IAEA Safety Standards

for protecting people and the environment

Remediation Process for Areas Affected by Past Activities and Accidents

Safety Guide

No. WS-G-3.1

IAEA
International Atomic Energy Agency

REMEDIATION PROCESS FOR AREAS AFFECTED BY PAST ACTIVITIES AND ACCIDENTS

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

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LATVIA
LEBANON
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
PAKISTAN
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

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

IAEA SAFETY STANDARDS SERIES No. WS-G-3.1

REMEDIATION PROCESS FOR AREAS AFFECTED BY PAST ACTIVITIES AND ACCIDENTS

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2007

COPYRIGHT NOTICE

Sales and Promotion, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
March 2007
STI/PUB/1282

IAEA Library Cataloguing in Publication Data

Remediation process for areas affected by past activities and accidents : safety guide. — Vienna : International Atomic Energy Agency, 2007.
p. ; 24 cm. (IAEA safety standards series, ISSN 1020–525X ; no. WS-G-3.1)
STI/PUB/1282
ISBN 92–0–113306–5
Includes bibliographical references.

1. Nuclear power plants — Accidents — Environmental aspects. 2. In situ remediation. I. International Atomic Energy Agency. II. Series.

IAEAL 07–00475

FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. A large number of areas that have been contaminated by residual radioactive material as a result of past activities or accidents require intervention[1]. These areas may be very large and of specific interest and may call for major commitments of resources in terms of funding and personnel. Some past activities and accidents have led to significant radioactive contamination of areas in many Member States. This contamination may represent a hazard to the general public and the environment. Other areas that were contaminated as a result of past or current practices[2] are small and can be remediated as part of a larger decommissioning project, if such a project is being prepared, or as a standalone project. Member States have expressed a need for guidance on remediating areas contaminated by past activities and accidents.

1.2. The IAEA Safety Requirements publication on Remediation of Areas Contaminated by Past Activities and Accidents [1] establishes safety requirements for the remediation of areas that require intervention. Guidance on the remediation of smaller areas as part of the decommissioning process for practices is provided in Ref. [2].

OBJECTIVE

1.3. The objective of this Safety Guide is to provide guidance on implementing the requirements for the remediation of areas contaminated by past activities and accidents [1]. It is intended to be used by regulatory bodies, operators and others responsible for remediating sites and, in the case of an accident, contributing to the recovery process.

---

[1] An intervention is defined as any action intended to reduce or avert exposure or the likelihood of exposure to sources which are not a part of a controlled practice or which are out of control as a consequence of an accident [3].

[2] A practice is defined as any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed [3].

SCOPE

1.4. The situations dealt with in this Safety Guide are interventions for areas that have been contaminated as a result of human activities and that could cause prolonged radiation exposure. In this context, the term 'areas' is used in its broadest sense and can include land, water bodies and industrial sites. These areas may have been contaminated as a result of inadequate practices for radioactive waste management and disposal, accidental radioactive discharges to the environment that did not meet regulatory requirements, nuclear accidents, atomic weapon tests, incidents involving releases of radionuclides by users of radioactive material or past practices that were not adequately controlled. This Safety Guide also applies to radioactive discharges from facilities that were managed in accordance with less stringent requirements than those that are applied today. It could also be relevant in the event of malicious action involving radioactive material. This Safety Guide does not apply to facilities that are currently under regulatory control and that may have had emergencies that have contaminated small areas within the facility.

1.5. This publication provides recommendations for protective and remedial actions that are intended to reduce existing prolonged exposures due to contamination and to avert potential prolonged exposure or the likelihood of such exposure from related contamination. This includes remedial actions such as the removal of the source of exposure, as well as other long term protective actions such as restrictions on consumption of foodstuffs produced in the area and restriction of access to land areas or of land use. It covers other important measures linked to remediation activities, such as the need for monitoring programmes, although these do not contribute directly to the reduction of exposure.

1.6. In certain situations, non-radiological hazards may be present together with the radioactive contamination. Although the non-radiological hazards should be assessed in conjunction with radiological hazards to find an optimal remediation strategy, the scope of this publication does not include the manner in which this can be accomplished.

1.7. In the context of intervention situations, the term 'remediation' has a meaning that is similar to rehabilitation, reclamation and cleanup. It does not include decommissioning, as decommissioning refers to the full range of activities leading to the termination of an authorized activity.

STRUCTURE

1.8. Section 2 of this Safety Guide discusses the regulatory framework and responsibilities. It also provides guidance concerning the prioritization of remediation at the national level. Section 3 presents an overview of the general remediation process and the first steps in the process. Section 4 provides guidance on planning for remediation, while Section 5 covers the implementation of remediation and includes guidance on such activities as staffing and training, organization and administrative control, waste management and radiation protection. Section 6 deals with post-remediation issues, including the setting and removal of restrictions.

2. REGULATORY INFRASTRUCTURE AND RESPONSIBILITIES

GENERAL

2.1. Many factors should be considered when ensuring the overall protection of workers, the public and the environment during the remediation process. In particular, several key administrative and technical issues should be addressed before any remediation is considered. First, the regulatory framework of the Member State should have adequate provisions for a governmental authority to oversee the process. The responsibilities and powers of the regulatory bodies should be clearly established, and the remediation process should be designed and implemented in a systematic way, with each step and all decisions clearly documented. Finally, the criteria should be established for making decisions on whether remediation is required, and to what extent. General requirements for the legal and governmental infrastructure are established in Ref. [4] and are not repeated in this Safety Guide.

