DOSES AND OILs FOR INITIATING CONSIDERATIONS TO ADAPT OR LIFT SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS (cont.)

Protective action	Generic criteria for taking the action [2]		Generic criteria for considering to adapt/lift the action		OILs for considering to adapt/lift the action	Consideration
	E^*	H_{fetus}^{**}	E^*	H_{fetus}^{**} for the full period of in utero development		
Food, milk and drinking water restrictions in affected areas	≥10 mSv in the first year	≥10 mSv for the full period of in utero development	<10 mSv in the first year	<10 mSv	<OIL6 [5]	Lifting the restriction only after estimation of the actual doses from the ingestion pathway and their contribution to the residual dose from all exposure pathways
Food, milk and drinking water restrictions for international trade	≥1 mSv per year	≥1 mSv for the full period of in utero development	<1 mSv per year	<1 mSv	<Guideline levels in Ref. [34]	Lifting restrictions on international trade for infant and non-infant food in line with Ref. [34]

TABLE 3. GENERIC CRITERIA FOR THE PROJECTED DOSES AND OILs FOR INITIATING CONSIDERATIONS TO ADAPT OR LIFT SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS (cont.)

Protective action	Generic criteria for taking the action [2]		Generic criteria for considering to adapt/lift the action		OILs for considering to adapt/lift the action	Consideration
	E *	H_{fetus} **	E *	H_{fetus} ** for the full period of in utero development		
Non-food commodity restrictions in affected areas	≥10 mSv in the first year	≥10 mSv for the full period of in utero development	<10 mSv in the first year	<10 mSv	< OIL_C (derived on the basis of the method outlined in para. A.8)	Lifting the restriction only after estimation of the actual doses from the use of non-food commodities and their contribution to the residual dose from all exposure pathways
Non-food commodity restrictions in affected areas for international trade	≥1 mSv per year	≥1 mSv for the full period of in utero development	<1 mSv per year	<1 mSv	< OIL_C (derived on the basis of the method outlined in para. A.8)	Lifting restrictions on trading non-food commodities internationally

* Effective dose.
** Equivalent dose to the fetus.

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Annex I

CASE STUDIES

I–1. This annex provides case studies that consider the guidance and recommendations provided in this Safety Guide in the context of the emergency response to the Fukushima Daiichi accident in Japan (2011), the radiological accident in Goiânia, Brazil (1987), the Paks fuel damage incident in Hungary (2003) and the incident involving a stolen radioactive source in Hueypoxtla, Mexico (2013). The case studies include brief descriptions of the management of the incidents and accidents and their consequences, from the declaration of the emergency to the preparation for dealing with the recovery aspects and with the long term consequences under a different exposure situation.

I–2. The four case studies were selected to present representative examples for transition to either a planned exposure situation (the Paks fuel damage incident and the stolen radioactive source in Hueypoxtla) or an existing exposure situation (the Fukushima Daiichi accident and the radiological accident in Goiânia). The examples have also been chosen to cover emergencies associated with the nuclear industry as well as with the use of radioactive sources in other applications, and to cover a range of initiating circumstances.

I–3. The case studies in this annex are not intended to give an extended description of the incidents or accidents and the respective emergency response, nor are they intended to provide an evaluation of the manner in which these events were managed. Each case study is used to draw conclusions from a comparison with the prerequisites described in Section 3 of this Safety Guide, with the aim of facilitating understanding of this guidance.

I–4. The terminology used in these case studies generally follows that used in the associated references and employed by the Member States in which the incidents or accidents occurred; thus, it does not necessarily correspond to the terminology used in the IAEA Safety Standards Series.

I–5. The description of each case study includes a figure that presents a retrospective sequencing of the events and milestones associated with the emergency under consideration. These figures do not represent the official dates on which termination of the emergency was declared but rather the results of a retrospective analysis of the case study to determine when the prerequisites contained in Section 3 had been fulfilled. This process serves to demonstrate, from experience, when the prerequisites could be met in a large scale or a small scale emergency and to test the appropriateness of the guidance given in this Safety Guide (e.g. the guidance in Section 3 on the time frames in which an emergency can be terminated).

THE FUKUSHIMA DAIICHI ACCIDENT, JAPAN

I–6. The Great East Japan Earthquake, with a moment magnitude of 9.0, occurred at 14:46 (Japanese Standard Time) on 11 March 2011. The seismic motions and the tsunami caused by the earthquake led to severe damage to the Fukushima Daiichi nuclear power plant, operated by the Tokyo Electric Power Company (TEPCO), and associated infrastructure. As a result, the plant, which had six boiling water reactors, experienced a station blackout (i.e. the loss of all external power and practically all of the alternative power supply). At Units 1–3, which were operating at full power at the time of the accident, the reactor cores eventually melted, and radioactive material was released to the environment. The information presented in this section is taken from Ref. [I–1], except where otherwise stated.

Emergency declaration and urgent protective actions

I–7. At 19:03 on 11 March 2011, the national Government established the Nuclear Emergency Response Headquarters (NERHQ); at the same time, the declaration of a ‘nuclear emergency’ was issued.

I–8. At 20:50 on 11 March 2011, the Fukushima Prefectural Government decided to evacuate residents within a radius of 2 km of the Fukushima Daiichi nuclear power plant. However, just over half an hour later, at 21:23, the national Government issued an order for evacuation within a 3 km radius of the plant and for sheltering within a radius of 3 to 10 km. At 05:44 on 12 March 2011, the national Government extended evacuation to a radius of 3 to 10 km. At 18:25, after the hydrogen explosion in Unit 1 of the Fukushima Daiichi nuclear power plant, evacuation was further extended to the area within a 20 km radius of the plant.

I–9. The order for residents living in a 20 to 30 km radius of the plant to shelter was given at 11:00 on 15 March 2011 and continued to be in force for 10 days. On 25 March 2011, the national Government recommended that residents voluntarily evacuate the area because of the difficulties associated with prolonged sheltering.

I–10. The administration of stable iodine for iodine thyroid blocking was not implemented uniformly. Some local governments distributed stable iodine tablets but did not advise the public to take them, others distributed the tablets along with advice for their ingestion and others awaited instructions from the national Government.

I–11. On 21 March 2011, the national Government began to issue restrictions on the distribution of specific foods. These restrictions evolved with the changing situation. The restrictions were formulated on the basis of the results of monitoring food samples, which identified the foods that exceeded the national criteria and determined the geographical location(s) affected.

Early response actions

I–12. On 11 April 2011, the national Government announced that an effective dose criterion of 20 mSv, projected to be received within one year of the accident, would be used to determine the areas beyond the 20 km evacuation zone from which people might also need to be relocated. On 22 April 2011, a ‘deliberate evacuation area’ was established beyond the 20 km evacuation zone, which included the areas where the projected dose criterion of 20 mSv in one year might be exceeded. The national Government ordered that the relocation of people from this area should be implemented within approximately one month. On the same day, the NERHQ issued an instruction for restricted access to the 20 km evacuation zone (called the ‘restricted area’).

I–13. In addition to the deliberate evacuation area, an ‘evacuation prepared area in case of emergency’ (hereafter referred to as the ‘evacuation prepared area’) was established on 22 April 2011. Residents of the evacuation prepared area were advised to shelter or evacuate by their own means if there were renewed concerns about the Fukushima Daiichi nuclear power plant. The designation of the evacuation prepared area was lifted on 30 September 2011. From the monitoring conducted beyond the restricted area (i.e. the 20 km evacuation zone) and the deliberate evacuation area, specific locations were identified where residents were projected to receive effective doses in excess of 20 mSv within one year of the accident. On 16 June 2011, the national Government announced that such locations would be designated as ‘specific spots recommended for evacuation’. The designation of these locations commenced on 30 June 2011, and by May 2012 numerous locations with almost three hundred houses had been identified as ‘specific spots’. However, evacuation orders based on the Nuclear Emergency Act were not issued for residents of the ‘specific spots’. Instead, the national Government provided those residents with information that alerted them of the possibility of radiation exposure and supported them if they needed to be evacuated [I–2].

I–14. The areas and locations where protective actions were ordered or recommended until 30 September 2011 are shown in Fig. I–1.

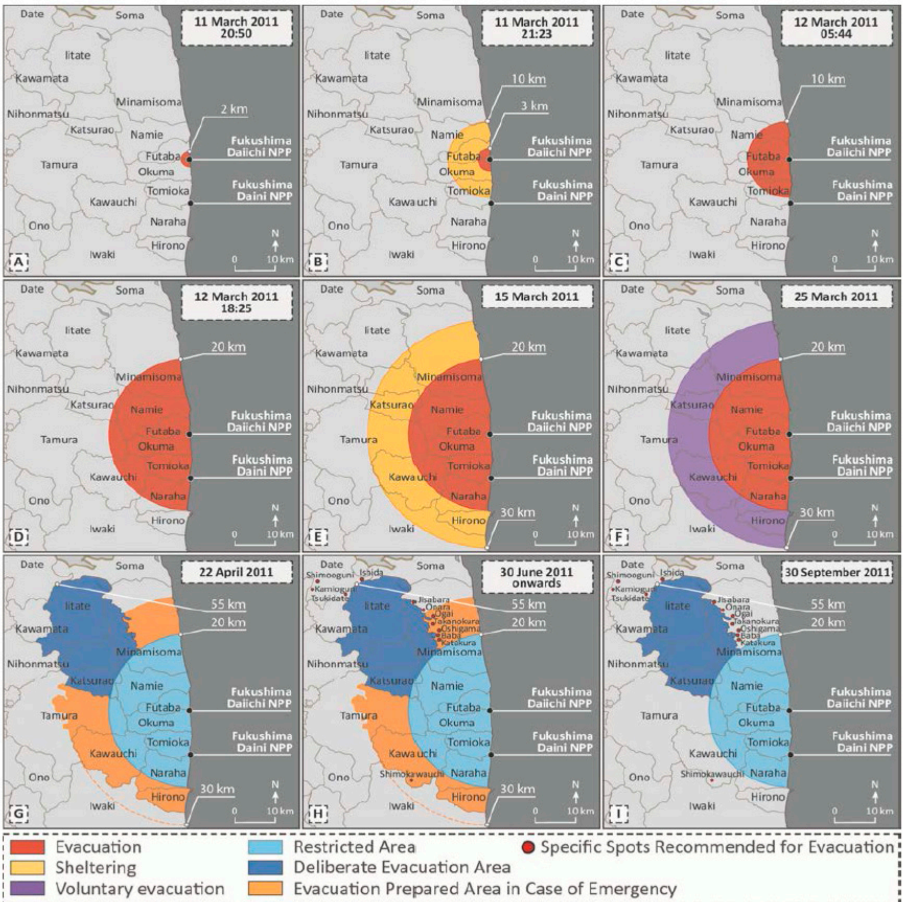

FIG. I–1. Areas and locations in which protective actions were ordered or recommended until 30 September 2011 [I–1].

Transition to long term recovery

I–15. In developing arrangements for the transition from the emergency response phase to the recovery phase after the accident, the Japanese authorities decided to apply the latest recommendations of the International Commission on Radiological Protection [I–3, I–4]. The Act on Special Measures Concerning Nuclear Emergency Preparedness [I–5] included a chapter on general measures for restoration from nuclear emergency. However, the specific policies, guidelines and criteria, as well as the overall arrangements for the transition from the emergency response phase to the recovery phase, were developed after the accident [I–6].

I–16. The overall responsibility for managing the process for returning to normality rested with the NERHQ. The Nuclear Emergency Act specified that the NERHQ would cease to exist when the termination of a nuclear emergency was declared. The Nuclear Safety Commission (NSC) had the responsibility to provide advice on the termination of the emergency.

I–17. On 17 April 2011, TEPCO issued a road map [I–7] that outlined the steps towards recovery on the site. In particular, the road map described the basic policy, targets and immediate actions in the areas of cooling, mitigation of consequences, monitoring and decontamination.

I–18. With regard to off-site recovery, the Policy for Immediate Actions for the Assistance of Nuclear Sufferers was issued and a road map was established by the NERHQ on 17 May 2011 that defined the objectives and conditions to be met for returning to normality [I–7]. The policy listed nine groups of actions, divided into steps, that were scheduled to be implemented over the following target periods and that were related to TEPCO's road map for on-site recovery: by mid-July 2011, within 3 to 6 months and in the mid-term.

I–19. The nine groups of actions were:

(1) Actions for the restoration of the Fukushima Daiichi nuclear power plant from the effects of the accident;
(2) Actions relating to the area evacuated on the basis of plant conditions within a 20 km radius of the nuclear power plant (restricted area);
(3) Actions relating to the area from which people were relocated (deliberate evacuation area);
(4) Actions relating to the area in which people were advised to shelter (evacuation prepared area);

(5) Actions to ensure the safety and reassurance of those affected;
(6) Actions to secure employment and to provide support for farms and industries;
(7) Actions to support the local municipalities in the affected areas;
(8) Actions relating to compensation of sufferers, affected businesses, etc.;
(9) Actions to assist those returning to areas that had been evacuated.

I–20. The road map was intended to facilitate communication and preparations for the transition to long term recovery operations and the resumption of normal social and economic activity. The road map allocated responsibilities and specified other organizational aspects of the transition process and specified the objectives and conditions for the termination of the emergency response phase.

I–21. The attainment of step 1 of action 1 (radiation dose is in steady decline) and the transition to step 2 (release of radioactive materials is under control and radiation dose is being significantly held down) was confirmed on 19 July 2011 by monitoring results that indicated that the release of radioactive materials had steadily declined since the onset of the accident. Actions 2–4 outlined the steps to be taken in the areas where the population had been evacuated, relocated or advised to shelter.

I–22. During the emergency and transition phases, the NSC gave various kinds of technical advice about the radiation protection of residents in the surrounding areas. On 19 July 2011, the NSC issued a policy that summarized its recommendations for the termination of protective actions and the restoration of normal life.

Reopening of schools

I–23. Fukushima Prefecture requested that the national Government provide advice on reopening schools and other educational facilities in the prefecture. In response, on 19 April 2011 the Ministry of Education, Culture, Sports, Science and Technology (MEXT), after consultation with the NSC, stated that a dose criterion of 20 mSv per year would be used for that purpose. In accordance with this criterion, the MEXT decided to restrict the outdoor activities of children and students only at school and kindergarten grounds where ambient dose rate measurements of more than 3.8 μSv/h had been measured. The reopening of schools was categorized as an action in an existing exposure situation, whereas the establishment of the deliberate evacuation area was handled as an emergency exposure situation. However, in both cases, the criterion of a 20 mSv projected annual dose was used.

I–24. The criterion of 20 mSv per year was later reduced to 1 mSv per year, in response to public concern. On 27 May 2011, a notification was issued by the MEXT for reducing the dose to children, students and others at schools and other facilities in Fukushima Prefecture. The notification specified a target dose of 1 mSv per year, stipulated that dosimeters should be distributed to schools and stated that financial support for decontamination was to be offered to schools at which ambient dose rate measurements higher than 1 μSv/h had been measured.

Environmental monitoring

I–25. On 13 June 2011, the Plan to Conduct Detailed Monitoring in Restricted Area and Planned Evacuation Zone [I–8] was announced. This plan addressed the monitoring of air, soil, forests, water and human-made materials (such as homes and roads) in the restricted area and the deliberate evacuation area. The results of this monitoring programme were intended to be used to develop model projects for decontamination. In July 2011, a coordination meeting was held at the national level among relevant ministries, officials from Fukushima Prefecture and TEPCO representatives to promote coordination in relation to monitoring. A comprehensive monitoring plan was then issued in August 2011, which also specified the roles of the various organizations. This plan was later revised. The plan stipulated that environmental restoration of the area surrounding the Fukushima Daiichi nuclear power plant and more detailed monitoring to meet the needs of children's health and people's safety and security would be implemented [I–9]. The plan was revised in March 2012 to enable a review of the areas where evacuation orders had been issued and to address increasing concerns about the release of radioactive materials into the sea from the rivers over the medium to long term.

Health surveillance

I–26. Long term health surveillance was initiated at the end of June 2011, after the establishment of the Fukushima Health Management Survey Committee on 27 May 2011 [I–2]. The terms of reference of the survey were "to assess residents' radiation dose, and to monitor residents' health conditions, which result in disease prevention, early detection and early medical treatment, thereby to maintain and promote their future health" (translation from the Japanese) [I–10]. The health management surveys included a basic survey that comprised self-administered questionnaires mailed out to people who met residential or location criteria connected with the accident [I–11]. In the basic survey, respondents were asked to record their movements in the weeks and months after the accident in order to allow the results to be used in estimating radiation exposure from assessments of the variations in ambient dose equivalent in time and location [I–11].

I–27. Four specialized surveys were undertaken that involved:

(a) A thyroid examination of children aged 18 and younger (target population: around 380 000);
(b) Comprehensive medical check-ups of evacuees (210 000);
(c) A survey of the mental health and lifestyle of the same evacuees;
(d) A survey of pregnant women and nursing mothers (approximately 15 000 each year) [I–11].

