Version 2.0

Dated: 2016-03-03

Arrangements for the Termination of a Nuclear or Radiological Emergency

Jointly sponsored by the
XXX

General Safety Guide
No. GSG-x

Draft DS474

Status: STEP 7 – First review of the draft publication by the Safety Standards Committees (EPReSC, RASSC, WASSC, TRANSSC and NUSSC).

Action: For approval for submission to Member States and relevant international organizations for comments.

IAEA
International Atomic Energy Agency

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 (the 'Assistance Convention') [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 such accidents or emergencies.

1.2. In March 2015, the IAEA's Board of Governors approved a Safety Requirements publication, Preparedness and Response for a Nuclear or Radiological Emergency, issued in the IAEA Safety Standards Series as Part 7 of the General Safety Requirements (hereinafter referred to as GSR Part 7) [2], which was jointly sponsored by thirteen international organizations. GSR Part 7 establishes requirements for an adequate level of preparedness and response for a nuclear or radiological emergency[1] irrespective of the initiator of the emergency; it is a revised and updated version of the IAEA Safety Standards Series No. GS-R-2[2] issued in 2002.

1.3. Requirement 18 of GSR Part 7 [2] requires governments to ensure that arrangements are made for the termination of a nuclear or radiological emergency, taking into account the need for a resumption of social and economic activity. Most Member States pay 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[3]. Past experience has clearly demonstrated the importance of being prepared to address these challenges. The present Safety Guide intends to help eliminate the lack of guidance that exists in this area by providing guidance and recommendations on emergency arrangements for the termination of an emergency and the subsequent transition to either a planned exposure situation[4] or an existing exposure situation[5] for meeting the relevant safety requirements established in GSR Part 7 [2].

1.4. Requirement 46 of the IAEA Safety Standards Series No. GSR Part 3 (hereinafter referred to as 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

[1] *Nuclear or radiological emergency*: An *emergency* in which there is, or is perceived to be, a hazard due to: 1) The energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction; or 2) Radiation exposure. [2]

[2] 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).

[3] A new situation compared with the situation prior to the emergency. In the context of this Safety Guide, the new normality represents either an existing exposure situation or a planned exposure situation.

[4] The 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 (as defined in Ref. [3]).

[5] A situation of exposure that already exists when a decision on the need for control has to be taken (as defined in Ref. [2]).

situation[6] to an existing exposure situation. The present 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.

OBJECTIVE

1.5. The objective of this Safety Guide is to provide guidance and recommendations to Member States on developing arrangements, at the preparedness stage, for responding to a nuclear or radiological emergency for 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 the general and specific prerequisites that are to be met in order to enable the termination of the emergency and to support the development of the arrangements for achieving this objective and prerequisites.

1.6. This Safety Guide should be used in conjunction with GSR Part 7 [2], with due account to be taken of the recommendations provided in Refs [4] and [5]. This Safety Guide provides guidance for meeting the Requirement 18 of GSR Part 7 [2] and Requirement 46 of GSR Part 3 [3] on the termination of a nuclear or radiological emergency and the transition from emergency exposure situation to existing exposure situation, respectively.

SCOPE

1.7. The guidance and recommendations provided in this Safety Guide are applicable to any nuclear or radiological emergency, irrespective of its cause, to facilitate an effective transition to either a planned exposure situation or an existing exposure situation and a well-defined termination of the emergency. Considering the full range of potential nuclear or radiological emergencies[7] they cover, these recommendations necessitate the application of a graded approach[8] in their implementation.

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

---

[6] 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 [2]. Each emergency exposure situation is a nuclear or radiological emergency; however, each nuclear or radiological emergency is not necessarily an emergency exposure situation.

[7] Examples of such emergencies include: a general emergency at a nuclear power plant, an emergency involving a lost dangerous source, a medical accidental overexposure, an emergency involving dispersal of radioactive material into the environment or a transport accident involving nuclear or radioactive material.

[8] (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 [2].

1.9. This Safety Guide is intended to help in decision making based on scientific considerations regarding radiological protection and the experience available. However it is also intended to serve as an input to a final and comprehensive decision making process concerning the termination of a nuclear or radiological emergency. As nuclear or radiological emergencies may lead to long term exposures due to residual radioactivity in the human habitat, this Safety Guide anticipates that the decision making processes will not only include emergency planners and radiological protection specialists, but will also involve consultation with the public and other interested parties[9].

1.10. The guidance and recommendations provided in this Safety Guide take into account the lessons learned from past experience, including the Fukushima Daiichi accident (2011) [6, 7], the radiological accident in Nueva Aldea (2005) [8], the fuel damage incident at the Paks nuclear power plant (NPP) (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 Chernobyl accident NPP (1986) [13, 14], and the accident at the Three Mile Island NPP (1979) [15]. Annex I of this Safety Guide provides case studies for several of past emergencies.

1.11. The guidance and recommendations provided 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.

1.12. As a 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:

- Emergencies that do not involve significant releases of radioactive material to the environment, and thus do not result in exposures of the public in the longer term due to residual radioactive material (e.g. the Paks NPP fuel damage, the accidental overexposures in Panama, the radiological accident in Nueva Aldea), may 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 either a normal operation or a clean-up, decommissioning or ending of the operational life of the source. In terms of public exposures, such emergencies will not result in an exposure situation that is different from the one that existed prior to the emergency. The decision to terminate the emergency of this type delineates also the beginning of a planned exposure situation. In such cases, within the context of this Safety Guide, the phrase “transition from emergency exposure situation to planned exposure situation” is used.

- Emergencies involving significant releases of radioactive material into the environment (such as the Chernobyl NPP accident, the Fukushima Daiichi accident and the Goiânia radiological accident) result in emergency exposure situations. In such emergencies, the public is exposed in the longer term due to 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 transitioning to an existing exposure situation. The decision to terminate the emergency exposure situation of this type also means entering into the existing exposure situation. In such cases, within the context of this

[9] *Interested party:* A person, company, etc. with a concern or interest in the activities and performance of an organization, business, system, etc. [2]

Safety Guide, the phrase “transition from emergency exposure situation to existing exposure situation” is used.

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

– The termination of radiological situations in which contamination has occurred due to a human activity that is not an emergency exposure situation. This would include, for example, situations arising from planned discharges of radioactive material into the environment or legacy sites.

– Arrangements for managing existing exposure situations and long term remediation, as well as arrangements for decommissioning of accident damaged facilities warranting permanent shutdown; relevant guidance 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, the planning for the management of the existing exposure situation following the termination of the nuclear or radiological emergency.

1.14. This Safety Guide does not provide guidance or recommendations on meeting the requirements set forth in GSR Part 7 [2] in relation to ensuring that arrangements are made for taking urgent and early protective actions and other response actions during the emergency phase; relevant guidance can be found in Refs [4] and [5]. However, this Safety Guide provides guidance for the integration and coordination of activities from the start of the emergency until its termination.

1.15. This Safety Guide does not provide recommendations on communication with the public in preparedness for and response to a nuclear or radiological emergency in relation to the termination of the emergency including the transition phase; relevant guidance is provided in Ref. [20].

1.16. This Safety Guide does not provide guidance concerning nuclear security considerations in relation to the termination of nuclear or radiological emergencies initiated by a nuclear security event. Relevant information related to nuclear security can be found in the Nuclear Security Series [21 −23].

1.17. Terms are used in this Safety Guide as defined in GSR Part 7 [2] and the IAEA Safety Glossary [24]. The use of various phases of a nuclear or radiological emergency in the context of this Safety Guide is clarified in Section 2.

STRUCTURE

1.18. This Safety Guide is comprised of four sections. Section 2 describes various phases of a nuclear or radiological emergency. It focusses on the concept of the ‘transition phase’ and discusses 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 provides the primary objective for terminating a nuclear or radiological emergency and elaborates the general and specific prerequisites that need to be met to terminate an emergency. Section 3 also provides generic guidance on the timeframes 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, in order to facilitate the implementation of activities that enable the termination of the emergency during the transition phase. The Appendix provides considerations for adjusting or lifting protective actions and other response actions during the transition phase. The Annexes provide case studies of several past nuclear or radiological emergencies that support the guidance and recommendations provided in this Safety Guide and present 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

2.1. This section elaborates on the various phases of a nuclear or radiological emergency, with a specific focus on explaining 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 (elaborated 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 when the situation is stable and the source has been brought under control; it ends when all the necessary prerequisites to terminate the emergency have been met. The termination of a nuclear or radiological emergency delineates the end of the emergency or 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 period covering the management of the existing exposure situation and the long term recovery operations after the emergency is declared to have ended is excluded from this consideration. The transition phase may last only several days for small scale emergencies (e.g. a found dangerous source) but could take months or years for large scale emergencies (e.g. a general emergency at an NPP).

2.3. In this Safety Guide, the distinction among the various phases of a nuclear or radiological emergency is intended to support the planning efforts for the respective phases at the preparedness stage. These efforts depend on the characteristics of each phase, including the information available and the specific activities to be carried out.

2.4. It should be recognized that the emergency response efforts are continuous; thus, during the response, the use of different phases or their distinguishing at different time periods is not intended.

EMERGENCY PHASE

2.5. Should conditions be detected in relation to a facility, an activity or a source indicating the occurrence of a nuclear or radiological emergency and warranting emergency response actions, the emergency class is to be declared and pre-planned response actions are to be initiated that correspond to the emergency class and the level of emergency response warranted (see Requirement 7 of GSR Part 7 [2]). During the preparedness stage, the main focus for this phase is on making arrangements that would facilitate recognition of such conditions, prompt declaration of the respective emergency class and activation and implementation of effective emergency response on site and, as relevant, off site. The arrangements made at the preparedness stage should provide for various functions to be performed in the emergency response in accordance with GSR Part 7 [2].

2.6. Early in the emergency response, the response organizations focus their response actions on mitigating the potential consequences of the emergency so that undesirable conditions are either prevented from developing or their development is delayed, making it possible to take effective protective actions on site and, as necessary, off 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[10], urgent protective actions[11] and other response actions[12]); however, some actions allow for more detailed assessments, primarily on the basis of monitoring, and can be taken within days or weeks and still be effective (i.e. early protective actions[13] and other response actions).

2.7. Safety requirements established in GSR Part 7 [2] and its supporting guidance and recommendations (Refs [4] and [5]) address emergency arrangements to be made and implemented for the period following 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[14]. This period is called 'emergency phase' and is defined as:

> "The period of time from the 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*. This phase typically ends when the situation is under *control*, the *off-site* radiological conditions have been characterized sufficiently well to identify where food restrictions and *temporary relocation* are *required*, and all *required* food restrictions and *temporary relocations* have been implemented." [24]

2.8. For the purposes of this Safety Guide, the emergency phase is divided into an urgent phase and an early phase (see Fig. 2.1) as follows:

– Urgent phase: The period following the identification of conditions indicating a nuclear or radiological emergency and warranting emergency response actions when urgent decisions need to be made, in consideration of the limitation of available information, to allow for taking effective precautionary urgent protective actions[15], urgent protective actions and other response actions and when these actions are being implemented. This phase may last from hours to days.

– Early phase: The period when a radiological situation has been characterized sufficiently well to identify a need for taking early protective actions and other response actions and when these actions are being implemented. This phase may last from days to weeks.

TRANSITION PHASE

2.9. For the purposes of this Safety Guide, the transition phase is the period following the emergency phase, when the situation is under control (see para. 2.7), detailed characterization of radiological situation has been carried out and activities are planned and implemented to enable the emergency to be declared terminated. The activities during this phase aim at achieving the primary

[10] A precautionary urgent protective action is an urgent protective action taken before or shortly after a release of radioactive material, or before an exposure, on the basis of the prevailing conditions to avoid or to minimize severe deterministic effects [2].

[11] A protective action which must be taken promptly in the event of an emergency (usually within hours to a day) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed [2].

[12] An emergency response action other than a protective action [2].

[13] A protective action in the event of a nuclear or radiological emergency that can be implemented within days to weeks and still be effective [2].

[14] They include arrangements for the implementation of urgent protective actions, early protective actions and other response actions.

[15] 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 [2].

objective and the prerequisites elaborated in Section 3. This phase may last from days to months. The termination of the nuclear or radiological emergency or the emergency exposure situation delineates the end of the transition phase and the beginning of either an existing exposure situation or a planned exposure situation (see Fig. 2.1).

2.10. In comparison to the urgent phase and, to some extent, the early phase, the transition phase is not driven by urgency and allows for planning, justifying and optimizing future protection strategies and for consultation with interested parties. 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. During this period, the implementation of remedial actions might be more efficient than carrying out further disruptive public protective actions.

2.11. 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 different phases of an emergency during the emergency response (see paras 2.3 and 2.4). This is particularly true for the early 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 phase may support both decision making on early protective actions and the assessment of the radiological situation, which may in turn help determining how protection strategies are to be adapted during the transition phase in order to enable the emergency to be declared terminated.

2.12. In the case of large scale emergencies, the complexity of the radiological situation may vary greatly within an affected area and may be transient in nature. It is therefore likely that the different phases and exposure situations may coexist geographically and temporarily (see Fig. 2.1). This challenges both the management of the situation and the communication with the interested parties. The termination of the emergency exposure situation within the whole affected area will occur gradually from one specific area to another. In this case, the transition phase will end when the termination has been declared for the final area that is in an emergency exposure situation. At the same time, this will denote the overall termination of the emergency.

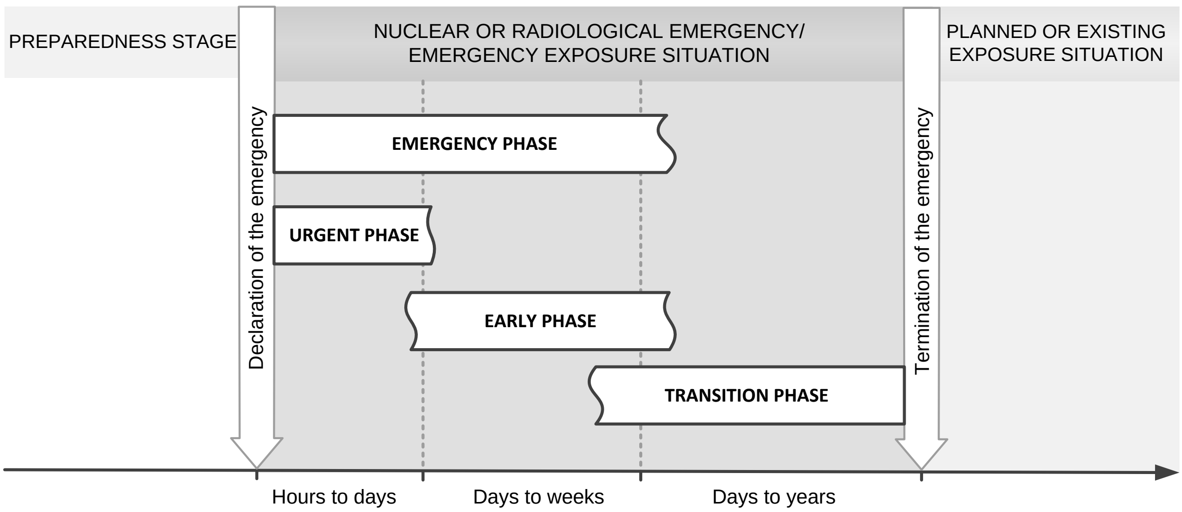

Fig. 2.1. Temporal sequence of the different phases and exposure situations of a nuclear or radiological emergency within one geographical area/one site.

3. PRIMARY OBJECTIVE AND PREREQUISITES TO TERMINATE THE EMERGENCY

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. It provides general guidance on a broad spectrum of aspects that authorities should consider in relation to the termination of the emergency, notwithstanding the need to use a graded approach to each specific postulated nuclear or radiological emergency and to consider national, local and site-specific circumstances.

3.2 The primary objective and the prerequisites should guide the development and implementation of the protection strategy for the transition phase. They should, therefore, also guide the arrangements that need to be put in place during the preparedness stage to implement the strategy in an efficient and coordinated manner during the transition phase. Any objectives that need to be developed for attainment in the longer term under an existing exposure situation, when applicable, should consider this intermediate objective and these prerequisites.

3.3 The emergency should be terminated if the prerequisites set forth in this section are fulfilled on the basis of a formal decision that is made public. The new exposure situation should then be managed as either a planned exposure situation or an existing exposure situation (see Fig. 2.1), in line with national legal and regulatory frameworks as required in Refs [2, 3, 25].

3.4 It should be recognized that the decision to terminate the emergency exposure situation will likely take place at different geographical areas or at different parts of the site at different points in time. Some geographical areas or some parts of the site may therefore be managed as a nuclear or radiological emergency while others may be managed as a planned or an existing exposure situation, as appropriate.

PRIMARY OBJECTIVE

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

GENERAL PREREQUISITES

3.6 A nuclear or radiological emergency should not be terminated until the necessary urgent and early protective actions have been implemented[16].

3.7 Prior to the termination of the emergency, the exposure situation should be well understood and confirmed to be stable. This means that the source has been brought under control, no further significant accidental releases or exposures resulting from the event are expected [2] and the future development of the situation is well understood.

---

[16] At the time of deciding on the termination of a nuclear or radiological emergency, some of these actions may be already under consideration to be adapted or lifted (e.g. evacuation). Other actions may remain in place in the longer term after the termination (e.g. restrictions on food, milk and drinking water), while some actions such as iodine thyroid blocking may have been implemented and require no further consideration during the transition phase. For more details see sub-section on Adapting and lifting protective actions in Section 4.

3.8 Prior to the termination of the emergency, the radiological situation should be well characterized, exposure pathways identified and doses[17] assessed for all affected populations[18] (including those most vulnerable to radiation exposure, such as pregnant women and children). 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 surfaces (e.g. imposing restrictions or identifying alternative ways in which they can be exploited).

3.9 Before any decision to terminate the emergency is made, a thorough hazard assessment of the situation and its future development should be performed, consistent with Requirement 4 of GSR Part 7 [2].

3.10 On the basis of the hazard assessment, potential emergencies warranting protective actions and other response actions should be identified, and the existing emergency arrangements should be reviewed[19]. The review should identify the need to revise the existing emergency arrangements and/or to establish new arrangements.

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

3.12 Prior to the termination of the emergency, it should be confirmed that the requirements for occupational exposure, as stipulated for a planned exposure situation[20] in GSR Part 3 [3], can be applied to all workers that will be engaged in recovery activities [2].

3.13 The radiological situation should be assessed, as appropriate, against reference levels, generic and operational criteria and dose limits, to determine if the relevant prerequisite for the transition to the respective exposure situation has been achieved (see Specific Prerequisites, paras 3.19–3.22).

3.14 Non-radiological consequences (psychosocial, economic) and other factors (technology, land use options, availability of resources, community resilience) relevant to the termination of the emergency should be identified and considered.

3.15 A registry of those individuals that require further medical follow up (see Refs [2, 5]) should be established prior to the termination of the emergency.

[17] Effective dose, equivalent dose to an organ or tissue and RBE weighted absorbed dose in an organ or tissue, as appropriate. See Ref. [5] for further details.

[18] This includes the public, workers (including emergency workers), helpers and patients, as appropriate.

[19] This implies revision of existing emergency arrangements and/or introducing new arrangements to meet the new hazards. For example, hazards associated with an NPP in normal operation and the associated emergency arrangements will differ from the hazards associated with an accident damaged NPP and its associated emergency arrangements.

[20] Regardless of the exposure situation. Para. 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 …".

3.16 A strategy for the management of radioactive waste arising from the emergency, if appropriate, should be developed prior to the termination of the emergency.

3.17 Consultation with interested parties is required prior to the termination of the emergency [2]. This process should not unduly impede the timely and effective decision making by the responsible authority to terminate the emergency.

3.18 Prior to the termination of the emergency, the following should be communicated to the public and other interested parties, as appropriate:

– The basis for the termination of the emergency;

– The need for adjusting imposed restrictions, for continuing protective actions or for introducing new ones;

– Any necessary modification in people’s personal behaviours and habits;

– Possible options for the implementation of self-help actions;

– The need for continued environmental, source and individual monitoring following the termination to the emergency;

– The need for continued efforts to restore services and workplaces;

– Radiological health hazards associated with the new exposure situation.

SPECIFIC PREREQUISITES

Transition to a planned exposure situation

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

– Circumstances surrounding 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. However, in some cases, the formal analysis and development of the action plan may be a lengthy process. Therefore, establishing administrative procedures that limit or prevent the use or handling of the source until a better understanding of the circumstances surrounding the emergency situation has been gathered should be considered with the aim to prevent the unnecessary delay of the termination of the emergency.

– Conditions have been assessed to ensure compliance with the safe and secure handling of the sources in accordance with the national requirements set forth for the respective planned exposure situation[21].

[21] Depending on the type of the emergency, the planned exposure situation can be associated with normal operation, clean-up and decommissioning or end of operational life of the source involved in the emergency.

– Compliance has been confirmed with the requirements for dose limits for public exposure in planned exposure situations and with requirements for medical exposure set forth in 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 prerequisites should be met in order to be able to declare the termination of an emergency exposure situation and to move to an existing exposure situation:

– Justified and optimized actions have been taken to reach the national generic criteria established to enable transitioning to an existing exposure situation, taking into account the criteria given in Appendix II of GSR Part 7 [2] and it has been verified that the assessed residual doses[22] approach the lower band of the reference level for an emergency exposure situation (see paras 4.53–4.70).

– Areas have been delineated which may not be inhabited and where it is not feasible to carry out social and economic activity. This delineation relates to areas which, earlier in the emergency response, were subject to evacuation and/or relocation, and/or where specific restrictions were imposed that continue to be implemented following the termination.

– For these delineated areas, administrative and other provisions have been established to monitor compliance with the restrictions imposed.

– A strategy for the restoration of infrastructure, workplaces and public services necessary to support normal living conditions in the affected areas (e.g. public transportation, shops and markets, schools, kindergartens, health care facilities, police and firefighting services, etc.), has been developed.

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

– 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.

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

– A long term monitoring strategy has been developed in relation to residual contamination.

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

– A strategy for mental health and psychosocial support of the affected population in relation to psychosocial health consequences has been developed.

[22] The dose expected to be incurred after protective actions have been terminated (or after a decision has been taken not to take protective actions). [2]

– Consideration has been given to the compensation of the victims for damage resulting from the emergency.

– Administrative arrangements, legislative provisions and regulatory provisions are in place and/or underway for the management of the existing exposure situation, including provisions for the allocation of the necessary financial, technical and human resources.

3.21 Following the termination of the emergency, individual monitoring[23] of members of the public should no longer be required for radiation protection purposes. This does not rule out the fact that doses of individuals may differ considerably depending on people's individual habits, and that this may still need to be addressed in the long term protection strategy.

3.22 There may be exceptional circumstances in which it has not been feasible, within a reasonable time, to reach the generic criteria for the termination of an emergency exposure situation (see first bullet of para. 3.20). 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 defined in GSR Part 7 [2] are not exceeded.

TIMEFRAMES FOR THE TERMINATION

3.23 At the preparedness stage, the timeframes anticipated in which to terminate the emergency should be agreed 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 during the decision making process with respect to timeframes for the termination of specific nuclear or radiological emergencies. However, this should not be considered an obstacle to deciding on a strategy to cope with specific aspects of the termination within a reasonable timeframe.

3.24 Based on past experience, timeframes in the range of weeks to one year, can be proposed for terminating large scale emergencies (for example, emergencies at nuclear installations resulting in significant off-site contamination); however, timeframes in the range of days to a few weeks may be adequate for terminating small scale emergencies (for example, a radiological emergency during transport or radiological emergencies involving sealed dangerous sources).

[23] Monitoring using measurements by equipment worn by individuals; or measurements of quantities of radioactive substances in, on or taken into the bodies of individuals; or measurements of quantities of radioactive substances excreted from the body by individuals.

4. ARRANGEMENTS FOR THE TRANSITION PHASE

4.1. This section provides detailed guidance on various aspects to be considered at the preparedness stage (see Fig. 2.1) when establishing arrangements for the transition phase of a nuclear or radiological emergency. Their implementation is intended to support meeting the prerequisites for the emergency to be declared terminated given in Section 3.

GENERAL

4.2. GSR Part 7 [2] requires that:

- Governments 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.
- Emergency arrangements include clear allocation of authorities and responsibilities and provide for coordination in all phases of the response to a nuclear or radiological emergency.
- 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.
- 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.
- Governments ensure that a hazard assessment is performed to provide a basis for a graded approach in developing generically justified and optimized arrangements in preparedness and response for a nuclear or radiological emergency.
- Governments ensure that arrangements are in place for operations in response to a nuclear or radiological emergency to be appropriately managed.
- Arrangements for delegation and/or transfer of authority be specified in the relevant emergency plans, together with arrangements for notifying all appropriate parties of the transfer.

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

- The legislative and regulatory framework for governing the preparedness and response for the transition phase of a nuclear or radiological emergency;
- The framework for radiation protection and safety regarding longer term issues associated with an existing exposure situation in order to ensure a smooth transitioning 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 recruitment of new staff to deal with the necessary activities during the transition phase and, in the longer term under an existing exposure situation; provision of ‘just-in-time’ training; and resource mobilization among relevant organizations should be identified, and arrangements to implement them when needed should be pre-planned.

Authority, role and responsibilities

4.5. In the urgent phase, the discharge of authority and assumption of responsibilities in the emergency response is, to the extent possible, straightforward and based on pre-planned arrangements. This allows for effective implementation of precautionary urgent protective actions and urgent protective actions. Thus, the input from different organizations required in the decision making process regarding the emergency response actions warranted during the urgent phase will be limited.

4.6. As the emergency evolves, the focus of 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. This will require the involvement of additional organizations, with relevant responsibilities at different levels, which may not necessarily have been directly engaged during the urgent phase. These organizations, in order to discharge their allocated roles and responsibilities, should gradually be involved, when appropriate, in the response to the emergency within the emergency response organization. This should be done in a way that enables on-going 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 during the transition phase, as well as the resources (human, technical and financial) required, should be identified at the preparedness stage. This should be undertaken on the basis of activities that are expected to be carried out during this phase to fulfil the prerequisites elaborated 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 authority and responsibility for making the formal decision may differ between the on-site and off-site areas.

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 the authorities and discharge of responsibilities from the emergency phase to the transition phase; and make the prompt resolution of any conflicting responsibilities possible. This should take into account that, during the transition phase, there will be a need for multi-disciplinary contributions, including those from the operating organization, which must be channelled efficiently and effectively.

4.9. During 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 organization

4.10. The differences in management required 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 established during the emergency phase should be gradually relieved of its duties, so that the organizations with the respective authority, roles and responsibilities can take over the activities on a routine basis within the planned 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 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 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 under an existing exposure situation.

4.12. The gradual change in the management during the transition phase should consider the need for the simultaneous existence of different administrative structures in different geographical areas.

Transfer of information and data

4.13. The respective organizations assuming responsibility for the activities in the transition phase, and in the longer term within an existing exposure situation, 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 during the emergency phase and the rationale supporting the decisions made during this phase.

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

- The type of information and data from the emergency phase that may be of relevance for the transition phase should be clearly identified.
- Relevant organizations that will need access to respective information and data should be identified.
- A mechanism should be established to record this information and data during the emergency phase and to exchange it efficiently among the relevant organizations.

4.15. During the transition phase, consideration should be given to ensuring an overlap of management and technical personnel involved in the emergency phase and those to be involved during the transition phase for an agreed period 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 developing generically justified and optimized arrangements 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. On the basis of the hazard assessment, Requirement 7 of GSR Part 7 [2] requires the establishment of a system for promptly classifying a nuclear or radiological emergency warranting protective actions and other response actions. Declaration of an emergency class triggers a coordinated and pre-planned level of emergency response on-site and, where appropriate, off-site, in accordance with the protection strategy. Ref. [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 implementation of protective actions and other response actions. This includes those facilities and activities, on-site areas, off-site areas and locations for which actions aimed at allowing the termination of the emergency may also be warranted.