REGULATORY FRAMEWORK

2.2. Provisions are required within the regulatory infrastructure for the regulatory body to review and approve proposed remediation plans that are submitted by the organization responsible for implementing remedial measures (Ref. [1], para. 5.5). The framework is required to include provisions

for the granting of licences or other authorizations as well as the imposition of fines or other penalties that may be necessary during the remediation process (Ref. [1], para. 4.9). A mechanism should be put in place that will ensure cost recovery and funding for the regulatory body.

2.3. The regulatory infrastructure should provide for the regulatory body to determine when a site or group of sites will require remediation. This is essential to minimize the detrimental effects of the prolonged exposure associated with some sites.

2.4. The regulatory framework should provide the basis for establishing restrictions that may be placed upon the use of or access to areas, before, during and, if necessary, after remediation.

2.5. "The legal framework shall provide for appropriate record keeping" of information (Ref. [1], para. 4.7). This is particularly important where restrictions are imposed on access to areas or on the activities that may be conducted in these areas. A complete set of records should be available to aid any subsequent actions necessary for the removal of any restrictions imposed. Within the regulatory framework, a wide range of interested parties should be consulted and kept informed of the site specific strategy and activities.

2.6. The legal framework is required to ensure that "adequate funding mechanisms are available" for providing the necessary resources when needed, even if responsible parties are unable to meet their liabilities (Ref. [1], para. 4.4).

2.7. In the absence of specific regulations for remediation, the process should be undertaken on a site specific basis under existing regulations for each activity associated with the remediation. In such a situation, the organization responsible for the remediation should consult, and obtain approval from, the regulatory body for compliance with the existing regulations.

RESPONSIBILITIES

2.8. When a contaminated area has been identified, remediation of that area should be the responsibility of the area's owner or the operator (defined as the responsible party) that caused the contamination, or of the legally responsible successor organization. Often, however, such parties can no longer be located, or they cannot fund the necessary remediation activities, or the contamination

was the result of an accident or of an activity that was supported by the government. Since the actual remediation of a contaminated area may involve several entities that include individuals who may be unfamiliar with radiation protection principles, the roles and responsibilities of the different parties involved in the remediation process should be clearly defined. In particular, those persons or organizations responsible for providing adequate human resources, equipment and supporting infrastructure and the necessary funding for accomplishing the remediation should be clearly identified to the regulatory body.

2.9. To discharge its responsibilities as defined in Ref. [4], the regulatory body should have the appropriate resources, including properly trained and experienced staff, facilities and financial commitments. Its responsibilities should include:

(a) Identifying and quantifying potentially contaminated areas and the associated responsible parties;
(b) Prioritizing contaminated areas;
(c) Establishing remediation criteria;
(d) Specifying the time when remediation activities should be initiated;
(e) Reviewing and approving the selected optimized remediation strategy, remediation plans and supporting documents relating to the performance of remediation activities associated with a contaminated site, in terms of radiological, non-radiological and conventional safety;
(f) Monitoring the remediation activities during implementation;
(g) Verifying that all final conditions have been met prior to terminating regulatory control over the area;
(h) Formally terminating regulatory control over the area;
(i) Reviewing and approving any restrictions or institutional controls if the area is released for restricted use;
(j) Ensuring public participation in all activities associated with the remediation process;
(k) Liaising with other regulatory organizations that have responsibilities for non-radiological hazards in the same area.

2.10. The overall responsibility for the planning and implementation of the remediation activities should remain with the responsible party, even when contractors are used to perform specific tasks or functions. “The identified responsible parties for the remediation of an area shall be responsible for all aspects of safety until the completion of the remediation effort” (Ref. [1], para. 4.10). The responsible party should develop a public information

programme to provide regular information throughout the remediation project and to allow public participation in the planning and implementation process. The responsible party should also:

(a) Retain the necessary resources, expertise and knowledge for remediation;
(b) Keep records and documentation relevant to the history, operation and remediation process so that such information can be transferred to any supporting or successor owner or operating organization;
(c) Prepare a remediation plan and all supporting documentation for review and approval by the regulatory body;
(d) Ensure the safety of workers and the public and protection of the environment during the safe implementation of the approved remediation plan;
(e) Report to the regulatory body on a scheduled basis any safety related information as required by the terms of the remediation plan;
(f) Report to the regulatory body any unusual incidents that may occur during the remediation process;
(g) Ensure the maintenance of records and documentation following the completion of remediation for a period of time as specified by the regulatory body.

PRIORITIZATION OF CONTAMINATED OR POTENTIALLY CONTAMINATED AREAS

2.11. To implement the requirement for a national remediation strategy, areas that have been identified as contaminated should be prioritized. Following the initial characterization of each area, an inventory of contaminated areas should be prepared, which includes their locations, the types and properties of the contaminants, the size and environmental characteristics of the areas, the populations actually or potentially exposed and any other relevant factors.

2.12. The inventory of contaminated areas should then be prioritized in accordance with the level of risk to human health and the environment. Other factors, such as socioeconomic impacts, availability of funds, availability of remediation techniques, availability of scientific data and potential effects on neighbouring States, may also have a strong influence in determining the priorities for remediation. If the parties responsible for some of the identified sites are ready to perform the remediation activities at their own cost, the remediation of these sites should not be postponed awaiting the national remediation strategy prioritization.

2.13. The identification and prioritization of contaminated areas should be aided by the involvement of government agencies other than the regulatory body and by private organizations. The national strategy should provide for their input into the process.