I–28. The first round of the thyroid examinations, which consisted of thyroid ultrasonic examinations and detailed examinations, started in October 2011 and was completed in March 2014. The second round of thyroid ultrasound examinations began in April 2014 and was completed in March 2016 while the detailed examinations from the first round continued. An ultrasound examination of children will continue to be carried out biennially until the participants reach the age of 20; thereafter, the participants will be examined every five years [I–12]. The comprehensive medical check-ups started in July 2011 and include tests for body mass index, glycated haemoglobin (HbA1c), liver function and blood pressure. The survey of pregnant women and nursing mothers involved a questionnaire that was sent out to all mothers who were given a Maternal and Child Health Handbook between 1 August 2010 and 31 July 2011; the questionnaire was returned by about 15 000 respondents. When answers to the questionnaire indicated that consultation was needed, doctors provided telephone consultations in some cases. This survey is being updated every year to take account of new data, particularly on pregnancies and births. The mental health and lifestyle survey started in January 2012 and has been conducted every year through questionnaires covering physiological and mental conditions, lifestyle changes, experiences of the earthquake and tsunami, and radiation related issues, with the intent of providing adequate mental care and lifestyle support for evacuees [I–11].

Emergency workers and helpers from the public

I–29. The provisions for the protection of workers were gradually modified during the transition phase, depending on the work being undertaken. The increased dose criterion for emergency workers of 250 mSv[1] was withdrawn gradually. From 1 November 2011, this criterion ceased to apply to newly engaged emergency workers and on 16 December 2011 (when the attainment of the cold shutdown state at the plant was announced) to most other emergency workers. On 30 April 2012, the higher criterion was withdrawn for a group of about fifty TEPCO employees with accumulated doses exceeding 100 mSv who had specialized knowledge and experience in operating the reactor cooling systems and in maintaining the facilities and equipment for suppressing the emission of radioactive materials.

I–30. In parallel, the preparation for the planned decontamination and restoration work had started. The Basic Policy for Emergency Response on Decontamination Work was issued on 26 August 2011. This policy and associated guidelines defined the responsibilities and requirements for the radiation protection of emergency workers. The framework for occupational exposure in normal operation was applied for workers engaged in decontamination work, restoration and waste management.

I–31. In the aftermath of the accident, people from the affected areas, as well as from other parts of Japan and from a number of non-governmental organizations (helpers), volunteered to assist in such activities as the provision of food, water and necessities and, later, in decontamination and monitoring activities. Relevant guidance was prepared to allow for the protection of these helpers within the dose limit for members of the public under normal operations (1 mSv per year).

Termination of urgent protective actions

I–32. On 19 July 2011, the Basic Policy of the Nuclear Safety Commission of Japan on Radiation Protection for Termination of Evacuation and Reconstruction [I–13] was issued. The policy outlined protection measures to be taken against radiation in accordance with the particular exposure situations, specifically the emergency exposure situations and existing exposure situations. The policy set forth the necessity of introducing systems for environmental monitoring and the dose estimation of individuals that would constitute the scientific basis for administrative decisions to implement protective measures, including decontamination and remediation, and to lift the evacuation measures. Over the long term, it recommended combining a full range of decontamination and improvement methods in setting forth radiation protection measures, and it

[1] Applicable for the duration of the emergency work.

stated that the public should participate in the planning of activities and policies relating to these measures.

I–33. On 4 August 2011, the NERHQ requested advice from the NSC on whether it was necessary to make any changes to the protective actions that were then being implemented (evacuation, relocation and sheltering). The NSC provided its response in the Standpoint of the Nuclear Safety Commission for the Termination of Urgent Protective Actions Implemented for the Accident at the Fukushima Daiichi Nuclear Power Plant. The guidance included three bases for determining whether the termination of the protective measures in place in specific areas was appropriate:

(a) The projected annual dose to the public is lower than the criterion of 20 mSv;
(b) Preparation for the implementation of long term protective actions has been made;
(c) A framework has been developed for the participation of the relevant local governments and residents in the decision making process for long term protective actions.

I–34. The NSC statement also specified conditions for the termination of the designation for each type of area (evacuation prepared area, deliberate evacuation area and restricted area) where major protective measures were applied [I–8].

I–35. On 9 August 2011, on the basis of this recommendation, the NERHQ prepared a review of evacuation areas. The following three requirements for the termination of protective actions were outlined in the review:

(a) The safety status of the nuclear power plant;
(b) A decrease in the dose rate;
(c) Restoration of the public service functions and infrastructure.

I–36. On the basis of the Radiation Monitoring Action Plan for Homecoming, regarding Evacuation-Prepared Areas in Case of an Emergency, which was established on 25 July 2011, the MEXT conducted various monitoring activities in municipalities in this area. As a result, ambient dose rates at all of the municipalities, including main spots near schools, were measured. Additionally, on 19 September 2011, all cities, towns and villages in the evacuation prepared areas began to prepare disaster recovery programmes for submission to the NERHQ. On the basis of these disaster recovery programmes, the NERHQ decided that conditions (a) to (c) for the termination of the evacuation prepared areas had been met [I–2].

I–37. The NERHQ consulted with the leaders of the cities, towns and villages concerned on the termination of the evacuation prepared areas and the disaster recovery programmes, and on 30 September 2011 the advice to shelter was withdrawn by the Japanese Government on the basis of an assessment of the safety status of the nuclear power plant and measurements of the dose rate in the relevant areas. The announcement stated that monitoring would continue to be conducted and that local governments would implement their restoration plans. It was also noted that the date by which the public could return to the area would vary among local governments and would be undertaken with support provided by the national Government.

Waste management and decontamination works

I–38. Off-site waste that was generated following the accident was classified either as debris from the earthquake or tsunami (often referred to as 'disaster waste') or as waste from remediation activities. The debris consisted of materials such as wood, concrete and metal, while the remediation waste included sludge from water and sewage treatments, incinerated ash, trees, plants and soil resulting from decontamination activities.

I–39. The arrangements for the management of radioactive waste established in Japan before the accident covered waste generated within facilities, such as nuclear power plants, but did not include radioactive waste that had been generated in public areas. The Waste Management and Public Cleansing Act did not apply to waste that was contaminated with radioactive material, and there was no other law that regulated the disposal of disaster waste contaminated with radioactive material [I–14].

I–40. On 25 March, 12 April, 26 April and 6 May 2011, instructions were issued on how to dispose of vegetables and raw milk in areas subject to food restriction(s) by the Ministry of Agriculture, Forestry and Fisheries; the instructions were based on technical advice from the NSC [I–15]. Instructions on what to do with foods that were not suitable for consumption were issued in the form of questions and answers on the Ministry of Agriculture, Forestry and Fisheries web site on 26 April 2011 [I–16].

I–41. The Near-term Policy to Ensure the Safety in Treating and Disposing Contaminated Waste around the Site of Fukushima Daiichi Nuclear Power

Plants [I–17] was issued by the NSC on 3 June 2011. This document provided dosimetric criteria for recycled materials, the protection of workers treating the materials and the protection of members of the public in the vicinity of treatment facilities and disposal sites. The NSC proposed that materials affected by the accident (i.e. debris, sludge from the water and sewage treatments, incinerated ash, trees, plants and soil resulting from decontamination activities) would be disposed of under proper management and that some materials may be considered for reuse. Products manufactured from these reused materials were checked for contamination and managed appropriately before being released onto the market. Appropriate protective measures were implemented to ensure that radiation exposures of workers and the public were kept as low as reasonably achievable. A final disposal strategy was derived on the basis of the quantities of waste, the types of radioactive material, the radioactivity concentration and evaluations of the long term safety of disposal facilities.

I–42. Legislative and regulatory instruments were developed after the accident for dealing with on-site and off-site waste. Post-accident issues concerning off-site waste management were addressed in the Act on Special Measures Concerning the Handling of Environmental Pollution [I–18], which was enacted after the issuance of governmental and ministerial ordinances by the Ministry of the Environment. This Act specified which wastes were the responsibility of the national Government and which were the responsibility of the prefectures and municipalities. The Act was enacted on 26 August 2011 (promulgated on 30 August 2011) and took full effect on 1 January 2012. In effect, the Act underpinned the remediation strategy for Japan, as it set out the means for achieving the principles and requirements stated in the national policy. The Act outlined the management of the contaminated areas and included the assignment of responsibilities to the national and local governments, the operator and the public. The Act facilitated the transition from an emergency exposure situation to an existing exposure situation. The Act also formalized the long term management of environmental monitoring, decontamination measures and the designation, treatment, storage and disposal of soil and waste contaminated by radioactive material. On the basis of this Act, the Ministry of Environment established guidelines on decontamination and on waste in December 2011.

I–43. In accordance with the basic principles of the Act [I–19], the goals for dose reduction were outlined as follows:

> “The following shall be aimed at areas where the additional radiation dose is less than 20 mSv/year:

(a) To reduce the additional radiation dose to 1 mSv/year or lower over the long term;

(b) To reduce the additional annual radiation dose the public is exposed to by around 50% (including the physical attenuation of radioactive materials) by the end of August 2013 from the level at the end of August 2011; and

(c) To reduce the additional annual radiation dose affecting children by around 60% (including the physical attenuation of radioactive materials) by the end of August 2013 from the level at the end of August 2011 by decontaminating the living environment of children, such as schools, playgrounds, etc., on a priority basis, since it is crucial to recover the environment under which children can live safely and securely.

"These targets shall be reviewed from time to time based on the effects of measures for the decontamination of the soil, etc. and so forth."

I–44. As decontamination was an urgent issue, the NERHQ established the Basic Policy for Emergency Response on Decontamination Work [I–20] on 26 August 2011 before the Act came fully into force. The policy permitted the commencement of decontamination in advance of the formal implementation of the Act. Act No. 110 of 2011 [I–18] outlined the management of the contaminated areas and included the assignment of responsibilities to the national and local governments, the operator and the public. The Act was enacted on 30 August 2011 and came into force in January 2012. The Act facilitated the transition from an emergency exposure situation to an existing exposure situation; the Act formalized the long term management of environmental monitoring, decontamination measures, and the designation, treatment, storage and disposal of radioactive waste.

Stabilization of the plant conditions and delineation of areas

I–45. On 16 December 2011, a 'cold shutdown' state was achieved at the nuclear power plant, which was used to indicate that control of the situation had been regained [I–21]. This cold shutdown meant that step 2 of action 1 of the road map issued in May had been completed.

I–46. A review of the areas where protective actions were being implemented was required for the completion of step 2 of action 1. The review of areas (restricted area and deliberate evacuation area) was issued on 26 December 2011 by the Japanese Government in a document called Basic Concept and Issues to Be

Challenged for Rearranging the Restricted Areas and Areas to which Evacuation Orders Have Been Issued where Step 2 has been Completed [I–21]. The review of the areas was undertaken in consideration of the dose criterion of 20 mSv per year in terms of projected dose. Its criteria and area designations are presented in Table I–1 and Fig. I–2.

Conclusions

I–47. Prior to the accident, the national framework for radiation protection and safety in Japan had not taken into account situations requiring long term recovery operations over wide areas. The specific policies, guidelines and criteria, as well as overall arrangements for the transition from the emergency response phase to the recovery phase, were developed after the accident and took into account the latest recommendations of the International Commission on Radiological Protection.

I–48. The emergency response phase began on 11 March 2011, when the loss of off-site and almost all on-site electric power was experienced as a consequence of the earthquake and tsunami. After the declaration of a nuclear emergency, urgent protective actions, such as the evacuation and sheltering of people in the vicinity of the site and restrictions on the distribution and consumption of food and the consumption of drinking water, were implemented during the following days. Early protective actions, such as the relocation of people outside the evacuation areas and the relocation of people from locations at which hot spots of activity had been identified, were taken on the basis of detailed monitoring. These actions

TABLE I–1. CRITERIA, DESIGNATION AND COLOUR OF AREA SHOWN IN FIG. I–2 [I–21]

Criterion	Designation	Colour shown in Fig. I–2
Annual cumulative dose would be less than or equal to 20 mSv	Areas in which evacuation orders are ready to be lifted	Green (Area 1)
Annual cumulative dose may exceed 20 mSv but is less than 50 mSv	Areas in which residents are not permitted to live	Orange (Area 2)
Annual cumulative dose exceeds 50 mSv	Areas in which residents will not be able to return for a long time	Red (Area 3)

took place within the first few months after the accident and were completed by November 2011. The emergency response phase, during which the radiation dose was in steady decline (the target of step 1), was generally completed by around 19 July 2011. However, some hot spots were detected up to November 2011, from which people were evacuated (or relocated).

I–49. The following months, from around July to December 2011, might be considered to be a transition period in which the policies and arrangements for the recovery phase were established. This included the following activities:

(a) Detailed monitoring to characterize the exposure situation and exposure pathways;
(b) Arrangements for the implementation of long term health surveillance;
(c) Determination of the criteria for the termination of protective measures;

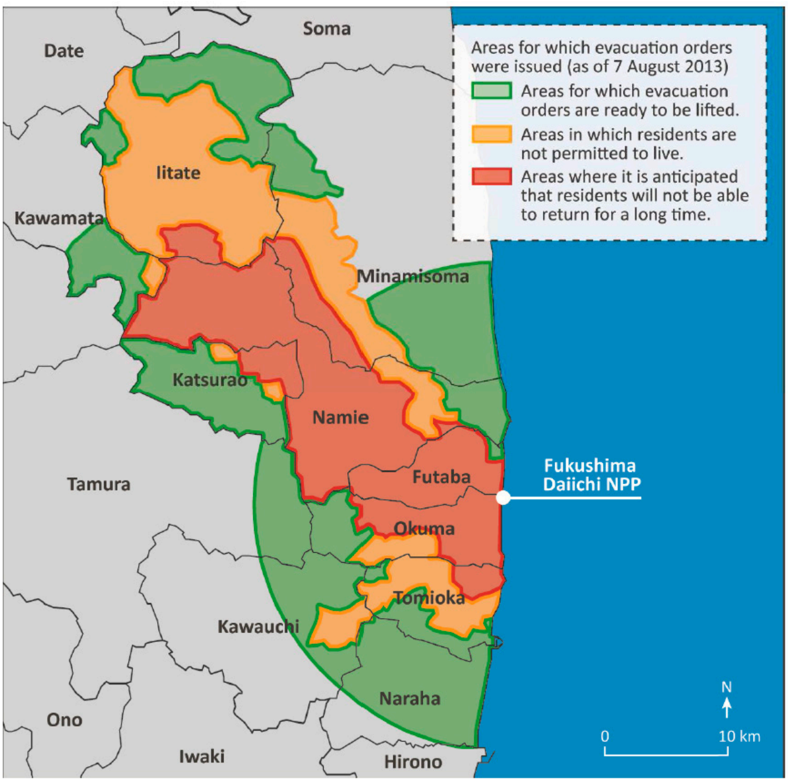

FIG. I–2. Completion of the arrangement for areas where evacuation orders were issued (7 August 2013) [I–1].

(d) Formalization of the long term management of radioactive waste;
(e) Adjustment of arrangements for the protection of emergency workers, other workers and helpers, both on and off the site;
(f) Re-evaluation and rearrangement of areas in which protective actions were in place;
(g) Establishment of long term plans for decontamination;
(h) Announcement that control of the situation had been regained at the plant.

I–50. On 16 December 2011, a cold shutdown state was reached at the nuclear power plant, but no termination of the emergency was officially declared at that time. The basic concept underlying the arrangement of the areas where evacuation orders had been in effect was issued on 26 December 2011. The Act on Special Measures Concerning the Handling of Environmental Pollution came into force on 1 January 2012. Among other things, the Act created the necessary institutional arrangements for the implementation of a coordinated work programme involving different organizations at the national level. Issues addressed by the Act also include the prioritization of sites to be remediated and the allocation of funds to carry out the remediation works. The Act recognized the need to involve different stakeholders in the overall remediation process. Further information on the implementation of remediation activities is provided in Refs [I–6, I–14].

I–51. The results of an analysis of the case study with regard to the fulfilment of the prerequisites for the termination of a nuclear or radiological emergency, contained in Section 3 of this Safety Guide, are presented in Tables I–2 and I–3. These tables reflect the situation that existed on 16 December 2011 (see Fig. I–3), which is the date at which the retrospective analysis indicates that the conditions for termination existed.