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; they should also be able 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) *General emergency* at a facility in emergency preparedness category I or II (e.g. the Fukushima Daiichi accident 2011 for which a case study is given in Annex I) leading to a significant release of radioactive material into the environment will warrant termination of the emergency through transitioning to an existing exposure situation.

(b) *A site area emergency* at a facility in emergency preparedness category I or II and a *facility emergency* at a facility in emergency preparedness category I, II, or III will warrant termination of the emergency through transitioning to a planned exposure situation (e.g. the PAKS fuel damage incident 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, clean-up and decommissioning activities or end of operational life of the source involved in the emergency, as applicable. However, postulated nuclear or radiological emergencies within this class are not expected to result in a different exposure situation to the public as compared to the situation that existed prior to the emergency.

(c) *Alert* at a facility of emergency preparedness category I, II, or III will be followed by the resumption of normal operations under a planned exposure situation.

(d) *Other nuclear or radiological emergency* covers a broad spectrum of emergencies in emergency preparedness category IV which may occur at any location [2]. In this class, depending on the type of emergency, transitioning to either an existing or a planned exposure situation is to be envisaged along with the termination of the emergency:

   – Postulated emergencies without dispersion of radioactive material into the environment are to be terminated simultaneously with returning to the exposure situation for the affected public as it existed prior to the emergency (e.g. the radiological incident in Mexico 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, it may be managed as radioactive waste under the requirements for a planned exposure situation.

   – Postulated emergencies with dispersion of radioactive material into the environment resulting in significant residual radioactivity in the environment are to be terminated with simultaneous transitioning 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 in consideration of:

– An inability to accurately predict when, where and what the actual impact of a range of postulated nuclear or radiological emergency might be;

– The complexity of potential recovery efforts;

– The potential impact of non-radiological factors, such as public concerns and the political situation, on decision making at the time of the emergency. [24]

4.20. The hazard assessment for all identified facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency could warrant taking protective actions and other response actions, should include the detailed characterization at all levels of the following:

- Consequences:
  - Source terms expected;
  - Projected doses[25] (for all potentially affected populations) and associated health hazards;
  - Exposure scenario, including dominant exposure pathways and period of exposure;
  - Population and areas (including infrastructure) affected, including detailed characterization of population groups and the use of land and water surfaces;
  - Other non-radiological impact on the economy and society;
  - Estimated time for declaring an emergency terminated (see Section 3);
- Resources (human, technical, financial) and infrastructure available;
- Applicable legislative framework in areas relevant to the termination of an emergency.

4.21. An emergency may result in changes in the hazards applicable to the State as compared to hazards prior to the emergency. This may warrant adjustment of the emergency arrangements in place prior to the emergency (i.e. revision of existing emergency arrangements and/or introduction of new arrangements to meet the new hazards). As a result, before a decision to terminate the emergency and transition to a different exposure situation can be made, a thorough hazard assessment of the situation and its future development should be performed consistently with Requirement 4 of GSR Part 7 [2]. Its implications on the existing emergency arrangements also need to be identified and addressed (see paras 3.9–3.11 of Section 3).

PROTECTION OF THE PUBLIC

Protection strategy

General

4.22. The concept of a protection strategy as used in this Safety Guide describes in a comprehensive manner what needs to be achieved in response to a nuclear or radiological emergency during all its phases and how this will be achieved through implementation of a justified and optimized set of protective actions and other response actions. Particular attention is given to the transition phase.

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

[25] The dose that would be expected to be received if planned protective actions were not taken [2]. For further details see Ref. [5].

4.23. The guidance in this sub-section focuses on considerations concerning the protection of the public and society in general, while the protection of emergency workers and helpers is addressed in a separate sub-section (see paras 4.103–4.141).

Development of protection strategies at the preparedness stage

4.24. GSR Part 7 [2] requires that:

- 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 on the basis of the hazards identified and their potential consequences.
- The protection strategy is safely and effectively implemented in an emergency response through execution of pre-established emergency arrangements.
- Interested parties are involved and consulted, as appropriate, in the development, justification and optimization of the protection strategy.

4.25. Protection strategies should cover, at least, the period from the declaration of the emergency until the termination of the emergency to allow for achieving all the goals of emergency response given in para. 3.2 of GSR Part 7 [2]. The primary objective and the prerequisites for the termination of the emergency elaborated in Section 3 of this Safety Guide should be the main drivers of the protection strategies for the transition phase.

4.26. For large scale emergencies, the implementation of a protection strategy could extend in the longer term within the framework of an existing exposure situation (see Refs [16, 17]). Comprehensive protection strategies developed at the preparedness stage should extend beyond the termination of an emergency, allowing for the necessary activities for achieving any long term objective.

4.27. The protection strategies for the transition phase may not be as detailed as those for the emergency phase. This 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 involve the 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 part of the protection strategies 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 strategy.

4.28. As part of the protection strategies, the process for justification and optimization to cope with the prevailing conditions as the emergency evolves should be agreed upon. In general, this should include the following elements:

- Processes and methodologies to be used during the transition phase, including designation of any particular decision aiding tools as necessary.

- Identification of parties that will need to be consulted on the specific inputs necessary to the process, and clearly defined roles and responsibilities for the justification and optimization process.

4.29. As part of the justification and optimization process, protection strategies should examine the impact that emergency response actions taken during the emergency phase may have on the actions warranted during the transition phase and in the longer term. This should be done along with an examination of the impact that emergency response actions may have on achieving the prerequisites for the termination of the emergency. For example, if two options within the protection strategy provide the same level of protection of the public during the emergency phase, the one that is less disruptive to society should be the preferred option, as it will support the later efforts associated with the termination of the emergency and the overall recovery. However, such considerations should not compromise the effectiveness of the protection strategy for the emergency phase.

4.30. Each protection strategy should include a reference level, expressed in terms of residual dose from all exposure pathways, to be used as a benchmark for optimization of the protection and safety; generic criteria for taking protective actions and other response actions; and pre-established operational criteria for initiating the different emergency response actions in line with Requirement 5 of GSR Part 7 [2], taking into account the guidance given in this Safety Guide and in Ref. [5].

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

4.32. The development of the protection strategies should involve all response organizations at all levels, as well as relevant interested parties (see paras 4.196–4.206) in order to allow for a common understanding and to enhance the acceptability, feasibility and any associated practicalities of the proposed strategy.

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

4.34. The developed 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 during the transition phase

4.35. During the response, 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 the circumstances, even if very little information is available, as may be the case during the urgent phase. As the emergency evolves during the early phase, and particularly during the transition phase, more information on the circumstances surrounding the emergency and its consequences becomes available. At this point, the implementation of the protection strategy should be continuously reassessed, and the protection strategy should be adapted based on the prevailing conditions [5].

4.36. The effectiveness of the protection strategy during the transition phase should be assessed against the pre-established prerequisites for the termination of the emergency (see Section 3) which includes consideration of the residual doses among affected population against the chosen reference level.

4.37. 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 4.40–4.53 and Fig. 4.1).

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

4.39. The transition phase is likely to have a gradual increase in both the need to engage with interested parties (see paras 4.196–4.206) and their interest in the decision making processes. While relevant interested parties are to be engaged and consulted, the process should be such that the responsibility for timely decision making clearly remains with the relevant authorities. During the transition phase, consideration should be given to the time allocated for such engagement and consultation and the need for timely and effective implementation of the protection strategy.

Justification and optimization

General

4.40. In contrast to the urgent phase, when radiation protection considerations dominate, the non-radiological factors become an important input to the decision making in the transition phase. Notwithstanding the need to consider both radiological and non-radiological factors in the justification and optimization of the protection strategy, for those situations involving higher doses (approaching or exceeding 100 mSv/y effective dose), protective actions are almost always justified[26], and the radiological protection considerations generally outweigh the non-radiological impacts.

4.41. The process 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 account for this range of factors, the process of justification and optimization of the protection strategy should allow for obtaining inputs from relevant authorities and other interested parties.

4.42. While some of the different factors to be considered in the process of justification and optimization can be known or estimated during the preparedness stage, some of them cannot be known, or may be known without sufficient accuracy. Examples include seasonal and weather conditions, the occurrence of simultaneous events that may have caused a major loss of critical infrastructure (such as a conventional emergency), exact radionuclides involved or different lifestyles and dietary habits of the population. The process of justification and optimization should recognize and allow for such uncertainties and limitations of the information available at the preparedness stage to ensure that they are appropriately considered during the response.

4.43. During all phases of an emergency, and especially during the transition phase, the process of justification and optimization of the protection strategy should continuously assess the impact of the protection strategy on the overall radiological situation, including assessing the residual doses incurred by people compared to the reference levels, the impact on society and other non-radiological impacts. This should be done in order to account for the state of achieving the prerequisites for terminating the emergency. This continuous reassessment should lead to an adaptation of the protection strategy when necessary to allow for achieving the relevant prerequisites given in Section 3 (see Fig. 4.1).

[26] Examples of unjustified actions at this level of doses include unsafe evacuation of patients from hospitals in areas where evacuation has been ordered.

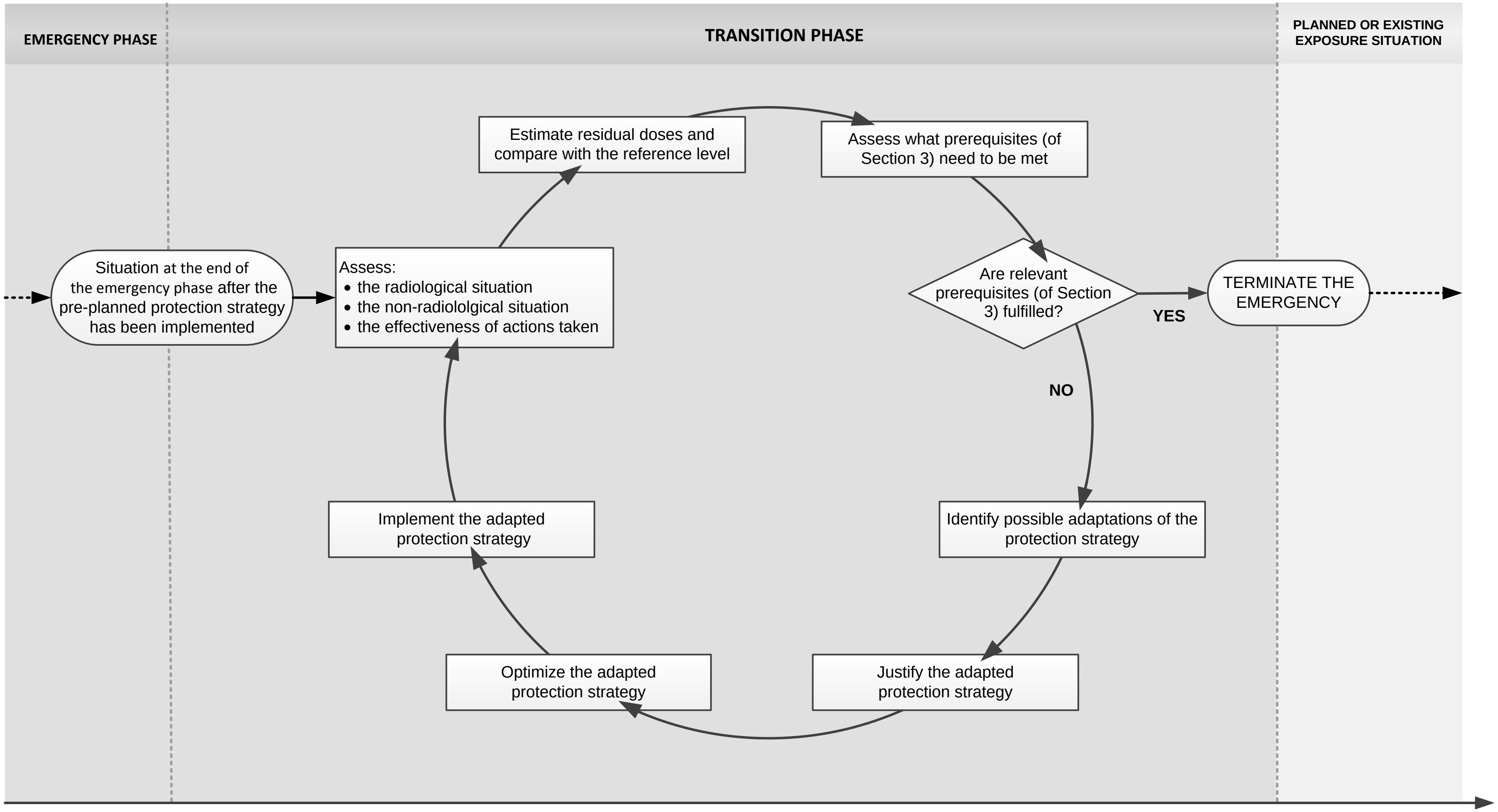

Fig. 4.1. *The iterative process of assessment of the implementation and adaptation of the protection strategy during the transition phase.*

Justification

4.44. GSR Part 7 [2] requires that the justification principle be applied for each protective action, in the context of the protection strategy, and for the protection strategy itself. This principle allows 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" [3].

4.45. In determining if the proposed actions and the protection strategy are justified, the reduction in radiation detriment should be weighed against the other impacts to public health, social and economic disruption, ethical considerations, environmental impacts, etc. Examples of such impacts include: possible reduced life expectancy due to stress associated with resettlement; costs associated with the loss of critical infrastructures; loss of productivity of industrial facilities; the need for compensation payments to those impacted; societal impact owing to the loss of places of great cultural or historical importance; and the costs to society and its economy associated with the management of the radioactive waste produced.

4.46. Justified actions within a protection strategy should be determined during the preparedness stage. Protective actions and other response actions solely justified on the basis of political pressure or public concerns that do not have any technical merit, should be avoided, as they may lead to remediation activities that are not justified considering the associated harm and costs they may cause, 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, causing unnecessary anxiety and psychological harm.

4.47. A periodic reassessment of the protective actions and the protection strategy should be undertaken during the transition phase to ensure they continue to do more good than harm considering any new information that becomes available.

4.48. GSR Part 7 [2] requires that protective actions and other response actions be discontinued when they are no longer justified.

Optimization

4.49. The process of optimization of protection and safety should be applied to protective actions and the protection strategy that have been demonstrated to be justified in line with paras 4.40–4.48.

4.50. Optimization of protection and safety is defined as the process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals subject to exposure and the likelihood of exposure being "as low as reasonably achievable, economic and social factors being taken into account" [3]. This means that the level of protection would be the best possible under the prevailing circumstances and will thus not necessarily be the option with the lowest dose.

4.51. The process for optimization should allow for all relevant factors (see Table II.1 of Annex II for examples) to be considered in making the decisions. 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, as described in para. 4.43.

4.52. Implementation of the 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. Optimization should be applied even if the initially projected doses are below the defined reference level, but only if actions which are justified are available to reduce exposures.

Reference levels

4.53. For emergency exposure situations, Refs [2, 3, 26] recommend that the typical reference level be selected for residual doses in the band of 20 to 100 mSv acute or annual dose. 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, taking into account the implementation of the protection strategy, if any.

4.54. The reference levels are introduced as a tool for optimization of the protection strategy so that any optimization of protection gives priority to exposures above the reference level; at the same time, the optimization of protection may continue to be implemented below the reference level as long as this is justified, i.e. does more good than harm. Exposures above 100 mSv are justified under some circumstances, either because the exposure is unavoidable or in exceptional situations in which the expected benefits clearly outweigh the health risks. This would apply, for example, to critically ill patients when their removal or evacuation would present a higher risk to their health than the dose they are likely to incur by remaining in place until a safe evacuation can be arranged.

4.55. The reference level, during the response, should also serve as a benchmark for a retrospective assessment of the effectiveness of actions and the strategy taken in an emergency response (see Refs [2, 26, 27]. This comparison should be used to assess the effectiveness of the implemented protective strategy and to identify the need for its adaptation in addressing the prevailing conditions. In this process, further protective actions should be determined and implemented so that they focus, as a priority, on those groups/individuals whose doses exceed the reference level. The available resources should then be allocated accordingly.

4.56. The decision to select specific numerical values within the proposed band of reference levels remains the responsibility of the national authorities. Such selection will depend on a range of circumstances surrounding the emergency, including national and local conditions (e.g. prevailing economic and societal circumstances, 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 do so. The process of selecting specific numerical values within the band should be based on the results of the hazard assessment and consideration of the urgent and 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 the lower levels will not necessarily provide for better protection when also considering other factors (see Annex II) in the overall process of justification and optimization.

4.57. The two examples may help to clarify the process for the selection of the reference level during the transition phase for large scale and small scale emergencies:

– Emergencies involving large scale contamination resulting in exposures of the public due to long lasting residual radioactive material in the environment would result in longer term exposures, which are expected to decrease with time. Therefore, the reference level to be chosen may change with time. For example, it may start with a level of 100 mSv acute or annual effective dose for the urgent phase and approach an effective dose of 20 mSv per year residual dose after successful implementation of the protective strategy to allow for the termination of the emergency exposure situation. The timing of the reduction of the reference level will depend on various circumstances, including the effectiveness and the efficiency of the implementation of the protection strategy.

– Emergencies that do not result in long lasting residual radioactive material in the environment will not require the gradual decrease in reference levels as in the above example. As such, while the reference level for the emergency exposure situation may be selected from the band proposed (see para. 4.53) for the purpose of the emergency response, once the source is recovered safely, the concept of the reference level will no longer apply, as the situation returns to a planned exposure situation.

4.58. In general, a reference level of the magnitude used in an emergency exposure situation will not be acceptable as a long term benchmark, and the termination of the emergency should not be considered if the annual effective dose (residual) for the affected population is expected to be approaching the higher end of the band of the reference level for the emergency exposure situation.

4.59. In exceptional cases, however, when no justified and optimized actions can be taken to further minimize the residual doses, values exceeding the lower level of the range of the reference level typical for an emergency exposure situation (or the upper level for an existing exposure situation) can be selected to terminate the emergency after consultation with all parties concerned. In this case, efforts should be continued to investigate the possible options and to further assess and minimize, as far as practicable and reasonable, the exposures to the people affected. This may include efforts to provide advice and support to individuals for minimizing their exposures (for example, self-help actions such as avoiding prolonged visits to certain areas, changing farming practices and land use or reducing the consumption of certain foods).

4.60. Approaching the lower end of the band for the reference level for the emergency exposure situation, in the order of 20 mSv effective dose in a year (see Table 4.1), should be acceptable for the termination of the emergency, while continued efforts will likely be necessary to progressively reduce doses further in the longer term.

TABLE 4.1. OVERVIEW OF THE APPLICABILITY OF REFERENCE LEVELS FOR DIFFERENT EXPOSURE SITUATIONS

REFERENCE LEVELS 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. After terminating the emergency and entering in the existing exposure situation, the reference level for the residual dose in an existing exposure situation should be applied in the band of 1–20 mSv per year as required in Ref. [3] (see Table 4.1). The International Commission on Radiological Protection (ICRP) recommends that the reference level for the optimization of the protection strategy is selected from the lower part of the reference band of 1–20 mSv per year as a long term objective for existing exposure situations (see Refs [26, 28]). Further guidance in this regard can be found in Refs [16, 17].

4.62. What is feasible to achieve in a given timeframe may differ from area to area. The application of different reference levels as benchmarks for the optimization process and for the termination the emergency exposure situation may be necessary 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

4.63. Generic and operational criteria are concepts within the protection strategy that are to be used to implement protective actions and other response actions in a nuclear or radiological emergency as described in Refs [2, 5]. Should the doses projected or received doses[27] in an emergency exceed the generic criteria, protective actions and other response actions, either individually or in combination, are to be implemented.

4.64. GSR Part 7 [2] requires that governments develop national generic criteria for the full range of protective actions and other response actions to be taken in an emergency response, which covers the period from the start of an emergency until the point in time when the emergency is terminated. Appendix II of GSR Part 7 [2] provides a comprehensive set of generic criteria to be considered when developing the justified and optimized protection strategy at the national level including when establishing the national generic criteria. The generic criteria given in Appendix II of GSR Part 7 [2] are considered to be generically justified and optimized to prevent severe deterministic effects, to reduce the risk of stochastic effects, to mitigate the economic impact by providing a basis for the resumption of international trade and to guide the actions aimed at enabling the transition to an existing exposure situation.

4.65. GSR Part 7 [2] establishes the generic criteria for enabling the transition to an existing exposure situation to be the projected doses of 20 mSv effective dose per year and 20 mSv equivalent dose to a foetus for the full period of in utero development.

4.66. Should an emergency occur, 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 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 Ref. [5].

4.67. During the transition phase, OILs based on the generic criteria for enabling the transitioning to an existing exposure situation (see para. 4.65) should be used as a tool to support:

– Decision making on lifting or adapting protective actions, including the determination of what protective actions may need to be lifted, when this might happen and to whom it may apply.
– Implementation of activities to enable the termination of the emergency exposure situation by providing basis to guide simple dose reduction activities.

[27] For further details see Ref. [5].

4.68. The Appendix of this Safety Guide provides OILs that should be taken into account when establishing national OILs to be applied consistently with para. 4.67. They should be established taking into account those derived for taking protective actions in a nuclear or radiological emergency (see Table I.1). The Appendix also provides considerations as well as a methodology for deriving the operational intervention level for the transition to an existing exposure situation, i.e. OIL_T, to support the implementation of generic criteria for enabling the transitioning to an existing exposure situation given in para. 4.67.

4.69. As for any default OILs, default OIL_T values are to 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 OILs, OIL_T values should be recalculated using the same methodology under the new available information. Consequently, GSR Part 7 [2] requires that a process be established to revise the default OILs to take into account the prevailing emergency conditions. Methodology and processes for the recalculation of OIL_T in these circumstances to address the prevailing conditions should constitute an integral part of the protection strategies.

4.70. The default OILs during an emergency should be revised if the situation is well understood and there are compelling reasons to do so. The public and other interested parties should be informed of the reasons for any change in the OILs applied in an actual emergency.

Adapting and lifting the protective actions

General

4.71. The most commonly considered urgent protective actions within a protection strategy are: evacuation; sheltering; iodine thyroid blocking; restrictions on local produce, milk from grazing animals, rain water or other open sources of drinking water; restrictions on the use of commodities that have the potential of resulting in significant exposures; decontamination of individuals and medical treatment when appropriate; and actions to prevent inadvertent ingestion. Many of these urgent protective actions may be implemented as a precaution on the basis of observables or plant conditions, prior to a release of radioactive material or prior to the occurrence of radiation exposures. The decision on these actions is often based on limited information about the emergency situation and is guided by conservative assumptions on the potential development and impacts of the situation.

4.72. The most commonly considered early protective actions within a protection strategy are: relocation; long-term restrictions on the consumption of food, milk and drinking water; restrictions on the use of commodities that have the potential to result in significant exposures; actions to prevent inadvertent ingestion and to control the spread of contamination; and 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 improved knowledge of the radiological exposure situation.

4.73. 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 in order to identify where and for whom new protective actions are needed; those protective actions that are no longer needed are lifted or modified. 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. This might be the result of the positive evolution of the situation and the return to safe conditions, or it may be due to evidence that the protective action was not necessary because of limited deposition or impact.

4.74. Adapting and/or lifting protective actions in the transition phase should be justified and optimized based on the prevailing conditions, taking into account the results from 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.

4.75. Decisions on adapting and/or lifting protective actions (such as lifting evacuation, relocation or restrictions on certain foods for consumption) should be made after their impact on the residual doses among the affected population has been assessed.

4.76. To initiate considerations for making decision on adapting, including lifting protective actions in the transition phase, OILs should be established at the preparedness stage, taking into account those provided in the Appendix of this Safety Guide. The pre-established OILs should be used to consider when and for whom what kinds of specific protective actions may need to be lifted. Following this preliminary screening, the final decision on adapting protective actions, including the lifting of relevant ones, should be based on an assessment of the residual dose (see para. 4.75) from all exposure pathways against the pre-set reference level for enabling the transition (see para. 4.58).

4.77. As the prevailing conditions may vary within an affected area, consideration should be given to the fact that adapting and/or lifting the protective actions may vary at different times in different locations. Overly frequent changes should be avoided, unless they provide significant benefits, as this could risk losing public trust in the decisions of the authorities.

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

Considerations for lifting or adapting specific protective actions

Iodine thyroid blocking

4.79. Iodine thyroid blocking is a short term urgent protective action that provides protection for the thyroid against radioactive iodine; it may be implemented as a precaution, although usually not as a standalone action. Due to its nature, iodine thyroid blocking is not a protective action to be implemented for prolonged periods. Thus, whenever there is a need to implement this action for a longer duration (e.g. days), consideration should be given to resorting to evacuation or relocation instead. Iodine thyroid blocking is suitable for use in the emergency phase and is not appropriate for implementation, adaptation or lifting during the transition phase.

Sheltering

4.80. Sheltering is also an urgent protective action that is easy to implement in an emergency situation, either as a precautionary action or as a transitional action before more effective but more disruptive actions (such as evacuation) can be implemented safely. Sheltering should not be carried out for long periods (more than approximately two days). Due to its nature, sheltering is not appropriate for implementation during the transition phase but may be lifted or adapted during this phase.

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

- The level of protection offered by the type of buildings used for sheltering (shielding factor and tightness against diffusion of outside atmosphere);
- Need for continued simultaneous implementation of iodine thyroid blocking;
- The medical care and hygiene needs of those sheltered (availability of medicines, food supplies, etc.);
- Any necessity to gradually increase the time allowed for members of the public to spend outdoors until sheltering is fully lifted;
- Need for further protective actions based on generic criteria and OILs to replace sheltering (e.g. evacuation or relocation).

Evacuation

4.82. Evacuation may be taken as a precautionary action based on observable conditions or plant conditions (i.e. EALs), or an urgent protective action based on EALs and/or OILs. Due to its temporary nature, priority should be given to lifting evacuation in consideration of the following (see the Appendix):

- In evacuated areas where the monitoring results indicate that the projected doses may exceed the generic criteria for relocation (i.e. OIL2 of Ref. [5]), evacuation should be substituted by relocation to provide better living conditions to evacuees.

- In evacuated areas where the monitoring results indicate that OIL2 of Ref. [5] is not exceeded, evacuation should be lifted only if limited restrictions (e.g. restriction 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 pre-conditions in para. 4.102 are fulfilled.

- In evacuated areas where the monitoring results indicate that OIL2 of Ref. [5] is not exceeded but limited restrictions are not sufficient for the protection of the people returning to live normally in the area, or the pre-conditions in para. 4.102 are not fulfilled, evacuation should not be lifted until the termination of the emergency is declared for this area, following fulfilment of the prerequisites in Section 3 and of the preconditions in para. 4.102.

4.83. In areas with circumstances like referred to in the last bullet in para. 4.82, OIL_T 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 received based on the actual circumstances should be considered, taking into account the limited restrictions continuing to be in place.

4.84. When substituting evacuation with relocation, people evacuated should be granted short access to the evacuated areas in a controlled manner, in order to allow for the preparation of longer term relocation.

Relocation

4.85. Relocation is an early protective action intended for longer duration (months). Its adaptation or lifting is less urgent in comparison to evacuation, and it allows more time for planning. This action should be lifted under the same conditions as those applicable for lifting evacuation outlined in paras 4.82, second and third bullets, and 4.83.

Restrictions on food, milk and drinking water

4.86. Restrictions imposed on food, milk and drinking water taken as a precaution in the emergency phase on the basis of estimates (e.g. on the basis of EALs or OIL3 of Ref. [5] and thereafter adjusted based on OIL5 of Ref. [5] or OIL7 of Ref. [29]) should be subject to detailed characterization during the transition phase. Its purpose is to identify foodstuffs that are justified to remain under restriction even in the longer term and to identify those restrictions that need to be lifted. OILs for food, milk and drinking water derived on the basis of sampling and analysis, i.e. OIL6 in Ref. [5], should be used when considering whether to adapt or lift this protective action.