2.14. To assist in determining priorities, the regulatory body should use reference levels (see paras 3.18–3.23 of this Safety Guide and Ref. [5]) on the basis of an a priori assessment of situations that could occur. The priorities may also be established by comparison with other similar areas where exposures or activity concentrations are considered to be acceptable. Documentation of the process used for the prioritization of the list should be maintained. As new areas are identified, they should be added to the list and the list should be prioritized once again; however, repriorization should not prevent remediation from progressing.

3. OVERVIEW OF THE REMEDIATION PROCESS AND INITIAL DECISION MAKING

GENERAL

3.1. The overall remediation process shown in Fig. 1 involves four main activities: (a) initial site characterization and selection of remediation criteria; (b) identification of remediation options and their optimization, followed by subsequent development and approval of the remediation plan; (c) implementation of the remediation plan; and (d) post-remediation management. Following the completion of each of these main activities, a decision should be made about whether to release the area or part of the area for either restricted or unrestricted use, or to proceed to the next activity. The differences in implementation for specific areas will be in the degree of detail and complexity of the activities undertaken in each step in the process. An iterative approach based on the potential risks should be used in this process.

OVERALL APPROACH IN THE REMEDIATION PROCESS

3.2. Planning for remediation should begin once the regulatory body has identified a contaminated site or in accordance with the prioritization list. The

necessary funds should be available either from the responsible party or through other mechanisms provided for in the legislation. The responsible party should collect available information about the contaminated area and should perform a historical site assessment (see paras 3.14–3.17). Interested

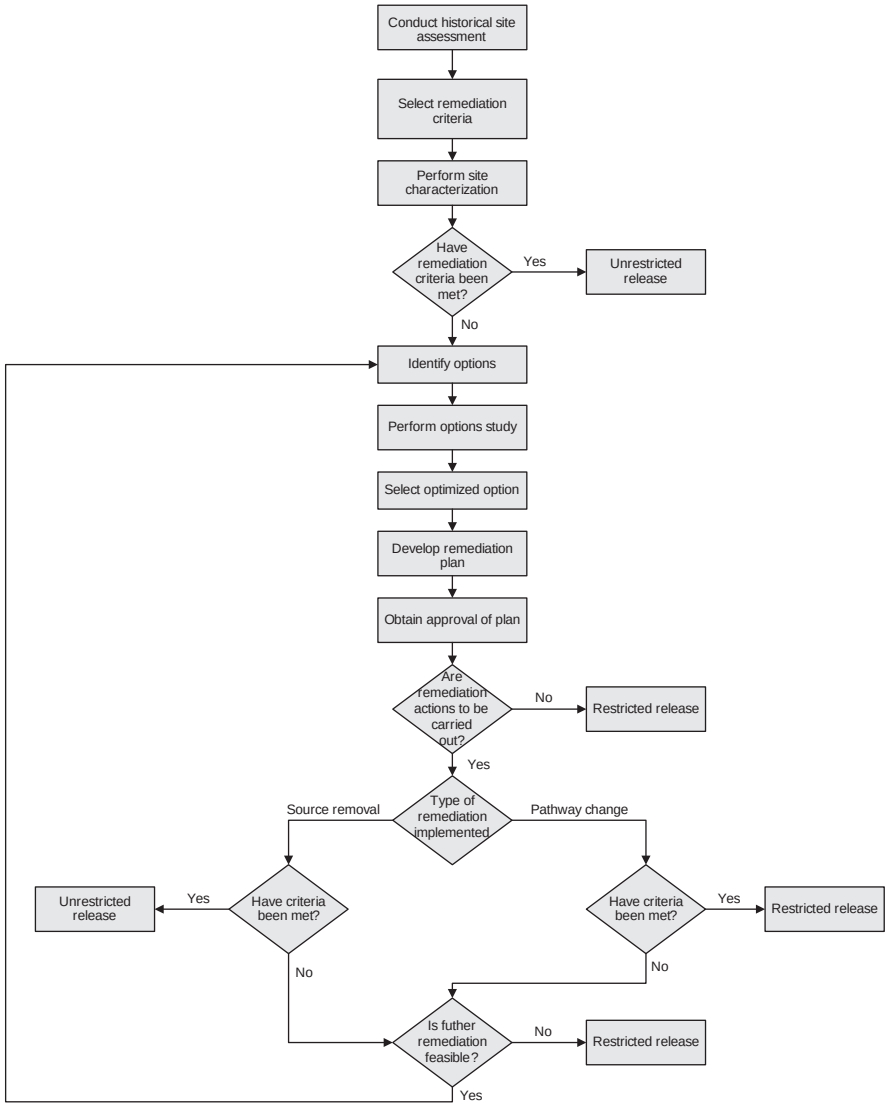

FIG. 1. The remediation process.

parties, including past and present owners, workers, local industry, residents, neighbouring States and local governments, should be consulted to obtain information, as appropriate.

3.3. General or specific reference levels should be used for an early analysis to determine the type and extent of contamination that would require remediation. These levels provide assistance in the early planning and can help to establish the end criteria of any possible remediation activities. Paragraphs 3.18–3.23 provide additional guidance on selecting these remediation end criteria.

3.4. A site characterization (see paras 3.24–3.27) should then be performed on the basis of the relevant site information to determine whether the remediation end criteria (in terms of individual doses or derived concentration values) have been met. If the criteria have been met and this is confirmed by a survey, the area can be released without restrictions (i.e. no remedial actions are necessary).