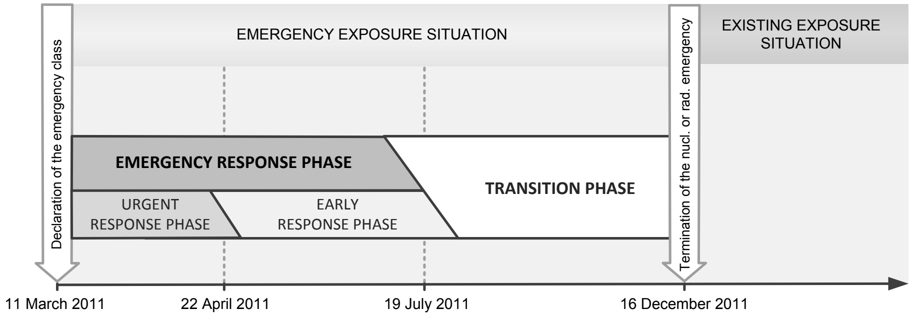

FIG. I–3. Retrospective sequencing and milestones of the Fukushima Daiichi accident.

TABLE I–2. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: FUKUSHIMA DAIICHI CASE STUDY

General prerequisite	Status with respect to the prerequisite
Had the necessary urgent and early protective actions been implemented?	The majority of the public protective actions had been identified and implemented by July 2011. These actions included the implementation of food monitoring and restrictions, as well as access controls to the areas from which people had been evacuated. However, in November 2011, some additional locations were found at which hot spots of activity were identified and from which it was necessary for people to be relocated.
Was the exposure situation stable and well understood?	No further significant release of radioactive materials to the environment was expected; extensive monitoring had been carried out, which had given the authorities a clear understanding of the exposure situation.
Was the radiological situation well characterized, and were the exposure pathways identified and doses assessed for all the affected people?	Intensive monitoring had been carried out, most of the affected people and areas had been identified, and doses had been assessed and regularly reassessed as the amount of information concerning the situation increased.
Was the source of exposure brought under control, and were no further significant accidental releases or exposures expected due to the event?	Completion of the objective of step 2 (release of radioactive materials is under control and radiation doses are being significantly held down) was declared on 16 December 2011.

TABLE I–2. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: FUKUSHIMA DAIICHI CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?	Many analyses were carried out after the accident to investigate the circumstances that led to the accident and to identify improvements that needed to be implemented in the regulatory control and emergency arrangements in Japan. Lessons identified from these analyses were incorporated into the respective arrangements of different organizations and at different levels by 2012. Upon declaration of the achievement of step 2 on 16 December 2011, a new organization, the Government–TEPCO Mid-to-Long Term Response Council, was created at TEPCO headquarters. On 21 December 2011, the Council issued the Mid-and-Long-Term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1–4. The NSC established a working group to review the regulatory guide on emergency preparedness for nuclear facilities in July 2011 and submitted its interim report on its revision in March 2012. This document was then used as a basis for developing the new regulatory guidelines issued in October 2012 by the newly established Nuclear Regulatory Authority. On 7 November 2012, the Nuclear Regulatory Authority designated the Fukushima Daiichi nuclear power plant as a ‘specified reactor facility’, which is a facility at which a nuclear accident has occurred and special regulations commensurate with the condition of the equipment are stipulated [I–14].

TABLE I–2. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: FUKUSHIMA DAIICHI CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Were the requirements for occupational exposure in a planned exposure situation confirmed for all workers engaged in recovery activities?	All the recovery work off the site (e.g. decontamination work) had been carried out to ensure that workers did not exceed the national dose limits for planned exposure situations. However, it was necessary to continue to apply higher dose limits (specified for emergency work) to complete some on-site work. The increased dose criterion for emergency workers of 250 mSv was withdrawn gradually starting on 1 November 2011. From that date, this limit was not applied to newly engaged emergency workers, and from 16 December 2011 the limit no longer applied to most of the remaining emergency workers. However, there was a continued need to apply the higher criterion for a group of about fifty TEPCO employees who had received accumulated doses exceeding 100 mSv but who had the necessary specialized knowledge and experience to complete some on-site activities. On 30 April 2012, it was announced that the increased dose criterion of 250 mSv had also been withdrawn for this group of on-site emergency workers.
Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?	This radiological situation was assessed on a continual basis to account for any new information that had become available. A criterion of 20 mSv annual projected effective dose was generally used for this purpose. However, from the end of May 2011 dose rates associated with the selected long term criterion of an additional annual effective dose of 1 mSv were applied to assess the need for the decontamination of schools and their surrounding areas.
Were non-radiological consequences (e.g. psychosocial, economic) and other factors (e.g. technology, land use options, availability of resources, community resilience) identified and considered?	The arrangements implemented during the transition phase and the strategies or policies that were developed considered the need for the restoration of normal social and economic activities, the mitigation of economic impacts and the restoration of public services. Remediation work and dialogues had been carried out with local communities, and support centres had been established to help those returning to the affected areas. Long term screening for psychological and psychosocial consequences among the affected population had also been planned and implemented.

TABLE I–2. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: FUKUSHIMA DAIICHI CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was a registry of those individuals requiring further medical follow-up established before the termination of the emergency?	Activities to identify these individuals and to conduct the respective surveys were initiated in May 2011.
Was a strategy for the management of radioactive waste arising from the emergency developed when appropriate?	The first policy on the management of radioactive waste was issued in June 2011. The Act on Special Measures Concerning the Handling of Environmental Pollution was adopted in August 2011 and entered into force on 1 January 2012. The Act defined responsibilities for monitoring, decontamination and waste management, as well as for the provision of financial resources. An interim policy was in force from August 2011 to 1 January 2012 that allowed remediation work to commence and was used to guide the waste management operations.
Were the interested parties consulted?	The Roadmap for Immediate Actions for the Assistance of Nuclear Sufferers was issued by the Ministry of Economy, Trade and Industry on 17 May 2011. The road map was intended to facilitate communication and preparation for the transition to long term recovery operations and the resumption of normal social and economic activity. The road map allocated responsibilities and specified other organizational aspects of the transition process and the objectives of, and conditions for, the termination of the emergency response phase. The road map was revised in July 2011. Status updates on the progress in implementing the policy were issued each month until December 2011. For example, consultations were held between the local governments and the national Government on the evacuation prepared areas before the designation of such areas was withdrawn on 30 September 2011.

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY

Specific prerequisite	Status with respect to the prerequisite
Were justified and optimized actions taken to reach the generic dose criteria that would enable transition to an existing exposure situation and to ensure that the assessed residual doses would approach the lower bound of the reference level for an emergency exposure situation?	Remedial actions were being implemented with the aim of reaching the projected effective dose criterion of 20 mSv per year within the affected areas. The relevant policies had also specified a long term target for additional exposure of 1 mSv per year.
Were areas delineated before the termination of the emergency that were not open for unrestricted use by the public?	The initial delineation of areas was carried out in March and April 2011, when urgent and early protective actions were implemented. On 22 April 2011, the status of these restrictions was clarified and announced, and in the period up to November 2011 further areas were specified where hot spots of activity had been found and from which people were advised to relocate. By 26 December 2011, clear policies and directions for each restricted area had been formulated.
Were administrative and other provisions put in place for these delineated areas to monitor compliance with the restrictions?	On 28 March 2011, a decision was taken to prohibit access to the evacuated areas, and evacuees were informed about this decision on 30 March 2011. The 20 km zone was announced as a restricted area on 22 April 2011. Conditions for temporary access to the area within a 20 km radius of the nuclear power plant were defined. On 9 May 2011, the NSC provided advice on the implementation of temporary access. Access was sequentially permitted after coordination of relevant local governments, Fukushima Prefecture and others. The arrangements included specific instructions and monitoring for contamination.

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was a strategy developed for the restoration of infrastructure, workplaces and public services necessary to support normal living in the affected areas (e.g. public transportation, shops and markets, schools, kindergartens, health care facilities, police and firefighting services)?	The arrangements implemented during the transition phase and the strategies or policies that were developed considered the restoration of normal social and economic activities, the mitigation of economic impacts and the restoration of public services. Remediation work and dialogues had been carried out with local communities, and centres had been established to help those returning to the affected areas.
Were mechanisms and means in place for continued communication and consultation with all interested parties, including local communities?	Different radiation protection measures were implemented in different areas, and it was necessary to provide affected people with more detailed information on radiation safety and matters affecting their daily lives after the accident. One of the challenges in distributing the information was the unavailability of television and the Internet in many areas. The local NERHQs published a newsletter and distributed it to each evacuation site; as of April 2011, this information was also periodically broadcast by local radio stations. Instructions from the Director General of the NERHQ, press releases on monitoring data from the MEXT, and materials on support measures for local business corporations were provided to local municipalities in accordance with their need. Such information was also released to the local media through press conferences.

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was any change or transfer of authority and responsibilities from the emergency response organization to organizations responsible for the long term recovery operations completed?	The adopted policies for the management of different areas identified the conditions under which the situation would be managed by local authorities. For example, according to the Act on Special Measures Concerning the Handling of Environmental Pollution, the contaminated areas were arranged into two categories on the basis of the additional annual effective dose estimated in the autumn of 2011; these categories were ‘special decontamination area’ and ‘intensive contamination survey area’. Within the special decontamination area, which overlaps the former restricted areas, the national Government has responsibility for formulating and effecting remediation plans. The intensive contamination survey area includes those municipalities where the additional radiation doses in the first year were estimated to be between 1 mSv and 20 mSv. Municipalities conduct monitoring surveys to identify areas requiring decontamination implementation plans and implement remediation activities in these areas; the national Government provides financial and technical support to facilitate the remediation.
Were the information and data gathered during the emergency relevant for the long term planning shared among relevant organizations and authorities?	The MEXT opened a portal site on radiation monitoring in August 2011 that included information on the monitoring being conducted by related ministries and agencies in line with their own administrative objectives. To collate and facilitate the use of monitoring data, the Japan Atomic Energy Agency created a database that linked the data to geographical information. The response to the accident provided a number of examples that show the benefits of involving affected populations in activities for recovery, from consultation and dialogue to involvement in remediation actions (so-called self-help actions). An information hub, called the Decontamination Information Plaza, was opened in Fukushima City in January 2012 as a joint project of Fukushima Prefecture and the Ministry of the Environment.
Was a long term monitoring strategy developed in relation to residual contamination?	The plan for detailed monitoring was announced on 13 June 2011. Further activities to formulate a comprehensive monitoring plan continued in August 2011. The plan was subsequently revised in April 2012.

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was a long term medical follow-up programme for the registered individuals developed?	The first stage of a screening and monitoring programme was initiated in June 2011. It included programmes for the early detection of radiation induced cancers and effects on mental health and lifestyle.
Was a strategy developed for mental health and psychosocial support of the affected population and for consultation on psychosocial health consequences?	Comprehensive medical check-ups for evacuees were conducted, and the mental health and lifestyle survey, which was conducted as part of the Fukushima Health Management Survey, included questionnaires covering physiological conditions, lifestyle changes, experiences of the earthquake and tsunami and radiation related issues. With regard to the general public, the Ministry of Health, Labour and Welfare has been engaged in efforts to dispatch mental health care teams. These efforts include providing access to telephone counselling for persons who were found by the Fukushima Health Management Survey to be at high risk, or those who indicated a wish to talk about their concerns. Public health officials (e.g. district nurses, midwives) have set up a number of initiatives on a local basis, including focus group discussions and counselling for pregnant women and young mothers [I–14]. With regard to mental health care resources, new major facilities were established in Fukushima after the accident. For example, a mental health support team from Fukushima Medical University has been providing counselling by telephone to approximately four thousand evacuees at risk of psychiatric disorders, such as post-traumatic responses or depression, every year since the accident [I–22]. Another facility, the Fukushima Kokoro no Care Centre, with around fifty members — psychiatrists, social workers, clinical psychologists, nurses and occupational therapists — also began to provide mental health intervention programmes in 2012 [I–22].

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was a strategy under consideration to compensate victims of damage resulting from the emergency?	The Dispute Reconciliation Committee for Nuclear Damage Compensation was established in April 2011 to provide guidelines defining the scope and amount of compensation falling under the responsibility of the operator (TEPCO). The committee's first interim guidelines were published on 5 August 2011. These guidelines clarify the compensation associated with evacuation, the establishment of marine exclusion zones and no-fly zones, restrictions on shipping agricultural products, other government orders, 'rumour related' damage, radiation exposure, decontamination and other indirect damage [I–14]. The enactment on 5 August 2011 of the Act on Emergency Measures Related to Damage Caused by the 2011 Nuclear Accident (Act No. 91 of 2011) [I–23] enabled the Government of Japan to start making provisional compensation payments in place of TEPCO as an emergency measure. The Government also implemented other means to allow the operator to fulfil its obligations to the victims of the accident. In September 2011, the Government, pursuant to the Nuclear Damage Compensation Facilitation Corporation Act (Act No. 94 of 2011, 10 August 2011) [I–24], set up the Nuclear Damage Compensation Facilitation Corporation (currently the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF)). The Act envisages a procedure in which the liable operator may request financial support from the NDF in cases where the actual amount of damage to be compensated is expected to exceed the financial security amount envisaged in the Act. Additionally, in July 2012 the NDF paid 1 trillion yen for preferred shares and became the controlling shareholder of TEPCO with a little over 50% voting rights [I–25].

TABLE I–3. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: FUKUSHIMA DAIICHI CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Were administrative arrangements and legislative and regulatory provisions in place, or were the corresponding amendments under way, for the management of the existing exposure situation, including provisions for the necessary financial, technical and human resources?	The national system in place prior to the emergency did not cover the management of an existing exposure situation of this size. All the necessary policies, guidelines and acts were therefore prepared after the accident, beginning in June 2011. Resource needs (expertise, staffing, equipment and material) were mobilized from all over Japan, and the logistic support (e.g. transport, housing) was organized accordingly.
Was individual monitoring of members of the general public still required for radiation protection purposes?	No, only for the affected population.

THE RADIOLOGICAL ACCIDENT IN GOIÂNIA, BRAZIL

I–52. In 1985 a radiotherapy institute, the Instituto Goiano de Radioterapia in Goiânia, Brazil, moved to new premises. During this process a ^{137}Cs teletherapy unit was left in place. The licensing authority, the Brazilian National Nuclear Energy Commission (CNEN), was not notified, even though such a notification was required under the terms of the institute's licence. The former premises of the institute were subsequently partly demolished. As a result, the radioactive source remained in an insecure condition, which subsequently led to the radiological accident (elaborated in detail in Ref. [I–26]).

I–53. On 13 September 1987, two people (W.P. and R.A.) entered the premises looking for valuable material and scrap they could sell. They found and dismantled the abandoned teletherapy unit with common tools and removed the rotating radiation head that contained the source assembly. They transported these items in a wheelbarrow to their homes, half a kilometre from the site of the institute. In the evening both people began to vomit.

I–54. On 14 September 1987, W.P. suffered from diarrhoea, dizziness and oedema on one hand. He consulted a medical doctor on 15 September 1987, and his symptoms were diagnosed as an allergic reaction to food. In the meantime R.A. proceeded to dismantle the radiation head in his backyard. He finally extracted the ^{137}Cs capsule from the source wheel, punctured the 1 mm thick window of the source capsule with a screwdriver and scooped out some of the radioactive material.

I–55. On 18 September 1987, the remnants of the source assembly were sold for scrap to a junkyard. The junkyard owner (D.F.) noticed that the source material glowed blue in the dark and took the capsule into his house. In the following days, several persons — neighbours, relatives and acquaintances — were invited to see this phenomenon. Fragments of the source, the size of grains of rice, were distributed among several families. These visits continued for several days, by which time a number of people, including D.F.'s wife, suffered from vomiting and diarrhoea.

I–56. On 25 September 1987, D.F. sold the lead shielding that had been removed from the unit and the remnants of the source assembly to another junkyard. By 28 September 1987, D.F.'s wife suspected that the glowing powder was the cause of the symptoms of ill health. She reclaimed the materials from the second junkyard and transported them by bus in a bag to the Vigilância Sanitária, a public health department in Goiânia. In the morning of 29 September 1987, a medical physicist visiting the Vigilância Sanitária identified the presence of radioactivity using a scintillation counter.

Emergency declaration and urgent protective actions

I–57. On 29 September 1987, the Director of the Department of Nuclear Installations at the CNEN was notified of the accident by telephone. He suggested that more information should be gathered about the radioactive source, the nature of the accident and the extent of the contamination. He also called the Instituto Goiano de Radioterapia. In Goiânia, the authorities alerted the police, the fire brigade, ambulance services and hospitals. The local authorities transferred management responsibilities to the CNEN when the first CNEN teams arrived on 30 September 1987. The CNEN teams were supported by the state military police and fire brigades, and later by the Brazilian army.

I–58. Existing emergency arrangements at the time of the accident were designed to respond to possible nuclear accidents at the Central Nuclear Almirante Álvaro Alberto nuclear power plant or to small scale radiological emergencies in the non-nuclear power sector, such as transport accidents or accidents with radiography sources. The Goiânia accident did not fall into either category; it was therefore necessary to establish specific arrangements based on an appropriate combination of elements from the existing plans.

I–59. Priority in the emergency response was given to the medical aspects, the isolation of the radioactive source and the contaminated areas that had been identified, the assessment of environmental contamination and the reinforcement of human and technical resources.