4.87. OIL6 in Ref. [5] has been derived on the basis of the generic criterion of 10 mSv/y projected effective dose and on extremely conservative assumptions (see Ref. [5] for more details). During the transition phase, the actual doses received from the ingestion pathway and their contribution to the residual dose should be estimated based on actual conditions to aid in decision making on the adaption or lifting of this protective action. Under actual conditions, the contribution of actual doses to the total residual dose is expected to be significantly less than 10 mSv/y.

4.88. GSR Part 3 [3] establishes the specific reference level for food and drinking water in the longer term in an existing exposure situation at about 1 mSv/y effective dose. In addition, the World Health Organization (WHO) has issued guidelines for drinking water quality [30] that provide guidance levels for radionuclides in drinking water for prolonged exposure situations resulting from past emergencies. Thus, restrictions on food, milk and drinking water extending into the longer term in an existing exposure situation might be subject to a gradual dose reduction in order to eventually achieve these levels. However, this discussion goes beyond considerations concerning the termination of the emergency exposure situation and is therefore beyond the scope of this Safety Guide.

4.89. The implementation or lifting of restrictions on the international trade of food, milk and drinking water should take into account the guideline values contained in Ref. [31], ensuring consistency with GSR Part 7 [2] and GSR Part 3 [3].

4.90. In order to reassure the public of the safety of food and milk during the transition phase, certification by the relevant authorities should be ensured. The reassurance of the safety of drinking water should include reporting the available monitoring results to the public.

Restriction on non-food commodities

4.91. Lifting or adapting restrictions on non-food commodities implemented during the emergency phase as a precaution or based on estimates (e.g. on the basis of EALs or OIL3 of Ref. [5]) should be based on more 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 analysis, i.e. OIL_C, should be used for this purpose. A methodology to derive default OIL_C values is given in the Appendix.

4.92. During the transition phase, the actual doses received from the use of non-food commodities and their contribution to the residual dose should be estimated based on the actual circumstances to inform the decision making on adapting or lifting this protective action.

4.93. GSR Part 3 [3] establishes the specific reference level for commodities in the longer term in an existing exposure situation at about 1 mSv/y effective dose. Restrictions on non-food commodities extending in the longer term in an existing exposure situation might be subject to a gradual dose reduction on the basis of actual doses in order to achieve this reference level. However, this discussion goes beyond considerations concerning the termination of the emergency exposure situation and is thus beyond the scope of this Safety Guide.

4.94. The implementation 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 criterion given in GSR Part 7 [2]. The methodology given in Appendix can also be used for this purpose.

4.95. In order to reassure the public of the safety of non-food commodities during the transition phase certification by the relevant authorities should be considered.

Dose reduction considerations during the transition phase

Prevention of inadvertent ingestion and inhalation

4.96. Actions to prevent inadvertent ingestion (such as limitations regarding playing on the ground, working in gardens or washing hands) could be advised during the urgent phase. However, as a protective action, advice on preventing inadvertent ingestion and the inhalation of re-suspended material should also be implemented during the transition phase, on the basis of actual conditions, along with lifting evacuation or relocation, to allow for dose reduction among those returning to live in an affected area.

Decontamination, control of access and other actions

4.97. Long term remediation may be needed after large scale emergencies with significant releases of radioactive material into the environment (for which further guidance is provided in Ref. [16]). However, control of access, decontamination of the area or commodities and other simple dose reduction techniques should be used during the transition phase to allow for the progressive lifting of protective actions. These actions should be considered for application beyond the areas where evacuation and relocation were implemented during the emergency phase and for areas to which people are returning.

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

Delineation of areas

4.99. Those areas identified during the transition phase that cannot be socially and economically inhabited should be delineated. These 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 the respective prerequisite in Section 3). Subject to these measures for access control, the delineation of an area as inadequate for inhabitation should not constitute an obstacle to terminating the emergency.

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

4.101. Delineation of areas as inadequate for inhabitation should consider radiological aspects, along with the other prerequisites mentioned in Section 3; in addition, social factors, such as public acceptance to return to the area, should also be taken into account. The existing geographic or jurisdictional boundaries may also be considered for social reasons when deciding on the delineation.

Additional preconditions for lifting protective actions that include people returning to an area

4.102. The areas to which people are returning should not endanger their well-being and enable them to carry out their routine social and economic activities. It should be recognized, however, that limited restrictions on normal living habits may still need to be observed and possibly extend into the longer term. The following preconditions should be fulfilled before allowing people to return to the area that was evacuated or from which people were relocated:

– 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, etc.).

– Clear instructions and advice on the restrictions still in place and the required changes to behaviours and habits, including land use, have been provided to those returning.

– Public support center(s) and information material (e.g. leaflets, posters) for public reassurance and psychosocial care are available for those returning to an area.

– A strategy has been established for the restoration of workplaces and for the provision of social support for individuals working in the area.

PROTECTION OF EMERGENCY WORKERS AND HELPERS

General

4.103. GSR Part 7 [2] and GSR Part 3 [3] define '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.

4.104. Emergency workers may include:

– Relevant employees of operating organizations (those employed directly by the operating organization and also 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.
– Relevant personnel from other response organizations and services, such as response managers, rescuers, firefighters, drivers and crews of evacuation vehicles, medical personnel, members of monitoring teams, members of decontamination teams, workers engaged in various activities on the site and off the site, including the restoration of critical infrastructure and the management of waste generated in the emergency.
– Relevant personnel engaged in providing medical support and care to the affected population.

4.105. GSR Part 7 [2] require that emergency workers be designated prior to an emergency and that the involvement of emergency workers not designated prior to the emergency be limited to the extent possible. Designated emergency workers are assessed for their fitness for the intended duties prior to their engagement as emergency workers and on a regular basis thereafter.

4.106. GSR Part 7 [2] defines '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 (s)he is aware that (s)he can be exposed to ionizing radiation while doing so. While engagement of helpers during the urgent phase is less expected, as seen in the emergency response to the Fukushima Daiichi accident, helpers can be increasingly engaged as the emergency evolves, particularly during the transition phase.[28]

4.107. The IAEA safety standards [2, 3, 5, 32] 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 protection of emergency workers and helpers during the transition phase and complements these standards.

4.108. GSR Part 7 [2] requires that, once the emergency has been terminated, all workers are subject to the relevant requirements for occupational exposure in a planned exposure situation given in 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 engaged in different works to be protected in the framework for occupational exposure in planned exposure situation. Ref. [32] provides further recommendations and guidance on occupational radiation protection in planned and existing exposure situations.

4.109. Any decision to terminate a nuclear or radiological emergency and to transition to a planned or an existing exposure situation should consider the feasibility of compliance with the requirements for occupational exposure as it would for a planned exposure situation (see Section 3).

Identification and designation

Emergency workers

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

4.111. Relevant organizations should use the process of designation of emergency workers that will be engaged during the transition phase:

– To inform emergency workers of their rights, duties and responsibilities with regard to occupational radiation protection; and
– To recognize their responsibilities, commitments and duties as employers in occupational radiation protection, so that they can be effectively discharged at the preparedness stage and during the transition phase.

4.112. The relevant organizations that may assume a role and assume responsibilities during the transition phase may not have the necessary expertise and capabilities to provide for radiation protection of their employees (i.e. emergency workers). Examples of such organizations may include those coping with the restoration of infrastructure or dealing with conventional waste within an

[28] Helpers in an emergency are coming from among the public and thus, they do not have a status of workers (for an employer) as defined in GSR Part 3 [3]. However, once registered and integrated in the emergency response operations, they should be protected in accordance with Requirement 11 of GSR Part 7 [2].

affected area. Thus, these organizations may need an institution[29] to provide such services and should make arrangements for this.

4.113. The arrangement referred to in para. 4.112 should not transfer the responsibilities, commitments and duties in occupational radiation protection of the relevant organization to the institution providing the services.

Helpers

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

4.115. As part of the emergency arrangements, designated organizations should determine:

– What type of work helpers may be engaged in during the transition phase;
– A mechanism for their engagement (e.g., where and how volunteers from the public may express their interest and willingness to help, information and instructions with which helpers will be provided, organization(s) or tasks to which they will be assigned, etc.);
– The process of informing and training helpers about their rights, duties and responsibilities.

Specific considerations for the transition phase

4.116. For emergencies involving significant long lasting contamination of the environment that would require transition to an existing exposure situation, the protection of emergency workers and helpers during the transition phase will be challenged by:

– Large variations in the radiological conditions expected within the affected area under an emergency exposure situation warranting simultaneous application of different measures for the protection of emergency workers and helpers;
– Severe radiological conditions being present at the site for longer period and, thus, challenging the on-site response efforts;
– Different exposure situations existing simultaneously in different areas, warranting workers undertaking the same work to be subject to different dose restrictions;
– The large number of emergency workers involved from different organizations and services with diverse backgrounds, knowledge and expertise, some of which may not necessarily have been identified and designated as emergency workers prior to the emergency;
– Numerous members of the public volunteering to help in activities taken during the transition phase.

4.117. The need for adequate arrangements to protect emergency workers and helpers should account for the simultaneous implementation of different schemes for the protection of emergency workers and helpers as necessary. However, a consistent approach should be applied for the protection of emergency workers and helpers, to the extent possible, taking into account Refs [2, 3, 5, 32].

4.118. The application of different measures and dose restrictions to protect emergency workers and helpers during the transition phase could be a source of confusion among all concerned parties. Thus,

[29] Depending on the national legal and regulatory framework, technical service providers as specified in Ref. [32], for example, may be identified and used for this purpose.

any inconsistency in dose restrictions and measures to be applied for the protection of emergency workers and helpers, and its basis, should be clearly communicated to all concerned parties.

Justification and optimization

Justification

4.119. The detriment associated with doses received during the implementation of the protection strategy by the 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 during the transition phase when justifying and optimizing the strategy to meet the actual circumstances.

Optimization

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

Dose restrictions for emergency workers and helpers

4.121. Paras 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] be applied, on the basis of a graded approach, for emergency workers, except for the following tasks: saving human life or preventing serious injury; actions to prevent severe deterministic effects or prevent the development of catastrophic conditions that could significantly affect people and the environment; and actions to avert a large collective dose. For these tasks, guidance values are to be established for restricting the exposures of emergency workers, taking into account those given in Appendix I of GSR Part 7 [2].

4.122. 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 for the urgent phase of a nuclear or radiological emergency. Although the implementation of these actions should be pre-planned, it is expected that they would be driven by the prevailing conditions as the emergency situation evolves. They would be carried out early in the emergency response when there is a scarcity of information regarding the radiological situation where the emergency work is to be performed. Due to the urgency associated with implementing these actions and its importance, detailed planning of the work of emergency workers may not be possible; thus, higher 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.

4.123. Actions to avert a large collective dose may extend through the early phase and the transition phase of an emergency owing to the range of activities that are warranted to be taken to allow for the termination of an emergency and the timely resumption of social and economic activity. During the transition phase, the knowledge and understanding of the situation where 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 this phase can be taken after detailed planning. This provides the opportunity for a more stringent protection of emergency workers by following the occupational radiation protection requirements for planned exposure situations, including the application of dose limits for occupational exposure in line with Refs [2] and [3].

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

4.125. Protection and safety of emergency workers and helpers during the transition phase should be optimized, taking into account the characteristics and the necessity of the work to be carried out and the abovementioned dose restrictions (summarized in Table 4.2).

Dose restrictions for female emergency workers

4.126. The IAEA safety standards [2, 5, 32] do not limit the involvement of female emergency workers in an emergency response. However, these standards provide requirements and guidance for protecting the foetus in case of a possible pregnancy of the female emergency worker.

4.127. In the circumstance of para. 4.126, the IAEA safety standards [2] set requirements and guidelines for female workers to be informed of the risk of severe deterministic effects to a foetus following exposure greater than 100 mSv equivalent dose to the foetus. Therefore, any pregnant female worker is to be excluded from taking actions to avert a large collective dose, if this may result in an equivalent dose to the embryo and foetus exceeding 50 mSv for the full period of in utero development. Situations in which a female worker may receive doses at these levels are primarily expected early in the emergency response (i.e. during the urgent phase).

4.128. For those activities to be carried out within occupational radiation protection requirements for a planned exposure situation given in GSR Part 3 [3], working conditions need to be ensured for pregnant or potentially pregnant female workers that afford the same broad level of protection to the embryo or foetus or the breastfed infant as that required for members of the public in a planned exposure situation.

4.129. To allow for the adequate protection of the foetus, female workers who are aware that they are, or might be, pregnant should notify their employer prior to undertaking the relevant work. Following notification, the employer has the responsibility to inform the female emergency worker of the associated health risks to the foetus and to ensure adequate working conditions and protective measures to ensure compliance with the dose restrictions mentioned in paras 4.127 and 4.128.

TABLE 4.2. DOSE RESTICTIONS FOR WORKERS AND HELPERS DURING THE TRANSITION PHASE

Tasks	**Guidance value**[a]		
	$\boldsymbol{H_p(10)}$[b]	$\boldsymbol{E}$[c]	$\boldsymbol{AD_T}$[d]
Emergency workers			
Actions to avert a large collective dose, such as: - Actions to keep the affected facility/source stable - Monitoring (environmental, source, individual)	< 100 mSv	E < 100 mSv	$< \frac{1}{10} AD_{T,\ Table\ II.1}$[e]
Other activities, such as: - Remedial actions including decontamination on the site and off the site - Repairing the affected facility and restoring the relevant critical infrastructure. Waste and radioactive waste management - Monitoring (environmental, source, individual) - Medical management of contaminated patients - Implementing corrective actions	Dose limits for occupational exposure in planned exposure situation given in GSR Part 3 [3]		
Helpers			
	$\boldsymbol{E}$[c]		
Identified activities in the national arrangements such as: - Restoring critical infrastructure (e.g. roads, public transportation networks) - Conventional waste management	E < 50 mSv		

[a] 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 this 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; and

(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. both dose from external exposure and committed dose from intakes), which are to be estimated as early as possible in order to make it possible for any further exposure to be restricted as appropriate.

[b] Personal dose equivalent $H_p(d)$ where d = 10 mm.

[c] Effective dose.

[d] RBE weighted absorbed dose to a tissue or organ.

[e] Values of RBE weighted absorbed dose to a tissue or organ given in Table II.1 of Appendix II of GSR Part 7 [2].

4.130. In order to protect female workers who are aware that they are pregnant, all relevant organizations should make adequate arrangements for:

– Notification of an actual or suspected pregnancy;
– Informing the female worker of the associated health risks prior to undertaking the assigned work;
– Assessing and monitoring the conditions in which the female emergency worker may need to undertake the assigned work;
– Ensuring that adequate protective equipment is provided to the female emergency worker and that she is trained in its use;
– Assessing the equivalent dose to the embryo or foetus following the emergency work as a basis for determining if 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

4.131. The implementation of adequate dose management for emergency workers and helpers warrants the establishment of a comprehensive system for monitoring and controlling the doses that considers the use of individual dosimeters or other appropriate methods. Ref. [32] provides guidance regarding monitoring for the assessment of internal and external exposures relevant to occupational radiation protection.

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

– Register the emergency workers and helpers engaged in the emergency response.
– Continuously monitor hazardous conditions in which emergency workers and helpers are to perform their duties.
– Comprehensively plan the expected work in an emergency exposure situation, while accounting for the hazardous conditions present and the time needed to complete the work.
– Assess the total effective dose and the RBE weighted absorbed doses to an organ or tissue of emergency workers and helpers via all exposure pathways.
– Record doses received.
– Communicate to emergency workers and helpers the doses received, placing the associated health hazards in perspective in plain and understandable language.

4.133. Considering the anticipated hazardous conditions and expected duties in an emergency response, 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, and should identify:

– The training needs and needs for personal protective and monitoring equipment.
– The need for implementing iodine thyroid blocking or supplying adequate personal protective equipment to emergency workers against inhalation of radioactive iodine in cases of prolonged working activities during the transition phase.
– Tasks during the performance of which emergency workers may be subject to exposures exceeding occupational dose limits.
– To whom employers need to provide comprehensive information on the risk involved as a basis for obtaining informed consent.

– The need for regular health surveillance to assess the initial and continued fitness of emergency workers for their intended duties.

4.134. The implementation of the arrangements addressed in paras 4.132 and 4.133 for emergency workers not designated in advance and also for helpers may encounter the following challenges:

– They may not have had any recognized rights and duties in occupational radiation protection prior to their involvement and. thus, may not have been trained at all in radiation protection.
– Their employers may not have the capacity to discharge their responsibilities, duties and commitments in the occupational radiation protection of these workers.
– Helpers will not have an employer who would provide for their protection.
– No assessment of their health condition (i.e. fitness for duty) may be possible prior to undertaking emergency work.

4.135. In the circumstance described in para. 4.134, GSR Part 7 [2] require that designated organization(s), at the preparedness stage, register and integrate these emergency workers and helpers into emergency response operations and, thus, provide for their protection. The designated organization should be given the responsibility to implement, as appropriate, the arrangements for undesignated emergency workers and helpers mentioned in paras 4.132 and 4.133.

4.136. The organization designated in accordance with para. 4.135 should also be responsible for the provision of ‘just-in-time’ training to undesignated emergency workers and helpers before they carry out of their specified duties. This includes:

– Instructions on their assigned duties and how to carry them out under the assessed conditions.
– Information on the health risks associated with performing these duties.
– The protective measures available and how they should be implemented effectively.

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 4.2, which exceed the dose limits for occupational radiation protection in a planned exposure situation.

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 includes generic criteria, in terms of received dose, consistent with the criteria for members of the public (effective dose of 100 mSv in a month) at which longer term medical actions need to be taken. These 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. During the transition phase, it is not expected that emergency workers and helpers may incur doses exceeding 100 mSv effective dose or approaching the thresholds for severe deterministic effects. Should this occur 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 Ref. [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 during the transition phase. Thus, emergency arrangements should ensure that both can be provided, and the responsible organizations and facilities should be identified.

Consideration for other workers

4.140. During the transition phase, other categories of workers may carry out work within an affected area. Examples include teachers and medical staff of hospitals, working in an affected area to prepare it 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, they should be subject to the reference levels agreed to be applied for members of the public to allow for the transition to happen (see para. on ref lev). The application of the reference level for the residual dose for these workers needs to take into account the fact that some of these workers may come from the affected area (and are thus spending 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, one of the prerequisites to be met prior to the termination of the emergency is the detailed characterization of the radiological situation and the exposure pathways and the assessment of the doses to the affected populations. This characterization of the exposure situation should be performed during the transition phase to support, as appropriate:

– Adjusting the implementation of the protection strategy on the basis of actual circumstances, including adapting or lifting specific protective actions.
– Identifying measures necessary for protecting emergency workers and helpers.
– Identifying those individuals that should be registered and subjected to long term medical follow up.
– Decision making on the termination of the emergency.
– Planning for long term recovery within the new exposure situation.

4.143. Emergencies resulting in long term exposures due to residual radioactive material in the environment warrant the continued monitoring in the longer term within an existing exposure situation. Guidance provided in this Safety Guide should allow for the development of a long term monitoring strategy during the transition phase to enable achieving the respective prerequisite in para. 3.20.

4.144. This guidance complements the IAEA Safety Standards Series No. RS-G-1.8 [33], which provides recommendations and guidance on environmental and source monitoring for the purposes of radiation protection in various circumstances and in emergency exposure situations, including considerations on dose assessments and on the interpretation of monitoring results.

Preparedness stage

4.145. To characterize the exposure situation in detail, monitoring (environmental, source, individual—as appropriate) should be carried out. A monitoring strategy should be developed at the preparedness stage on the basis of postulated emergency scenarios and associated hazards and consequences, taking into account the available resources. The monitoring strategy should stipulate priorities for different phases of the emergency consistently with the protection strategy.

4.146. The monitoring strategy should be used for assessing doses to the affected population and should consider targeting the following exposure pathways associated with the transition phase:

– External exposure from the radioactive material deposited on the ground;
– Internal exposure due to ingestion of food, milk and drinking water;

– Internal exposure due to inhalation of resuspended contaminated material.

4.147. As part of the monitoring strategies, the available monitoring resources should be identified to include, *inter alia*:

– Organizations, expert bodies, local and national laboratories, private institutes, universities and research centres responsible for implementing the monitoring strategy.
– 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.
– A mechanism for ensuring the comparability and consistency of measurements and for their interpretation, including training, quality management and inter-comparison exercises.
– An organization designated as responsible for validation, recording and retention of monitoring results and assessments.
– A mechanism for incorporating monitoring results and assessments into the decision making processes.

4.148. In the transition phase, the monitoring strategy may be supported by decision aiding (modelling) tools in identifying 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 directions and not just in those areas indicated by modelling tools. The objective of using these tools and their limitations should be clearly communicated to all concerned parties and documented in the monitoring strategy.

4.149. Monitoring data are an important basis for decision making in all phases of the emergency. However, the uncertainties associated with the results of the monitoring may impact 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 non-representativeness of samples and/or measurements and/or human error (e.g. lack of training). In order to reduce as much as possible the technical uncertainties, appropriate quality assurance requirements should be agreed upon, at the preparedness stage, and observed by all parties providing measurements during the emergency response. To reduce human errors, people involved in radiation monitoring should be periodically trained.

Transition phase

4.150. In emergencies involving radioactive releases into the environment, depending on the severity of the emergency, characterization of the radiological conditions may evolve from atmospheric monitoring to wide area survey and to direct measurement (see Ref. [33]). During the transition phase, reliable data from monitoring should be obtained by 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 (to be) received and on the contribution of each exposure pathway. Therefore, the radionuclide composition of the release or contamination should be identified as early as possible.

4.152. To evaluate the external dose, gamma dose rate and deposition measurements should be carried out. Therefore, as soon as possible, detailed radionuclide specific deposition maps and external gamma dose rate maps should be established and periodically updated, taking into account 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 for heterogeneity of the deposition patterns due to the variation in the released radionuclides spectrum and the meteorological conditions prevailing during the emergency phase. In this regard, a comparison of the atmospheric releases and dispersion patterns with meteorological rainfall data may help to identify areas of potentially higher deposition.

4.154. Mapping of deposition patterns and of external gamma dose rate should be prepared during the transition phase. The maps should be shared with interested parties, and they should be accompanied with plain language explanations regarding the associated health hazards and the need for protective actions.

4.155. Exposure from ingestion of contaminated food, milk and drinking water may result from episodic or continuous intakes, depending on the abundance of the locally produced food in the diet of people living in contaminated areas. To evaluate the ingestion dose for people living in long term contaminated areas, a comprehensive environmental sampling and monitoring programme should be carried out to allow for continuous monitoring of the presence of radionuclides in food, milk and drinking water, taking into account the local diet, as well as in crops and animal feed.

4.156. During the transition phase, the 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, special circumstances (e.g. carrying out activities in an arid, windy environment or a dusty environment) may lead to it contributing significantly to total doses. This should be taken into consideration and monitoring for resuspended particles, as appropriate, included in the monitoring programme.

4.157. Doses should be reassessed using the monitoring results and the dose assessment tools/models foreseen in the monitoring strategy developed at the preparedness stage. The estimations should be carried out as realistically as possible, focussing on the doses to the representative person or groups and taking into account realistic habits, the real pattern of contamination and the food, milk and drinking water that are used by people in the contaminated areas. Assessed doses (either projected, received or residual) should be compared with the generic criteria and reference levels pre-set in the protection strategy or with dose restrictions applicable for emergency workers and helpers.

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

General

4.158. This sub-section describes emergency arrangements to be made for implementing long term medical follow-up and for providing mental health and psychosocial support following a nuclear or radiological emergency in the light of its perception and impact on the termination of the emergency.

4.159. GSR Part 7 [2] requires that arrangements are made:

- To identify individuals with possible contamination or individuals who have possibly been sufficiently exposed to result in radiation induced health effects, and to provide them with appropriate medical attention, including longer term medical follow-up; and
- For the identification of individuals 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 warranting 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 include:

– Guidelines for effective diagnosis and treatment.
– Designation of medical personnel trained in clinical management of radiation injuries.
– Designation of institutions for evaluating radiation exposure (external and internal), for providing specialized medical treatment and for longer term medical actions.
– Criteria for identifying these individuals and for their registration (see Appendix II of GSR Part 7 [2] and Ref. [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 registry of those individuals identified as requiring longer 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 Ref. [5] for further details), has been established.
– A programme for longer term medical follow-up for registered individuals has been established.
– When transitioning 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:

– To provide for the long-term medical care for individuals who suffered deterministic effects or for those individuals incurring doses that exceed the thresholds for these health effects; and
– Provide for the early detection and diagnosis of stochastic effects (e.g. thyroid cancer) in asymptomatic affected population in order to allow for an effective treatment.

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

4.164. The objectives of medical follow-ups and mental health and psychosocial support should be clearly explained to those involved to ensure that the expectations among them are appropriate.

Coordinating mechanism

4.165. The mechanism to coordinate 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 comprise an existing organization that is designated to act as a coordinating authority in this area or a newly established body consisting of representatives from public health, radiation protection, emergency management, epidemiological and other relevant authorities.

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

4.167. The coordinating authority should, at the preparedness stage, establish criteria for identifying and registering those individuals requiring long term medical follow up and mental health and psychosocial support. These criteria should take into account those given in Refs [2, 5] and should be agreed upon by all relevant authorities.

Registering individuals for long term medical follow-up

4.168. Should a nuclear or radiological emergency occur, registering those individuals that 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 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 (location at the time of the event, duration of exposure, activities carried out, etc.); 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 but not limited to: the reason for their selection for a long term medical follow-up; assessed doses and associated health risks; a contact point in the institution responsible for the medical follow-up; a copy of the record on the performed procedures and laboratory tests, if appropriate (e.g. radiological and clinical assessment, blood tests etc.); a description of symptoms that may eventually present and whom to consult in case of the presentation of symptoms. These individuals should also be given the opportunity to ask questions and be offered psychosocial support.

4.172. The information on a patient's dose received, as well as the medical history and records, should comply with the usual conditions of doctor-patient confidentiality and should be securely stored for a period of time 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:

– Initial duration of the medical follow-up.
– Management of the information and reporting and sharing of results.
– Choice of medical specialists to be involved in the medical follow-up.
– Management of biological and non-biological samples.
– Management of mental health and psychosocial consequences.
– Ethical and cost-benefit aspects.

4.174. Arrangements for the long-term medical follow-up should provide individuals an access to information about the results of their medical evaluations and to adequate source for information such as respective health care providers.

4.175. Decision on the medical follow-up 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 Refs [2, 3]) and individual health risk assessment. Consideration should be given to patients that may also be included in screening and monitoring programmes for stochastic effects.

4.176. Screening and monitoring programmes for stochastic effects should be based on the criteria supported by sound scientific evidence for observing an increase in the incidence of cancer among the exposed population (see Refs [2, 3]). The inclusion of non-cancer health effects in the monitoring programme should be carefully considered. In case of limited resources being available, a priority for a long-term medical follow-up should be given to most vulnerable populations, such as infants, children and pregnant women.

Mental health and psychosocial support

4.177. Arrangements should be made to provide mental health and psychosocial support to cope with psychological stress among people being evacuated, relocated or returning to live normally in the affected area and to support their well-being. In this, people's life styles and their need for reassurance following a nuclear or radiological emergency should be taken into account. These arrangements should allow for facilitating a two-way communication between the authorities and members of the concerned parties.

4.178. As part of the arrangements set forth in para. 4.177, the establishment of a public support centre for the affected populations should be considered. Local doctors, nurses, pharmacists, psychologists 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. Instructions that place the health hazards in perspective and training on efficient risk communication approaches tailored for various population groups should also be given to the local doctors, nurses, pharmacists, psychologists and other health care specialists in order to enable them to provide advice to the public in the settings of their practices.