3.5. If the area does not meet the criteria for unrestricted release, suitable remedial measures should be identified and an options study should be performed to compare the benefits and detriments of these measures. These options should cover a broad range of situations and should be based on a set of credible exposure scenarios.

3.6. For all the options identified, a study should be performed to determine the option that is best for the area. The study should factor in both justification and optimization. This study should include estimates of the costs and other resources associated with the treatment, removal, transport and disposal of contaminated material for each option; the estimated doses to workers and the public due to exposure before, during and after the remediation; the overall safety issues during remediation; the available technologies; the considerations for monitoring and sampling; the amount of waste that will be generated; and the institutional controls required after implementation of the option, if applicable.

3.7. For the set of options under consideration, optimization of protection should be performed for the justified options, as explained in para. 3.6, to determine the option that has the highest net benefit. On the basis of this optimization, a preferred option should be selected that also takes into account non-quantitative considerations such as social and political aspects.

3.8. For the selected option, a detailed "remediation plan showing that remediation can be accomplished safely shall be prepared for each contaminated area, unless otherwise required by the regulatory body" and the "remediation plan shall be subject to the approval of the regulatory body prior to its implementation" (Ref. [1], para. 5.5).

3.9. Plans should be provided for both the remediation work and the necessary measures for post-remediation, such as maintenance, monitoring and institutional controls to enforce restrictions on land use and buildings, if applicable. Although institutional controls may last for a long period of time, they are part of the post-remediation as defined in this context and should thus be covered in the remediation plan.

3.10. Once the plan has been approved, it should be implemented as soon as possible. If it is decided not to remediate the area, decisions should be made on imposing restrictions on its use or access prior to release (see paras 6.6–6.8). If remedial actions are required, they should be implemented as soon as possible (see Section 5).

3.11. Two types of remedial action are possible: (a) source removal or (b) pathway change. After the approved remedial actions have been completed, the regulatory body should evaluate the effectiveness of the implementation.

3.12. If the established remediation criteria have been met after source removal actions, the area should be released without further restrictions. If the criteria have been met after pathway change actions, the area should be released with appropriate restrictions. These restrictions would be in the form of institutional control on the use of the area, for example to ensure that restrictions on grazing are followed.

3.13. If, after remedial actions have been carried out, the criteria have not been met, the responsible party should determine whether further remediation is feasible or whether the area should be released with restrictions, and should submit a proposal accordingly to the regulatory body for approval. If conditions have changed or additional information has been collected, and further remediation is justified, the process (illustrated in Fig. 1) should again be followed, starting at the stage at which the options are to be identified (see para. 3.5).

HISTORICAL SITE ASSESSMENT

3.14. A historical site assessment should be performed for all areas included in the remediation project to determine the historical radiological conditions in the area and to identify what additional information may be necessary to enable an evaluation of the area to be performed. This assessment should be made on the basis of operational and currently available information.

3.15. The objectives of the historical site assessment are:

(a) To identify possible sources of radiological and non-radiological contamination and other hazards;
(b) To identify the characteristics of the contaminants;
(c) To identify related past activities or accidents that occurred in the area;
(d) To determine whether the site poses a threat to human health or the environment;
(e) To provide input into the design of the characterization survey;
(f) To provide an assessment of the likelihood of migration of contaminants;
(g) To determine possible responsible parties.

3.16. Existing information that provides a physical description of the area should be collected, including aspects such as location, buildings, buried material, physical barriers, geological and hydrogeological characteristics, type of soil and human activities on or near the area that may help to identify individuals who may potentially be affected by the remediation. The information should be collected by means of (i) a review of old operational records, past radiological and non-radiological surveys and local government records and files, and (ii) interviews with present and former employees.

3.17. In the assessment of any environmental contamination, all the available information should be used to estimate the scope of the problem and to determine the type, quality and quantity of measurements necessary to make a decision on the extent of the remediation required.

REMEDIATION CRITERIA

General

3.18. In the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (Basic Safety

Standards) [3], reference levels have been defined for use within the system of protection. These are referred to as intervention levels, expressed in terms of avertable dose, and action levels, expressed in terms of dose rate or activity concentration. In this Safety Guide, the term 'reference levels' includes reference levels, intervention levels, investigation levels and recording levels as defined in the Basic Safety Standards [3]. The reference level (often expressed in terms of annual effective dose[3]) indicates a level below which remediation is normally unlikely to be justified, and it serves as a criterion for the unrestricted release of a site. Within the scope of this Safety Guide, the reference level can be chosen to be identical to the generic reference level introduced in Ref. [1]. "A generic reference level for aiding decisions on remediation is an existing annual effective dose of 10 mSv from all sources, including the natural background radiation. This will normally be assessed as the mean dose for an appropriately defined critical group. Remedial measures would often be justified below the generic reference level and national authorities may define a lower reference level for identifying areas that might need remediation" (Ref. [1], para. 3.2).

3.19. Additionally, a reference level specific to a particular component of the dose (such as that due to the inhalation of radon) may be established to limit the contribution of this component to the annual dose. This 'specific reference level' should be expressed in terms of annual dose as an appropriate fraction of the generic reference level, or in terms of a subsidiary quantity such as dose rate or activity concentration.

3.20. In addition to a generic reference level for the total effective dose, a generic reference level for organ doses is also required. "An existing annual equivalent dose of 100 mSv (inclusive of all existing contributions, including doses due to natural background radiation) to any organ shall justify intervention under almost any circumstances" (Ref. [1], para. 3.4).