Isolation of the source

I–60. The remnants of the source located in the courtyard of the Vigilância Sanitária were shielded in place on 30 September 1987. A section of sewer pipe was placed over the remnants by crane and filled with concrete pumped over the wall of the courtyard. This operation was completed by the early afternoon of the second day. As a result, the dose rates in the surrounding area were significantly reduced, and since contamination was not a major problem in this area, most of the area that had been cordoned off around the site could be reopened.

Monitoring and medical response

I–61. Upon identification of the accident, the Goiás State Secretary for Health made plans to use the city's Olympic stadium to receive and isolate identified patients and screen people who might have been exposed. The areas surrounding the known contaminated sites, where the dose rate exceeded 2.5 μSv/h[2], were evacuated and the residents directed to the stadium for contamination control. Access to these areas was further restricted.

I–62. As the environmental monitoring proceeded, several other sites of significant contamination were identified. Residents at these sites were evacuated and sent to the local soccer stadium for medical examination and contamination checks. Blood, urine and faeces samples were obtained from each of the patients for bioassays.

I–63. At the stadium, individuals identified with symptoms of overexposure to radiation were sent to the Tropical Diseases Hospital for medical care. Contaminated persons were requested to place their clothes into bags and to take showers. People showing signs of internal contamination were referred for further medical care.

I–64. As a consequence of spreading rumours, many people went to the stadium for reassurance, which strained the limited monitoring resources that were available at that time.

I–65. On 1 October 1987, six patients, and two days later four more patients, were transported to the Marcilio Dias Naval Hospital in Rio de Janeiro for intensive medical care.

I–66. Monitoring teams mapped the main contaminated sites and identified all hot spots, ensuring that no one else was at risk of serious exposure. These steps, however, did not preclude the possibility of later discovering other, less severely contaminated areas that might also require action and control.

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[2] This first approximation was roughly based on the occupational dose limit of 5 rem (50 mSv) per year (about 240 workdays at 8 h/day) recommended at the time and considering that the dose limit for the public was ten times lower. This value was confirmed later because the underestimation of residential occupancy compared with occupational occupancy was counteracted by the fact that the cleanup lasted about three months.

Transition phase

I–67. By 3 October 1987, the situation had been brought under control; there was no further risk of high exposures, and the most contaminated sites had been identified and evacuated. The main concerns were the continuing treatment of the injured, improvement of the conditions at the sites of contamination, cleanup operations and waste management.

I–68. The following week was devoted to the preparation of plans and strategies for the recovery. Resource needs (expertise, staffing, equipment and material) were assessed and mobilized. Logistic support (e.g. transport, housing) was organized, with account taken of the expected increase in resources.

I–69. Patients in hospital and inhabitants of contaminated residences were interviewed concerning their own movements and those of any visitors to identify potential additional routes by which contamination may have spread. Further surveys were conducted to confirm and localize less contaminated spots. Prior to the environmental decontamination, plans were made to carry out a comprehensive survey by car based and airborne gamma spectrometry and to organize an environmental survey programme. Various procedures were developed and written for access control to contaminated areas, action criteria, equipment quality assurance and control and medical follow-up (selection for cytogenetic and other blood tests). Plans for dealing with the large amount of waste expected to be generated by cleanup activities were also established (including procuring the necessary equipment, chemicals, machinery and staff (professional, technical and support); identifying a suitable temporary disposal site; and defining the specifications for waste containers).

I–70. The dose rate criterion of 2.5 μSv/h for evacuation, established at the beginning of the emergency, was reconsidered to take into account the annual exposure limit for members of the public (5 mSv per year) and more realistic, but still conservative, estimates for occupancy and the spatial distribution of activity to relate the mean dose rate to the maximum dose rate. A time factor was also applied to reflect the decrease in radioactivity due to, for example, cleaning or weathering. A revised criterion of 10 μSv/h for evacuation (and return) was adopted.

Medical follow-up

I–71. Measures were taken to protect medical staff from contamination and exposure during the treatment of patients in hospital. The doses received by the medical staff over the three month duration of the patients' hospital care were below 5 mSv.

I–72. Follow-up studies, including a continuing bioassay and whole body monitoring programme, were performed on the contaminated persons. Prussian blue was used to speed up the biological excretion processes for ^{137}Cs.

Comprehensive environmental monitoring

I–73. The subsequent monitoring efforts encountered various difficulties in surveying the urban area and the river basin. Because of the heavy rain that had fallen between 21 and 28 September 1987, the caesium contamination had been dispersed from the ruptured capsule into the environment. Instead of being washed out as expected, radioactive materials were deposited on roofs and became the major contributor to dose rates in houses.

I–74. Samples of soil, vegetation (leaves, branches and fruits), water (from the nearby river, wells and public water supply), rainwater and air were collected and measured.

Post-accident recovery operations

I–75. Some 550 workers were engaged in the decontamination operations.

I–76. Significant contamination was found in 85 houses. Movable items (e.g. clothes, furniture) were removed to a nearby uncontaminated area for monitoring. Items free of contamination were wrapped in plastic, while contaminated items were decontaminated, when possible, or disposed of as waste. When the contents of a house had been removed, the inside and roofs were cleaned. Seven highly contaminated houses were demolished because decontamination was not feasible.

I–77. Forty-five public places, including pavements, squares, shops and bars were decontaminated. Contamination was also found on about fifty vehicles.

I–78. In gardens, fruits were pruned from trees and disposed of. Much of the soil from enclosed gardens and yards was also removed, following soil profile measurements. The site of the highest contamination was the house where the source capsule had been dismantled. Exposure rates were very high, necessitating rotation among workers to keep their daily exposure below a criterion of 1.5 mSv.

I–79. After the removal of rubble and soil, the decontaminated area was covered by concrete or clean soil.

Waste management and disposal

I–80. By 3 October 1987, it was evident that large volumes of radioactive waste would be generated. Plans were developed for dealing with the decontamination operations and waste management.

I–81. The preparation of decontamination operations included:

(a) Choice of a suitable disposal site;
(b) Design and construction of waste containers;
(c) Collection of heavy machinery, such as excavators and back- and front-loaders;
(d) Update of written operational procedures;
(e) Testing of various decontamination techniques;
(f) Preparation of a work timetable.

I–82. It was necessary to find a suitable location for the disposal site and to identify and address the constraints associated with the disposal and transport conditions. As a consequence of public concern, it was not possible to locate the disposal site in Goiânia. Deciding on the location and planning and constructing the waste storage site took more time than expected. A site 20 km outside the city was chosen as a temporary disposal site on 16 October 1987, and major decontamination work started in mid-November. The decontamination operations continued until the end of December 1987. The total volume of waste stored was approximately 3500 m^3 [I–26].

Conclusions

I–83. The different stages of the management of the accident, and a number of key milestones, can be recognized by retrospective analysis and roughly associated with the different phases of an emergency described in Section 2 of this Safety Guide (see Fig. I–4). However, the complexity of the accident, together with the absence of specific emergency plans to address such a situation, resulted in the demarcations between the specific activities and phases being less clear at the time.

I–84. The emergency response phase began on 29 September 1987, when the broken ^{137}Cs source was identified as the cause of the symptoms affecting those

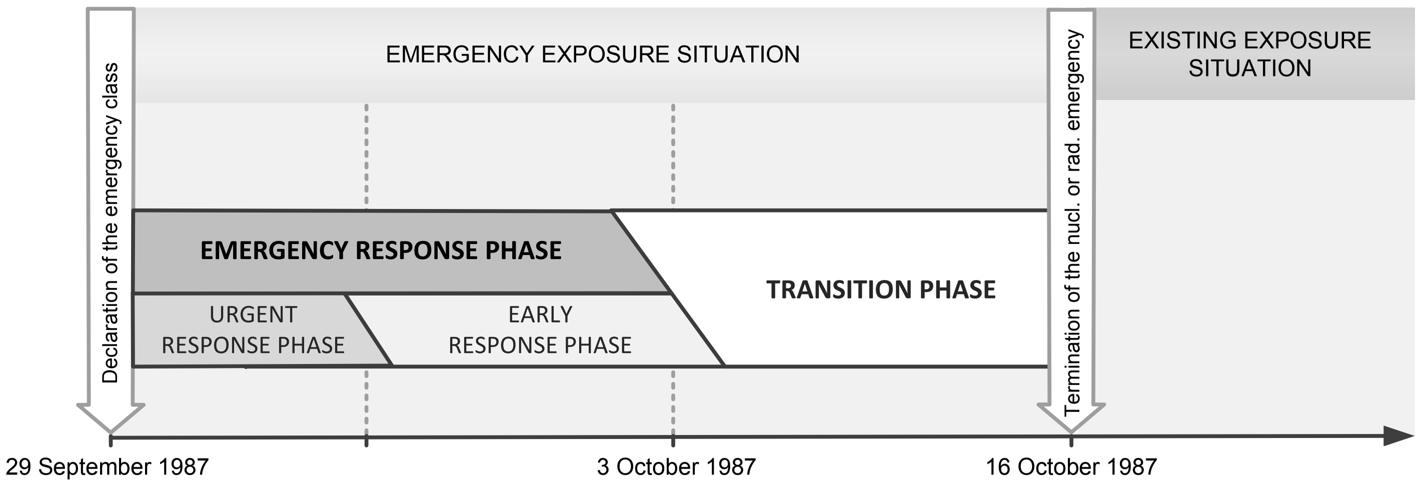

FIG. I–4. Retrospective sequencing and milestones of the Goiânia accident management.

who had been in contact with it, and when the CNEN was notified. Urgent and early protective actions, such as the identification and care of severely exposed people, the identification and isolation of the source, the evacuation and cordoning off of the most heavily contaminated areas and the contamination control and decontamination of evacuees were carried out during the following days. The emergency response phase, during which all potential sources of contamination were brought under control, was completed by around 3 October 1987.

I–85. The following two weeks, from 3 to 16 October 1987, can be considered to be the transition phase, during which the main focus of the response was to set up a general strategy for the overall recovery. This strategy included:

(a) Organizing the management structure for the recovery operations;
(b) Re-evaluating or setting dosimetric criteria and operational criteria for implementing relevant work;
(c) Assessing and gathering the resources needed;
(d) Mapping the geographical distribution of the contamination;
(e) Developing and writing procedures for access control, equipment QA/QC and the selection of health screening methods (cytogenetic and other blood tests);
(f) Choosing a suitable location for the disposal of waste;
(g) Defining specifications for waste containers;
(h) Setting up an environmental monitoring network;
(i) Developing a public communication strategy.

I–86. Although there was no clear termination of the emergency, 16 October 1987 (when the decision on the temporary waste disposal site was made) might be considered as the beginning of the existing exposure situation. Decontamination operations started in the middle of November, following the necessary preparations. The decontamination of the main locations where the source was handled and of the remaining areas was carried out from mid-November until the end of December 1987. The rehabilitation phase, with the aim of restoring normal living conditions, continued until March 1988.

I–87. The results of an analysis of the case study with regard to the fulfilment of the prerequisites for the termination of a nuclear or radiological emergency, contained in Section 3 of this Safety Guide, are presented in Tables I–4 and I–5. These tables reflect the situation that existed on 16 October 1987 (see Fig. I–4), which is the date at which the retrospective analysis indicates that the conditions for termination existed.

TABLE I–4. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: GOIÂNIA CASE STUDY

General prerequisite	Status with respect to the prerequisite
Had the necessary urgent and early protective actions been implemented?	The affected people had been identified and were taken care of. The contaminated areas had been delineated. Residents had been evacuated, and access controls were in place. The radioactive source had been located and isolated.
Was the exposure situation stable and well understood?	The radioactive source had been isolated. No further significant dispersion of the contamination was expected. The history, affected individuals and responsible parties associated with the accident were known.
Was the radiological situation well characterized, and were the exposure pathways identified and doses assessed for all the affected people?	Monitoring had been carried out. The affected people and the contaminated areas had been identified, and doses had been assessed. Initial intervention criteria had been revised, taking into account more realistic and site specific parameters associated with the habits of the affected people.
Was the source of exposure brought under control, and were no further significant accidental releases or exposures expected due to the event?	The radioactive source had been located and brought under control. Residents had been evacuated from contaminated areas, and access controls were in place, preventing further significant exposure.

TABLE I–4. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: GOIÂNIA CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?	The IAEA report on the accident states that “preparedness to respond to radiological emergencies should extend not only to nuclear accidents but to the entire range of possible radiological accidents” [I–26]. Before the accident, Brazil had not considered the potential for radiological emergencies in its emergency arrangements. Any changes in the national arrangements that followed the accident occurred during a time frame beyond that of the references consulted.
Were the requirements for occupational exposure in a planned exposure situation confirmed for all workers engaged in recovery activities?	A daily effective dose criterion for workers was set at 1.5 mSv; other criteria were used for longer periods of work (5 mSv per week, 15 mSv per month and 30 mSv per quarter). These limits were compatible with the annual effective dose limit of 50 mSv in force at the time.
Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?	A maximum effective dose level of 5 mSv was set and used as the reference for public exposure; operational criteria for evacuation and remedial actions were defined accordingly.
Were non-radiological (e.g. psychosocial, economic) consequences and other factors (e.g. technology, land use options, availability of resources, community resilience) identified and considered?	It is not clear whether, and to what extent, these aspects had been thoroughly considered and to what extent such consideration would have been necessary, given the nature of the emergency. However, it was noted that some of the inhabitants of Goiânia were subjected to discrimination, even by their own relatives. Sales of the main economic products of Goiás State (cattle, cereals and other agricultural products, as well as cloth and cotton products) fell by one quarter in the period after the accident.

TABLE I–4. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: GOIÂNIA CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was a registry of those individuals requiring further medical follow-up established before the termination of the emergency?	The affected people had been identified and were receiving the necessary medical attention.
Was a strategy for the management of radioactive waste arising from the emergency developed when appropriate?	In the period up to 16 October 1987, various activities associated with choosing a suitable location for the disposal of waste and for defining the specifications for waste containers were carried out.
Were the interested parties consulted?	It is not clear whether or to what extent consultation with interested parties occurred before 16 October 1987. A communication strategy was, however, under consideration at that time.

TABLE I–5. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: GOIÂNIA CASE STUDY

Specific prerequisite	Status with respect to the prerequisite
Were justified and optimized actions taken to reach the generic dose criteria that would enable transition to an existing exposure situation and to ensure that the assessed residual doses would approach the lower bound of the reference level for an emergency exposure situation?	The dosimetric and operational criteria were developed during the accident on the basis of dose limits for planned operations. Thus, the criteria were more conservative than might be considered appropriate for short term exposures. These values were the main drivers for the response actions and remedial actions taken, and the limited monitoring and medical response resources were placed under additional pressure as a consequence. The decision on the criteria was influenced by the pressure of public opinion.
Were areas delineated before the termination of the emergency that were not open for unrestricted use by the public?	By 16 October 1987, the evacuated areas to which access was restricted were known.
Were administrative and other provisions put in place for these delineated areas to monitor compliance with the restrictions?	Access to these restricted areas was controlled.
Was a strategy developed for the restoration of infrastructure, workplaces and public services necessary to support normal living in the affected areas (e.g. public transportation, shops and markets, schools, kindergartens, health care facilities, police and firefighting services)?	No relevant information was found or expected, in view of the limited area and number of people affected by the accident.

TABLE I–5. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: GOIÂNIA CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Were mechanisms and means in place for continued communication and consultation with all interested parties, including local communities?	In order to restore public trust and improve credibility, decontamination workers were encouraged to explain to people what they were doing and why and to accept offers of drinking water and food from people's houses. Decontamination workers also made frequent appearances on television, during which they used simple language and made analogies with common applications of radiation, such as medical X rays. Several dialogues were held with different sections of the population, community groups and journalists. Around 250 000 copies of a pamphlet explaining radioactivity and radiation were distributed. A telephone service was operated 24 hours a day to answer enquiries or receive information about other possibly contaminated people or sites.
Was any change or transfer of authority and responsibilities from the emergency response organization to organizations responsible for the long term recovery operations completed?	The authority remained with the CNEN, and thus there was no need for any transfer of responsibilities.
Were the information and data gathered during the emergency relevant for the long term planning shared among relevant organizations and authorities?	Not applicable, as the CNEN remained in charge.

TABLE I–5. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: GOIÂNIA CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was a long term monitoring strategy developed in relation to residual contamination?	Consideration had been given to the development of a monitoring strategy for residual contamination by 16 October 1987. The general environmental monitoring programme continued in 1988. The monitoring of decontaminated sites was maintained on a continual basis until 1996.
Was a long term medical follow-up programme for the registered individuals developed?	Follow-up studies, including a continuing bioassay and whole body monitoring programme, were performed on the contaminated persons. These studies continued until the beginning of 1988.
Was a strategy developed for mental health and psychosocial support of the affected population and for consultation on psychosocial health consequences?	Some consideration was given to supportive psychological therapy for the exposed people, but it was recognized that further development of the system of social and psychological support was needed.
Was a strategy under consideration to compensate victims of damage resulting from the emergency?	No information was found.