RADIOACTIVE WASTE MANAGEMENT

General

4.179. A nuclear or radiological emergency may generate radioactive waste. In particular, nuclear or radiological emergencies resulting in significant contamination of the environment (such as the Chernobyl accident, the Goiânia radiological accident and 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 to the implementation of the national policy and strategy for radioactive waste management, as well as to overall efforts to enable the termination of the emergency and achieving long term recovery objectives.

4.180. As an activity following the emergency, the management of radioactive waste will not be of primary importance early in the response (especially during the urgent phase), when the focus will be on the effective implementation of the protection strategy and on bringing the situation under control. However, the impact on radioactive waste to be generated and its management should be one of many factors to be considered in the processes for justification and optimization of the protection strategy at the preparedness stage.

4.181. As the emergency evolves, 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 this 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 in GSR Part 7 [2].

4.182. While it should be recognized that each emergency will be specific and detailed planning for all aspects of waste management may 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, the following should be considered:

– Responsibilities for radioactive waste management after an emergency should be allocated clearly and consistently, to the extent possible, with the national policy and strategy for radioactive waste management.

– Responsibilities for conventional waste management and conditions under which conventional waste arising from the emergency and emergency response actions will be managed should be agreed upon.

– 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, waste management during the emergency response.

– Characteristics of 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, taking into account past experience.

– Guidance should be put in place on the characterization and categorization of radioactive waste, which takes into account the diversity of radiological, chemical, physical, mechanical and biological properties of the waste to be generated in a range of postulated emergencies in accordance with the existing national regulations and guidance on radioactive waste management.

– Guidance should be put in place on the handling of conventional waste and radioactive waste during an emergency, which describes what types of radioactive waste can be accepted in existing storage or disposal facilities. Guidance on measures for the handling of waste that deviates from the acceptance criteria of existing facilities should also be given. This guidance should be in accordance with the existing national regulations and guidance on waste management.

– Methodologies should be developed for initiating radioactive waste pre-disposal management activities (e.g. segregation, packaging, transport, storage) in a timely and appropriate manner following the emergency. As part of these methodologies:

    – Options for radioactive waste minimization (such as reuse and recycling) that are feasible should be identified.

    – Necessary tools, equipment, procedures, training, drills and exercises to support effective waste management should be identified and put in place.

– 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 categorization of radioactive waste should take into account the complexity of the characteristics of radioactive waste generated during the emergency, compared to radioactive waste arising from normal operations. Thus, it may necessitate identifying new techniques and methodologies to characterize the waste to complement those used for waste arising from normal operations. The general requirements and guidance on waste characterisation can be found in Refs [34–36].

Review of the national framework

4.184. Establishment of the emergency arrangements described in para. 4.182 should be accompanied by a review of the national framework for the safe and secure management of the radioactive waste established in accordance with Ref. [34]. The aim of this review is to identify if there is a need to improve the national framework to accommodate radioactive waste generated in a nuclear or radiological emergency. Considerations should include, but are not limited to: the applicability of a set exemption/clearance and categorization schemes for such waste, if available; the robustness of safety demonstrations and licensing processes; and their impact 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 management of radioactive waste following a nuclear or radiological emergency in a timely manner, taking into account that, for small scale emergencies, the management of radioactive waste may easily fit within the available waste management options and respective licensing framework established in accordance with Refs [34] and [37].

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 management of waste and its impact on the economy and society can be further complicated by introducing low criteria, compared with those derived from radiological protection considerations. In the IAEA safety standards, radioactive waste is defined as follows: :

> "For legal and regulatory purposes, *waste* that contains, or is contaminated with, radionuclides at concentrations or *activities* greater than *clearance levels* as established by the *regulatory body*." [24]

This definition recognizes that material with activity concentrations equal to, or less than, clearance levels is radioactive from a physical point of view, but the associated radiological hazards are considered to be negligible.

4.187. The identification and classification of radioactive waste generated in an emergency should consider the exemption/clearance levels given 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 the waste 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. Where exemption/clearance levels and concepts are appropriately applied, conventional measures taken by workers for their protection, while dealing with such waste (e.g. gloves, masks etc.), should be assessed as adequate in providing for their radiation protection.

4.188. Considering para. 4.187, 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.

Pre-disposal management

4.189. The radioactive waste should be properly segregated and characterized as early as possible in the transition phase taking into account both radiological and non-radiological aspects of waste (see Refs [34–36]). Emergency arrangements should also consider that, in order to support rather than delay, the emergency response actions, radioactive waste may need to be managed during the urgent and early phase, before its characteristics are fully understood (e.g. to allow for mitigatory actions to be taken while protecting emergency workers). In all circumstances, the mixing of waste from different origins and/or composition should be carefully considered for compliance with national regulations and guidance for radioactive waste management.

4.190. Based on the characteristics of the radioactive waste, predisposal options should be selected taking into account the general requirements for the predisposal management of radioactive waste set forth in Ref. [34].

4.191. Advanced arrangements for predisposal management (e.g. pre-treatment, treatment, conditioning, transport, storage) of radioactive waste arising from a nuclear or radiological emergency should include consideration of:

– National experience in radioactive waste management;

– Acceptable waste collection points and their characteristics;

– Acceptable storage site characteristics (such as geographical, physical and demographic aspects, as well as the proximity to the affected site/area and the availability of necessary public infrastructure); and

– The need for transport of radioactive waste, adherence to transport regulations [38] and any deviation from established practices, as necessary.

Disposal management

4.192. 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 compared with other aspects of predisposal management. Thus, identifying final disposal options should not delay the timely decision for terminating a nuclear or radiological emergency and the subsequent transition to the new normality.

Managing human remains and animal remains

4.193. GSR Part 7 [2] requires that consideration 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.

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

– Identification of religious practices and cultural practices within the State;

– Identification of possible management options applicable to the identified practices and the type of exposure (internal or external);

– Consultation on what management options may be acceptable with the relevant interested parties that include representatives of different religious groups; and

– Training of workers assigned to handle the remains on basic radiation protection principles, including ways to prevent the spread of contamination and inadvertent ingestion.

4.195. Conventional measures taken by workers for their general protection while handling remains (e.g. gloves, masks, etc.) should be considered adequate to provide for their radiation protection.

CONSULTATION WITH THE PUBLIC AND OTHER INTERESTED PARTIES

General

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

4.197. In recognition of para. 4.196, GSR Part 7 [2] requires:

– The termination of a nuclear or radiological emergency includes prior consultation with interested parties, as appropriate.

– The government ensures that, as part of its emergency preparedness, arrangements are in place for the termination of a nuclear or radiological emergency. The planning process includes arrangements for consultation of interested parties.

– Adjustment of protective actions and other response actions and of other arrangements that are aimed at enabling the termination of an emergency be made by a formal process that includes consultation of interested parties.

4.198. Involvement of, and consultation with, relevant interested parties should start as early as possible during the preparedness stage and should develop with an aim to continue, as appropriate, during the transition phase and after the termination of the emergency.

4.199. As shown in Fig. 4.2, the consultation process should vary in form and extent throughout the various phases of an emergency, allowing for an effective response during the emergency phase with limited 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 a progressive engagement of interested parties and their contributions to implementing an effective protection strategy.

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

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

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

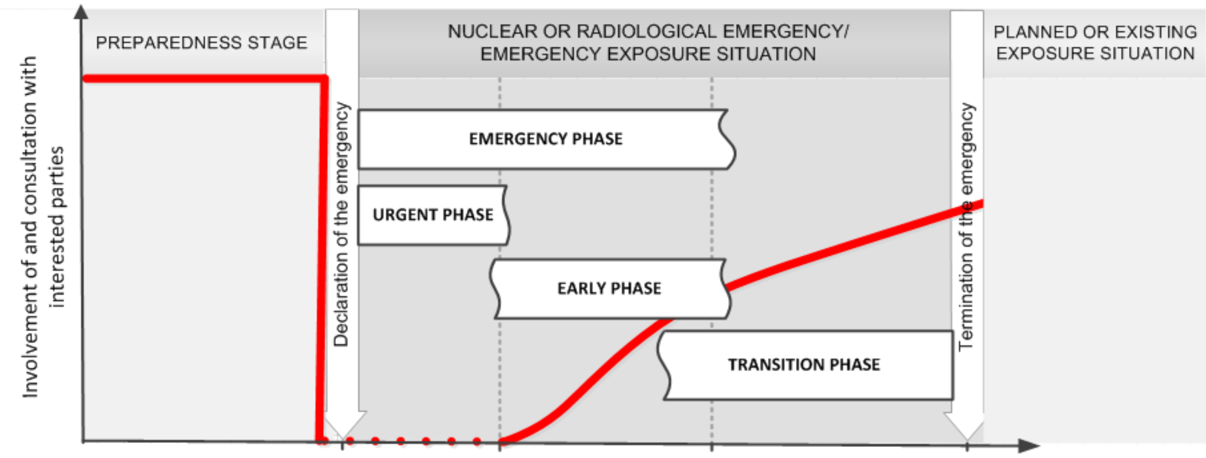

Fig. 4.2. Involvement of, and consultation with, interested parties during different phases of a nuclear or radiological emergency

Preparedness stage

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

4.204. Mechanisms to involve and consult with relevant interested parties should be developed to allow for understanding the complexity of the community, recognizing the community's capabilities and needs, fostering a relationship with community leaders, building and maintaining partnerships and empowering local actions. The actual involvement of different interested parties will depend on the actual situation (type of emergency, source involved, consequences expected), the scale of the emergency expected and the phase of the emergency.

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

– The objectives of the consultation;
– The targeted interested parties;
– Applicable legal and regulatory requirements;
– Timeframes for effective consultation;
– Relevant documents to be published or otherwise made publicly available;
– Ways in which the interested parties may comment, directly or through representative consultative bodies, on relevant documents;

– The possibility for public meetings, formal hearings and other appropriate means of consultation;
– Arrangements for reviewing and assessing the result of the consultation;
– Provisions to consider the result of the consultation in the decision making processes.

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

COMPENSATION OF VICTIMS FOR DAMAGE

4.207. Many past nuclear or radiological emergencies resulted in the loss of life, health consequences and loss of or damage to property and the environment. This loss and damage may have an adverse impact on the economy, industry, 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 payment of compensation for the damage caused either by the emergency or by the emergency response actions taken.

4.208. GSR Part 7 [2] requires that governments "ensure that arrangements are in place for effectively governing the provision of prompt and adequate compensation of victims for damage caused by a nuclear or radiological emergency". The following paragraphs address the compensation based on the legal regime of civil liability. Other possible forms of compensation that are not based on the civil liability regime are not covered.

4.209. Compensation for damage caused by radiological (i.e. non-nuclear) emergencies is exclusively governed by the national law 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.

4.210. In the case of nuclear emergencies, a number of treaties (see Refs [39–46]) have been adopted 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 course of 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.

4.211. All of these treaties are based on the same basic principles of civil liability for nuclear damage. These principles are: exclusive liability of the operator of a nuclear installation; strict (no fault) liability of the operator; minimum liability amount; the operator's obligation to cover liability through insurance or other financial security; limitation of liability in time; equal treatment of victims; and 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 where the financial amount available under the civil liability regime is insufficient to compensate for nuclear damage.

INFRASTRUCTURE

Plans and procedures

4.212. 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 timely and effective response from the onset of the emergency until the time the emergency is terminated, these arrangements should cover the transition phase consistently with the guidance provided in this Safety Guide.

4.213. The emergency plans, procedures and other arrangements for the transition phase should be developed by all relevant organizations in a manner that would allow for the effective implementation of the protection strategy, which includes considerations for meeting the prerequisites in Section 3 and taking into account the results from the hazards assessment.

4.214. As more organizations and parties become involved 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 this phase and beyond. This should account for any changes in the authority and discharge of responsibilities between different phases, the triggering mechanism of this change, the coordination arrangements, the decision making processes and criteria, the staffing resources required, the type of data and information that needs to be transferred or made accessible by relevant parties and the arrangements and mechanism for carrying it out.

Training, drills and exercises

4.215. GSR Part 7 [2] requires that:

- Governments ensure that personnel relevant for emergency response 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.
- The operating organization and response organizations identify the knowledge, skills and abilities necessary to perform the functions for emergency response.
- Exercise programmes are developed and implemented to ensure all functions for emergency response and all organizational interfaces are tested at suitable intervals.
- The operating organization and response organizations make arrangements to review and evaluate responses in exercises, in order to record the areas in which improvements are necessary and to ensure that the necessary improvements are made.

4.216. The knowledge, skills and abilities necessary to carry out activities during the transition phase may differ from and may extend beyond those necessary for the emergency phase. Therefore, the selection of the requisite knowledge, skills and abilities for personnel that will be involved during the transition phase should consider the different aspects of the transition phase, and should also target those personnel that will be engaged.

4.217. The training programmes developed in the area of emergency preparedness and response at different levels for the transition phase should consider the personnel that will participate in the training and re-training. These programmes should also consider the level of the training (duration, frequency, type and format, performance review, etc.) warranted for the different personnel carrying out the different activities during the transition phase.

4.218. The exercise programmes developed and implemented to systematically test the overall adequacy and effectiveness of the emergency arrangements should include the objective of facilitating the timely resumption of normal social and economic activity being tested within an agreed timeframe (once every three to few years), including the participation of the relevant organizations. Small scale exercises (e.g. table top exercises) should also be designed and used frequently to test various aspects of the transition phase (coordination, information exchange, transfer of information and data, changes in authority and in discharge of responsibilities decision-making processes, etc.) within an organization at the facility, local, regional or national levels.

4.219. As part of the management system, training and exercise programmes should be evaluated, and areas of improvements should be identified. The feedback from this evaluation should be used for review and, as necessary, revision of the emergency arrangements for the transition phase.

Logistical support and facilities

4.220. Requirement 24 of GSR Part 7 [2] requires that governments ensure that adequate logistical support and facilities are provided to enable emergency response functions to be performed effectively. To enable the termination of the emergency, adequate logistical support and facilities should be made available, when and where necessary, during the transition phase.

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

Quality management system

4.222. Requirement 26 of GSR Part 7 [2] requires that governments ensure that a programme is established within an integrated management system to warrant 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, which includes periodic and independent appraisals, arrangements for incorporating lessons learned from research, operating experience and exercise and for record keeping. The programme should cover all the arrangements for the transition phase.

APPENDIX
CONSIDERATIONS FOR ADAPTING OR LIFTING PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

I.1. This Appendix provides the generic criteria and operational intervention levels (OILs) that should be considered as initiators for adapting or lifting protective actions and other response actions implemented in a nuclear or radiological emergency, taking into account those established in Refs [2, 5]. It also provides guidance on further considerations for adapting or lifting specific protective actions and other response actions.

I.2. National generic criteria and OILs should be established at the preparedness stage to support adapting or lifting specific protective actions and other response actions, taking into account those contained in Table I.1. These pre-established OILs for the transition phase should be used to initiate considerations for adapting or lifting specific protective actions (i.e. what protective actions may need to be lifted, when this might happen and to whom it may apply) in accordance with para. 4.67.

I.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 on an assessment of the residual dose from all exposure pathways against the pre-set reference level (see paras 4.58 and 4.75).

I.4. The pre-established OILs for adapting or lifting protective actions and other response actions should consider[30]:

– The generic criteria established in Ref. [2] for enabling the transitioning to an existing exposure situation (see para. 4.65);
– 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 such as pregnant women and children, will be living normally[31] and that the lifting of restrictions on food, milk or drinking water will be implemented through the use of OIL6 [5][32] (see Table I.1);
– All individuals being exposed;
– The contribution from all relevant radionuclides and their progenies;
– The contribution from all relevant exposure pathways;
– Any behaviour of the radionuclides that will have a significant impact on the OIL value;
– The relevant effective dose (annual) and, as appropriate, organ dose calculations (annual or for the full period of in-utero development);
– The response of the monitoring instruments;
– Relevant operational requirements (e.g. usability of OILs under field conditions);
– The overall protection strategy.

[30] Further details on the methodology for deriving OILs can be found in Ref. [47].

[31] That is, carrying out normal activities, such as children playing on the ground and people working outside.

[32] The combined 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), the external exposure from radioactive material deposited on the ground (i.e. ground shine), external exposure from resuspended radioactive material (i.e. air shine), inhalation of resuspended radioactive material and inadvertent ingestion of soil (e.g. from dirt on the hands) (with OIL_T).

I.5. A methodology that can be used for deriving a default OIL_T[33] value for a specific radionuclide mix is given below. The relative activity of the radionuclides composing the radionuclide mix will vary over time due to processes such as radioactive decay, resulting in a time dependent $OIL_T(t,mix)$, given by:

$$OIL_T(t,mix) = \left(\sum_i (RA_i(t,mix) \times IR_{grd,i})\right) \times Min\left\{ \begin{array}{l} \left(\dfrac{GC(Transition, E, 1a)}{\sum_i (E_{grd-scenario,i}(1a) \times RA_i(t,mix))}\right), \\ \left(\dfrac{GC(Transition, H_{fetus}, 9mo)}{\sum_i (H_{foetus,grd-scenario,i}(1a) \times RA_i(t,mix))}\right) \end{array} \right\} \times WF$$

where:

- $RA_i(t,mix)$ [unitless] is the relative activity of radionuclide i at time t for a specific radionuclide mix. It is determined by $RA_i(t,mix) = A_i(t,mix) / \Sigma_i[A_i(t,mix)]$, where $A_i(t,mix)$ [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 transitioning to an existing exposure situation based on the total effective dose to the representative person over 1 year [2];
- GC(Transition,H_{foetus},9mo) = 0.02 Sv is the generic criterion used for transitioning to an existing exposure situation based on the total equivalent dose to the fetus over the period of in utero development [2];
- $E_{grd-scenario,i}$ (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 [47];
- $H_{foetus,grd-scenario,i}$ (9mo) [Sv/(Bq/m^2)] is the total equivalent dose to the foetus over the period of in-utero development for the ground exposure scenario, per unit ground surface activity of radionuclide i [47];
- WF [unitless] is a weighting factor used to allow for the quantification of other considerations. For the example values given below, it was set to 1 for simplicity.

I.6. For a single radionuclide, the equation in para. I.5 will result in a single time independent OIL_T value. For a single radionuclide mix, it will result in a time dependent $OIL_T(t)$ curve based on which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. a nuclear accident), this will result in a set of time dependent $OIL_T(t,mix)$ curves based on which a single time independent value should be chosen.

I.7. Examples of default OIL_T values[34] calculated using the methodology in para. I.5 for a light water reactor emergency and for an emergency involving a specific radionuclide, e.g. Cs-137, are given below:

- $OIL_{T,LWR}$[35] = 4.8 µSv/h ambient dose equivalent rate above gamma background at 1m above ground level.

[33] See para. I.6 of this Appendix.

[34] For a nuclear or radiological emergency involving a large scale dispersion of radioactive material in the environment. The default value was calculated following the assumptions outlined in Ref. [47]. The contribution from the progenies that are in equilibrium with respective radionuclides are also considered.

[35] OIL_T for a release of radioactive material resulting from a severe emergency at a light water reactor (LWR) or its spent fuel, following the assumptions outlined in Ref. [47].

– $OIL_{T,Cs\text{-}137}$ = 4.8 µSv/h ambient dose equivalent rate above gamma background at 1m above ground level.

I.8. A methodology for deriving a default OIL_C value for a specific radionuclide mix is given below. The relative activity of the radionuclides composing the radionuclide mix will vary over time due to processes such as radioactive decay, resulting in a time dependent $OIL_C(t,mix)$, given by:

$$OIL_C(t,mix) = \left(\sum_i (RA_i(t,mix) \times IR_{comm,i}) \right) \times Min \left\{ \begin{array}{l} \left(\dfrac{GC(Commodities,E,1a)}{\sum_i (E_{comm-scenario,i}(1a) \times RA_i(t,mix))} \right), \\ \left(\dfrac{GC(Commodities,H_{foetus},9mo)}{\sum_i (H_{foetus,comm-scenario,i}(1a) \times RA_i(t,mix))} \right) \end{array} \right\} \times WF$$

where the factors are described in I.5. and:

– $IR_{comm,i}$ [(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 1 year [2];
– GC(Commodities,H_{foetus},9mo) = 0.01 Sv is the generic criterion for non-food commodities based on the total equivalent dose to the foetus 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;
– $H_{foetus,comm\text{-}scenario,i}$ (9mo) [Sv/(Bq/m^2)] is the total equivalent dose to the foetus 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.

I.9. For a single radionuclide this equation will result in a single time independent OIL_C value. For a single radionuclide mix it will result in a time dependent $OIL_C(t)$ curve based on which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. a nuclear accident), it will result in a set of time dependent $OIL_C(t,mix)$ curves based on which a single time independent value should be chosen.

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

TABLE I.1. GENERIC CRITERIA (GC) FOR THE PROJECTED DOSES AND OILs FOR INITIATING CONSIDERATIONS TO ADAPT OR LIFT SPECIFIC PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

Protective action	**GC for taking the action [2]**		**GC for considering to adapt/lift the action**		**OILs for considering to adapt/lift the action**	**Consideration**
	E[a]	$\boldsymbol{H}_{\mathbf{foetus}}$[b]	***E***[a]	$\boldsymbol{H}_{\mathbf{foetus}}$[b] 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, taking into account: (1) the actual residual doses in comparison to the pre-set reference level, and (2) the preconditions referred to in para. 4.102.
			≤ 20 mSv per year	≤ 20 mSv	< OIL_T (see paras I.5 and I.6)	Lifting the evacuation along with the decision to terminate the emergency exposure situation if the prerequisites specified in Section 3 and the preconditions referred to in para. 4.102 are fulfilled.

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, taking into account: (1) the actual residual doses in comparison to the pre-set reference level, and (2) the preconditions referred to in para. 4.102.
			≤ 20 mSv per year	≤ 20 mSv	< OIL_T (derived based on the methodology outlined in para. I.5)	Lifting the relocation along with the decision to terminate the emergency exposure situation if the prerequisites specified in Section 3 and the preconditions referred in para. 4.102 are fulfilled.
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]	Estimating the actual doses from ingestion pathway and their contribution to the residual dose from all exposure pathways before lifting the restriction.
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	< Guidance values in Ref. [31]	Lifting restrictions on trading food, milk and drinking water internationally.
Non-food commodities 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 based on the methodology outlined in para. 1.8)	Estimating the actual doses from the use of non-food commodities and their contribution to the residual dose from all exposure pathways before lifting the restriction.
Non-food commodities 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 based on the methodology outlined in para. 1.8)	Lifting restrictions on trading non-food commodities internationally.

[a] Effective dose.

[b] Equivalent dose to the fetus.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Legal Series No. 14, IAEA, Vienna (1987).

[2] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE CO¬ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).

[3] EUROPEAN COMMISSION, 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 ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

[4] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE CO-ORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1, IAEA, Vienna (2007).

[5] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, Report by the Director General, IAEA, Vienna (2015).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, Technical Volume 3/5 Emergency Preparedness and Response, IAEA, Vienna (2015).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Nueva Aldea, IAEA, Vienna (2009).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, OECD-IAEA Paks Fuel Project, Final Report, IAEA, Vienna (2009).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Lia, Georgia, IAEA, Vienna (2014).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Investigation of an Accidental Exposure of Radiotherapy Patients in Panama, IAEA, Vienna (2001).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Goiânia, IAEA, Vienna (1988).
[13] INTERNATIONAL ATOMIC ENERGY AGENCY, The International Chernobyl Project Technical Report, Assessment of Radiological Consequences and Evaluation of Protective Measures, Report by an International Advisory Committee, (1991).
[14] WORLD HEALTH ORGANIZATION, Health Effects of the Chernobyl Accident and Special Health Care Programmes, Report of the UN Chernobyl Forum Expert Group 'Health', Bennett, B., Repacholi, M., Carr, Z. (eds.), WHO, Geneva (2006).
[15] US NUCLEAR REGULATORY COMMISSION, Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement, NUREG-600, USNRC, Washington, DC (1979).
[16] DS468: Remediation Process for Areas with Residual Radioactive Material (under development).
[17] DS432: Radiation Protection of the Public and the Environment (under development).
[18] DS403: Decommissioning of Medical, Industrial and Research Facilities (under development).
[19] DS452: Decommissioning of Nuclear Power Plants, Research Reactors and other Nuclear Fuel Cycle Facilities (under development).
[20] DS475: Arrangements for Public Communications in Preparedness and Response for a Nuclear or Radiological Emergency (under development).
[21] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).
[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Radioactive Material and Associated Facilities, IAEA Nuclear Security Series No. 14, IAEA, Vienna (2011).
[23] EUROPEAN POLICE OFFICE, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL CRIMINAL POLICE ORGANIZATION–INTERPOL, UNITED NATIONS INTERREGIONAL CRIME AND JUSTICE RESEARCH INSTITUTE, UNITED NATIONS OFFICE ON DRUGS AND CRIME, WORLD CUSTOMS ORGANIZATION, Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, IAEA Nuclear Security Series No. 15, IAEA, Vienna (2011).
[24] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection, 2007 Edition, IAEA, Vienna (2007).
[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Governmental, Legal and Regulatory Framework for Safety, IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), IAEA, Vienna (in preparation).
[26] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4).
[27] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations. ICRP Publication 109. Ann. ICRP 39 (1).
[28] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency. ICRP Publication 111. Ann. ICRP 39 (3).

[29] INTERNATIONAL ATOMIC ENERGY AGENCY, Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, Emergency Preparedness and Response Series, EPR−NPP Public Protective Actions [2013], IAEA, Vienna (2013).
[30] WORLD HEALTH ORGANIZATION, Guidelines for Drinking-water Quality, Fourth Edition, WHO, Geneva (2011).
[31] CODEX ALIMENTARIUS COMMISSION, Codex General Standard for Contaminants and Toxins in Food and Feed, Schedule 1 — Radionuclides, CODEX STAN 193-1995, Codex Alimentarius Commission, Rome (2006).
[32] DS453: Occupational radiation protection (in preparation).
[33] INTERNATIONAL ATOMIC ENERGY AGENCY, Environmental and Source Monitoring for Purposes of Radiation Protection, IAEA Safety Standards Series No. RS-G-1.8, IAEA, Vienna (2005).
[34] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).
[35] DS447: Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities (under development).
[36] DS448: Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors (under development).
[37] INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR-5, IAEA, Vienna (2011).
[38] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 2012 Edition, IAEA Safety Standards Series No. SSR-6, IAEA, Vienna (2012).
[39] Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29th July 1960, as amended by the Additional Protocol of 28th January 1964 and by the Protocol of 16th November 1982 ("Paris Convention", 1960), http://www.oecd-nea.org/law/nlparis_conv.html.
[40] Convention of 31st January 1963 Supplementary to the Paris Convention of 29th July 1960, as amended by the additional Protocol of 28th January 1964 and by the Protocol of 16th November 1982 ("Brussels Supplementary Convention"), https://www.oecd-nea.org/law/brussels-supplementary-convention.html.
[41] Vienna Convention on Civil Liability for Nuclear Damage, IAEA-INFCIRC/500 ("Vienna Convention", 1963), https://www.iaea.org/sites/default/files/infcirc500.pdf.
[42] Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention (1988), https://www.oecd-nea.org/law/nljoint_prot.html.
[43] Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage, IAEA-INFCIRC/566 (1997), https://www.iaea.org/sites/default/files/infcirc566.pdf.
[44] Convention on Supplementary Compensation for Nuclear Damage, IAEA-INFCIRC/567 (1997), https://www.iaea.org/sites/default/files/infcirc567.pdf.
[45] Protocol to Amend the Paris Convention (2004), https://www.oecd-nea.org/law/brussels_supplementary_convention.pdf.
[46] Protocol to Amend the Brussels Convention (2004), https://www.oecd-nea.org/law/brussels_supplementary_convention.pdf.
[47] Operational intervention levels for light water reactor emergencies: Default values and methodology for their derivation, Emergency Preparedness and Response Series, IAEA, Vienna (under preparation).