[3] In this Safety Guide, the annual effective dose is the sum of all significant components of annual dose incurred by a typical individual in an exposed group of people, from all relevant sources and via all pathways of a human habitat subjected to prolonged exposure. The existing annual dose therefore includes: the annual dose from natural sources of radiation; the annual dose caused by the accumulation of long lived radionuclides released from practices under control; and the annual dose caused by long lived radioactive residues from previous human activities and from long standing accidental contamination of the environment.

3.21. The reference levels for the annual effective dose and equivalent organ doses, together with the specific reference levels for dominant components (as far as established by the regulatory body), establish the remediation end criteria. These levels should refer to the actual exposures as well as to potential future exposures. Potential future exposures should correspond to the scenarios considered in the options study, which is referred to in Fig. 1.

3.22. Dose criteria cannot be directly measured, and therefore it is necessary to use assessment models to derive operational quantities that can easily be measured. By proper modelling of the exposure pathways, both the generic reference levels and specific reference levels can be converted into operational quantities, such as activity concentrations in Bq/g or Bq/m^2, above which remedial actions should be implemented. This will enable the responsible party to implement remedial actions and demonstrate compliance with dose criteria.

3.23. On the basis of a generic reference level for the total effective dose of 10 mSv/a (or lower levels if specified by the regulatory body), radionuclide specific generic reference levels for remediation, expressed in terms of bulk activity concentration (for soil and other material) as well as surface activity concentration, should be calculated by acceptable methods and in consideration of the components (e.g. material characteristics).

SITE CHARACTERIZATION

3.24. In addition to the historical site assessment, a site characterization survey should be performed to collect current information and to validate the information provided in the historical site assessment. The survey will provide information: (a) to determine the nature and extent of radiological contamination; (b) to identify receptors and provide input to pathway analysis and dose assessment or risk assessment models; (c) to identify various options for the remediation; (d) to evaluate environmental, occupational and public health and safety issues during remediation; (e) to evaluate and select remediation technologies; (f) to classify and quantify potential waste; and (g) to assist in the final survey design.

3.25. The characterization survey requires proper selection and calibration of instruments, proper sampling and measurement techniques and recording of data. The survey should utilize all types of techniques for collecting the necessary data properly (i.e. sampling of surface and subsurface soil, ambient gamma measurements, sampling of airborne radioactive material, sampling of

water and biota). The design of the characterization survey should be determined by the conditions in the area, the type and extent of on-site contaminants and the available resources. The data should then be compiled and assessed to allow decisions to be made. The data from the characterization survey should be used as input to models for assessing the individual doses expected to arise from the contaminated environment.

3.26. The results of the characterization of the site and the evaluation of the possible remediation options should be reported to the regulatory body, and its review of the evaluation should constitute a key step in the decision making process. Interested parties should be involved in this process at an early stage before decisions are finalized.

3.27. A characterization report should be prepared and submitted to the regulatory body as part of the remediation plan.

Development of site specific criteria for remediation

3.28. If the responsible party introduces site specific reference levels in place of the generic reference levels, these should be derived from a process of justification and optimization of protection similar to that described in paras 4.3–4.12. Within this justification process, it should be demonstrated that the resulting avertable doses and other beneficial effects of the remediation are worthwhile in terms of costs, exposures of workers, any harmful environmental impacts and other disadvantages. From this, a site specific reference level should be derived in terms of an acceptable residual dose. A site specific reference level should not be interpreted as a strict limit but as a level against which the residual doses resulting from a justified and optimized remedial measure are to be compared.

3.29. While remediation may contribute to social and economic improvements in the area, remedial measures may also involve considerable cost and social inconvenience, and the line between caution and overreaction may be difficult to distinguish. In applying the site specific reference levels, therefore, the exposures to be compared with these levels should be assessed on the basis of the average dose to the critical group determined by making realistic assumptions about diet and lifestyle, using realistic socioeconomic factors and habitability data, and accounting for all possible pathways. The assumption of extreme or unrealistic characteristics in the dose assessment would be inconsistent with the goal of selecting the most appropriate remedial measure.

3.30. The outcome of the assessment of individual doses should be compared with the reference levels for remediation. If these reference levels correspond to doses that are lower than the average individual dose to the critical group, remedial measures are justified and should be implemented. The effects of different remediation options on individual doses should be calculated by using models that are consistent with those that are used to assess the individual doses from the contaminated environment.

3.31. As with using a generic reference level, the derivation of operational quantities expressed both as bulk activity concentration (for soil and other material) and as surface activity concentration (for surfaces) should also be performed. These calculations should yield remediation end criteria that are radionuclide specific and site specific. The calculations should be based on the same models, or at least models that are consistent with those that were used for calculating the radionuclide specific generic reference levels for remediation.

4. PLANNING OF REMEDIATION

GENERAL

4.1. When a decision has been made to remediate a contaminated area, a remediation plan should be made. The first steps in the development of this plan should be to determine and evaluate possible remediation options. These options can range from complete remediation and unrestricted release of the site to more limited remediation with some subsequent uses of the site being restricted.

4.2. The degree of complexity of a given remediation process may vary depending on site specific situations. However, there are several components of the remediation process that should be considered essential for any area being considered for remediation.