TABLE I–5. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO AN EXISTING EXPOSURE SITUATION: GOIÂNIA CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Were administrative arrangements and legislative and regulatory provisions in place, or were the corresponding amendments under way for the management of the existing exposure situation, including provisions for the necessary financial, technical and human resources?	Resource needs, such as expertise, staffing, equipment and material, were assessed and mobilized. The necessary logistic support (e.g. transport and housing) was organized accordingly.
Was individual monitoring of members of the general public still required for radiation protection purposes?	There was no need to continue individual monitoring of members of the general public, with the exception of the registered affected people.

THE NUCLEAR INCIDENT AT THE PAKS NUCLEAR POWER PLANT, HUNGARY

I–88. The Paks nuclear power plant in Hungary comprises four 440 MWe water cooled, water moderated power reactors that supply about 40% of the electricity to the country. Units 1–4 went into commercial operation between 1983 and 1987.

I–89. On 10 April 2003, an incident occurred in the course of operations to clean fuel assemblies during a scheduled maintenance shutdown for Unit 2. Thirty fuel assemblies had been removed from the Unit 2 reactor and placed in a fuel cleaning tank approximately 10 m under water in a shaft adjacent to the fuel pool. The external surfaces of the fuel assemblies were being cleaned, using a specially designed chemical cleaning process, to remove depositions of magnetite from the fuel assembly cladding [I–27 to I–30].

I–90. At 21:53[3] on 10 April 2003, workers detected an increase in the activity of ^{85}Kr, from a measurement system installed in the cleaning circuit. At about the same time, the instruments measuring the activity concentrations of noble gases in the reactor hall indicated that the 'emergency level' had been reached. The timeline of the different events during the incident is shown in Fig. I–5 [I–30].

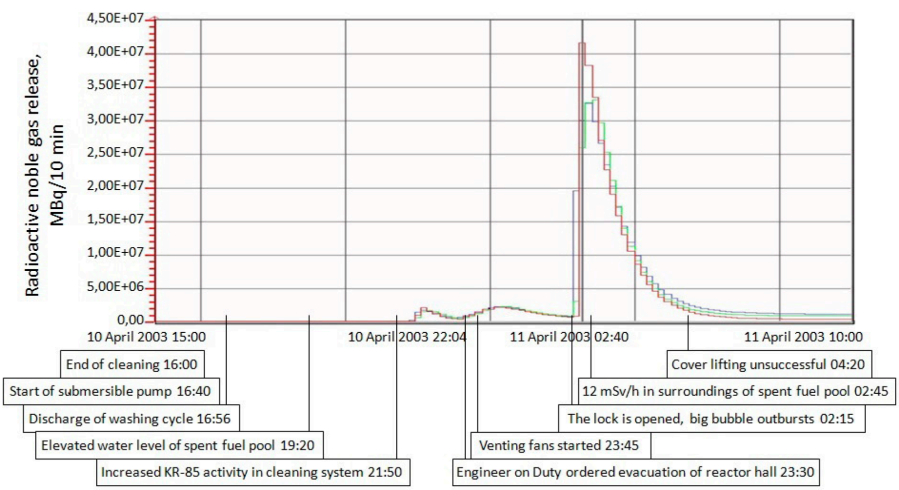

FIG. I–5. Timeline of events during the incident (courtesy of the Hungarian Atomic Energy Authority and the Paks nuclear power plant).

[3] All times are given in local time (UTC +02).

Taking response actions and activating the site emergency response organization

I–91. Once the noble gas instruments in the reactor hall indicated that the emergency level had been reached, the plant shift supervisor ordered the evacuation of workers from the area. Initially, it was suspected that a fuel assembly was leaking as a result of the cleaning operation. However, several days later, a video inspection indicated that most of the fuel had suffered heavy damage. About 16–17% of the fuel material was located at the bottom of the cleaning vessel in the form of debris. Figure I–6 illustrates the extent of the damage and the location of fuel debris.

I–92. The incident was of low significance in terms of its health impact. There was some increase in the release of radioactive noble gases to the environment compared with the normal operational situation. However, the rate of release initially exhibited a decreasing trend and did not approach the discharge limits. The shift supervisor (the primary head of the Site Emergency Response Organization (SERO)) evaluated the event in accordance with the site emergency response plan and decided that there was no need to take immediate emergency response action or to alert the SERO.

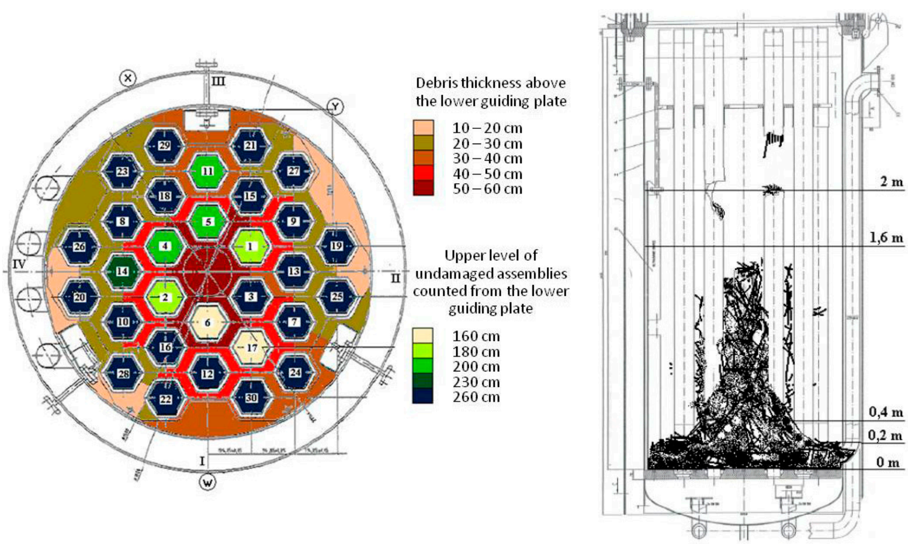

FIG. I–6. Extent of damage and location of fuel debris (courtesy of the Hungarian Atomic Energy Authority and the Paks nuclear power plant).

I–93. At 02:15 on 11 April 2003, the situation deteriorated. However, the version of the site emergency response plan valid at the time did not allow the event to be recognized as an accident on the basis of the conditions and information available at that time.

I–94. The rate of the release of noble gases did not reach the level specified in the site emergency response plan as a threshold for classifying the event as an accident. The readings from the monitors designed to detect radioiodine were distorted and increased by the release of noble gases, making the results difficult to interpret. The assessment of samples and laboratory analysis would have provided more accurate information on the release of iodine. This form of measurement was carried out at around 07:45 on 11 April 2003. With full knowledge of the more accurate data on the magnitude and the form of release, the situation was re-evaluated in line with the site emergency response plan. This re-evaluation confirmed that the event did not constitute an accident. Nevertheless, at 12:40 on 11 April 2003, the shift supervisor decided to partially set up the SERO to provide continuous control and evaluation of the situation. The SERO comprised a control team, a communication organization and a radiation situation evaluation group. The SERO functioned in accordance with the relevant procedures until 16:00 on 13 April 2003, when its operation was terminated.

I–95. After removal of the tank cover and completion of the visual inspection of the fuel assemblies within the tank, the SERO was fully reactivated at 22:30 on 16 April 2003 and remained in operation until 09:00 on 20 April 2003. In general, the assessment of the situation and the operation of the SERO were performed in compliance with the requirement to provide information to and support the decision making of local off-site organizations. The SERO operated in partial response mode (comprising the management group, the radiological assessment group, the staff support group and the technical support group) at the emergency response centre and continuously evaluated the situation, kept in contact with authorities and exercised readiness for full activation if the situation deteriorated.

I–96. The operator had on-line access to a network of nine continuously operating environmental gamma dose rate monitors located around the Paks nuclear power plant. The results from these monitors were also available to off-site authorities. The monitors had an alert level (500 nSv/h) based on the average dose rate over a 10 min period. The 10 min average level was not exceeded during the incident, but the dose rate at one monitor rose significantly during the peak in the initial release. The operating personnel at the site did not notice this change at the time, when it could have provided additional information about the nature of the release. Operating staff at the Paks nuclear power plant noted that they were faced with significant amounts of other information, which was a contributing factor to the inability to fully understand the situation at the time [I–27]. In addition, there were no specific plans in place for dealing with such releases.

Recovery operations

I–97. The continuous cooling of the cleaning tank was ensured by the use of an auxiliary cooling system, which was installed on 17 April 2003. In addition, continuous monitoring of the cleaning tank and its immediate surroundings was performed. Three days later, a plastic foil ‘greenhouse’ was built above the pond containing the cleaning tank. The air space within the greenhouse was subject to continuous analysis and purification. From 12 April to 20 April 2003, between forty and eighty workers per day performed work in the reactor hall. The workers wore personal protective equipment, consisting primarily of protective clothes, compressed air breathing apparatus and gas masks with iodine filters, depending on their workplace within the hall. Working hours were limited to ensure that the dose limits for normal operation were not exceeded.

I–98. Professional teams involving specialists in, for example, reactor physics, hydrodynamics and technical logistics were established to determine the safest options for recovery. Their work was supported by competent specialists from Hungarian universities and research institutes and by engineers from Germany. In addition, representatives of the Russian fuel manufacturer arrived at Paks in May 2003. The final solution for recovery involved removal of the damaged fuel assemblies and provision for long term cooling and storage. An autonomous cooling system and an emergency boron system for the service pool were established during the first half of 2004. For the recovery from the incident, the Paks nuclear power plant established a working group (called the Recovery Project), which was charged with the design of, preparation for and conduct of the removal of the damaged fuel. This group had previously been charged with the normalization of the state of the system and the preparation for and licensing of the recovery operations [I–30]. The licensing documentation was submitted to the Hungarian Atomic Energy Authority (HAEA) in November 2004. The HAEA issued a license for recovery operations in the service pool in July 2005 on the basis of the licensing documentation. Manufacturing licences for cases and containers for the storage of the damaged fuel assemblies and solid radioactive waste were issued in March 2006. Authorization for the removal of damaged fuel was granted in September 2006.

I–99. During the normalization of the system’s status, the following main steps were taken [I–30]:

(a) Separation of the refuelling pit with the damaged cleaning tank and the spent fuel pool from the reactor;
(b) Increase of the boric acid concentration in the refuelling pit to 20 g/kg;
(c) Development of the safety borating system for the cleaning tank;
(d) Construction of an independent cooling system for the cleaning tank;
(e) Separation of the refuelling pit from the spent fuel pool;
(f) Installation of redundant temperature, coolant level and neutron measurement instrumentation in order to provide the refuelling pit with an independently operated instrumentation and control system;
(g) Detailed visual exploration of the state and geometry of the damaged fuel assemblies and the cleaning tank.

I–100. Several criteria were used to ensure that occupational exposures, surface contamination levels and radionuclide activity concentrations in air during recovery operations were consistent with those for normal operation. The plant radiation protection code listed these criteria as well as the situations in which the use of personal protective equipment (e.g. protective clothing, breathing apparatus, gas masks) was necessary; the code also provided information on how to use the equipment.

I–101. In planning for radiation protection measures, it was necessary to determine the radiological situation inside the reactor hall. The activity of radionuclides accumulated in the fuel assemblies was calculated on the basis of the time the assemblies had spent in the reactor and some other parameters influencing the burnup of fuels. To validate the model calculations, gamma dose rate measurements were performed at several locations inside the cleaning tank with a gas ionization detector.

Monitoring and assessment

I–102. Following the incident, several activities were undertaken to monitor and assess the situation in detail and to confirm its stability. These activities also included assessments of the characteristics of the release to the environment.

I–103. National arrangements included a national radiation monitoring and warning system comprising organizations participating in the emergency response system and other professional organizations. The system was intended to be activated in the event of a radiation emergency and to support the availability of the information necessary for decision making.

I–104. To improve the understanding and assessment of the radiological situation, a coordinated environmental monitoring survey was initiated with the involvement of the national radiation monitoring and warning system. The objectives of the monitoring activities were to collect and evaluate detailed information on the radiological situation in the areas surrounding the Paks nuclear power plant to assess whether there was a need for any off-site protective actions and to provide authentic, trustworthy and timely information to the public. In addition, the Hungarian Meteorological Service provided trajectories of the likely dispersion and distribution of radioactive material over the territory of Hungary. Mobile laboratories of different organizations were involved in measuring the ambient gamma dose rates, and the system of fixed laboratories provided grass, soil and water samples and in situ measurement results from various locations in Hungary. The increased measurement campaign continued for the entire period of the incident, from 11 to 26 April 2003. The following figures show, respectively, the results of the extensive radiological measurement and assessment activities: Fig. I–7 presents estimates of the noble gas release, Fig. I–8 presents estimates of the ^{131}I equivalent release and Fig. I–9 presents the estimated airborne release; Fig. I–10 presents the ^{131}I equivalent activity in different plants in central Hungary, and Fig. I–11 shows the results of the same measurement types for the region surrounding Paks.

I–105. On the basis of the measurement results and the assessment of the situation following the incident, it was concluded that no significant release of radioactive material to the environment had occurred and no actions were needed for the protection of the public in the region surrounding the Paks nuclear power plant.

I–106. From 16 April 2003, the HAEA conducted model calculations to assess the doses to members of the public from the release of radioactive material to the atmosphere. The source term was provided by the operator of the Paks nuclear power plant. Initially, it was assumed that only a few fuel pins had been damaged. However, further calculations concerning the total amount of noble gases, iodine and fission products released indicated that this assumption was not correct. This subsequent information and evidence from a video recording of the interior of the cleaning tank led the HAEA and the operator of the Paks nuclear power plant to conclude that most, if not all, of the fuel rods had been damaged in the incident.

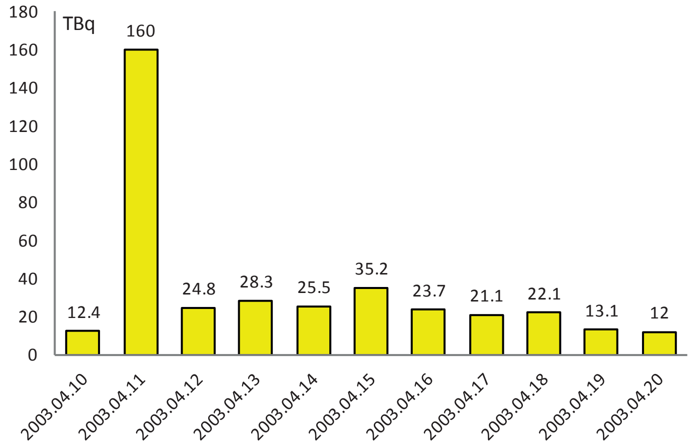

FIG. I–7. Estimates of noble gas release (courtesy of the HAEA and the Paks nuclear power plant).

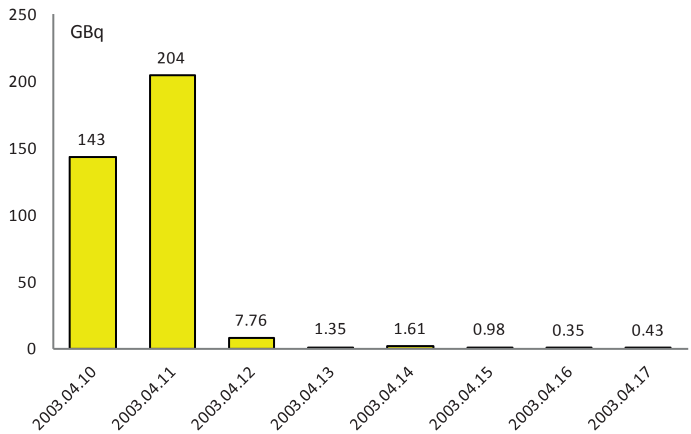

FIG. I–8. Estimates of ^{131}I equivalent release (courtesy of the HAEA and the Paks nuclear power plant).

I–107. The operator estimated the type and quantity of the release. Essentially, it consisted of:

(a) A few hundred TBq of noble gases, mostly ^{133}Xe (half-life of 5.2 days): see Fig. I–7;
(b) A few tenths of a TBq of radioiodine, mostly ^{131}I (half-life of 8 days): see Fig. I–8;

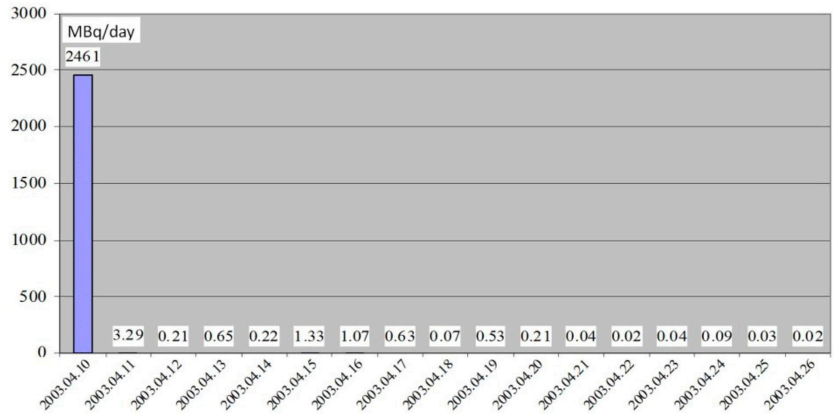

FIG. I–9. Estimates of airborne release (courtesy of the HAEA and the Paks nuclear power plant).