ANNEX I
CASE STUDIES

This Annex provides case studies, in consideration of the guidance and recommendations provided in this Safety Guide, of the emergency response to: the Fukushima Daiichi accident (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). They briefly cover the management of the incidents and accidents and their consequences, from the declaration of emergency to the period of preparation for dealing with the recovery aspects and with the long term consequences under a different exposure situation.

The four case studies have been selected to present representative examples for transitioning 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 are also intended to cover emergencies associated with the nuclear industry as well as with the use of radioactive source in other applications, irrespective of the initiating circumstances.

The case studies provided in this Annex are neither intended to give an extended description of the incidents or accidents and the respective emergency response nor to evaluate the manner these events were managed. Each case study is used to draw conclusions against the prerequisites elaborated in Section 3 of this Safety Guide, with the aim of facilitating the understanding of the guidance provided.

The terminology used in these case studies generally follows the terminology 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.1. THE FUKUSHIMA DAIICHI ACCIDENT, JAPAN

The Great East Japan Earthquake, with a moment magnitude 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 (NPP) operated by the Tokyo Electric Power Company (TEPCO). As a result, the plant, which had six boiling water reactors (BWRs), experienced a station blackout, i.e. the loss of all external power and practically its entire 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 a large amount of radioactive material was released into the environment.

Emergency declaration and urgent protective actions

At 19:03 on 11 March 2011, the national Government established the so-called Nuclear Emergency Response Headquarters (NERHQ); at the same time, the declaration of a “nuclear emergency” was issued.

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 NPP. However, just over half an hour later, at 21:23, the national Government issued an order for the evacuation of an area within a 3 km radius of the plant, and for sheltering in an area within a radius of 3–10 km. At 05:44 on 12 March 2011, the national Government extended the evacuation to an area within a radius of 3–10 km. At 18:25, following the hydrogen explosion in Unit 1 of the Fukushima Daiichi NPP, the evacuation was further extended to an area within a radius of 20 km of the plant.

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

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, while still others awaited instructions from the national Government.

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

Early response actions

On 11 April 2011, the national Government announced that the criterion of 20 mSv dose projected to be received within one year from the date 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 might be exceeded. The national Government ordered that relocation of people from this area should be implemented in approximately one month. On the same day, the NERHQ issued an instruction for restricted access to the 20 km evacuation zone (‘restricted area’).

In addition to the ‘deliberate evacuation area’, an ‘evacuation prepared area in case of emergency’ (hereinafter: ‘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 in the event of possible renewed concerns regarding the Fukushima Daiichi NPP. The designation of the ‘evacuation prepared area’ was lifted on 30 September 2011. As a result of the monitoring conducted beyond the ‘restricted area’ (i.e. the 20 km evacuation zone) and the ‘deliberate evacuation area’, specific locations were identified where the projected doses to be received by residents was above 20 mSv within one year after the occurrence of the accident. On 16 June 2011, the national Government announced a guideline which specified that these locations should be designated as ‘specific spots recommended for evacuation’. On 30 June 2011, designation of these locations commenced, and, by May 2012, numerous locations with almost 300 houses had been identified as such ‘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 them with information that alerted them of the possibility of radiation exposure and supported them if they needed to be evacuated.

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

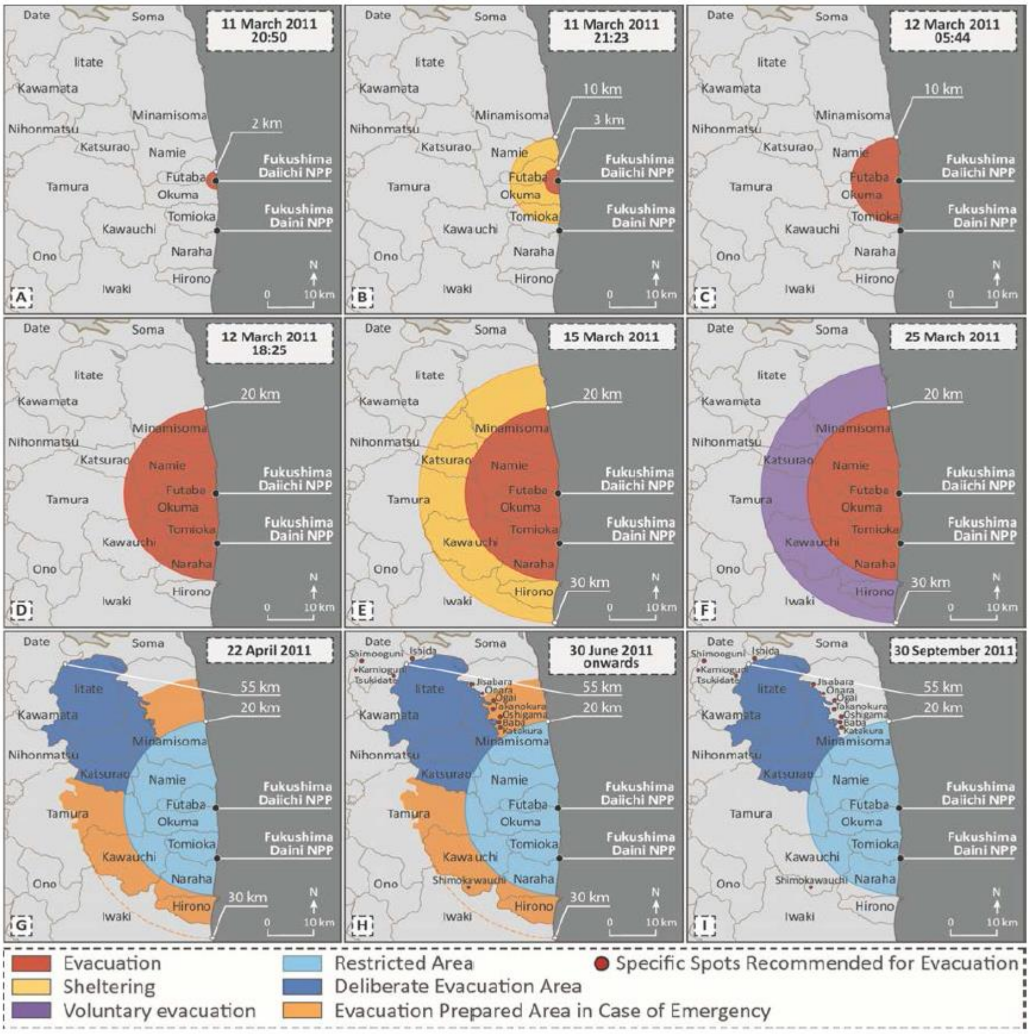

Fig. I-1. Areas and locations where protective actions were ordered in or recommended until 30 September 2011 [I-1]

Transition to long term recovery

In developing arrangements for the transition from the emergency phase to the recovery phase after the accident, the Japanese authorities decided to apply the latest recommendations of the International Commission on Radiological Protection (ICRP) [I-2, I-3]. Although the Nuclear Emergency Act [I-4] included a chapter on general ‘Measures for Restoration from Nuclear Emergency’, the specific policies, guidelines and criteria, as well as the overall arrangements for the transition from the emergency phase to the recovery phase, were developed after the accident [I-1, I-5].

The overall responsibility of managing the process for returning to normality rested with NERHQ. The Nuclear Emergency Act specified that termination of NERHQ would take place when the declaration of the cancellation of a nuclear emergency situation is issued. The Nuclear Safety Commission (NSC) was given responsibility to provide advice on the termination of the emergency [I-1].

On 17 April 2011, TEPCO issued a roadmap [I-6] that outlined the steps towards recovery on the site. In particular, the roadmap outlined the basic policy, targets and immediate actions in the areas of cooling, mitigation of consequences, and monitoring and decontamination [I-1].

With regard to off-site recovery, the ‘Policy for Immediate Actions for the Assistance of Nuclear Sufferers’ was issued and a roadmap was established by the NERHQ on 17 May 2011 [I-7] defining the objectives and conditions to be met for returning to normality. This roadmap indicated the need for reinforcement and continued implementation of monitoring, efforts related to evacuation areas, efforts to help evacuees return home, and other support measures. It listed nine groups of actions, divided into steps that were scheduled to be implemented over different target periods that were also related to the TEPCO's roadmap for on-site recovery: by mid-July 2011, within 3–6 months and in the mid-term.

The nine groups of actions were:

1. Actions for the restoration from the accident at the Fukushima Daiichi NPP;
2. Actions related to the area evacuated based on plant conditions up to a 20 km radius of the NPP ('restricted area');
3. Actions related to the area from which people were relocated ('deliberate evacuation area');
4. Actions related to the area in which people were advised to shelter ('evacuation prepared area in case of emergency');
5. Ensure the safety and reassurance of those affected;
6. Secure employment, and provide support for farms and industries;
7. Support the local municipalities in the affected areas;
8. Compensation to sufferers and affected businesses, etc.; and
9. Actions to assist those returning to areas that had been evacuated.

The roadmap was intended to facilitate communication and preparations for the transition to long term recovery operations and the resumption of normal social and economic activity. It allocated responsibilities and specified other organizational aspects of the transition process and specified the objectives and conditions for the termination of the emergency phase [I-1].

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 indicating 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.

During the emergency and transition phases, the NSC gave various kinds of technical advice about radiation protection to residents in the surrounding areas. On 19 May 2011, the NSC issued its views on the basis of advices on radiation protection.

Reopening of schools

Fukushima Prefecture requested the Local Nuclear Emergency Response Headquarters (Local NERHQ) to indicate the criteria for reopening the schools and the other educational facilities in the prefecture. In response, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), after consultation with the NSC, decided on 19 April 2011 that a dose criterion of 20 mSv/y is used for that purpose. In accordance with this criterion, MEXT decided to restrict the outdoor activities of children and students only at schools which had school and kindergarten grounds with air dose measurements of more than 3.8 μSv/h. The reopening of schools was categorized as an action in an existing exposure situation, while the establishment of the 'deliberate evacuation area' was handled as an emergency exposure situation. However, in both cases, the criterion of 20 mSv projected annual dose was used [I-1].

Environmental monitoring

On 13 June 2011, the 'Plan to Conduct Detailed Monitoring in Restricted Area and Planned Evacuation Area' [I-8] was announced. This plan addressed monitoring of air, soil, forests, water and human-made materials (such as homes roads)in the 'restricted area' and the 'deliberate evacuation area'. The results of the monitoring 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, Fukushima Prefecture and TEPCO in order to promote coordination in relation to monitoring. A comprehensive monitoring plan was finally issued in August 2011 that also specified the roles of various organizations which was revised later on. The plan stipulated that environmental restoration of the area surrounding the Fukushima Daiichi NPP and “more detailed monitoring” to meet the needs of children’s health and people’s safety and security would be implemented [I-9].

Health surveillance

On 19 May 2011, Fukushima Prefecture established the Fukushima Prefecture Health Management Survey Committee. The purpose of the different surveys was to alleviate the concerns of Fukushima residents related to the NPP accident and to ensure their safety and comfort in the long term through a health monitoring scheme. The health management surveys comprised a basic survey of all prefectural residents and a more detailed survey of children aged 18 or younger, pregnant women and others for whom additional surveying is deemed necessary. For the basic survey, questionnaires were sent to individual residents and the responses were used to estimate the external radiation exposure during the period of the highest air doses. On 30 June 2011, the Fukushima prefectural government began sending questionnaires to evacuees from higher contamination areas, which dealt mainly with dietary and behaviour issues in the weeks and months after 11 March 2011. The same set of questionnaires was sent to all remaining citizens of the prefecture on and after 26 August 2011. The detailed survey included four distinct parts: (1) a thyroid examination of children aged 18 and younger (target population: about 385 000); (2) a health survey with an additional comprehensive blood test (210 000); (3) a survey of pregnant women (approximately 15 000 each year); and (4) a survey on mental health and lifestyle (210 000).

The first round of the thyroid ultrasound examinations started in October 2011 and was completed in March 2014. The second round began in April 2014 and will be concluded in March 2016. An ultrasound examination of children will continue to be carried out biennially until the participants reach the age of 20 years; thereafter, they will be examined every five years. 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; it was returned by about 15 000 respondents. This survey is being updated every year to take account of new data, particularly on pregnancies and births. The mental health and lifestyle survey was conducted twice, in January 2012 and January 2013, with questionnaires covering physiological and mental conditions, lifestyle changes, experiences of the earthquake and tsunami, and radiation related issues, to provide adequate mental care and lifestyle support for evacuees [I-10].

Emergency workers and helpers from the public

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 was withdrawn gradually starting on 1 November 2011 for newly engaged emergency workers and, on 16 December 2011, (when the attainment of the cold shutdown state at the plant was announced) for most emergency workers [I-1]. However, there was a continued need for about 50 TEPCO employees working on the site to be subject to less stringent dose criteria, owing to the specifics of the duties they were carried out. Thus, it was not until 30 April 2012, about a year after the onset of the accident and several months after announcement of the cold shutdown state, that the increased dose criterion of 250 mSv was withdrawn also for these on-site emergency workers [I-1].

In parallel, the preparation for the planned decontamination and restoration work had started. This necessitated an establishment of a new legal framework for ensuring adequate protection of workers engaged in these works. This was mainly due to the fact regulations in Japan, at the time of the accident, did not sufficiently cover activities during the existing exposure situation following an emergency [I-1]. As of 26 August 2011, the requirements for occupational exposure in normal operation were applied for all workers who were engaged in decontamination work, restoration and waste management [I-1].

In the aftermath of the accident, people from the affected areas, as well as from all over 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 had been prepared to allow for their protection within the dose limit for the public under normal operations (1 mSv/y). [I-1]

Termination of urgent actions

On 19 July 2011, the NSC issued the 'Basic Policy on Radiation Protection for Termination of Evacuation and Reconstruction' [I-11]. It outlined protection measures to be taken against radiation in accordance with the particular exposure situations, specifically the emergency exposure situations and existing exposure situations. It 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 stated the public should participate in the planning of activities and policies related to these measures.

On 4 August 2011, in response to a request from the NERHQ for its advice on any necessary changes in the protective measures that were being implemented (evacuation, relocation and sheltering), the NSC provided the 'Standpoint of the Nuclear Safety Commission for the Termination of Urgent Protective Actions implemented for the Accident at Fukushima Daiichi Nuclear Power Plant', which included guidance on the termination of evacuation, relocation and sheltering [I-1]. The guidance included three recommendations for the termination of the protective measures specific to the areas that had been recommended to shelter, relocate and evacuate:

- The projected annual dose to the public is lower than the 20 mSv criterion;
- Preparation for the implementation of long term protective actions had been made;
- A framework for the participation of the relevant local governments and residents in the process of deciding on the long term protective actions is developed.

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.

On 9 August 2011, based on this recommendation, the NERHQ decided to prepare a review of evacuation areas which outlined the following three requirements for confirmation [I-1]:

(i) the safety status of the NPP;
(ii) a decrease of the dose rate; and
(iii) restoration of the public service functions and infrastructure.

Based on the 'Radiation Monitoring Action Plan for Homecoming regarding the Evacuation Prepared Area in Case of an Emergency', which was established on 25 July 2011, MEXT conducted various monitoring activities in municipalities of this area. As a result, ambient dose rates at all of the municipalities, including main spots near schools, were measured and did not exceed 1.9 μSv/h. Additionally, on 19 September 2011, all cities, towns and villages in the 'evacuation prepared areas' developed disaster recovery programs and submitted them to the NERHQ. Based on these disaster recovery programs, the NERHQ decided that conditions (i) to (iii) for the termination of the ‘evacuation prepared areas’ had been met.

The NERHQ exchanged opinions on the termination of the ‘evacuation prepared areas’ and the disaster recovery with the leaders of the cities, towns and villages concerned and, on 30 September 2011, asked the NSC for its advice on the lifting of ‘evacuation prepared area’. On the same day, the NSC replied that it had no objection to the NERHQ's decisions on the condition that appropriate measures were be taken on radiation monitoring as well as on decontamination activities. On the same day, the NERHQ issued a directive and a statement to the effect that the ‘evacuation prepared area’ should be lifted.

Waste management and decontamination works

Off-site waste that was generated following the accident may be classified either as debris from the earthquake/tsunami (often referred to as disaster waste) or as a consequence of remediation activities [I-1]. The debris consisted of materials such as wood, concrete and metal, while remediation waste included sludge from water and sewage treatments, incinerated ash, trees, plants and soil resulting from decontamination activities.

Arrangements for the management of radioactive waste established in Japan prior to the accident covered waste generated within facilities, such as NPPs, but it 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. Therefore, the Ministry of the Environment (MOE) established the criteria for treatment and disposal in consultation with the Ministry of Health, Labour and Welfare and the Ministry of Economy, Trade and Industry.

On 25 March, 12 April, 26 April and 6 May 2011, based on technical advice from the NSC [I-12], instructions were issued by MAFF on how to dispose of vegetables and raw milk in areas subject to food restriction(s). Instructions on what to do with foods that were not to be consumed were issued in the form of ‘Question and Answers’ on the Ministry of Agriculture, Forestry and Fisheries web site on 26 April 2011 [I-13].

The NSC proposed the policy and criteria regarding the management of waste affected by the accident in the ‘Near-term Policy to Ensure the Safety for Treating and Disposing Contaminated Waste around the Site of Fukushima Daiichi NPP” [I-14], issued 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 would be disposed of under proper management, and that some materials may be considered for reuse. Products manufactured from these reused materials would be checked for contamination and managed appropriately before being released onto the market. Appropriate protective measures would ensure that radiation exposures of workers and the public were kept as low as reasonably achievable. A final disposal strategy would be derived based on the quantities of waste, types of radioactive material, radioactivity concentration and evaluations of the long term safety of disposal facilities [I-1].

The ‘Act on Special Measures Concerning the Handling of Environmental Pollution by Radioactive Materials Discharged by the Nuclear Power Station Accident Associated with the Tohoku District — Off the Pacific Ocean Earthquake that Occurred on March 11, 2011’ (Act on Special Measures Concerning the Handling of Environmental Pollution) [I-15] was enacted on 26 August 2011 and took full effect on 1 January 2012. This Act became the main legal instrument for dealing with all remediation activities in the affected areas as well as the management of removed materials resulting from the remediation activities. It outlined the management of the contaminated areas and included the assignment of responsibilities to the national and local governments, the operator and the public. It facilitated the transition from an emergency exposure situation to an existing exposure situation. It 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 [I-1].

As decontamination was an urgent issue, the NERHQ established the ’Basic Policy for Emergency Response on Decontamination Work’ [I-16] on 26 August 2011 without waiting until the Act took full effect. The policy summarized specific targets and working principles in implementing decontamination, including the intended reduction of the estimated annual radiation dose to the public in the affected areas by approximately 50% in the next two years. This policy focussed on: (a) areas where the estimated annual radiation dose exceeded 20 mSv and for which the national government would directly promote decontamination to reduce the estimated annual radiation dose quickly to below 20 mSv; (b) areas with the estimated annual radiation dose of less than 20 mSv, where the national government would work with municipalities and local residents to conduct effective decontamination activities so that the estimated annual exposure dose would be closer to 1 mSv; and (c) areas frequented by children, such as schools or parks, for which thorough decontamination work was to assume a high priority, with the government aiming to reduce the estimated annual radiation dose closer to 1 mSv as soon as possible and continuing to implement measures that would result in further reductions.

Stabilization of the plant conditions and delineation of areas

Since the designation of restricted areas and areas for which evacuation orders had been issued brought many hardships to both residents and local communities, it was to be promptly rearranged. The new arrangements would be conditioned by changes in the overall situation, such as the confirmation of the safety of the NPP or the reduced risk of radiation exposure to residents, on the major premise that the safety of the residents would be ensured. On 16 December 2011, the NERHQ reached the judgement that the overall safety of the power plant had been secured in light of the achievement of such targets as the ‘cold shutdown’ of the reactor (Step 2), more stable cooling of the spent nuclear fuel pool, reduction in the overall quantity of accumulated water and control of the dispersion of radioactive material.

By the completion of Step 2, the safety of the NPP was ensured and a situation had been established which allowed a specific discussion about rearranging the restricted areas and areas for which evacuation orders had been issued. These included: (1) restricted areas within a 20 km radius from the NPP and (2) deliberate evacuation areas beyond a 20 km radius from the NPP. On 26 December 2011, the NERHQ, as a first step, adopted a basic concept for rearranging the areas. It then considered the responses it had received to the various issues resulting from the rearrangement, as well as the management of newly designated areas. The process was characterized by a careful discussion and coordination among the parties concerned, such as the prefectural and municipal governments and the residents.

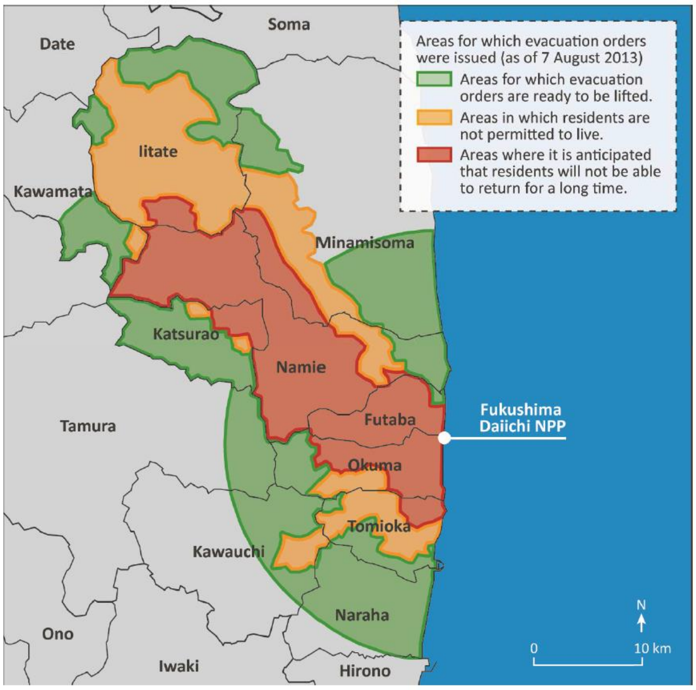

Fig. I-2. Completion of the arrangement for areas where evacuation orders were issued (7 August 2013) [I-1].

The restricted areas and areas for which evacuation orders had been issued would be rearranged into three areas: areas for which evacuation orders were ready to be lifted (Area 1); areas in which the residents were not permitted to live (Area 2); and areas where it was expected that the residents would not be able to return for a long time (Area 3).

Based on this policy, the NERHQ held consultations and made adjustments with Fukushima Prefecture and the relevant municipalities, as well as their residents. On 30 March 2012, it decided to rearrange the restricted areas and evacuation areas for first three municipalities. As shown in Fig. I-2, the arrangement for the areas where evacuation orders had been issued was completed in all eleven affected municipalities on 7 August 2013.

Conclusions

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 phase to the recovery phase, were developed after the accident taking into account the latest recommendations of the ICRP.

The emergency 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 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 relocation of people at hot spot locations, were taken on the basis of detailed monitoring within the first few months after the accident and were completed by November 2011. The emergency phase, during which the radiation dose was in steady decline (the target of Step 1), was completed by around 19 July 2011. However, some hot spots requiring evacuation were detected up to November 2011.

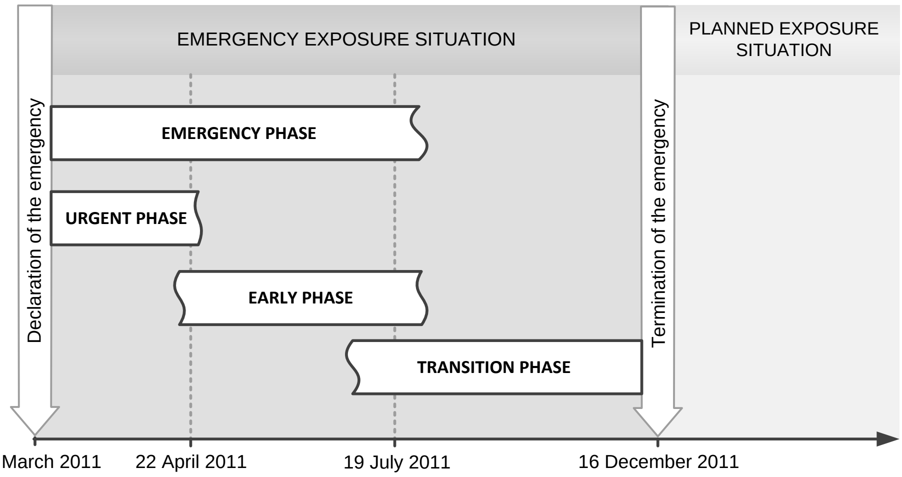

Fig. I-3. Retrospective sequencing and milestones of the Fukushima Daiichi accident.

The following months, from around July to December 2011, might be considered a transition period to set up arrangements for the recovery phase. This included:

- Detailed monitoring to characterize the exposure situation and exposure pathways;
- Arrangements for the implementation of long term health surveillance;
- Determination of the criteria for termination of protective measures;
- Formalization of the long term management of radioactive waste;
- Adjusting of arrangements for the protection of emergency workers, other workers and helpers, both on and off the site;
- Rearrangement of protective action areas;
- Establishment of long term plans for decontamination;
- Announcement that control of the situation had been regained at the plant.

On 16 December 2011, a 'cold shutdown' state was reached at the NPP, but no termination of the emergency situation and entering in the existing exposure situation was officially declared. The basic concept for the arrangement for areas where evacuation orders had been issued was decided on 26 December 2011 too. The Act on Special Measures Concerning the Handling of Environmental Pollution took full effect from 1 January 2012 and accelerated the remediation activities for the affected areas and preparation for returning of people. Arrangements for the evacuation areas have been completed in all eleven municipalities in August 2013. The evacuation order was officially first lifted in Tamura City on 1 April 2014.

Conclusions against the prerequisites for the termination of the emergency

General prerequisites

– Had the necessary urgent and early protective actions been implemented?
  All the public protective actions had been identified and implemented primarily by July 2011. However, remaining relocations warranted in some hot spot areas were being implemented by November 2011. Access controls to evacuated areas and food control and restrictions were put in place.

– Was the exposure situation stable and well understood?
  No further significant dispersion of radioactive materials into the environment was expected; extensive monitoring carried out 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, the affected people and areas had been identified, doses had been assessed and regularly reassessed as the understanding of the situation improved.

– Was the source of exposure brought under control and were no further significant accidental releases or exposure 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 at the NPP on 16 December 2011.

– Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?
Many analyses were carried out following the accident (since 2011) to investigate the circumstances surrounding the accident and to identify improvements warranted in the regulatory control and emergency arrangements in place. Lessons identified from these analyses were incorporated in the respective arrangements of different organizations and at different levels as of 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', TEPCO.

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 the development of the new regulatory guidelines issued in October 2012 by the newly established Nuclear Regulatory Authority (NRA). Necessary off-site emergency arrangements had been discussed for the first time after the NRA designated TEPCO's Fukushima Daiichi NPP as a specified nuclear power facility on 7 November 2012, based on the Reactor Regulation Act.

No further consideration was given on the emergency arrangements warranted for the accident damaged facility at that time. However, this was an aspects considered in the national regulatory framework established after the accident.

– Were the requirements for occupational exposure as for a planned exposure situation confirmed for all workers engaged in recovery activities?
All the recovery work off-site (e.g. decontamination works) had been carried out under the national dose limits for normal operations involving ionizing radiation (i.e. dose limits for a planned exposure situation). However, relevant work, particularly on-site, remained to be carried out under the dose limits for emergency work. The increased dose criterion for emergency workers of 250 mSv was withdrawn gradually starting on 1 November 2011 for newly engaged emergency workers and, on 16 December 2011, for most emergency workers. This did not apply for about 50 TEPCO employees working on the site who remained subject to less stringent dose criteria, owing to the specifics of the duties they were carried out. On 30 April 2012, about a year after the onset of the accident and several months after announcement of the attainment of the cold shutdown state, it was announced that the increased dose criterion of 250 mSv was fully withdrawn also for these on-site emergency workers.

- Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?
  This was done on a continuous basis to also account for any new information that had become available. For the most part, 20 mSv annual projected effective dose was used for this purpose.

- Were non-radiological consequences (psychosocial, economic) and other factors (technology, land use options, availability of resources, community resilience) identified and considered?
  Arrangements implemented during the transition phase and strategies/policies developed considered restoration of normal social and economic activities and mitigation of economic impacts and restoration of public services to some extent. Major work and dialogues had been carried out with local communities, and different centres had been established to support those returning in the affected areas. Long term monitoring for psychosocial consequences among affected population was also planned and implemented.

- Was a registry of those individuals requiring further medical follow-up established prior to the termination of the emergency?
  Activities to identify these individuals and respective surveys had been initiated since May 2011.

- Was a strategy for the management of radioactive waste arising from the emergency developed when appropriate?
  The first policy in this regard was issued in June 2011. The Act on Radioactive Waste Management was adopted in August 2011 and entered into force on 1 January 2012. Meanwhile, the policy was in force and used to guide the waste management operations.

- Were the interested parties consulted?
  The 'Policy for Immediate Actions for the Assistance of Nuclear Sufferers' established by the NERHQ on 17 May 2011 was intended to facilitate communication and preparations for the transition to long term recovery operations and the resumption of normal social and economic activity. It allocated responsibilities and specified other organizational aspects of the transition process and the objectives of, and conditions for, the termination of the emergency phase. The policy was revised in July 2011. Status updates on the progress in implementing the policy were issued each month until December 2011. For example, the NERHQ exchanged opinions on the termination of the evacuation prepared areas and the disaster recovery with the leaders of the cities, towns and villages concerned and, on 30 September 2011, asked the NSC for advice on the lifting of emergency evacuation preparation zones.

Specific prerequisites

Transition to existing exposure situation

- Were justified and optimized actions taken to reach the generic dose criteria which would enable transition to an existing exposure situation and to ensure that the assessed residual doses would approach the lower band of the reference level for an emergency exposure situation?
  Remedial actions were being implemented with the aim to reach the 20 mSv/y projected effective dose criterion within affected areas. The policies adopted had foreseen continuation of actions within an existing exposure situation to reach 1 mSv in the long term.

- Were areas delineated which were not open for unrestricted use by the public prior to the termination of the emergency?
  Initial delineation had been carried out in March and April, when urgent and early protective actions had been implemented. On 22 April 2011, restrictions were also clearly announced for these areas, and, in the period up to November 2011, such announcement had been given for

hot spot areas. By 26 December 2011, clear directions for each restricted area were formulated.

- 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. On 28 March 2011, it was decided to control access to the evacuation areas and evacuees were informed. The 20 km zone was announced as a restricted area on 22 April 2011. Conditions for temporary access to the area within a 3–20 km radius of the NPP 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.

- 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 service, etc.)?
  Arrangements implemented during the transition phase and strategies/policies developed considered restoration of normal social and economic activities and mitigation of economic impacts and restoration of public services to some extent. Major work and dialogues had been carried out with local communities, and different centres had been established to support those returning in the affected areas.

- Were mechanisms and means in place for continued communication and consultation with all interested parties, including local communities?
  As different radiation protection measures had to be taken in different impacted areas, and as many people in these areas had been living in shelters, people had to be provided with more detailed information on radiation safety as well as about matters affecting their daily lives soon after the accident. One of the challenges in doing so was that television and the Internet were not available in many areas. To respond to the needs of this population, from 29 March to 30 June 2011, the Local NERHQs published a newsletter and distributed it at each evacuation site; as of April 2011, this information was periodically broadcasted through local radio stations. Materials regarding instructions under the name of the Director-General of the NERHQ, press releases on monitoring data of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), monitoring data by geographic area and materials on support measures for local business corporations were provided to local municipalities depending on their need. Such information was immediately released to the local media through press conferences etc. As of September 2011, the Support Team for Residents Affected by Nuclear Incidents in the NERHQ has been publishing a newsletter every month for evacuees outside of Fukushima Prefecture featuring a broad range of information on the restoration of Fukushima.

- 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 clearly 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, based on the additional annual effective dose estimated in the autumn of 2011: Special Decontamination Area and Intensive Contamination Survey Area. Within the Special Decontamination Area, which overlaps the former restricted areas, the national Government has the responsibility of formulating and effecting remediation plans. The Intensive Contamination Survey Area includes those municipalities where the additional radiation dose in the first year was estimated to be between 1 mSv and 20 mSv for individuals in some parts of the municipality. Municipalities conduct

monitoring surveys to identify areas requiring decontamination implementation plans and implement remediation activities in these areas, with the national Government providing financial and technical support to facilitate the remediation.

– Were the information and data gathered during the emergency with regards to the long term planning shared among relevant organizations and authorities?
MEXT opened a portal site on radiation monitoring in August 2011 by compiling information on monitoring being conducted by related ministries and agencies in line with their own administrative objectives, and updated the site as needed. In order to aggregate and accumulate monitoring data and facilitate the utilization thereof, the Japan Atomic Energy Agency took the initiative in creating a database linking to geographical information.
The response to the accident has provided a number of examples that show the benefits of involving affected populations in activities for recovery, from consultation and dialogue to remediation actions (so-called self-help actions). Open and effective communication with the public is an essential part of revitalization. An information hub for the area on decontamination (Decontamination Information Plaza) was opened in Fukushima City in January 2012 as a joint project of Fukushima Prefecture and the MOE.

– 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.

– Was a long term medical follow-up programme for the registered individuals developed?
Consideration of the need for a screening and monitoring programme for the affected population was initiated in May 2011, which included those programmes for early detection of radiation induced cancers and for mental health and lifestyle.

– Was a strategy for mental health and psychosocial support of the affected population and for consultation in relation to psychosocial health consequences developed?
Comprehensive medical check-ups were conducted with a routine medical examination organized by the municipalities. The mental health and lifestyle survey also included questionnaires covering physiological and mental conditions, lifestyle changes, experiences of the earthquake and tsunami and radiation related issues in order to be able to provide adequate mental care and lifestyle support for evacuees under the Fukushima Prefecture Health Management Survey.
From December 2011 to March 2012, a Center for Disaster Mental Health opened in succession in Miyagi, Fukushima and Iwate prefectures. The main office of the Fukushima Center was created in February 2012. In April 2012, six regional offices and two posts were established. In each office or branch, the staff is working as a member of multi-disciplinary teams which include a psychiatrist, nurses, public health nurses, psychiatric social workers, social workers, occupational therapists and clinical psychologists to provide comprehensive support for the various needs of refugees. They are also receiving full technical support from the School of Disaster Mental Health that has been newly established at the Fukushima Medical University.

– Was a strategy under consideration to compensate victims of damage resulting from the emergency?
The Dispute Reconciliation Committee for Nuclear Damage Compensation (Reconciliation Committee), which was established under the Act on Compensation for Nuclear Damage (Compensation Act), summarized on 28 April 2011 the 'Preliminary Guidelines for Determination of the Scope of Nuclear Damage due to TEPCO's Fukushima Daiichi and Daini

Nuclear Power Stations'. The Preliminary Guidelines clarify the basic concept of the scope of nuclear damage, considering evacuation costs, business losses and losses of property values, etc. suffered due to the Government's orders for evacuation and suspension of shipments. On the same day, TEPCO, taking into account the Preliminary Guidelines, set up a consultation office dedicated to nuclear damage compensation and initiated procedures to consult with and receive claims submitted from all people who suffered nuclear damage, including those who suffered damage due to harmful rumours caused by the accident. On 29 August 2011, the Dispute Reconciliation Center for Nuclear Damage Compensation was set up by the government to resolve disputes related to the nuclear accident by acting as a mediator between the parties involved.

However, since it was expected that it would take a certain amount of time until all procedures for damage compensation claims were completed and compensation was actually paid, the Government Headquarters on Nuclear Power Station Accident Economic Impacts Response decided on 15 April 2011 that TEPCO should provide immediate and necessary funds that should be allocated as compensation for the damage caused. The funds for provisional lump sum payments were regarded as temporary payments of the total amount of damages until the final amount was fixed. The government took the necessary measures in accordance with the agreement for compensation of nuclear damage under the Compensation Act.

In response to the TEPCO's request for the Government's financial support, the Act on the Nuclear Damage Liability Facilitation Fund was adopted on 3 August 2011 as the Government's support framework for compensation for nuclear damages. The act was to ensure: (1) the implementation of prompt and appropriate compensation for damages; (2) the avoidance of adverse effects on business operators involved in NPP stabilization and incident management; and (3) a stable supply of electricity essential for everyday life of the nation. The fund was established on 12 September 2011, and full scale operation commenced on 26 September 2011.

– Were administrative arrangements, legislative and regulatory provisions in place, or were the corresponding amendments underway, for the management of the existing exposure situation, including provisions for the necessary financial, technical and human resources?

As the national system that was in place prior to the emergency did not cover the management of an existing exposure situation of this extent, all the necessary policies, guidelines and acts had been urgently prepared starting in June 2011. Resource needs (expertise, manpower, equipment and material) had been mobilized from all over Japan, and the logistic support (transport, housing, etc.) was organized accordingly.

– Was individual monitoring of members of the general public still required for radiation protection purposes?

No, only for the affected population.

I.2. THE RADIOLOGICAL ACCIDENT IN GOIÂNIA, BRAZIL

In 1985, a radiotherapy institute, the Instituto Goiano de Radioterapia (IGR) in Goiânia (Brazil), moved to new premises, leaving in place a caesium-137 teletherapy unit without notifying the licensing authority, the Brazilian National Nuclear Energy Commission (CNEN) as required under the terms of the institute's licence. The former premises were subsequently partly demolished. As a result, the radioactive source remained insecure leading to the radiological accident (elaborated in details in Ref. [I-17]).

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

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

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 the phenomenon. Fragments of the source, with the size of rice grains, were distributed to several families. This proceeded for several days, by which time a number of people suffered from vomiting and diarrhoea including D.F.'s wife.

On 25 September 1987, D.F. sold the removed lead shielding and the remnants of the source assembly to another junkyard. By 28 September 1987, D.F.'s wife suspected that the glowing powder was causing the symptoms. 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 visiting medical physicist using a scintillation counter identified the presence of radioactivity at the Vigilância Sanitária.

Emergency declaration and urgent actions

On 29 September 1987, the Director of the Department of Nuclear Installations at CNEN was notified by phone. He suggested to gather more information about the radioactive source, the nature of the accident and the extent of the contamination and called the IGR. In Goiânia, the authorities alerted the police, the fire brigade, ambulance services and hospitals. When the first CNEN teams arrived on 30 September 1987, the local authorities transferred management responsibilities to CNEN, which was supported by the state military police and fire brigades, and later by the Brazilian army.

Existing emergency arrangements at the time of the accident were designed to cope with nuclear accidents at the Central Nuclear Almirante Álvaro Alberto (CNAAA) NPP, or 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; therefore, specific arrangements had to be set up, combining elements from the existing plans in an appropriate re-invented structure.

Priority in the emergency response was given to the medical aspects, the isolation of the radioactive source and contaminated areas already identified, the assessment of the environmental contamination and the reinforcement of human and technical resources.

Isolation of the source

The remnants of the source located in the courtyard at the Vigilância Sanitária were shielded in place on 30 September 1987. Using a crane, a section of sewer pipe was placed over the remnants and filled with concrete pumped over the courtyard's wall. This operation was completed by 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, most of the area cordoned off around the site could be reopened.

Monitoring and medical response

Upon identification of the accident, the Goiás State Secretary for Health made plans for receiving and isolating identified patients and screening people who had possibly been exposed at the city's Olympic stadium. The areas surrounding the known contaminated sites, where the dose rate exceeded 2.5 μSv/h[36], were evacuated and the residents directed to the stadium for contamination control. Access to these areas was further controlled.

As the environmental monitoring proceeded, several other sites of significant contamination were quickly identified, and their residents were evacuated and sent to the local soccer stadium for medical examination and contamination check. Blood, urine and faeces samples were obtained from each of the patients for bioassays.

At the stadium, individuals identified with radiological overexposure symptoms had been sent to the Tropical Diseases Hospital for medical care. Contaminated persons were requested to place their clothes in bags and take a shower. Those with internal contamination were referred for further medical care.

Due to spreading rumours, many people went to the stadium for reassurance, straining the limited monitoring resources then available.

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

Monitoring teams mapped the main contaminated sites and identified all hot spots, ensuring that no one else was at risk of serious exposure. This, however, did not preclude the possibility of later discovering other, less severely contaminated, areas that could also request actions and control.

Transition phase

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 further treatment of the injured, the improvement of the conditions at the sites of contamination, the clean-up operation and waste management.

The following week was devoted to the preparation of plans and strategies for the recovery. Resource needs (expertise, manpower, equipment and material) were assessed and mobilized. Taking into account the expected increase of resources, the logistic support (transport, housing etc.) was organized accordingly.

Patients in hospital and inhabitants of contaminated residences were interviewed concerning visitors and their own movements to identify potential transfer of contamination. Further surveys were conducted to confirm and localize less contaminated spots. Prior to environmental decontamination, plans were made for carrying out a comprehensive survey by car- and airborne gamma spectrometry and organizing an environmental survey programme. Various procedures were develop and written, namely for access control to contaminated areas, action criteria, equipment QA/QC and medical

[36] 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 10 times lower. This value was confirmed later because the underestimation regarding the house occupancy compared to occupational occupancy was compensated by the fact that the clean-up would last about 3 months.

follow-up (selection for cytogenetic and other blood tests). Plans for dealing with the large amount of waste expected to be generated by clean-up activities were established (e.g. gathering professional, technical and support staff, equipment, chemicals and machinery; finding a temporary disposal site; defining the specifications for waste containers).

The dose rate criteria of 2.5 µSv/h for evacuation stated at the beginning of the emergency were reconsidered, taking into account the yearly exposure limit for the public (5 mSv/y) and more realistic, but still conservative, estimates for occupancy and geographical distribution to relate the mean dose rate to the maximum dose rate. A time factor was also applied to reflect the decrease in radioactivity due, for example, to cleaning or weathering. A new limit of 10 µSv/h for evacuation (and return) was adopted.

Medical follow-up

Strict measures were taken to protect the medical staff against contamination and exposure during the three months for which the patients were treated in hospital. The doses received by the medical staff were below 5 mSv over the duration of the patients' hospital care.

Follow-up studies, including a continuing bioassay and whole body monitoring programme, were performed on the contaminated persons. Prussian Blue was successfully used for the very first time in humans to speed up the ^{137}Cs biological excretion processes.

Comprehensive environmental monitoring

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

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

Some 550 workers were engaged in the decontamination operations.

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

Forty-five different public places, including pavements, squares, shops and bars were decontaminated. Contamination was also found on about 50 vehicles.

In gardens, fruits were pruned from trees and eliminated. Much of the soil from enclosed gardens and yards was also removed on the basis of soil profile measurements. The site of the highest contamination was the house where the source capsule had been broken open. Exposure rates were very high, necessitating rotation among workers to keep their daily dose limit below the 1.5 mSv criterion.

After removal of rubble and soil, the place was covered by concrete or clean soil.

Waste management and disposal

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.

The preparation of decontamination operations included:

- Choice of a suitable disposal site;
- Design and construction of waste containers;
- Assemblage of the heavy machinery, such as excavators and back- and front-loaders;
- Updating of written operational procedures;
- Testing of various decontamination techniques;
- Preparation of a work timetable.

A suitable location for the disposal site had to be found, suitable receptacles meeting the regulatory requirements had to be assembled, and the constraints associated with the disposal and transport conditions had to be dealt with. Because of public concern, any possible disposal site in Goiânia was ruled out. The decision on the location of the waste storage site, its planning and construction took more time than had been expected. A site, 20 km outside the city, was chosen as a temporary disposal site on 16 October 1987, but major decontamination work started only by mid-November.

The clean-up operations of the decontamination of the main foci and remaining areas started by the middle of November and were carried out until the end of December 1987. The total volume of waste stored was about 3150 m^3.

Conclusions

Retrospectively, different sequences of the accident management and milestones can be recognized (see Fig. I-4) and roughly associated with the different phases of an emergency discussed in Section 2 of this Safety Guide. However, the complexity of the accident, together with the absence of specific emergency plans to address such a situation, resulted in unclear demarcations between the specific activities and phases.

The emergency phase began on 29 September 1987, when the broken ^{137}Cs source was identified as the cause of the symptoms affecting those 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; identification and isolation of the source; evacuation and cordoning of the heavily contaminated places; and contamination controls and decontamination of evacuees were carried out during the following days. The emergency phase, during which all potential sources of contamination were brought under control, was completed around 3 October 1987.

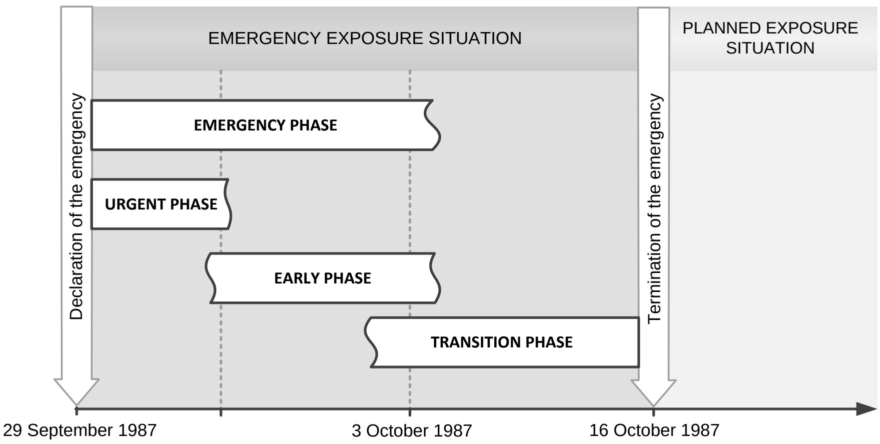

Fig. I-4. Retrospective sequencing and milestones of the Goiânia accident management.

The following two weeks, from 3 to 16 October 1987, can be considered as a transition period to set up a general strategy for the overall recovery. This included:

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

Although there was no clear termination of the emergency situation, 16 October 1987 might be considered as the beginning of the existing exposure situation, with the clean-up operations starting by the middle of November following the necessary preparations. The decontamination of the main foci and remaining areas was carried out from mid-November until the end of December 1987. The rehabilitation phase, aiming to restore normal living conditions, continued until March 1988.

Conclusions against the prerequisites for the termination of the emergency

General prerequisites

- Had the necessary urgent and early protective actions been implemented?
  The affected people had been identified and were taken care of; the contaminated places had been delimited, 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 and actors of 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 places had been identified and doses had been assessed; intervention criteria taking into account more realistic and site specific parameters associated with the consumption and living habits had been re-assessed.

- Was the source of exposure brought under control, and were no further significant accidental releases or exposure expected due to the event?
  The radioactive source had been located and 'neutralized'; residents had been evacuated from contaminated areas and access controls were in place, preventing further significant exposure.

- Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?
  Ref. [I-17] recommends that "preparedness to respond to radiological emergencies should extend not only to nuclear accidents but to the entire range of possible radiological accidents". Prior to the accident, Brazil did not consider such an emergency in its emergency arrangements. Any changes following the accident in the national arrangements required timeframes that go beyond those covered in the references consulted.

– Were the requirements for occupational exposure during a planned exposure situation confirmed for all workers engaged in the recovery activities?
The daily dose limit for workers was set at 1.5 mSv; other criteria were used for longer periods of activity (5.0 mSv per week; 15.0 mSv per month and 30.0 mSv per quarter). These limits were compatible with the yearly limit of 50 mSv used at the time.

– Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?
A maximum 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 consequences (psychosocial, economic) and other factors (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 given the type of the emergency. However, it was noted that some of the inhabitants of Goiânia were discriminated against, 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.

– Was a registry of those individuals requiring further medical follow-up established prior to the termination of the emergency?
The affected people had been identified and were taken care of.

– Was a strategy for the management of radioactive waste arising from the emergency, when appropriate, developed?
Within the period up to 16 October 1987, activities for choosing a suitable location for the disposal of waste and for defining specifications for waste containers were carried out.

– Were the interested parties consulted?
It is not clear if consultation with interested parties had occurred. A communication strategy had been under consideration in the period up to 16 October 1987.

Specific prerequisites

Transition to existing exposure situation

– Were justified and optimized actions taken to reach the generic dose criteria enabling transition to an existing exposure situation and to ensure that the assessed residual doses approach the lower band 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, they were too conservative, but they were the main drivers for the response actions and remedial actions taken. The decision on the criteria was strongly influenced by the pressure of public opinion, straining the limited monitoring and medical response resources.

– Were areas delineated for which it was feasible to allow unrestricted use by the public prior to the termination of the emergency?
By 16 October 1987, the evacuated areas to which access was restricted had been 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 service, etc.)?
  No relevant information was found considering the limited consequences of the accident.
- Were mechanism and means for continued communication and consultation with all interested parties, including local communities, in place?
  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. They also made frequent appearances on television, using analogies in simple language with common applications of radiation, such as medical X-rays. Several talks were given to different sections of the population, community groups and journalists. 250 000 copies of a pamphlet were distributed to explain radioactivity and radiation. A telephone service was operating 24 hours a day to answer inquiries 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 CNEN and, thus, there was no need for any transfer.
- Were information and data gathered during the emergency that was relevant to the long term planning shared between relevant organizations and authorities?
  Not applicable, as CNEN remained in charge.
- Was a long term monitoring strategy developed in relation to residual contamination?
  Consideration was given to this by 16 October 1987. The environmental monitoring programme continued in 1988, also on decontaminated sites, and lasted on a continuous 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 (that continued until the beginning of 1988), were performed on the contaminated persons.
- Was a strategy for mental health and psychosocial support of the affected population and for consultation in relation to psychosocial health consequences developed?
  Some emphasis was given to supportive psychological therapy of the victims, but it was recognized that a more adequate 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.
- Were administrative arrangements, legislative and regulatory provisions in place, or were the corresponding amendments underway, for the management of the existing exposure situation, including provisions for the necessary financial, technical and human resources?
  Resource needs (expertise, manpower, equipment and material) were assessed and mobilized, and the logistic support (transport, housing, etc.) was organised accordingly.

– Was individual monitoring of members of the general public still required for radiation protection purposes?
No, only for the registered affected people.

I.3. THE NUCLEAR INCIDENT AT PAKS NPP, HUNGARY

The Paks NPP in Hungary has four WWER 440 MWe reactors that supply about 40% of the electricity to the country. Units 1–4 went into commercial operation between 1983 and 1987.

On 10 April 2003, a fuel cleaning incident occurred 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 meters under water in a shaft adjacent to the fuel pool. The external surfaces of the fuel assemblies were being cleaned due to magnetite depositions on their cladding during a specially designed chemical cleaning process [I-118–I-20].

At 21:53[37] on 10 April 2003, activity was detected by the workers on the krypton-85 measurements installed in the cleaning circuit, and, at about the same time, the 'emergency' level was indicated by the noble gas activity concentration monitors within the reactor hall. The timeline of the different events during the incident is shown in Fig. I-5 [I-15].

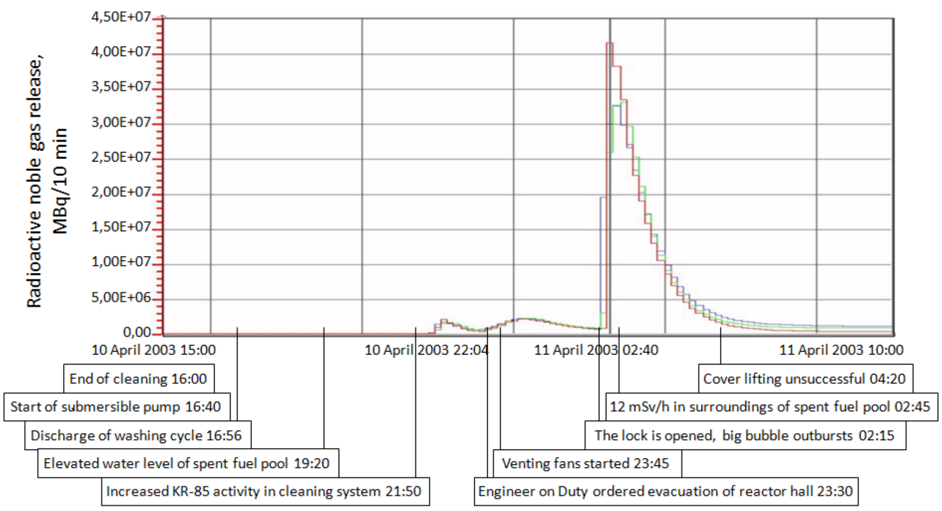

Fig. I-5. Timeline of events during the incident (courtesy of Hungarian Atomic Energy Authority (HAEA) and Paks NPP).

Taking response actions and activating the site emergency response organization

Once the noble gas activity concentration monitors within 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, it was observed during an inspection performed with the use of a video camera that most of the fuel had suffered heavy damage. About 16–17% of the fuel material was located at the bottom part of the cleaning vessel in form of debris. Figure I-6 shows the extent of the damage and the location of fuel debris.

[37] All times are given in local time (due to the summer time system, this is UTC +02:00 hours).

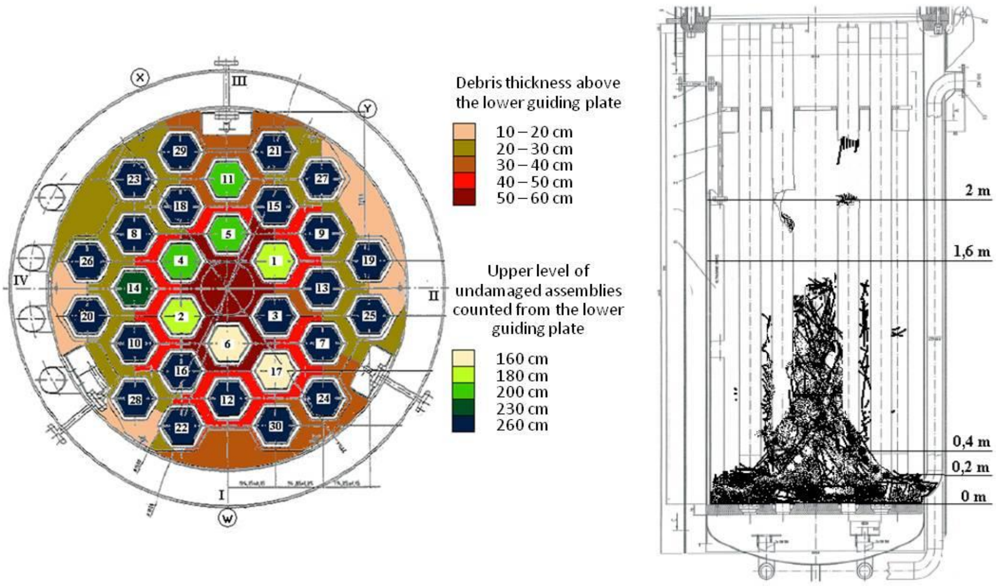

Fig. I-6. Extent of damage and location of fuel debris (courtesy of HAEA and Paks NPP).

The impact of the incident was of low significance in terms of health hazards. Although the discharge of radioactive noble gases into the environment increased compared to the normal situation, it was exhibiting a decreasing tendency, and, according to the data available, did not approach the discharge limits. The shift supervisor (the primary head of Site Emergency Response Organization — SERO) evaluated the event on the basis of the Site Emergency Response Plan (SERP) and decided that there was no need for immediate emergency response action or alert of SERO.