JUSTIFICATION AND OPTIMIZATION OF REMEDIAL MEASURES

4.3. Interventions in the form of remedial measures should be intended to decrease existing and potential annual exposures, by removing existing sources,

modifying pathways or reducing the number of exposed people. "For contamination resulting from past activities and accidents, the required level of remediation shall be established on a site specific basis and in accordance with the radiation protection principles that apply to intervention situations" (Ref. [1], para. 3.1). These principles include the justification of remedial measures and the selection of the optimum measures among those justified. In applying these two principles to derive an optimized option for protection, all relevant advantages and disadvantages should be taken into account. These include avertable[4] doses (individual and collective), radiological and non-radiological risks, environmental effects, risks to the workers implementing the remedial measures, economic costs, improvement of the economic situation, the generation of secondary waste, increased or reduced anxiety on the part of interested parties and social disruption arising during and after the implementation of the remedial measures.

Justification of remedial measures

4.4. "The remedial measures shall be justified by means of a decision aiding process requiring a positive balance of all relevant attributes relating to the contamination" (Ref. [1], para. 3.1(a)). The justification principle should be implemented by means of an assessment of the overall radiological impacts from the contaminated areas in question, identification of options for reducing these impacts, evaluation of the reductions achievable in doses and in other harmful impacts and assessment of the harm and costs associated with these remediation options. Decisions taken on this basis should involve balancing benefits from the reductions in impacts and costs and other factors of influence. An informed decision should be taken on the basis of a full integration of all the advantageous and disadvantageous attributes for society resulting from the proposed remediation options.

4.5. Situations giving rise to potential exposures as well as actual exposures should be considered during the assessment.

[4] Avertable dose is "the dose to be saved by a protective action; that is to say, the difference between the dose to be expected with the protective action and that to be expected without it" [3].

Optimization of remedial measures

4.6. "The remedial measures shall be optimized following the general approach to the optimization of protection in the context of practices. The optimum nature, scale and duration of the remedial measures shall be selected from a set of justified options for remediation" (Ref. [1], para. 3.1(b)). The aim is to obtain not only a positive benefit but also optimized protection. The decision aiding techniques for deciding on the optimum remediation option are independent of the nature of the situation causing the exposure [5]. Normally, there would be a range of justified remediation options for which the net benefit would be positive.

4.7. Some remediation options could involve restrictions on the use of the area, even when the remediation end criteria have been met. Such an option will, however, require institutional control as long as the restrictions are deemed necessary. Options that lead to unrestricted release of the area after the remediation criteria have been met have the additional benefit of not requiring institutional control or other regulatory burdens, and so should be favoured. It is recognized, however, that site specific features such as topography, size of the area and lack of waste management facilities might limit the feasibility of a remediation option that leads to unrestricted release.

4.8. In some circumstances, remediation may be required to protect the present population and may be justified on the basis of attributable health effects among people in future generations. While in most cases the cost of remediation, in terms of aspects such as disruption and inconvenience, will be borne by the present population, remedial measures taken to protect the present generation should be designed in such a way that predicted impacts on the health of future generations will not be greater than the levels of impact that are acceptable today.

4.9. When the performance and costs of all remediation options have been assessed, a comparison should be performed to determine the optimum option. If this optimum is not obvious, the comparison should be performed using a quantitative decision aiding technique. The result of the application of quantitative techniques is termed the analytical solution. If, in addition, there are non-quantifiable, non-radiological factors to be taken into account, the analytical solution may not be the optimum solution. These qualitative factors should be combined with the analytical solution to determine a true optimum solution, after consultation with interested parties.

4.10. The optimization of remedial measures should result in reference levels expressed in terms of a residual activity concentration or dose criteria for the remediated site.

4.11. Remedial measures may remove all of the contamination, or remove only part of it, or may only alter the exposure pathways or the number of people exposed without removing the contamination itself. Depending on the expected residual dose, which can be derived from the expected effectiveness of the proposed remedial measures, associated restrictions should be defined as part of the remediation option, if necessary. The residual dose, as well as the advantages and disadvantages of the associated restrictions, should be integrated into the optimization process. If the option includes on-site disposal of radioactive waste, the resulting exposure from this disposal option should also be taken into account [6, 7] (see also paras 5.11–5.14).

4.12. Owing to time or resource constraints, general sources of information or default parameters may have to be used for modelling calculations. Sensitivity analyses should be performed within the optimization procedure to assist in determining when and where generic input parameters should be replaced by site specific values.

REMEDIATION PLAN

4.13. "A remediation plan showing that remediation can be accomplished safely shall be prepared for each contaminated area, unless otherwise required by the regulatory body. The remediation plan shall be subject to the approval of the regulatory body prior to its implementation" (Ref. [1], para. 5.5).

4.14. The remediation plan and associated monitoring requirements should be designed and implemented so as to identify possible adverse health and environmental effects of the contaminants and to optimize protection. These considerations apply to the workers performing the remediation, to the public and to the environment.

4.15. To achieve the objectives of remediation, decisions should be taken concerning the following: the schedule and sequence of the remediation activities; operational quantities (e.g. instrument readings corresponding to the reference levels); the criteria for the termination of remedial actions; and post-remediation conditions with regard to access to or use of the area.

4.16. The criteria for deciding whether to terminate remedial actions should be clearly stated so that remediation is not unnecessarily continued beyond the point at which it is justified and optimized. As an integral part of any successful remediation there should be a clear understanding by the interested parties of the remediation end criteria.

4.17. Provisions for the post-remediation state should be addressed in the remediation plan. As remediation progresses, the plan should be updated to reflect any changes or provisions relating to the conduct and progress of the remediation. Specific guidance is provided in Section 5.