(c) Less than 0.01 TBq of other radionuclides, principally ^{134}Cs (half-life of 2 years) and ^{137}Cs (half-life of 30 years): see Fig. I–9.

I–108. The assessment of doses indicated that the radiological consequences of the incident were low. Doses to workers were maintained well within the limits set out for normal operation. Doses to members of the public were a very small fraction of the relevant dose limit and less than the dose from exposure to natural background radiation for one day.

I–109. Data provided by the Paks nuclear power plant staff were collected and evaluated independently by the regulatory body. No obvious discrepancies between expectations, data and model calculations were found. The data collected by the various bodies and agencies appeared to be consistent. For these reasons, no further detailed checks were performed on the dose assessment provided by the Paks nuclear power plant.

Protection of emergency workers and recovery workers

I–110. Appropriate procedures were followed to minimize the individual and collective doses to workers involved in the management of the incident. Dosimetry control, personal protective equipment, work order management, and training and education on relevant activities were employed for that purpose. The need for dose estimation and for medical consultation was also considered.

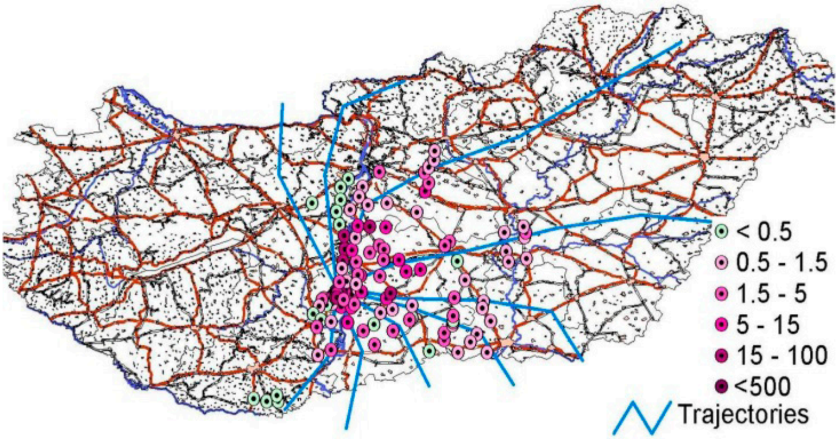

FIG. I–10. Iodine-131 equivalent activity in different plants in central Hungary [Bq/kg fresh weight] (courtesy of the HAEA and the Paks nuclear power plant).

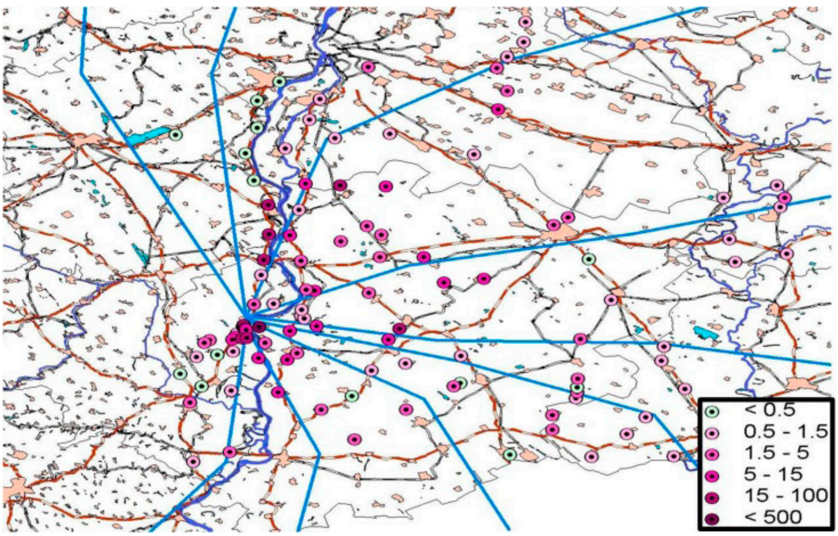

FIG. I–11. Iodine-131 equivalent activity in different plants in the region surrounding Paks [Bq/kg fresh weight] (courtesy of the HAEA and the Paks nuclear power plant).

I–111. Attempts to lift the lid of the cleaning tank, which started at 00:21 on 11 April 2003, required the presence of two Framatome advanced nuclear power operators — a crane operator and a fuel handling machine operator — as well as a member of the dosimetry control staff from among the Paks nuclear power plant personnel.

I–112. All personnel present were equipped with respirators connected to an external oxygen supply. The crane operator had a full beard underneath his respirator. He had not received formal training in the use of a respirator before the incident but was instructed at the time.

I–113. As part of the routine checks for contamination at the exit point from the reactor area, external contamination above the prescribed maximum level for normal operation was detected on the crane operator. He was decontaminated by repeated showering, after which his beard was shaved off and his hair cut. These activities reduced his external contamination levels to below the prescribed levels.

I–114. The operator implemented a programme to monitor the intakes of radionuclides by personnel present at the site during the incident, prioritized on the basis of the potential for intake. The first measurements were performed on the morning of 11 April 2003. Over six hundred personnel were measured using the whole body counter located at the Paks nuclear power plant. Only seven personnel had received intakes that indicated assessed doses of close to or above 0.1 mSv. Whole body monitoring of relevant personnel was also performed at the Frédéric Joliot Curie National Research Institute for Radiobiology and Radiohygiene. The two sets of results were consistent. Committed effective doses from the inhalation of radionuclides ranged up to approximately 1 mSv. The crane operator received the highest committed effective dose from intakes [I–28]. From the records reviewed, the highest doses from external gamma radiation, received by staff and contractors at the Paks nuclear power plant during and after the incident, were up to 7 mSv.

Communication and consultation with authorities and the public

I–115. With respect to emergency preparedness, the respective responsibilities of the HAEA and the operator appear to have been well defined, and there was no evidence to suggest that a lack of understanding of these responsibilities contributed to the impact of this incident.

I–116. The public was informed of the incident in the early hours of 11 April 2003. Thereafter, there was an emphasis on providing communications to the population of Paks and the regions in the vicinity of the plant. All locally available channels were used for this purpose. As new details became available, country-wide bulletins were issued. In addition, a number of press conferences were given. These channels generally provided objective and correct communications. The

Paks nuclear power plant answered all enquiries and accepted all requests for interview received from the press.

I–117. Two media releases were issued by the plant operator on 11 April 2003. The second one classified the incident as level 2 on the IAEA's International Nuclear and Radiological Event Scale (INES). The IAEA was informed on 17 April 2003, once the actual state of the fuel assemblies had been discovered, even though there was no obligation to do so under the Convention on Early Notification of a Nuclear Emergency. However, the use of the INES levels, which is intended to help to explain the severity of an emergency situation to the public, actually undermined the credibility of the authorities in this case. On 11 April 2003, the operator proposed, and the HAEA approved, the INES level 2 classification of the incident. On 17 April 2003, after the lid had been opened and a visual inspection of the fuel had revealed the full extent of the damage, the INES level was revised to level 3. Although this revision was correct, it created a public perception that either the incident was getting worse or that the authorities had not communicated fully in the first instance [I–28].

I–118. In accordance with national requirements included in the national emergency plan and the facility emergency plan, there was no need to warn the public of possible protective actions, given the nature of the hazard. However, the incident was immediately communicated to the mayors of the communities within a 30 km radius of the plant via a special SMS system provided for this purpose to allow the mayors to answer any questions that might be posed to them.

I–119. A press conference was held in the reactor hall of Unit 2 on 22 April 2003, and the Chair of the Environmental Committee of the Parliament was received at the plant on 27 April 2003 by the Chief Executive of the Paks nuclear power plant. On the following day, a number of parliamentary representatives accepted the invitation for an information meeting. On the same day, the Chief Executive met the mayors of the 13 neighbouring communities and the representatives of civilian organizations, who also visited the reactor hall.

I–120. The managers of the company also attended public hearings and meetings of local councils and regional associations for several months after the stabilization of the situation.

Investigation of the incident

I–121. The designers of the nuclear power plant had not expected that the fuel cleaning process could lead to an accidental release of radioactivity, and certainly not on the scale observed during the incident. A series of independent national and international investigations was conducted in order to understand the circumstances that led to the incident in order to draw conclusions for improving operational and emergency arrangements and to avoid the repetition of such an event [I–27 to I–30].

I–122. In accordance with regulatory requirements, the operator of the Paks nuclear power plant was required to conduct an investigation of the incident and to submit the investigation report to the HAEA. In parallel with this investigation, the HAEA conducted an independent investigation in line with its internal procedures. The HAEA investigation report was available and approved by the Director General of the organization on 29 May 2003 [I–27].

I–123. In view of the seriousness of the incident, the Hungarian parliament also appointed a parliamentary committee to investigate the causes of and responsibilities for the incident. This committee submitted its report to the Hungarian parliament by the end of 2003.

I–124. The Hungarian Government also invited an expert mission of the IAEA to assess the results of the HAEA investigation of the incident. The expert mission took place between 16 and 25 June 2003 and made several suggestions and recommendations for the improvement of the operation at the Paks nuclear power plant and the functioning of the regulatory system [I–28].

I–125. The Paks nuclear power plant invited an Operational Safety Review Team follow-up mission from 21 February to 1 March 2005 [I–29]. The mission focused primarily on the implementation of the suggestions and recommendations formulated during the previous Operational Safety Review Team mission, which had taken place between 8 and 25 October 2001, and the expert mission of the IAEA referred to above [I–29].

Revision of emergency arrangements following the incident

I–126. Following the IAEA expert mission, the Paks nuclear power plant prepared an action plan to address deficiencies identified in the following areas: management system, regulatory oversight, design, fuel cleaning operation, radiation protection, and emergency planning and preparedness. The action plan specified tasks and deadlines and was approved by the HAEA. Actions aimed at improving the arrangements that related to emergency preparedness and response were implemented by the Paks nuclear power plant by 2006 and included the following:

(a) The emergency classification scheme was revised to ensure that it covered all potential alert events and emergencies at the Paks nuclear power plant. The classification scheme included emergency action levels and readiness action levels[4] based on measured parameters. A comprehensive review of the plant hazard assessment was conducted to ensure that all potential accident sequences had been identified.
(b) The site emergency response plan was revised to include a procedure that took account of the revised emergency classification scheme and postulated emergency scenarios.
(c) The internal regulation on technological modifications at the Paks nuclear power plant was revised to ensure that the regulation covered interactions between the site emergency response plan and the impact of planned modifications. With this revision, it was necessary to conduct an analysis of the emergency related aspects of planned modifications before any decision on such modifications could be made.
(d) Verification and/or validation of the new Paks Release and Environmental Monitoring System related to critical parameters for emergency detection and classification was conducted. Actions were then taken to improve the system to better support emergency alert and notification activities.
(e) The emergency preparedness section and all contractors were required to participate in preparatory training for operative personnel on new safety relevant activities.
(f) The competent organization of the Paks nuclear power plant, which was responsible for the general management of emergency preparedness, was also involved in the assessment of the contractors' emergency procedures.
(g) The involvement of dosimetry control staff in the conduct of unanticipated drills or exercises.
(h) In addition, the Paks nuclear power plant decided to ensure that:
    (i) Emergency kits (containing gas masks, iodine tablets, breathing equipment, firefighters' clothes and personal dosimeters) for operating personnel would be available in each operational room;
    (ii) Field training on the application of breathing apparatus (for respiratory protection) would be adopted in relevant procedures for urgent protective actions;

[4] Readiness action levels represent the initiating levels for a new operational mode introduced for the Hungarian Nuclear Emergency Response System (referred to as 'Readiness Operational Mode') for implementation when no public protective actions are warranted but when coordination may be needed in the operation of the national radiation monitoring and warning system, in consequence assessment and in the provision of information to the public.

(iii) Training and field first aid tasks would be completed by facility fire brigade personnel.

Authorization for continuing normal operation

I–127. As a consequence of the incident, the conditions for safe operation could not be met and the operator of the Paks nuclear power plant could not complete its planned refuelling in April 2003. The following major activities were planned to be completed in the 2003–2004 period to recover conditions for safe operation:

(a) Ensure the subcriticality and cooling of the fuel debris structure.
(b) Decontaminate the internal surfaces of the primary circuit.
(c) Re-establish conditions for conducting refuelling.
(d) Ensure safe conditions for the long term storage of fuel debris.

I–128. These activities were implemented under the supervision of the HAEA. For each major step, a licence application was submitted by the operator of the Paks nuclear power plant to the HAEA, and a formal authorization process was conducted. Finally, when all safety conditions and regulatory requirements had been met, a new operational licence was issued for Unit 2 to restart operation in September 2004.

I–129. Other series of activities were aimed at the removal of the fuel debris from the chemical cleaning vessel, the establishment of safe conditions for storing the removed fuel debris and the removal of the chemical cleaning vessel from the service pool to re-establish safe operation in the service pool, which was an integral part of the pool system of Unit 2. In early 2004, at the beginning of these activities, the HAEA issued regulatory requirements for nuclear and radiation safety and security and for the management system of all recovery works and operations. The unique nature of the incident required an overview of the wide range of existing requirements at national and international levels and, in some cases, the derivation of further requirements. The removal and recovery process was designed, planned and implemented by several domestic and international expert organizations that provided support to the Paks nuclear power plant operational staff and independently to the HAEA. The operator of the Paks nuclear power plant was required to regularly submit reports on the progress of the recovery operations. At the end of the authorization process, licences were issued to produce and use debris fuel containers, to utilize various kinds of technical equipment necessary for the removal activities and to remove the fuel debris and the chemical vessel. All recovery operations were conducted by the end of 2007.

Conclusions

I–130. The fuel cleaning incident occurred on 10 April 2003 during a scheduled maintenance shutdown. Thirty fuel assemblies had been removed from the Unit 2 reactor and placed in a fuel cleaning tank under water in a shaft adjacent to the fuel pool. The plan was to remove magnetite deposition on fuel cladding by means of a specially designed chemical cleaning process.

I–131. An increase of activity within the reactor hall was detected by the workers. Once the noble gas monitors in the reactor hall had indicated that the emergency level had been reached, the evacuation of workers from the reactor hall was ordered. Although the airborne release was higher than the normal situation, it exhibited a decreasing tendency and, according to the data available, did not approach the national prescribed discharge limits. When all of the information and release data had been collated and reviewed, the situation was re-evaluated, and it was confirmed that the event did not constitute an accident.

I–132. After the incident had been identified, the SERO was partially set up to provide continuous control and evaluation of the occurrences. The SERO operated in accordance with the relevant procedures until 13 April 2003, when its operation was terminated. After the removal of the tank lid on 16 April 2003, the extent of the damage to the fuel assemblies within the tank was recognized and the SERO was reactivated. This status was maintained until 20 April 2003. During this period, the SERO operated in partial response mode at the emergency response centre and continually evaluated the situation, kept in contact with authorities and exercised readiness for full activation if the situation got worse.

I–133. During the recovery operations, professional teams involving specialists from various fields of expertise were established to identify alternatives for recovery. An autonomous cooling system and the emergency boron system for the service pool were established during the first half of 2004.

I–134. A coordinated environmental monitoring survey was initiated to assess the radiological situation in the areas surrounding the Paks nuclear power plant to determine whether any off-site protective actions were needed and to provide authentic, trustworthy and timely information to the public. The survey covered the entire period of the incident from 10 to 26 April 2003. On the basis of the measurements results and the assessment of the situation after the incident, it was concluded that no significant release had occurred and that no actions were needed for the protection of the public.

I–135. Appropriate procedures (e.g. collective and personal protective measures) were followed to minimize the doses to workers involved in the management of the incident and to keep the worker doses within the occupational dose limits for normal operation. Dose estimation and medical consultation for workers were also considered.

I–136. The national requirements and the nature of the hazard did not necessitate warning the public of impending protective actions. However, the incident was immediately communicated to the mayors of communities within a 30 km range of the power plant. The public was informed of the incident in the early morning of 11 April 2003. Particular emphasis was placed on public communications, and all locally available channels of communication were used for this purpose.

I–137. A series of independent national and international investigations was conducted following the incident to determine its causes and the circumstances that led to the incident in order to draw conclusions for improving operational and emergency arrangements and for avoiding the repetition of such an event.

I–138. As a consequence of the incident, the Paks nuclear power plant could not complete its planned refuelling in April 2003, and a series of activities was planned to re-establish the conditions for safe operation, to be completed in the 2003–2004 period. These activities were implemented under the supervision of the HAEA.