As of 02:15 on 11 April 2003, the situation deteriorated. However, the assessment of the conditions and information available at that time did not allow the event to be recognized as an accident based on the SERP version valid at the time.

For the noble gas discharge, it was clearly stated that the rate of the discharge did not reach the level specified by the SERP as a threshold value for classifying the event as accident. However, the signals from the radioiodine monitor were distorted and increased by the significant discharge of noble gas. Therefore, the evaluation of the readings from these measurement units was difficult. The assessment of samples taken by the use of a radiation control system, and the determination of the iodine discharge by laboratory measurements, would have provided more accurate information on the iodine discharge. However, this was done out until 07:45 on 11 April 2003. With full knowledge of the exact discharge data, the evaluation of the situation in line with SERP was performed again, which resulted in the finding that no accident had occurred. Nevertheless, in order to provide a continuous control and evaluation of the occurrences, the head of SERO decided at 12:40 on 11 April 2003, to partially set up the SERO (comprising of a control team, communication organization and radiation situation evaluation group). The SERO functioned as intended in the relevant procedures until 16:00 on 13 April 2003, when its operation was terminated.

After removal of the tank cover and completion of the visual inspection of the fuel assemblies within the tank, the SERO was fully activated again at 22:30 on 16 April 2003 and remained in operation until 09:00 on 20 April 2003. All in all, the assessment of the situation and the operation of the SERO were performed in compliance with the requirement for providing information to, and support decision making of, local off-site organizations until the termination of the operation of the SERO. The SERO operated in partial response mode (comprising the management group, radiological assessment group, staff support group and technical support group) at the Emergency Response Centre and continuously evaluated the situation, kept contact with authorities and exercised readiness for full activation if the situation would get worse.

The operator had on-line access to a network of nine continuously operating environmental gamma dose rate monitors located around the Paks NPP. Results from these monitors were also received at off-site authorities. The monitors had an alert level (500 mSv per hour) based on the average dose rate over a ten minute period. The ten minute average level was not exceeded during the incident, but the dose rate at one monitor rose significantly during the period of the initial release peak. The operating personnel at the site did not notice this change until later. Had they observed this change earlier, they would have gained additional information that would have helped to gain a better understanding of a release for which they did not have specific plans. It was noted by the operating staff at the Paks NPP that a contributing factor to the inability to understand the situation was the significant number of other information inputs that the staff was faced with at the time [I-18].

Recovery operations

The continuous cooling of the cleaning tank was ensured by the use of auxiliary cooling system, which was installed on 17 April 2003. In addition, continuous monitoring of the cleaning tank and its immediate surroundings was ensured. Three days later, a plastic foil 'greenhouse' was built above the pond accommodating the cleaning tank. The air space within the 'greenhouse' was subject to continuous analysis and purification. Between 40 and 80 workers per day performed work in the reactor hall from 12 April to 20 April 2003. Depending on their workplace within the hall, they wore personal protective equipment consisting primarily of protective clothes, compressed air breathing apparatus and gas masks with iodine filters. Their working hours were limited so that normal operational dose limits were not to be exceeded.

Professional teams involving various areas of specialty (reactor physics, hydrodynamics and technical logistics) had been set up for elaborating alternatives for the recovery. They applied careful planning to choose the safest possible options. Their work was supported by competent specialists of Hungarian universities and research institutes as well as by German engineers. In addition, representatives of the Russian fuel manufacturer arrived at Paks in May 2003. The final solution — i.e. the removal of the damaged fuel assemblies, the provision for long term cooling and the decision on storage — was the outcome of a major refurbishment effort.. 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 NPP established a working group (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-20]. The licensing documentation was submitted to the Hungarian Atomic Energy Authority (HAEA) in November 2004. HAEA issued a license for recovery operations in the Service Pool based on the licensing documentation in July 2005. Manufacturing licences of cases and containers for the storage of damaged fuel assemblies and solid radioactive waste were issued in March 2006. Authorization for the removal of damaged fuel was granted in September 2006.

During the normalization of the system's status, the following main steps were taken [I-20]:

- Separation of the refuelling pit with the damaged cleaning tank and the spent fuel pool from the reactor;
- Increase of the boric acid concentration up to 20 g/kg in the refuelling pit;
- Development of the safety borating system of the cleaning tank;
- Construction of an independent cooling system of the cleaning tank;

- Separation of the refuelling pit from the spent fuel pool;
- Installation of redundant temperature, coolant level and neutron measurement instrumentation in order to provide the refuelling pit with independently operated instrumentation and control (I&C) system;
- Visual exploration of the state and geometry of the damaged fuel assemblies and the cleaning tank in deep details.

Several criteria were used to ensure that response actions were taken on a routine basis (as for normal operation) in terms of workers' exposures, surface contamination or air activity concentrations. The Plant Radiation Protection Code listed these criteria as well as the situations in which the use self-protective equipment (such as protective clothes, breathing apparatuses, gas masks, etc.) was necessary; it also provided information on how to apply the equipment.

In planning for radiation protection measures while performing the recovery work, the main task of the Radiological Protection Department was to determine the radiological situation inside the reactor hall, in order to remain within occupational dose limits for normal operation. The activity of radionuclides accumulated in the fuel assemblies had been calculated on the basis of the time which the assemblies spent in the reactor and some other parameters influencing the burnup of fuels. To validate the model calculations, control measurements were carried out. Gamma dose rate measurements were performed on several locations inside the cleaning tank with a gas ionization detector.

Monitoring and assessment

Several activities were taken in response to the incident to monitor and assess the situation in detail (including characteristics of the release to the environment) and to confirm its stability.

In accordance with the national arrangements, the national radiation monitoring and warning system (comprising of organizations appointed by central administration organs participating in the emergency response system and by other professional organizations) starts the operation in an event of a radiation emergency. The system operates to support the availability of the information necessary for the decision preparation and decision making.

For the understanding and assessment of the radiological situation, a coordinated environmental monitoring survey was initiated with the involvement of this system. The objectives of the monitoring activities were to collect and evaluate the detailed information on the radiological situation in the closer and wider surrounding areas of the Paks NPP in order to assess the situation and the 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 dispersion and distribution of radioactive material in 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 over the territory of Hungary. The duration of increased measurements covered 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 the noble gas, Fig.I-8 the I-131 equivalent and Fig. I-9 the airborne releases; Fig. I-10 presents the I-131 equivalent activity in different plants for the central part of Hungary; and Fig. I-11 shows the results of the same measurement types for the region near Paks (all figures courtesy of HAEA and Paks NPP).

Based on the measurements results and the assessment of the situation following the incident, it was concluded that no significant release of radioactive material into the environment had occurred and no actions were needed for the protection of the public in near and farther regions around the Paks NPP.

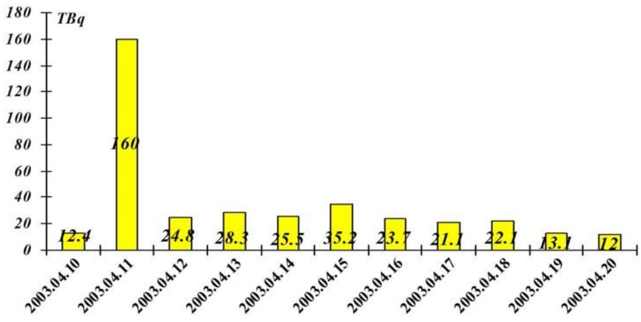

Fig. I-7. Noble gas release.

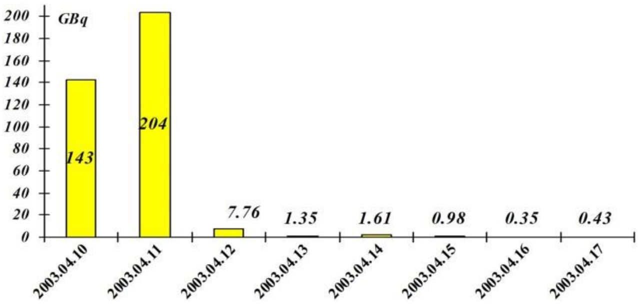

Fig. I-8. I-131 equivalent release.

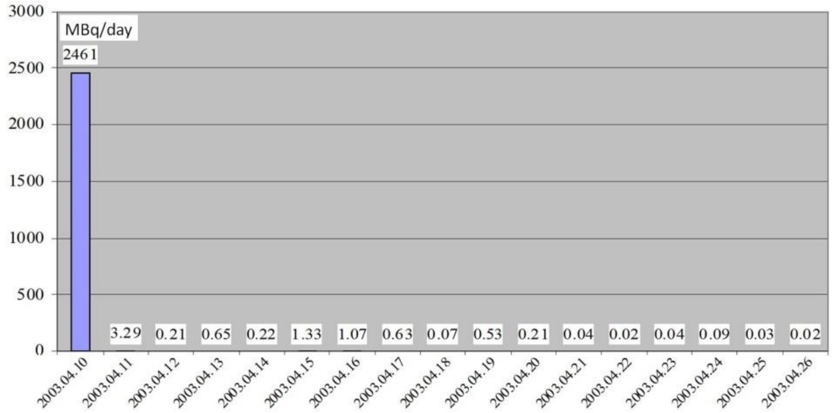

Fig. I-9. Airborne release.

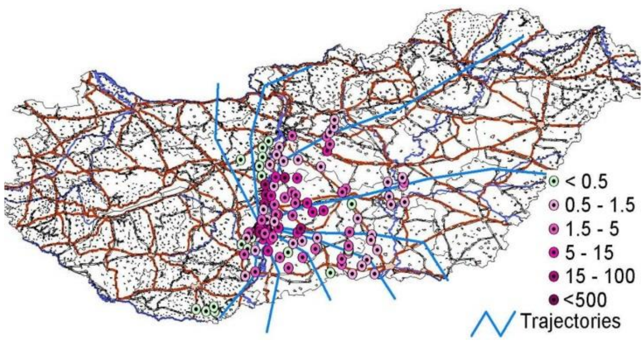

Fig. I-10. I-131 equivalent activity in different plants for the central part of Hungary [Bq/kg fresh weight].

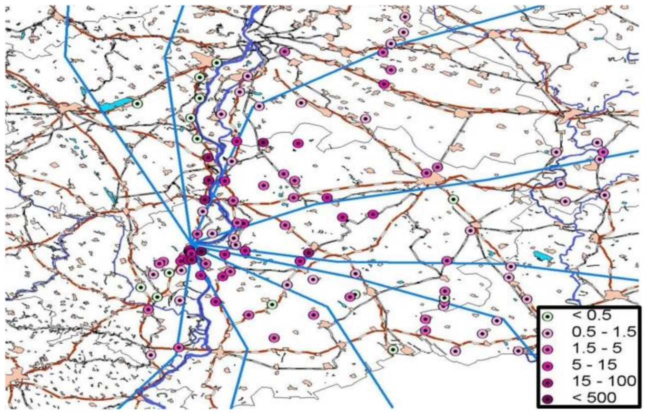

Fig. I-11. I-131 equivalent activity in different plants for the region near Paks [Bq/kg fresh weight].

Starting on 16 April 2003, HAEA conducted model calculations to assess the dose to the public due to the release of radioactive material to the atmosphere. The source term that served as input for the models were the data provided by the operator of Paks NPP. Further calculations concerning the total amount of noble gases, iodine and fission products released indicated that the initial assumptions by Paks NPP that only a few fuel pins had been damaged were incorrect. In fact, based on the information from the total amount of radioactive material released and the video recording of the interior of the cleaning tank, HAEA (as well as the Paks NPP operator) considered that most, if not all, of the fuel rods were damaged in the incident.

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

— a few hundreds of TBq of noble gases, mostly xenon-133 (half-life of 5.2 days) — see Fig. I-7.
— a few tens of TBq of radioiodine, mostly iodine-131 (half-life of 8 days) — see Fig. I-8.
— less than one hundredth of a TBq of other radionuclides principally caesium-134 (half-life 2 years) and caesium-137 (half-life of 30 years) — see Fig. I-9.

The assessment of doses showed that the radiological consequences of the incident were small. Doses to workers were maintained well within the limits set out for normal operation. Doses to members of the public were only a very small fraction of the public dose limits and less than the dose from an exposure due to a day's natural background radiation.

Data provided by the Paks NPP 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 detailed checks were performed on the dose assessment provided by Paks NPP.

Protection of emergency workers and recovery workers

Appropriate procedures were followed to minimize the doses to workers involved in the management of the incident (e.g. collective and personal protective measures). Dosimetry control, personal protective equipment, work order management, training and education on relevant activities, etc. were used for that purpose. The need for dose estimation and for medical consultation was also considered.

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 (FANP) operators — a crane operator, a fuel handling machine operator — as well as a member of the dosimetry control staff from among the Paks NPP personnel.

All personnel present were equipped with respirators with 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 prior to the incident but was instructed at the time.

As part of the routine checks for contamination at the exit point from the reactor area, an external contamination above the prescribed maximum level for normal operation was detected at the crane operator. He was decontaminated by repeated showering, followed by shaving of his beard and cutting of his hair. These activities reduced his external contamination levels to below prescribed levels.

The operator implemented an extensive programme for monitoring intakes of radionuclides by personnel present at the site during the incident, prioritizing the monitoring on the basis of the potential for intake. The first measurements were performed in the morning of 11 April 2003. Over 600 personnel were measured at the Paks NPP whole body counter. Only seven of the assessed doses were close to or above 0.1 mSv. This whole body counting arrangement was also implemented for relevant personnel at the National "Frederic Joliot Curie" Radiobiology and Radio-diagnostic Research Institute, OSSKI. The two sets of results were consistent. From the records reviewed, doses from external gamma radiation for the Paks NPP and contractor staff during and after the incident ranged up to approximately 7 mSv. Committed effective doses from inhalation of radionuclides ranged up to approximately 1 mSv. The crane operator had received the highest committed effective dose from intakes [I-19].

Communication and consultation with authorities and the public

With respect to emergency preparedness, the basic respective responsibilities of the HAEA and the operator appear to have been well defined and did not contribute to the impact of this incident.

The public was being informed as of the early hours on 11 April 2003. Special emphasis was placed on the communication to the population of Paks and the regions in the vicinity of the plant, where all locally available channels were used for that purpose. As new details became available, countrywide bulletins were issued. In addition, a number of press appearances were given. Through most of these communication channels, an objective and correct communication to the readers, listeners and viewers was given. The Paks NPP answered every inquiry and accepted all interview requests from the press.

Two media releases were issued by the plant 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, after the actual state of the fuel assemblies was 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 facilitate conveying to the public the severity of a situation, actually undermined the credibility of the authorities in this case. On 11 April 2003, the Plant had proposed, and the HAEA had approved, the INES-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 the authorities had not told everything in the first instance [I-19].

Based on national requirements (national emergency plan, facility emergency plan) and the nature of the hazard, there was no need to warn the public of impeding protective actions. However, the incident was immediately communicated to the mayors of communities within a 30 km radius of the plant via a special SMS system provided for his purpose in order to allow them to satisfactorily answer the questions that may arise.

A press conference was held in the reactor hall of Unit 2 on 22 April 2003, and the Chairman of the Environmental Committee of the Parliament was received at the plant on 27 April 2003 by the Chief Executive of Paks NPP. On the following day, the parliamentary representatives of the Paks region and the members of the one parliamentary faction 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, which was followed by a visit to the reactor hall.

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

Investigation of the incident

The designers of the NPP had not expected that the fuel cleaning process might cause the release of radioactivity of the scale observed during the incident, nor had it been recognized as a situation for which accidental releases needed to be considered. A series of independent (national and international) investigations were conducted in order to understand its causes and the circumstances that lead to the incident and to draw conclusions and lessons for improving the operation and emergency arrangements and avoiding a repetition of similar events ([I-18]–[I-20]).

According to the regulatory requirements, Paks NPP was required to conduct an investigation of the incident and to submit the investigation report to the HAEA. Parallel with the investigation that was conducted by Paks NPP, the HAEA also conducted its 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-18].

Considering the seriousness of the incident, the Hungarian Parliament also appointed a Parliamentary Committee to investigate the causes and major responsibilities of the incident. The Parliamentary

Committee conducted its assessment and submitted its report to the Hungarian Parliament by the end of 2003.

The Hungarian Government also invited an Expert Mission of the IAEA in order to assess the results of the HAEA's investigation of the incident. The Expert Mission took place from 16 to 25 June 2003 and made several suggestions and recommendations for the improvement of the Paks NPP operation and the functioning of the regulatory system [I-19].

The Paks NPP invited an Operational Safety Review Team (OSART) Follow-up Mission from 21 February to 1 March 2005 [I-19]. The mission focused primarily on the implementation of suggestions and recommendations formulated during the original OSART mission of 8–25 October 2001 and the Expert Mission of the IAEA of 16–25 June 2003 [I-19].

Revision of emergency arrangements following the incident

Following the IAEA Expert Mission, the Paks NPP prepared an action plan for the elimination of deficiencies identified in the observed areas (management system, regulatory oversight, design deficiencies, fuel cleaning operation, radiation protection and emergency planning and preparedness). The action plan contained concrete tasks and deadlines and was approved by the Hungarian Atomic Energy Authority. Actions aimed at improving the arrangements that related to emergency preparedness and response were implemented by Paks NPP by 2006 and included the following [I-19]:

— The emergency classification scheme was revised to ensure that it covers all potential alert events and emergency situations at Paks NPP. The classification scheme included EALs and RALs based on measured parameters. A comprehensive review of the plant hazard assessment was conducted to ensure that all potential accident sequences were identified.

— A procedure to the Site Emergency Response Plan was created that took into account the revised emergency classification scheme and postulated emergency scenarios.

— The internal regulation on technological modifications at the Paks NPP was revised to ensure that it covered interactions between the Site Emergency Response Plan and the impact of a planned modification. With this revision, an analysis of the emergency related aspects of modification had to be conducted before a decision on any modification was to be made.

— Verification and/or validation of the new Release and Environmental Monitoring System of the Paks NPP on critical parameters for emergency detection and classification was conducted and actions were taken to improve the system supporting emergency alert and notification activities.

— The Emergency Preparedness section had to participate in preparatory trainings for operative personnel on a new — safety relevant — activity, together with all contractors.

— The competent organization of the Paks NPP (which is responsible for the general management of emergency preparedness) needed to be involved/admitted in the assessment of the contractors' emergency procedures.

— Involvement of dosimetry control staff in the conduct of unanticipated drills or exercises.

— In addition, the Paks NPP decided to ensure that:

  - Emergency kits (containing gasmasks, iodine tablets, self-breathing equipment, fire-fighters' clothes and personal dosimeters) for operating personnel were to be available in each operational room.

  - Field training on the application of breathing apparatuses (for respiratory protection) was to be adopted in relevant procedures for urgent actions.

- Training and field first aid tasks were to be fulfilled by facility fire brigade personnel.

Authorization for continuing normal operation

As a consequence of the incident, the Paks NPP could not finish its planned refuelling in April 2003, as the conditions for safe operation were not met. Therefore, the following major activities were planned to be completed in the 2003–2004 period to recover the conditions for safe operation:

(i) assure sub-criticality and cooling of the fuel debris structure;

(ii) decontaminate internal surfaces of the primary circuit;

(iii) re-establish conditions for conducting refuelling; and

(iv) assure safe conditions of long term storage for fuel debris.

All these activities were implemented under the very thorough supervision of the HAEA. For each major step, a licence application was submitted by the Paks NPP to the HAEA, and a formal authorization process was conducted. Finally, when all safety conditions and regulatory requirements were met, a new operational licence was issued for Unit 2 to restart its operation as of September 2004.

Other series of activities were aimed at the removal of the fuel debris from the chemical cleaning vessel, the establishment of the safe conditions of storing the removed fuel debris, the removal of the chemical cleaning vessel itself from the Service Pool and on the establishment of 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 the activities, a comprehensive set of regulatory requirements for nuclear and radiation safety and security and for the management system of all recovery works and operations was established and issued by the HAEA. The unique nature of the incident required an overview of the wide range of existing requirements existing at national and international levels, and the derivation of further requirements in cases where no adequate prescriptions were found. The very detailed removal and recovery process was designed, planned and implemented by several domestic and international expert organizations, providing support to the Paks NPP operational staff and also independently to the HAEA. The Paks NPP was required to regularly submit reports on the progress of the recovery operations. At the end of the detailed 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

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 magnetite depositions on their cladding were to be removed by means of a specially designed chemical cleaning process.

An increase of activity within the reactor hall was detected by the workers. Once the noble gas activity concentration monitors in the reactor hall had indicated that the ‘emergency’ level was reached, the evacuation of workers from the reactor hall was ordered. Although the airborne discharge increased compared to the normal situation, it was exhibiting a decreasing tendency, and according to the data available, did not challenge the national prescribed discharge limits. When the full knowledge of the exact discharge data had become available, the evaluation of the situation was performed again, which resulted in the statement that no accident occurred.

After the incident had been identified, the SERO was partially set up in order to provide continuous control and evaluation of the occurrences. The SERO was operating as per the relevant procedures until 13 April 2003, when its operation was terminated. After the removal of the tank lid and the recognition of the extent of the damage of the fuel assemblies within the tank, the SERO was activated again on 16 April 2003; this status was maintained until 20 April 2003. The assessment of the situation was conducted until the termination of the operation of the SERO in compliance with the requirement for providing information to, and support of, the decision-making and the local off-site organizations. The SERO operated in partial response mode at the Emergency Response Centre and continuously evaluated the situation, kept contact with authorities and exercised readiness for full activation if the situation would get worse.

During the recovery operations, professional teams involving various fields of expertise had been set up for elaborating alternatives for the recovery. Their work was supported by competent specialists. The autonomous cooling system and the emergency boron system for the Service Pool were established during the first half of 2004.

For the understanding and assessment of the radiological situation, a coordinated environmental monitoring survey was initiated. The objectives of the monitoring activities were to collect and evaluate the detailed information on the radiological situation in the closer and wider surroundings areas of the Paks NPP in order to assess the situation and the need for any off-site protective actions and to provide authentic, trustworthy and timely information to the public. The extensive measurements covered the entire period of the incident from 11 to 26 April 2003. Based on the measurements results and the assessment of the situation following the incident, it was concluded that no significant release had occurred and that no actions were needed for the protection of the public in near and farther regions around the Paks NPP.

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

Based on national requirements and the nature of the hazard, there was no need to warn the public of impeding 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 being informed as of the early morning of 11 April 2003. Special emphasis was put on the communication to the population of Paks and the regions around the plant, where all locally available channels were used for the purpose.

A series of independent national and international investigations was conducted following the incident to understand its causes and the circumstances that lead to it and to draw conclusions and learn lessons for improving the operation and emergency arrangements and for avoiding a repetition of similar events.

As a consequence of the incident, the Paks NPP could not finish its planned refuelling in April 2003, as the conditions for safe operation were not met. Therefore, a series of activities was planned to be completed in the 2003–2004 period to recover the conditions for safe operation. All these activities were implemented under the very thorough supervision of the HAEA.

In a retrospective analysis of the event, the specific phases and their timing is represented in Fig. I-12, as they can be associated with different phases discussed in Section 2 of this Safety Guide. The emergency started on 10 April 2003, requiring limited urgent actions on the site to protect personnel present. This state lasted from 11 April to 20 April 2003, when efforts focused on assessing the situation and its severity through undertaking various activities. During this period, all necessary measures were taken to ensure continuous the cooling and monitoring of the damaged fuel and stabilizing 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-site as well as off-site were being assessed. Following this period, particularly as of May 2003, a more thorough planning for the recovery and investigation of the circumstances under which the incident had occurred were carried out. As a result, in the second half of 2004, the PAKS NPP was able to resume normal operation in compliance with national regulations. The public did not experience a new exposure situation resulting from this incident.

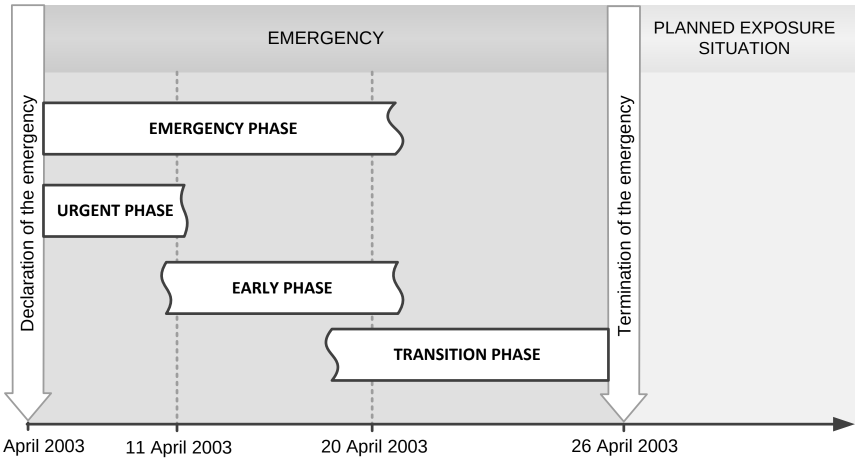

Fig. I-12. Retrospective sequencing and milestones of the PAKS fuel damage incident.

Conclusions against the prerequisites for the termination of the emergency

General prerequisites

– Had the necessary urgent and early protective actions been implemented?
Evacuation of workers from the Reactor Hall area was completed immediately following the detection of emergency levels due to the presence of noble gas. No other protective actions needed to be implemented for other site personnel and for the public based on assessment results.

– Was the exposure situation stable and well understood?
For the understanding and assessment of the radiological situation, various activities were carried out in a coordinated manner. This resulted in adequate estimation of the release source term. The airborne releases were continuously monitored and their stability confirmed already 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. Assessment of doses showed 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 exposure expected due to the event?
After lifting of the cover of the cleaning tank, the possibility of further radioactive release was recognized and, thus, SERO was partially activated. SERO managed the situation and focused on preventing further releases. An important measure in this regard was the establishment of a plastic foil 'greenhouse' by the maintenance staff above the pond accommodating the cleaning tank on 20 April 2003.

– Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?

SERO continuously assessed the situation and possible impacts on the plant safety measures and on emergency arrangements in place. Several independent assessments were also conducted in 2003. As a result, the Paks NPP reviewed on-site emergency plans and on-site regulations and prepared an action plan to address necessary corrective measures and to revise the emergency arrangements in place. The necessary improvements of the emergency arrangements were implemented by 2006.

– Were the requirements for occupational exposure during a planned exposure situation confirmed for all workers engaged in recovery activities?

Due to the nature of the hazard, all response actions and the recovery operations were conducted 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 everyone 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 thermoluminscent (TL) dosimeter was also provided for the recovery workers by the Paks NPP. People entering the reactor areas received also an electronic dosimeter. Reactor operation and maintenance personnel were equipped with TL neutron dosimeters. Contractors also wore their own dosimeters. Dosimetric data from external monitoring of the contractor and Paks NPP staff on-site were collected and recorded. Results were provided from the dosimeters of the workers involved in the incident. 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 them was met. The doses assessed remained within the dose limit for normal operation for both the public and the workers.

– Were non-radiological consequences (psychosocial, economic) and other factors (technology, land use options, availability of resources, community resilience) identified and considered?

The off-site radiological consequences of the incident were of low significance. Therefore, the non-radiological consequences of the incident were negligible. No specific actions were taken to reduce the off-site non-radiological impact, except for the provision of timely and consistent public information. On the other hand, an 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 NPP, the HAEA and the National Directorate General for Disaster Management in order to harmonize the ways of communicating with the public and the content of the information to be provided. The HAEA regularly uploaded on its website public information articles about the results of assessments and measurements.