4.18. The process of designing a remediation strategy should take advantage of lessons learned from similar remediation projects that have been completed in the past. These lessons learned provide both positive and cautionary advice. In effect, information on the failure of a particular method of remediation in certain circumstances may help to narrow the choice of feasible remediation strategies when planning new remedial actions.

4.19. The waste streams resulting from the remediation should be identified early in the planning process. The quantity and types of waste that will be generated should be considered during the planning to ensure that the waste management system will be capable of accommodating this waste.

RADIOLOGICAL SURVEYS

4.20. Several types of survey, with different objectives, may be necessary during the remediation process (e.g. detailed site characterization surveys, surveys during remedial operations and surveys to confirm that the objectives of the remediation have been achieved). The types and frequency of each survey should be discussed in the remediation plan. Provision should be made to allow changes in the type and frequency of surveys if situations arise that might lead to a change in radiological conditions.

4.21. The IAEA is developing information that addresses the monitoring of sites to ensure compliance with regulatory requirements for remediation. The general survey methodology can also be used for the site characterization survey.

DOSE ASSESSMENT

4.22. A key parameter in any decision making process for selecting the appropriate remedial measures is the distribution of individual doses to the population affected by the radioactive residues in the area. The ingestion of contaminated foodstuffs or the inhalation of contaminated dust is often a major exposure pathway, and sometimes the associated doses cannot be measured, even though the contamination levels may be rather high. In such cases the doses should be estimated on the basis of model calculations, with input from the radiological monitoring programme and with realistic scenarios.

4.23. The calculation of projected doses requires modelling of the various exposure pathways from an environmental contaminant to people. The models adopted may be of differing complexity depending on the processes involved in this transfer. In general, the models used should be as realistic as is appropriate for making dose projections. Incorporating excessive conservatism can result in operational quantities being impractical or impossible to measure, or in remediation that is more costly than necessary. The models should readily be able to address all relevant exposure pathways. They should readily be able to use site specific data, and they should be tested or validated. Particular attention should be paid to matching the assumptions of the model to the circumstances under consideration.

SAFETY AND ENVIRONMENTAL ASSESSMENTS

4.24. Both the radiological and non-radiological hazards involved in the various proposed remedial actions should be identified in safety and environmental assessments. They should include release criteria for the end point, dose predictions and risk assessments for each proposed activity associated with the remediation. The impact on the public and the environment of possible accidents or emergencies associated with the remediation should also be considered. The safety and environmental assessments should detail the protective measures that will be taken to ensure the safety of workers and the public and protection of the environment.

4.25. Specific consideration should be given to activities associated with waste management and their possible effects on neighbouring States.

FUNDING OF REMEDIATION

4.26. When the responsible parties who caused the contamination or allowed it to occur can be identified, those parties should be held responsible for the remediation programme and its funding (in accordance with the 'polluter pays' principle). However, it should be recognized in the regulatory framework that circumstances in many instances may be complex and that the total remediation costs may be disproportionately high in comparison with the actions of the organization that is causing or has caused the contamination; for example, the contamination may have been caused by changes to exposure pathways that were unforeseen when a discharge authorization was given, or by an accident. It may also be that the economic costs apportioned to an organization would be such that they could lead to its bankruptcy and consequent inability to pay. The legislation should therefore be such as to ensure that adequate funding mechanisms are available. Costs may fall wholly or in part on owners, industry, developers, local communities or national governments, as well as on the original polluter.

4.27. Since the apportionment of liabilities may be contentious, particularly when large sums of money are involved, and formally designating an area as requiring intervention may bring an unwelcome depreciation in the value of the surrounding properties, the responsible party should engage with interested parties to negotiate voluntary and cooperative action in preference to the regulatory body initiating enforcement action. Among interested parties should be included: local authorities, owners, tenants, users, potential developers, liability insurance companies, local communities near the site who may benefit from the intervention, those responsible for the source of the pollution and environmental groups.

4.28. Regulatory oversight should be maintained, and adequate and proportionate funding should be provided, to enable the regulatory body to ensure that any remediation is carried out properly. The government should fund regulatory oversight, or otherwise the regulatory body may fund its regulatory activities through a system of fees chargeable to the project. When urgent action is needed, responsibilities for the remediation should be assigned to a specific organization with adequate technical and human resources to establish and perform the remediation programme urgently and to recover the costs at a later time.

5. OPERATIONAL ASPECTS OF REMEDIATION

GENERAL

5.1. Once the preferred option has been selected and the planning for remediation has been completed and approved, implementation of the remediation should begin within an appropriate time frame, normally within one to two years. The following sections identify issues that should be addressed during the implementation phase.

STAFF AND TRAINING

5.2. The organization responsible for implementing the remediation activities should have, or should have access to, competent staff to cover the following areas adequately:

(a) Safety requirements of any permits or authorizations issued;
(b) Regulatory standards and issues;
(c) Radiation protection;
(d) Conventional industrial hazards;
(e) Data collection and evaluation;
(f) Environmental monitoring;
(g) Quality assurance and quality control;
(h) Radiochemical analysis;
(i) Geological and hydrogeological expertise;
(j) Waste management;
(k) Site security;
(l) Project management.

5.3. In many cases contractors may be used to perform some or all steps of the remediation plan; however, the responsible parties, as identified by the regulatory body, are required to remain responsible for the safety of all activities (Ref. [1], para. 4.10), including those performed by contractors. Non-radiological hazards, such as hazards due to chemical contamination, may also be present, and existing staff may not be familiar with the various aspects of the requirements for protection against these hazards. Appropriate levels of control, supervision and training should be provided to ensure the safety of workers with regard to all hazards.