I–139. In a retrospective analysis of the event, the specific phases and their timing are represented in Fig. I–12, shown against the phases described in Section 2 of this Safety Guide. The emergency started on 10 April 2003, when limited urgent protective actions on the site to protect the personnel present were required. This state lasted from 10 to 20 April 2003, when efforts focused on assessing the situation and its severity. During this period, all necessary measures were taken to ensure continuous cooling and monitoring of the damaged fuel and stabilization of the situation. Until 26 April 2003, the monitoring and assessment efforts continued to confirm the stability of the situation. The damaged fuel was brought under control, and the consequences on the site as well as off the site were in the process of being assessed. After this period, beginning in May 2003, further planning for the recovery and investigation of the circumstances that led to the incident were carried out. As a result, in the second half of 2004, the Paks nuclear power plant was able to resume normal operation in compliance with national regulations. The public did not experience a new exposure situation as a result of this incident.

I–140. The results of an analysis of the case study that looked at the fulfilment of the prerequisites for the termination of a nuclear or radiological emergency, contained in Section 3 of this Safety Guide, are presented in Tables I–6 and I–7. These tables reflect the situation that existed on 26 April 2003 (see Fig. I–12), which is the date at which the retrospective analysis indicates that the conditions for termination existed.

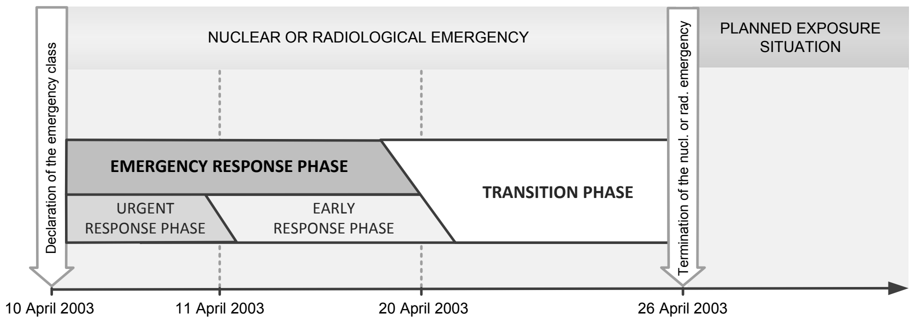

FIG. I–12. Retrospective sequencing and milestones of the Paks fuel damage incident.

TABLE I–6. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: PAKS FUEL DAMAGE CASE STUDY

General prerequisite	Status with respect to the prerequisite
Had the necessary urgent and early protective actions been implemented?	Workers were evacuated from the reactor hall area immediately after the detection of emergency levels of noble gases. The assessment results indicated that no other protective actions needed to be implemented for other site personnel or for members of the public.
Was the exposure situation stable and well understood?	To develop a more detailed understanding and assessment of the radiological situation, various activities were carried out in a coordinated manner. These activities resulted in an adequate estimation of the release source term. The airborne releases were continuously monitored, and the reduction and stability of the levels were confirmed within the first week after the onset of the incident.
Was the radiological situation well characterized, and were the exposure pathways identified and doses assessed for all the affected people?	The radiological situation was well characterized, potential exposure pathways were identified and doses were assessed for potentially affected people. An assessment of the doses showed that the radiological consequences of the incident were of low significance.
Was the source of exposure brought under control, and were no further significant accidental releases or exposures expected due to the event?	After the cover of the cleaning tank had been lifted, the possibility of further radioactive release was recognized and the SERO was partially reactivated. The SERO managed the situation and focused on preventing further releases. An important measure was the establishment on 20 April 2003 of a plastic foil greenhouse above the pond containing the cleaning tank.
Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?	The SERO continuously assessed the situation and the possible impacts on the plant safety measures and on emergency arrangements. Several independent assessments were also conducted in 2003. As a result, the operator of the Paks nuclear power plant reviewed on-site emergency plans and prepared an action plan to address necessary corrective measures and to revise the emergency arrangements. The necessary improvements were implemented by 2006.

TABLE I–6. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: PAKS FUEL DAMAGE CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Were the requirements for occupational exposure in a planned exposure situation confirmed for all workers engaged in recovery activities?	Because of the nature of the hazard it was possible to conduct all response actions and recovery operations within the dose limits for normal operations. Various measures were implemented to monitor the doses received by recovery workers. Personal external dosimeters were provided for anyone entering the main operational areas of the site. A film badge, distributed and evaluated by the radiation protection authority, provided the legal dose measurement. A thermoluminescent dosimeter was also provided for the recovery workers by the Paks nuclear power plant. People entering the reactor areas also received an electronic dosimeter. Reactor operation and maintenance personnel were equipped with thermoluminescent neutron dosimeters. Contractors also wore their own dosimeters. Dosimetric data from external monitoring of the contractors and of the Paks nuclear power plant staff on-site were collected and recorded. Results were provided from the dosimeters of the workers involved in the incident. The results were found to be consistent.
Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?	The radiological situation was assessed against the different response criteria, and it was concluded that none of the criteria had been exceeded. The doses assessed remained within the dose limit for normal operation for both the public and the workers.

TABLE I–6. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: PAKS FUEL DAMAGE CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Were non-radiological consequences (e.g. psychosocial, economic) and other factors (e.g. technology, land use options, availability of resources, community resilience) identified and considered?	The off-site radiological consequences of the incident were of low significance. No specific actions were taken to reduce the off-site non-radiological impact, except for the provision of timely and consistent public information. However, increased pressure from the media was observed during the first few weeks after the incident. An ad hoc public information policy was launched for the Paks nuclear power plant, the HAEA and the National Directorate General for Disaster Management to harmonize the ways of communicating with the public and the content of the information provided. The HAEA regularly uploaded to its web site public information articles about the results of assessments and measurements. A major contributor to the non-radiological consequences of the incident was the economic loss sustained. One component of the economic loss was the damage to the fuel assemblies, which if undamaged could have been used for electricity production. Another component was the prolonged shutdown of Unit 2, which lasted about 1.5 years, with no generation of electricity. The third component was the expense associated with the re-establishment of safe operating conditions of Unit 2, especially given that the service pool was unavailable. The fourth major component involved the costs of the removal of the fuel debris and the cleaning vessel and the establishment of safe storage conditions for the damaged fuel.
Was a registry of those individuals requiring further medical follow-up established before the termination of the emergency?	Doses to members of the public and workers were within the dose limits for normal operation. Therefore, no individuals required medical treatment or further medical follow-up after the incident.

TABLE I–6. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: PAKS FUEL DAMAGE CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was a strategy for the management of radioactive waste arising from the emergency developed when appropriate?	The Paks nuclear power plant had (and has) in place internal regulations and a general strategy for the management of radioactive waste arising from normal operations and emergencies. During the incident, the plant was confronted with a new situation for which standard solutions were not available. After the initial measures, the operator of the Paks nuclear power plant introduced a recovery plan in 2004, which established dedicated strategies for the management of radioactive waste and the development of the storage areas, as needed. The radioactive waste generated during the time of recovery works was managed by applying this strategy. The Paks nuclear power plant completed the corrective action plan by the end of 2006.
Were the interested parties consulted?	In cases of abnormal conditions, the site emergency plan requires that off-site authorities receive information within two hours of detecting the abnormal event, and that this information is updated within 24 hours. During this incident, the authorities required information from the operator with greater frequency and detail. The public was also informed promptly. The IAEA was informed on 17 April 2003, after the actual status of the fuel assemblies had been discovered, even though there was no obligation under the Convention on Early Notification of a Nuclear Accident to do so. Because of the nature of the hazard, the incident did not warrant consultation with interested parties other than the off-site authorities, technical support organizations and scientific institutions. Consultation was initiated as early as possible after the incident to assess the situation and plan the recovery operations.

TABLE I–7. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO A PLANNED EXPOSURE SITUATION: PAKS FUEL DAMAGE CASE STUDY

Specific prerequisite	Status with respect to the prerequisite
Were the circumstances that led to the emergency analysed and corrective actions identified?	The SERO of the Paks nuclear power plant investigated the circumstances that led to the incident to identify the causes and any necessary improvements in existing arrangements. Additional, independent investigations and missions (including from the IAEA) were carried out in 2003.
Was an action plan developed for implementation of corrective actions by the respective authorities?	Corrective actions in various areas were identified on the basis of the outcomes of the specific investigations. An action plan was developed to address the findings, identify corrective actions to be implemented and identify lessons for improving the existing arrangements. All the findings were addressed in the 2004–2007 period. A set of corrective actions in relation to the management and operation of the Paks nuclear power plant was required in the HAEA regulatory resolution. The HAEA then followed the implementation of the corrective actions before issuing an operational licence in September 2004. The status of the implementation of these corrective actions was also reviewed during several international follow-up missions.
Were the conditions assessed to ensure compliance with the safe and secure handling of the sources in accordance with the national requirements set forth for the planned exposure situation?	Because of the unique nature of the damaged fuel debris, specific regulatory requirements for nuclear and radiation safety and security and for the management of all recovery works and operations were established and issued by the HAEA. Compliance with these requirements was assessed throughout the recovery operations.

TABLE I–7. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO A PLANNED EXPOSURE SITUATION: PAKS FUEL DAMAGE CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was there a necessity for administrative procedures to limit or prevent any use or handling of the source until a better understanding of the circumstances that led to the emergency had been obtained?	The refuelling, planned for April 2003, was halted until it could be carried out safely, after the necessary recovery work. This work was conducted in accordance with plans and specific instructions so that the work could be carried out safely and securely as a normal operation. Finally, after compliance with all the regulatory requirements for the safe operation of Unit 2 had been achieved, a licence was granted to the operator to resume normal operation.
Was compliance with the requirements for dose limits for public exposure in planned exposure situations confirmed?	Doses to members of the public were continuously assessed. It was confirmed that throughout the incident the doses remained below the dose limits for members of the public in normal operation.

THE RADIOLOGICAL INCIDENT IN HUEYPOXTLA, MEXICO[5]

I–141. At 08:13[6] on 2 December 2013, the Mexican nuclear regulatory body, the National Commission of Nuclear Safety and Safeguards (CNSNS), received a notification from a worker of a company authorized to transport radioactive material about the theft of a vehicle transporting the head of a teleterapy unit containing a ^{60}Co source (see Fig. I–13). The activity of the source was estimated to be 111 TBq[7]. The vehicle was stolen from a gas station near Tepojaco, in the municipality of Tizayuca, in Hidalgo State. The source belonged to the Mexican Social Security hospital in the city of Tijuana, Baja California State, and was being transported to the radioactive waste storage facility located near the town of Santa María Maquixco, Temascalapa municipality, Mexico State.

I–142. After the notification, CNSNS personnel contacted the transport company to validate the information and to investigate the circumstances under which the incident had occurred. At that point, the CNSNS learned that, at approximately 02:00 on 2 December 2013, a group of armed individuals assaulted the driver of

FIG. I–13. Vehicle transporting the teletherapy unit with ^{60}Co (courtesy of CNSNS).

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[5] This summary was drafted by the National Commission for Nuclear Safety and Safeguards of Mexico on the basis of internal records related to the incident and does not include nuclear security considerations in relation to the incident.

[6] All times in the case study are local time (UTC –06).

[7] On the basis of this activity, the ^{60}Co source falls into Category 1 of radioactive sources in line with the IAEA Safety Standards Series No. RS-G-1.9, Categorization of Radioactive Sources [I–31].

the vehicle, who had been resting at the gas station, before taking the vehicle, together with the radioactive source.

Emergency declaration and urgent protective actions

I–143. The CNSNS personnel reviewed their databases to obtain more precise information about the stolen radioactive source, including its activity (95.24 TBq), the serial number of the source and the characteristics of its shielding. CNSNS then drafted an information bulletin for distribution by the Civil Protection Agency. The bulletin described the incident, the potential risks of handling the radioactive source, the immediate actions to be taken by responders and the public should they encounter the source and the telephone numbers to contact if the source were found. This bulletin was transmitted on 2 December 2013 at 13:00 to the governments of the states of Hidalgo, Veracruz, Puebla, Tlaxcala, Mexico City, Mexico State, Querétaro and San Luis Potosí, as well as the federal authorities. Later, the IAEA was also informed via the Unified System for Information Exchange in Incidents and Emergencies.

I–144. After the receipt of a communication from the army informing the federal police that the vehicle had been found near the municipality of Hueypoxtla on 2 December 2013, federal police officers were sent to verify the information and to search the area for the radioactive source. A person from the community allowed the federal police officers to enter his house, where they found the empty shielding of the radioactive source in the backyard (see Fig. I–14). The police officers reported their discovery to the CNSNS on 4 December 2013. On the same day, at approximately 08:00, the CNSNS sent two teams equipped with vehicle based radiation detectors to perform a search within a 10 km radius of the site, and the federal police searched locations in the municipalities of Tizayuca and Zumpango and the surrounding areas.

I–145. The federal police officers detected unusual radiation levels in a corn field approximately 1 km from where the shielding had been found. The police then contacted the CNSNS to request that personnel be sent to search for the source and that the area be cordoned off. The federal police and the army were asked to secure and guard the area in the meantime to ensure that only authorized personnel could enter it.

Isolation of the source

I–146. On 4 December 2013, the CNSNS sent two teams from the CNSNS Radiological Contingencies Organization to continue the search for the

FIG. I–14. The empty shielding of the radioactive source (courtesy of the CNSNS).

radioactive source. The federal police briefed the CNSNS staff about the possible discoveries in Hueypoxtla. The CNSNS staff analysed the photographs taken by the federal police officers and confirmed that the photographs appeared to be of an empty source container. The federal police guided the CNSNS staff to the areas where elevated radiation levels (ambient dose equivalent rates), exceeding 100 μSv/h, had been detected. The federal police also assisted additional staff from the CNSNS, who were equipped with specialized equipment and arrived at Hueypoxtla by helicopter. With no lighting available, initial area monitoring was carried out quickly during the evening to identify the location of the radioactive source; the federal police were asked to control access to this area in particular.

I–147. On 5 December 2013, the activities aimed at delineating the areas exhibiting elevated radiation levels and locating the source continued. Once the search perimeter of the source had been reduced sufficiently, the CNSNS contacted the CFE–Laguna Verde Nuclear Power Plant (CNLV) and the Ministry of the Navy to assist in planning actions to recover the radioactive source.

I–148. On 6 December 2013, the CNSNS team at Hueypoxtla was reinforced by the arrival of staff from the CNLV and the Ministry of the Navy. CNLV staff entered the area previously identified by the CNSNS and determined the approximate location of the source. The National Institute of Nuclear Research was requested to provide a suitable container to contain the radioactive source for further transfer. Although such a container was not readily accessible, some adjustments to an available container were made to allow that container to be used for the intended purpose.

I–149. On 7 December 2013, staff of the CNSNS, the CNLV, the Ministry of the Navy and the federal police started planning to remove crops from the area by using a robot belonging to the federal police to enable the source to be located more exactly. On the same day, the CNSNS received information that the person who had found the radioactive source was willing to indicate where it had been hidden. With the help of this person, the exact location of the source (which had previously been unshielded) was determined. CNLV and CNSNS staff asked the person about the amount of time he had spent near the source and offered to give him a medical examination, but the person declined.

I–150. On 8 December 2013, staff of the CNSNS, the CNLV, the Ministry of the Navy and the federal police returned to the area to continue the crop removal process remotely, so that the radioactive source would become more visible. These tasks continued until the robot had a mechanical failure. The CNSNS headquarters arranged for the transportation of the radioactive source after its recovery. In parallel, additional resources, such as concrete containers and lead blankets, were brought from CNLV facilities in Veracruz to help improve protection during transportation.

I–151. On 9 December 2013, CNLV personnel entered the area and finished the crop removal process, allowing the radioactive source to be seen (see Fig. I–15). The integrity of the source was confirmed. However, as repair work on the robot continued, alternative plans for the recovery of the source were necessary.

I–152. On 10 December 2013, the modified container arrived from the National Institute of Nuclear Research and the repaired robot also became available. The arrangements for the recovery of the radioactive source began on that day and included logistical support from the federal police and the Mexican Navy. The images taken by the robot camera confirmed that the source was intact, and after two attempts the robot was able to hold the source and deposit it inside the container, which was then closed. After the container was closed, the CNSNS staff measured the radiation levels at the surface of the container and found the levels to be very low. This action was followed by a survey of radiation levels in the area in which the source had been found, and only background radiation levels were detected. An additional survey of the area conducted on 13 December 2013 confirmed these results.

I–153. The CNSNS, the National Institute of Nuclear Research, the federal police and the transport service provider agreed on the time, route and escort for the transportation of the radioactive source to the facilities of the National Institute of Nuclear Research at Ocoyoacac, Mexico State, where the source was to be

FIG. I–15. Exposed radioactive source (courtesy of Federal Commission for Electricity of Mexico).

conditioned and stored before its disposal at the National Institute of Nuclear Research radioactive waste disposal facility in Temascalapa.