A major contributor to the non-radiological consequences on the site was the economic loss sustained. A component of the economic loss was the damage to the fuel assemblies, which, if undamaged, could have still been used for electricity production. Another component was the prolonged shutdown of the Unit 2, which lasted for about 1.5 years, with no production of electricity. The third component was the expense associated with the establishment of the safe operation of Unit 2, especially given that the Service Pool was unavailable. The fourth major component arose in relation to the costs of the removal of the fuel debris and the cleaning vessel and the establishment of conditions of safe storage of the damaged fuels.

– Was a registry of those individuals requiring further medical follow up established prior to the termination of the emergency?

Doses to members of the public and workers were within the dose limits for normal operation. Therefore, there were no individuals requiring any medical treatment and further medical follow up following the incident.

– Was a strategy for the management of radioactive waste arising from the emergency, when appropriate, developed?
The Paks NPP had (and has) in place internal regulations and a general strategy for the management of radioactive waste in normal and emergency situations. During the incident, the plant was confronted with a special new situation for which standard solutions were not available. After the initial measures, the Paks NPP introduced a recovery plan in 2004, which established special strategies for the management of radioactive waste and the development of storage areas as needed. Applying this strategy, the radioactive waste generated during the time of recovery works was managed in a comprehensive manner. The Paks NPP completed the corrective action plan by the end 2006.

– Were the interested parties consulted?
In case of abnormal conditions, off-site authorities receive information within two hours after detecting the abnormal event, and this information is thereafter updated within 24 hours. During the incident, the authorities required information from the operator with enhanced frequency and details. The public was also informed promptly. The IAEA was informed on 17 April 2003, after the actual status of the fuel assemblies was discovered, even though there was no obligation under the Convention on Early Notification of a Nuclear Accident to do so. Due to the nature of the hazard, the incident did not warrant consultation of interested parties other than the off-site authorities, technical support organizations, scientific institutions, etc. Consultation was initiated as early as possible following the incident to assess the situation as well as to plan the recovery operations.

Specific prerequisites

Transition to a planned exposure situation

– Were the circumstances surrounding the emergency analysed and corrective actions identified?
The SERO of the Paks NPP investigated the circumstances surrounding 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?
Based on the outcomes of the specific investigations, corrective actions in various areas were identified. An action plan was developed to address the findings, to identify corrective actions to be implemented and to draw lessons to be learned for improving the existing arrangements. All the findings were addressed in the period 2004–2007. A set of corrective actions in relation to the management and operation of the Paks NPP was required in the HAEA regulatory resolution. The HAEA then closely followed the implementation of the corrective actions. Implementation of these corrective actions contributed, among other things, to the issuance of the operational licence by the HAEA in September 2004. The status of implementation of these corrective actions was reviewed by several international follow-up missions as well.

– 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 respective planned exposure situation?
Due to the unique subject of the incident (the damaged fuel debris), a comprehensive set of regulatory requirements for nuclear and radiation safety and security and for the management system of all recovery works and operations was established and issued by the HAEA. Compliance with these requirements was assessed throughout the recovery operations.

– 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 surrounding the emergency situation had been obtained?
All the recovery work was carefully planned and specific instructions were followed so that the work could be carried out safely and securely as a normal operation. Finally, following the compliance with all the regulatory requirements for the safe operation of Unit 2, a licence was granted to the operator to resume normal operation. Meanwhile, the refuelling planned for April 2003 had been halted until it could be carried out safely.

– 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 and confirmed to remain within the dose limits for members of the public in normal operation.

I.4. THE RADIOLOGICAL INCIDENT IN HUEYPOXTLA, MEXICO STATE, MEXICO[38]

At 08:13 local time[39] on 2 December 2013, the Mexican nuclear regulatory body, the Comisión Nacional de Seguridad Nuclear y Salvaguardias (CNSNS), received a notification from a worker in a company authorized for the transport of radioactive material, about the theft of a vehicle transporting the head of a teleteraphy unit with a cobalt-60 source (see Fig. I-13). The approximate activity of the source was estimated to 3000 Ci[40]. The vehicle was stolen from a gas station near Tepojaco, municipality of Tizayuca, in the State of Hidalgo. The source belonged to the Mexical Social Security (a hospital) from 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.

Following 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, CNSNS learned that, at approximately 02:00 on 2 December 2013, a group of armed individuals assaulted the driver of the vehicle, who was resting at a rest stop within the gas station, and took the vehicle together with the radioactive source.

[38] This summary has been drafted by the National Commission for Nuclear Safety and Safeguards of Mexico on the basis of internal records related to the incident.

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

[40] $1\ \mathrm{Ci} = 3.7 \times 10^{10}\ \mathrm{Bq}$

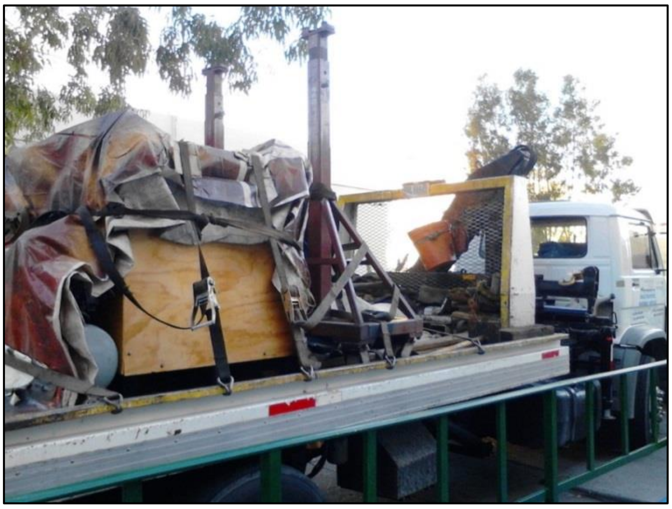

Fig. I-13. Vehicle transporting the teletherapy unit with Co-60 (Credit: CNSNS).

Emergency declaration and urgent actions

The CNSNS personnel looked for information on the stolen radioactive source in their databases in order to get the actual activity (of 2574 Ci) and the serial number of the source and its shielding They then proceeded to draw up an information bulletin for distribution by the Civil Protection Agency with information on the incident, the potential risks of handling the radioactive source, the immediate actions to be taken by responders and the public should they come across the source and the telephone numbers to contact if the source was 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 (USIE).

Following the receipt of a communication from the army informing them that the vehicle transporting the source had been found near the municipality of Hueypoxtla, the Federal Police, 2 December 2013, sent out its officers 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); they reported their discovery to the CNSNS on 4 December 2013. On the same day, at approximately 08:00, CNSNS sent two teams equipped with vehicle based radiation detectors to perform a search within a 10 km radius of the zone of the robbery, and the Federal Police searched in the municipalities of Tizayuca and Zumpango and in the surrounding areas.

Fig. I-14. The empty shielding of the radioactive source (Credit: CNSNS).

The Federal Police officers detected unusual radiation levels in a corn field approximately 1 km from where the shielding had been found, and they contacted the CNSNS in order to send personnel for searching the source and cordoning off the area. The Federal Police and the Army were asked to secure and guard the area so that only authorized personnel could enter it.

Isolation of the source

On 4 December 2013, CNSNS sent two brigades of members of the CNSNS Radiological Contingencies Organization (OCR) to continue the search for the radioactive source. The Federal Police informed the CNSNS about the alleged discovery of the stolen source in Hueypoxtla. Staff of CNSNS analysed the photographs made by the Federal Police and determined that, indeed, it was the source container, but apparently the source was not inside. The Federal Police guided the CNSNS staff close to the areas where radiation levels (ambient dose equivalent rates) above 100 µSv/h had been detected, so they could carry out a delineation of the locations. They also assisted the additional staff from CNSNS who were equipped with specialized equipment and arrived at Hueypoxtla by helicopter. With no lighting available, area monitoring was carried out quickly in the same evening to identify the location of the radioactive source; the Federal Police was asked to control the access to this area in particular.

On 5 December 2013, the activities to delineate the area and to locate the source continued. Once the search perimeter of the source had been reduced, CNSNS contacted CFE-Laguna Verde Nuclear Power Plant (CNLV) and the Ministry of the Navy (SM-AM) to assist in planning actions to recover the radioactive source.

On 6 December 2013, in addition to CNSNS personnel, staff from CNLV and SM-AM arrived at Hueypoxtla. CNLV staff entered the area previously identified by CNSNS and determined the approximate location of the source. A container was requested from the National Institute of Nuclear Research (ININ) for receiving and transferring the radioactive source. Although such a container was not readily available, some adjustments made it possible for an appropriate container to be used for the intended purpose.

On 7 December 2013, staff of CNSNS, CNLV, SM-AM and the Federal Police started planning the cleaning of the area (from the crops) by using a robot belonging to the Federal Police in order to be able to exactly locate the source. On the same day, CNSNS received information about the person who had found the radioactive source and was willing to indicate to the responders the place 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 asked the person about the amount of time he had spent near the source. They offered to give him a medical examination, but the person declined.

On 8 December 2013, staff of CNSNS, CNLV, SM-AM and the Federal Police returned to the area to continue the cleaning process remotely so that the radioactive source could be exposed from being hidden in the corn field. From CNLV facilities in Veracruz, SM-AM brought materials and additional resources to help with the transport of radioactive material (concrete containers, lead blankets). In parallel, the headquarters of CNSNS arranged for a transport of the radioactive source after its recovery. The cleaning tasks continued until the robot had a mechanical failure.

On 9 December 2013, CNLV personnel entered the area and finished the cleaning tasks, exposing the radioactive source (see Fig. I-15). The integrity of the source was confirmed. However, as the repair work on the robot continued, alternative plans for the recovery of the source needed to be made.

On 10 December 2013, the modified container arrived from ININ, together with the repaired robot. 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. After two attempts, the robot was able to hold the source. The images taken by the robot camera confirmed that the source was intact. The maneuver succeeded to deposit the radioactive source inside the container and to close it (see Fig. I-16). Following this, the CNSNS measured the radiation levels at the contact with the container, finding very low levels. This 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 was conducted on 13 December 2013, which confirmed the results.

Fig. I-14. Exposed radioactive source
(Credit: Federal Commission for Electricity of Mexico).

CNSNS, ININ, the Federal Police and the transport service provider agreed on the time, route and escort for the transport of the radioactive source to the facilities of ININ at Ocoyoacac, Mexico State, for conditioning and storage, prior its disposal at ININ's Radioactive Waste Disposal Facility in Temascalapa.

A dose limit of 50 mSv effective dose was set for the workers that were involved in the recovery process. The average dose received by them was 2.45 mSv, with the highest value at 19.99 mSv.

Fig. I-15. Placing the source in the container using the robot (Credit: CNSNS).

Communicating with the public

On 4 December 2013, the public was informed by the Incident Command Group (consisting of representatives from CNSNS and the Ministry of Health) of the dangers of manipulating and being close to the source, although it was located far away from any settlements. The Incident Command Group called on all those who may have been in contact or in the immediate vicinity of the source to attend the hospital in Pachuca in order to estimate their doses and to identify whether medical follow-up needed to be offered to them. Many enquires were received from the villagers and were answered by CNSNS on the spot regarding the status of the situation, the measures being taken and the progress of the operation. However, as the situation became unstable, the Federal Police removed the representative of CNSNS from among the crowd discontinuing this interaction.

Medical response and assessment of doses

On 8 December 2013, CNSNS contacted personnel from the Ministry of Health of the State of Veracruz (SSAEV), who acted as members of the External Radiological Emergency Plan of CNLV, for support in examining individuals who may have been in contact with the radioactive source. The SSAEV contacted staff of the Ministry of Health (SSA) to ask for support in case it was deemed necessary. The SSA confirmed the activation of its staff along with that of the SSAEV as of 9 December 2013.

On 9 December 2013, SSA and SSAEV staff were accompanied by CNSNS personnel to the Hospital de Pachuca to begin examination of individuals who may have been exposed to the source. They then moved to Hueypoxtla to examine the individual who had been in contact with the radioactive source and had assisted in locating it, as well as another individual who had allegedly had contact with the source when it had still been contained in its shield. The second individual was found with no symptoms of radiation exposure. The first individual was found with symptoms of radiation exposure on the left shoulder and right leg, so he 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.

On 10 December 2013, the SSA implemented a field investigation, questioning the people who were present at the site on the day the source was found, reconstructing events and assessing the acute radiation exposure risk among these people. A total of 59 people who were presumably exposed were identified, out of which 31 were found not to have been related to the event according to the dates and times that it had happened. For 22 persons, the reconstruction of events was carried out in order to evaluate the presumable exposure and to estimate the received dose as a basis for assessing the acute radiation exposure risk.

On 13 December 2013, SSA and CNSNS requested ININ to perform biologic dosimetry studies of 10 persons, four of which presented alleged acute radiation syndromes associated symptomatology.

On 15 December 2013, ININ performed the biologic dosimetry study of the persons identified by SSA who had presumably been exposed. The findings showed that only the person who had handled the source after it had been taken out of the shielding and who had helped the Mexican authorities to locate the source exceeded the limit of the Mexican regulation for non-stochastic effects for occupationally exposed personnel (500 mSv annual whole body effective dose).[41]

Transition phase

On 4 December 2013, the area where the radioactive source was found had already been cordoned off, and a security perimeter had been established, so the risk of members of the public being exposed by entering this area and handling the source had been minimized. The radioactive source had been found intact in a corn field away from any settlements. The next six days were used for planning and actual recovery of the source.

[41] 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.

The dose criterion of 500 mSv was established for medical examinations and follow-up of the allegedly exposed persons of the public, and a 50 mSv limit was also established for the personnel involved in the actual source recovery.

The person who had exceeded the limit of 500 mSv (i.e. the same person who had actual contact with the radioactive source) was transferred on 7 December 2013 to the Hospital de Nutrición in Mexico City for treatment and follow-up.

Conclusions

The Hueypoxtla accident served as an example that a radiological emergency in Mexico could occur outside of the licensed installations and that such an emergency may arise as a consequence of security events that may or may not have a direct relation with the radioactive material itself. The incident highlighted the need to care for all the members of the public who may be involved in such events, even for the purpose of their reassurance. The incident made the Mexican authorities realize that such emergencies cannot be attended to by a single agency but that it is necessary to develop a plan of response to radiological emergencies in which the responsibilities and resources of every agency involved are outlined and clearly defined.

In a retrospective analysis of the event, the specific phases and their timing are represented in Fig. I-16, as they can be associated with different phases discussed in Section 2 of this Safety Guide. The emergency started on 2 December 2013, when the vehicle transporting the dangerous radioactive source was stolen. The urgent phase lasted until 4 December 2013, with focus on the efforts to locate the source and to issue warning and information to the public and the media. As of 4 December 2013, the source was located in an area of Hueypoxtla, which was cordoned off to secure the source. This protected any individual from being unnecessarily exposed to the source and allowed the authorities to further identify its exact location and status. This phase lasted until 9 December 2013, when the source was finally being exposed from being hidden in the corn field and its integrity was confirmed. Meanwhile, the plan for storing the source was developed and organized, resulting in fast source recovery and its transport for conditioning prior to final disposal on 10 December 2013. By this date, the monitoring activities to ensure that no contamination was caused were completed, and all individuals who may have been in close vicinity of the source had been identified for dose assessment and medical follow-up. Thus, this milestone is considered to represent the termination of the emergency situation and the move to the planned exposure situation in relation to further management of the source as radioactive waste. No new exposure situation was raised for the public in this incident.

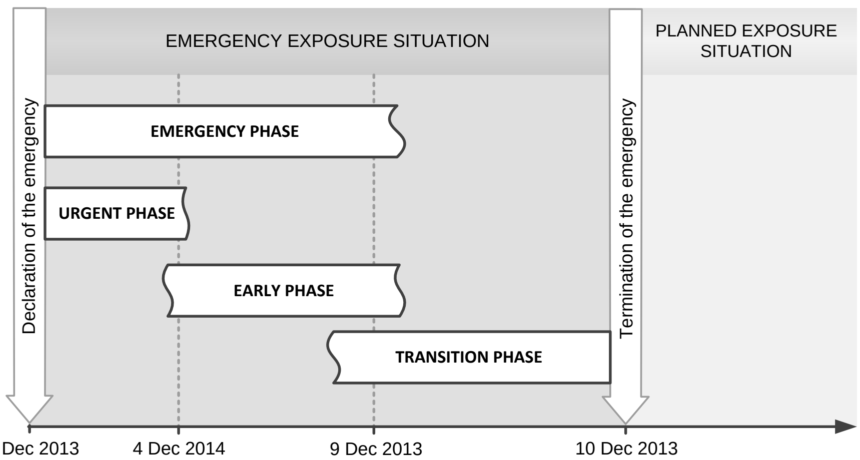

Fig. I-16. Retrospective sequencing and milestones of the radiological incident in Hueypoxtla.

Conclusions against the prerequisites for the termination of the emergency

General prerequisites

- Had the necessary urgent and early protective actions been implemented?
  The public and first responders had been informed of the risks associated with the stolen radioactive source and the precautions needed to be taken in case the source was found. The location of the radioactive source had been identified, the area cordoned off and access controls put in place. The person handling the unshielded radioactive source had been identified.

- Was the exposure situation stable and well understood?
  The radioactive source had been isolated and confirmed not to have been dispersed. Thus, further unexpected evolution of the situation was not expected.

- 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 to do so.

- 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 cordoned and access controls were in place excluding further significant exposure due to the unshielded source.

- Was the current situation assessed, and were the existing emergency arrangements reviewed and new arrangements established?
  Mexico had accounted for a nuclear emergency in the CNLV, but there were no plans for response to a radiological emergency at the national level. Inter-institutional plans had not been developed either. As lesson identified from this incident, at the time of the drafting this case study, CNSNS was already working in cooperation with the Civil Protection Agency to develop such a plan.

- Were the requirements for occupational exposure as for a planned exposure situation confirmed for all workers engaged in recovery activities?
  The response to this incident, including the locating the radioactive source and its recovery, were 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 2.45 mSv, with the highest value at 19.99 mSv.

- Was the radiological situation assessed against reference levels, generic criteria and operational criteria, as appropriate?
  A maximum 500 mSv for non-stochastic effects for presumably exposed persons was set; occupational dose limits for source recovery for engaged workers was established at 50 mSv effective dose, which were used in assessing the situation.

- Were non-radiological consequences (psychosocial, economic) and other factors (technology, land use options, availability of resources, community resilience) identified and considered?
  The SSA and CNSNS made dedicated efforts to provide public information as a mechanism to reassure the public living in the area where source was found and to directly respond to questions regarding the situation. The public was constantly reassured by these authorities that there was no danger in continuing daily activities as carried out before the incident.

- Was a registry of those individuals requiring further medical follow-up established prior to the termination of the emergency?

The affected people had been identified by 10 December through reconstruction of the event. This was followed by dose assessments for each identified individual which provided a basis for medical treatment to be provided by health professionals.

– Was a strategy for management of radioactive waste arising from the emergency, when appropriate, developed?
The planning for the management of the source as radioactive waste took place during the days in which the source was located and isolated. On 10 December 2013, the radioactive source was transported to the Nuclear Center Facility of ININ in order to be conditioned prior to its transfer to the radioactive waste disposal facility.

– Were the interested parties consulted?
Limited consultation was ensured due to the type of event, in particularly in relation to the decision for storage and disposal of the source. However, CNSNS created a bulletin for the Civil Protection Agency for distribution among the involved agencies, providing information of 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 risks and precautions that needed to be taken. CNSNS informed the public present at the incident site of the development of the recovery tasks, and that there was no risk of contamination or exposure in the area after the source had been recovered.

Specific prerequisites

Transition to a planned exposure situation

– Were the circumstances surrounding the emergency analysed and corrective actions identified?
During the incident, the need of taking measures to strengthen the security during transport of radioactive sources in category 1 by licensees in cooperation with the Federal Police and CNSNS became evident. In addition, the necessity of developing and maintaining a national response plan for radiological emergencies has also been identified, as well as the need to identify all the involved agencies and their responsibilities.

– Was an action plan developed for implementation of corrective actions by respective authorities?
Shortly following the incident, CNSNS set the measures to be followed by licensees during the transport of radioactive sources in category 1 as a requirement. At the time of the drafting of this case study, CNSNS and the Civil Protection Agency were already working on the development of the national response plan for a radiological emergency as well as on identifying agencies to be 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?
It is considered that this was achieved by complementing the additional measures for secure transport as explained above.

– Was there a necessity for administrative procedures to limit or prevent any use or handling of the source until better understanding on circumstances surrounding the emergency situation was gathered?
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 measure except those implemented during the recovery process.

– Was compliance confirmed with the requirements for dose limits for public exposure in planned exposure situations?

All the recovery operations were carried out within the dose limits for normal operation. The management of the radioactive source as a radioactive waste followed the national regulations for normal operation.

REFERENCES TO THE ANNEX

[I-1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015).

[I-2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2–4).

[I-3] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission’s Recommendations for the Protection of People in Emergency Exposure Situations. ICRP Publication 109. Ann. ICRP 39 (1).

[I-4] Act on Special Measures Concerning Nuclear Emergency Preparedness, as last amended by Act No. 156, 17 December 1999 (Japan), http://www.cas.go.jp/jp/seisaku/hourei/data/ASMCNEP.pdf

[I-5]INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, Report by the IAEA Director General, IAEA, Vienna (2015).

[I-6] GOVERNMENT OF JAPAN, NUCLEAR EMERGENCY RESPONSE HEADQUARTERS, Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety — The Accident at TEPCO’s Fukushima Nuclear Power Stations, Attachment X, Tokyo (2011).

[I-7] TOKYO ELECTRIC POWER COMPANY, Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station (2011), http://www.meti.go.jp/english/speeches/pdf/20110417_a.pdf

[1-8] MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY, Plan to Conduct Detailed Monitoring in Restricted Area and Planned Evacuation Zone (2011), http://www.mext.go.jp/component/english/__icsFiles/afieldfile/2011/06/29/1304084_0613.pdf

[I-9] GOVERNMENT OF JAPAN, NUCLEAR EMERGENCY RESPONSE HEADQUARTERS, Additional Report of the Japanese Government to the IAEA — The Accident at TEPCO's Fukushima Nuclear Power Stations — Second Report, Tokyo (2011).

[I-10] INTERNATIONAL ATOMIC ENERGY AGENCY, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015).

[I-11] NUCLEAR SAFETY COMMISSION OF JAPAN, Basic Policy of the Nuclear Safety Commission of Japan on Radiation Protection for Termination of Evacuation and Reconstruction (2011), http://www.nsr.go.jp/archive/nsc/NSCenglish/geje/20110719suggest_4.pdf

[I-12] NUCLEAR EMERGENCY RESPONSE HEADQUARTERS, Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety: The Accident at TEPCO’s Fukushima Nuclear Power Stations, Government of Japan (2011), http://www.iaea.org/newscenter/focus/fukushima/japan-report

[I-13] MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES, Actions such as Shipment Restraint Due to the Accident (as of April 26) (2011), http://www.maff.go.jp/e/quake/press_110426-3.html

[I-14] NUCLEAR SAFETY COMMISSION, Near-term Policy to Ensure the Safety in Treating and Disposing Contaminated Waste around the Site of Fukushima Dai-ichi Nuclear Power Plants, NSC, Tokyo (2011).

[I-15] Act on Special Measures concerning the Handling of Environment Pollution by Radioactive Materials Discharged by the Nuclear Power Station Accident Associated with the Tohoku District — Off the Pacific Ocean Earthquake that Occurred on March 11, 2011, Act No. 110 as of 2011 (Japan), http://josen.env.go.jp/en/framework/pdf/special_act.pdf?20130118

[I-16] NUCLEAR EMERGENCY RESPONSE HEADQUARTERS, Basic Policy for Emergency Response on Decontamination Work (2011), http://www.kantei.go.jp/jp/singi/genshiryoku/dai19/19_03_gensai.pdf

[I-17] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Goiânia, IAEA, Vienna (1988).

[I-18] HUNGARIAN ATOMIC ENERGY AUTHORITY, Report to the Chairman of the Hungarian Atomic Energy Commission on the Authority’s Investigation of the Incident at Paks Nuclear Power Plant on 10 April 2003, (Event Id. No. 1120), 23 May 2003, http://www.oah.hu/web/v3/HAEAPortal.nsf/7860FD50CC2E8C5FC1257C5C00381618/$FILE/haecreport041003_corrected.pdf.

[I-19] INTERNATIONAL ATOMIC ENERGY AGENCY, Report of the Expert Mission ‘To Assess the Results of the Hungarian Atomic Energy Authorities Investigation of the 10 April 2003 Fuel Cleaning Incident at Paks NPP’, 16–25 June 2003; and Operational Safety Review Team (OSART) Mission, 8–25 October 2001 to the Hungarian Atomic Energy Authority and Paks Nuclear Power Plant, Hungary; and Follow-Up Visit, 21 February–1 March 2005 (TC Project HUN/9/022, IAEA-TCR 02581, IAEA NSNI 112F), IAEA, Vienna (2005), http://www.haea.gov.hu/web/v2/portal.nsf/download_en/DA42E209CADCC741C125710B0057E2BF/$file/osart.pdf.

[I-20] INTERNATIONAL ATOMIC ENERGY AGENCY, OECD-IAEA Paks Fuel Project, Final Report, IAEA, Vienna (2009).

ANNEX II

FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY

A.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, different organizations and bodies may contribute to the decision-making processes. The table below lists a number of these factors to help emergency planners and decision-makers in identifying the organizations and relevant interested parties that should be prepared to contribute to, and should be involved in, the development and implementation of justified and optimized protection strategies, as appropriate, as discussed in the sub-section on the Protection Strategy.

A.2. Table II.1 builds upon the guidance provided in the Nordic Guidelines and Recommendations[42] on the factors affecting the choice of protective measures especially in the intermediate phase. It is not intended to be an exhaustive list of such factors, but can be used as a starting point for the development of a national list of factors for consideration in the justification and optimization of the protection strategy at the preparedness stage. It could also be used during the transition phase of a nuclear or radiological emergency.

[42] Protective Measures in Early and Intermediate Phases of a Nuclear or Radiological Emergency, Nordic Guidelines and Recommendations (2014).

TABLE II.1: COMPILATION OF FACTORS FOR CONSIDERATION IN THE JUSTIFICATION AND OPTIMIZATION OF THE PROTECTION STRATEGY

Factors	
General goals	Goals of emergency response Primary objective for the termination of an emergency Primary prerequisites for the termination of the emergency Specific prerequisites for the termination of the emergency
Legislation and regulations	Criteria for implementing protective actions and other response actions • Generic criteria • Operational criteria (OILs, EALs, observables) Reference level for emergency exposure situation Measures for protecting emergency workers, including guideline values for restricting their exposures in emergency response Other respective requirements and guidance for: • Planned, emergency and existing exposure situations Commitments under relevant international instruments, bi-lateral and multilateral agreements in relation to transnational and/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 phases
Radiation protection	Radiological situation: • Exposure scenario and dominant exposure pathways • Contamination of 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 and/or are received
Efficiency	Feasibility of actions (season of the year, weather conditions, etc.) Reducing exposure and contamination in consideration of pre-set reference level Limitations (technical, social, environmental, economical) Acceptability of protective actions Interaction between different actions
Resources	Availability of human resources

	Knowledge, skill and training needs Availability of material (trucks, busses, machinery etc.) Availability of financial resources Availability of stable iodine pills Availability of chemicals and other means/resources for decontamination and decorporation Availability of infrastructures (e.g. for the relocation of people, for waste treatment, storage and disposal, for land use reconversion and change in industrial processes) Availability of logistical support
Environmental aspects	Type of affected area: urban, recreational, industrial, agricultural, forest, etc. Type of surfaces: buildings, roads, agricultural or forest soil Geographical location of area (coast, mountain…) 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 Compensation issues Interruptions in international trade Expected market response and evolution in the future
Social and ethical aspects	Disrupted living conditions Reduction in life expectancy due to stress associated with resettlement Psycho-social effects Possibility of public self-help 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 pre-disposal management and for minimizing amount of waste Available waste management facilities and practices