I–154. A dose limit of 50 mSv effective dose was set for the workers involved in the recovery process. The average dose received was less than 3 mSv, and the highest value was around 20 mSv.

Communicating with the public

I–155. On 4 December 2013, the public was informed by the Incident Command Group, consisting of representatives from the CNSNS and the Ministry of Health, of the dangers of handling and being close to the source, although the source was known to be located far away from any settlements. The Incident Command Group called on all those who may have been in contact with or in the immediate vicinity of the source to attend the hospital in Pachuca to have their doses estimated and to identify whether medical follow-up would be needed. Many enquires were received from villagers in Hueypoxtla regarding the status of the situation, the measures being taken and the progress of the operation. These queries were answered by a member of CNSNS staff at the scene. However, as the situation showed signs of becoming unstable, the federal police discontinued this interaction by removing the representative of the CNSNS from among the crowd.

Medical response and assessment of doses

I–156. On 8 December 2013, the CNSNS contacted personnel from the Ministry of Health of the State of Veracruz, who acted as members of the external radiological emergency team of the CNLV, for support in examining individuals who may have been in contact with the radioactive source. The state Ministry of Health contacted staff of the federal Ministry of Health to ask for support in case it became necessary. The federal Ministry of Health confirmed the activation of its staff along with that of the state Ministry of Health on 9 December 2013.

I–157. On 9 December 2013, representatives of the state and federal Ministries of Health were accompanied by CNSNS personnel to the Hospital de Pachuca to begin examination of individuals who may have been exposed to the source. The personnel then moved to Hueypoxtla to examine the individual who had assisted in locating the source and another individual who was believed to have had contact with the source in its shielded state. The second individual was found to have no symptoms of radiation exposure. The first individual was found with symptoms of radiation exposure on the left shoulder and right leg and was taken to the Hospital de Nutrición in Mexico City for treatment and follow-up. No dose assessment for this individual was performed at that time.

I–158. On 10 December 2013, the federal Ministry of Health implemented a field investigation, questioning the people who were present at the site on the day the source had been found, reconstructing events and assessing the acute radiation exposure risk among these people. A total of 59 people who were presumed to have been exposed were identified. Within this group, 31 of the people were found not to have been present at the relevant dates and times. For 22 persons, a reconstruction of events was carried out to evaluate their possible exposure and to estimate the received doses, as a basis for assessing the acute radiation exposure risk.

I–159. On 13 December 2013, the federal Ministry of Health and the CNSNS requested that the National Institute of Nuclear Research perform biological dosimetry studies on ten people, four of whom presented symptoms that could be associated with acute radiation syndromes.

I–160. On 15 December 2013, the National Institute of Nuclear Research performed the biological dosimetry studies of the ten people identified by the federal Ministry of Health as presumed to have been exposed. The findings indicated that only one person exceeded the limit specified in the Mexican regulation to prevent non-stochastic effects among occupationally exposed personnel (500 mSv annual whole body effective dose).[8] This finding suggested that the person who had helped the Mexican authorities to locate the source was the only person who had handled the source after it had been removed from its shielding.

Transition phase

I–161. By 4 December 2013, the area where the radioactive source had been found had been cordoned off, and a security perimeter had been established. The risk of members of the public being exposed by entering this area and handling the source had thus been minimized. The radioactive source was found to be intact in a cornfield at some distance from any settlements. The next six days were used to plan and prepare for the recovery of the source.

I–162. A dose criterion of 500 mSv was established for medical examinations and follow-up of members of the public who may have been exposed. A limit of 50 mSv was also established for the personnel involved in the source recovery.

I–163. The person who had been in contact with the radioactive source, and had received a dose in excess of 500 mSv as a consequence, was transferred to the Hospital de Nutrición in Mexico City on 7 December 2013 for treatment and follow-up.

Conclusions

I–164. The Hueypoxtla accident demonstrated that a radiological emergency could occur outside of the licensed installations in Mexico. The incident also showed that such an emergency could arise as a consequence of security events that might not be directly related to radioactive material itself. The incident highlighted the need to care for all the members of the public who may be involved in such events and to provide for their reassurance. As a consequence of this incident, the Mexican authorities concluded that such emergencies could not be dealt with by a single agency and that it was necessary to develop a multiagency plan for response to radiological emergencies, in which the responsibilities and resources of every agency would be described and clearly defined.

I–165. In a retrospective analysis of the event, the specific phases and their timing are represented in Fig. I–16, shown against the phases described in Section 2 of

[8] Since, in the Mexican regulation, there are no exposure limits to the public in case of a radiological emergency, it was agreed to use the limit of non-stochastic effects for the occupationally exposed personnel.

this Safety Guide. The emergency started on 2 December 2013, when the vehicle transporting a dangerous radioactive source was stolen. The urgent response phase lasted until 4 December 2013, during which time the focus was on the efforts to locate the source and to issue warnings and information to the public and the media. On 4 December 2013, the source was located in an area of Hueypoxtla. The source location was cordoned off to secure the source and to prevent any individual from being unnecessarily exposed, while allowing the authorities to further identify the exact location and status of the source. This phase lasted until 9 December 2013, when the crops surrounding the source had been removed. The source was then visible, and its integrity could be confirmed. Meanwhile, the plan for storing the source had been developed and organized, resulting in rapid recovery of the source and its transport for conditioning before final disposal on 10 December 2013. By this date, the monitoring activities to confirm the absence of contamination had been completed, and all individuals who may have been in contact with the source had been identified for dose assessment and medical follow-up. Thus, this milestone is considered to represent the termination of the emergency and the move to a planned exposure situation related to the further management of the source as radioactive waste. No new exposure situation for members of the public arose as a result of this incident.

I–166. The results of an analysis of the case study that looked at the fulfilment of the prerequisites for the termination of a nuclear or radiological emergency contained in Section 3 of this Safety Guide are presented in Tables I–8 and I–9. These tables reflect the situation that existed on 10 December 2013 (see Fig. I–16), which is the date at which the retrospective analysis indicates that the conditions for termination existed.

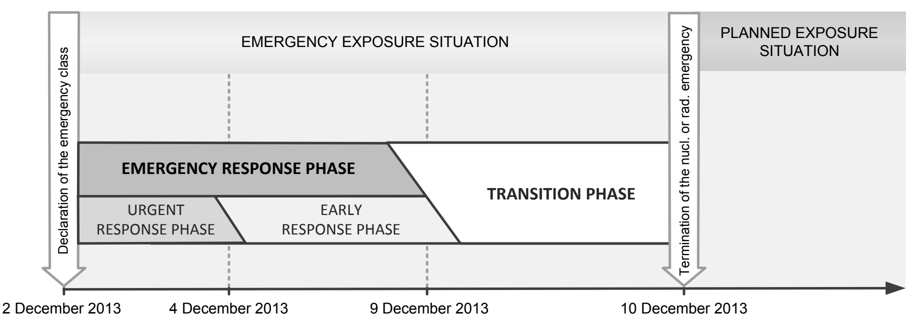

FIG. I–16. Retrospective sequencing and milestones of the radiological incident in Hueypoxtla.

TABLE I–8. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: HUEYPOXTLA CASE STUDY

General prerequisite	Status with respect to the prerequisite
Had the necessary urgent and early protective actions been implemented?	Members of the public and first responders had been informed of the risks associated with the stolen radioactive source and the precautions that needed to be taken in the event that the source was found. The location of the radioactive source had been identified, the area had been cordoned off and access controls had been established. The person who had handled the unshielded radioactive source had been identified.
Was the exposure situation stable and well understood?	The radioactive source had been isolated, and it had been confirmed that the source was intact and that radioactive material had not been dispersed. Thus, further unexpected evolution of the situation was not anticipated.
Was the radiological situation well characterized, and were the exposure pathways identified and doses assessed for all the affected people?	Monitoring had been carried out, the affected people had been identified by 10 December 2013 and doses had been either assessed or arrangements had been made for dose assessment.
Was the source of exposure brought under control, and were no further significant accidental releases or exposures expected due to the event?	The radioactive source had been located, the area had been cordoned off and access controls were in place, preventing further significant exposure due to the unshielded source.

TABLE I–8. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: HUEYPOXTLA CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?	Mexico had developed plans and arrangements for a nuclear emergency at the CNLV, but there were no plans in place for responding to a radiological emergency at the national level. Interinstitutional plans had also not been developed. As a lesson learned from this incident, the CNSNS was working in cooperation with the Civil Protection Agency to develop such a plan, at the time of drafting this case study.
Were the requirements for occupational exposure in a planned exposure situation confirmed for all workers engaged in recovery activities?	The response to this incident, including locating the radioactive source and its recovery, was carried out within the dose limits for normal operation of 50 mSv annual effective dose prescribed in the Mexican regulations. The average dose received by the workers was less than 3 mSv, and the highest value was around 20 mSv.
Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?	A criterion of 500 mSv was set to determine the possibility of non-stochastic effects among members of the public who were presumed to have been exposed. An occupational dose limit of 50 mSv effective dose was established for workers engaged in the recovery of the source.
Were non-radiological consequences (e.g. psychosocial, economic) and other factors (e.g. technology, land use options, availability of resources, community resilience) identified and considered?	The federal Ministry of Health and the CNSNS endeavoured to provide public information to reassure the public living in the area where source was found and to directly respond to questions regarding the situation. The public was repeatedly assured that there was no danger in continuing daily activities as normal.

TABLE I–8. STATUS WITH RESPECT TO THE GENERAL PREREQUISITES FOR TERMINATION OF AN EMERGENCY: HUEYPOXTLA CASE STUDY (cont.)

General prerequisite	Status with respect to the prerequisite
Was a registry of those individuals requiring further medical follow-up established before the termination of the emergency?	The affected people had been identified by 10 December 2013 through a reconstruction of the event. Dose assessments for each identified individual were then conducted. These assessments provided a basis for medical treatment by health professionals.
Was a strategy for the management of radioactive waste arising from the emergency developed when appropriate?	Planning for the management of the source as radioactive waste took place during the period in which the source was being located and isolated. On 10 December 2013, the radioactive source was transported to the National Institute of Nuclear Research facilities at Ocoyoacac to be conditioned before its transfer to the radioactive waste disposal facility.
Were the interested parties consulted?	Limited consultation was necessary because of the type of event. However, the CNSNS created a bulletin for distribution by the Civil Protection Agency among the involved agencies. The bulletin provided information about the event, the associated risks and the precautions that needed to be taken. National authorities gave information to the national and international media regarding the incident and the risks and precautions that needed to be taken. The CNSNS informed members of the public present at the site of the incident of the development of the recovery tasks and assured the public that there was no risk of contamination or exposure in the area after the source had been recovered.

TABLE I–9. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO A PLANNED EXPOSURE SITUATION: HUEYPOXTLA CASE STUDY

Specific prerequisite	Status with respect to the prerequisite
Were the circumstances that led to the emergency analysed and corrective actions identified?	During the incident, it became evident that licensees needed to take measures to strengthen security arrangements during the transport of Category 1 radioactive sources, in cooperation with the federal police and the CNSNS. In addition, the necessity of developing and maintaining a national response plan for radiological emergencies was identified, including the need to identify all the involved agencies and their responsibilities.
Was an action plan developed for implementation of corrective actions by the respective authorities?	Shortly after the incident, the CNSNS established requirements for the measures to be undertaken by licensees during the transport of Category 1 radioactive sources. At the time of the drafting of this case study, the CNSNS and the Civil Protection Agency were working on the development of a national response plan for radiological emergencies, including identifying the agencies involved and their respective responsibilities.
Were the conditions assessed to ensure compliance with safe and secure handling of the sources in accordance with the national requirements set forth for the planned exposure situation?	The conditions were assessed to ensure compliance, and new measures for the secure transport of radioactive sources were introduced, as explained above.

TABLE I–9. STATUS WITH RESPECT TO THE SPECIFIC PREREQUISITES FOR TRANSITION TO A PLANNED EXPOSURE SITUATION: HUEYPOXTLA CASE STUDY (cont.)

Specific prerequisite	Status with respect to the prerequisite
Was there a necessity for administrative procedures to limit or prevent any use or handling of the source until a better understanding of the circumstances that led to the emergency had been obtained?	The operational life of the radioactive source involved in the incident was ended following the recovery, and the radioactive source was dealt with as radioactive waste. Thus, there was not a need to set any such administrative measures, except those implemented during the recovery process.
Was compliance with the requirements for dose limits for public exposure in planned exposure situations confirmed?	All the recovery operations were carried out within the dose limits for normal operation. The management of the radioactive source as radioactive waste followed the national regulations for normal operation.

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Annex II

FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY

II–1. Many factors, both radiological and non-radiological, influence the choice of protective actions and other response actions within a protection strategy for a nuclear or radiological emergency. For each of these factors, it may be necessary for different organizations and bodies to contribute to the decision making processes. The table below lists a number of these factors to help emergency planners and decision makers to identify the organizations and relevant interested parties that need to be prepared to contribute to, and should be involved in, the development and implementation of justified and optimized protection strategies, as appropriate, as described in Section 4.

II–2. Table II–1 builds on the guidance provided in the Nordic Guidelines and Recommendations[1] on the factors affecting the choice of protective measures, especially in the intermediate phase[2]. The list of factors in the table is not intended to be exhaustive, but this list can be used as a starting point for the development of a national list of factors to be considered in the justification and optimization of the protection strategy at the preparedness stage. The list could also be used for the transition phase of a nuclear or radiological emergency.

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[2] The concept of an 'intermediate phase' as used in the Nordic Guidelines and Recommendations (see previous footnote) roughly equates to the transition phase, as the term is used in this Safety Guide.

TABLE II–1. COMPILATION OF FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY

Category	Factors
General goals	Goals of emergency response Primary objective of the termination of an emergency Primary prerequisites for the termination of an emergency Specific prerequisites for the termination of an emergency
Legislation and regulations	Criteria for implementing protective actions and other response actions: — Generic criteria — Operational criteria (operational intervention levels, emergency action levels, observables) Reference level for emergency exposure situation Measures for protecting emergency workers, including guidance values for restricting the exposures of emergency workers in emergency response Other respective requirements and guidance for planned, emergency and existing exposure situations Commitments under relevant international instruments or bilateral and multilateral agreements in relation to transnational or transboundary emergencies
Nature of the emergency exposure situation	Radionuclides involved Activities and associated hazards Expected evolution of the situation Location and size of the affected area Number of exposed people Emergency response actions implemented during the urgent and early response phases

TABLE II–1. COMPILATION OF FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY (cont.)

Category	Factors
Radiation protection	Radiological situation: — Exposure scenario and dominant exposure pathways — Contamination of the living environment (dose rates, surface activity concentrations, activity concentrations in samples) — Contamination of food, milk and drinking water — Contamination of non-food commodities Dose to the public (projected doses, received doses, residual doses) Dose to the emergency workers and helpers Radiation induced health effects Need for medical follow-up
Timing	Urgency associated with implementation of effective protective actions Time needed for the implementation of protective actions Duration of protective actions Timescale over which doses will be or are received
Efficiency	Feasibility of actions (e.g. constraints of season of the year, weather conditions including meteorological hazards) Reducing exposure and contamination in consideration of pre-set reference level Limitations (technical, social, environmental, economical) Acceptability of protective actions Interaction between different actions

TABLE II–1. COMPILATION OF FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY (cont.)

Category	Factors
Resources	Availability of human resources Knowledge, skill and training needs Availability of material (trucks, buses, machinery, etc.) Availability of financial resources Availability of iodine thyroid blocking agents Availability of chemicals and other means/resources for decontamination and decorporation Availability of infrastructure and services (e.g. for the relocation of people; for waste treatment, storage and disposal; for land use reconversion and change in industrial processes; for longer term medical follow-up and psychosocial support) Availability of logistical support
Environmental aspects	Type of affected area: urban, recreational, industrial, agricultural, forest, etc. Type of surface: buildings, roads, agricultural or forest soil, etc. Geographical location of area (coast, mountain, etc.) and geology Indirect effect (e.g. use of land for other purposes)
Economic aspects	Direct costs associated with the implementation of emergency response actions Indirect costs associated with impacts from consequences of the emergency (e.g. costs of management of waste generated in the nuclear or radiological emergency) Compensation issues Interruptions in international trade Expected market response and evolution in the future

TABLE II–1. COMPILATION OF FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY (cont.)

Category	Factors
Social and ethical aspects	Disrupted living conditions Reduction in life expectancy due to stress (e.g. associated with resettlement) Impact on mental health and well-being Psychosocial effects Possibility of public self-help actions Feedback from interested parties on their concerns Socioeconomic aspects, including issues associated with public trust and credibility of authorities Need for routine public services (transport, shops, medical care, education, etc.)
Waste	Production of radioactive waste and its relation to emergency response actions Type of waste and options for its characterization Options for predisposal management and for minimizing amount of waste Available waste management facilities and practices

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