5.4. All persons involved in the remediation should be made familiar with the contaminated area, the hazards and the safety procedures for the safe and effective performance of their duties. Specialized training may be needed in certain areas of work. For some activities, the use of mock-ups and models in training can enhance efficiency and safety.

5.5. The requirements for a basic training programme and for refresher training should be stated in the remediation plan.

ORGANIZATION AND ADMINISTRATIVE CONTROL

5.6. Information should be provided to all interested parties concerning the implementation of the remediation programme, including: identification of the organizations responsible for implementing the programme; the provision of adequate human resources, equipment and supporting infrastructure; the organization and allocation of the required funding; the programme for waste management; the safety and health protection protocols for the remediation workers and the public; and the arrangements for pre- and post-remediation monitoring procedures for assessing the efficiency and effectiveness of the remediation programme. It should be noted that much of this information may already have been provided as part of the development process for the remediation programme.

RADIATION PROTECTION DURING REMEDIATION

5.7. Remediation workers will receive doses only if remedial measures are introduced. "In the implementation of remedial measures, the exposure of workers shall be controlled under the system of radiation protection for practices" (Ref. [1], para. 3.5). The actual radiological conditions and the effectiveness of specific protective actions taken during the remediation should be compared with initial estimates of exposures and releases and the goals established for their control.

5.8. If the remediation operations would give rise to exposure of the general public living in or near the contaminated areas, the resulting doses should be controlled under the system of radiation protection of the public that is applied for practices. Normally, these doses would be justified in the light of future doses that would be averted by the remediation. If the doses would be significant, evacuation or relocation of the public should be considered based

on the intervention levels for these measures, and the system of protection for interventions should be applied. Unacceptable effects on the environment should also be avoided during the remediation, and environmental protection programmes should be considered, to minimize any harmful consequences that might result in the near term or that might occur in the future.

ON-SITE AND OFF-SITE MONITORING DURING REMEDIATION

5.9. On-site and off-site monitoring should be performed during remediation activities. The extent of monitoring programmes should be determined on the basis of the activities that will be performed during the remediation and the degree of uncertainty concerning the performance of these activities, and should be consistent with longer term monitoring programmes set up to verify the long term stability of exposure conditions (e.g. by monitoring the covering of mining residues, protection against the infiltration of water and protection against erosion or atmospheric dispersion).

5.10. Monitoring should be performed to evaluate the expected and actual level of safety of workers and the public and protection of the environment during the remediation. On-site monitoring should be conducted to provide information for use in identifying and mitigating hazards. It should be ensured that all potential exposure pathways are monitored. Off-site monitoring should be designed to monitor whether and to what extent discharges to the environment occur and to verify that regulatory requirements for the protection of the public and the environment are being met.

WASTE MANAGEMENT

5.11. The waste arising from remediation operations should be accommodated within an existing waste management system established for practices, particularly if the amounts of waste expected are small. Waste may include: solid waste, such as vegetation or metallic waste from initial activities for site preparation; soil and rock; material from buildings or other structures; used personal protective equipment; disposable items used during the collection, preparation or packaging of samples; liquid and solid residues from samples sent for analysis; liquid and solid waste from hygiene and changing facilities; and water used for cleaning and decontamination or water abstracted from groundwater on the site. If the existing waste management system is not capable of dealing with the types and quantities of waste that will be generated

during the remediation activities, the system should be adapted or supplemented accordingly. During the planning activities, the inventory of contaminated areas should include an evaluation of the amounts and characteristics of the waste that could be generated by the remediation operations. "The management of radioactive waste arising from the implementation of remedial measures shall be considered one component of the entire decision making process" (Ref. [1], para. 6.5).

5.12. The management of radioactive waste should include predisposal management, transport and disposal. "The management of radioactive waste shall comply with the international and national requirements for waste management facilities" (Ref. [1], para. 6.6). An additional dose criterion of the order of 10 μSv/a should be used for the clearance of material from a site that contains radionuclides of artificial origin [8]. For material that is contaminated with radionuclides of natural origin (except for ^{40}K), a clearance criterion of an activity concentration of 1 Bq/g should be used [8].

5.13. The following factors should be considered for the operations relating to the management of the waste arising during the implementation of the remediation programme:

(a) The types of waste may be very different, ranging from spent fuel and fission products following a nuclear accident, to naturally occurring radionuclides resulting from past industrial processes such as fertilizer production and the mining and processing of uranium and thorium ores;
(b) The amount of waste arising from the remediation operations may be very high (e.g. in the event of the removal of contaminated soil);
(c) Transport options to disposal sites may be limited;
(d) There may be no appropriate waste management facilities available for dealing with waste of these types, or such facilities may be limited in capacity.

5.14. The above factors should already have been dealt with in the optimization process when the remediation option was selected; however, during remediation activities, situations may arise that necessitate modification of the remediation programme in response to changing conditions. The regulatory body and the organization responsible for the remediation should then evaluate whether there is a need to return to the justification and optimization process that is required for interventions.

EMERGENCY PLANNING

5.15. A programme for emergency planning that is applicable for remediation activities should be established and described in the remediation plan [9]. Operating organizations should ensure that procedures for dealing with unforeseen events that may occur during remediation are prepared and put into place. Personnel should be trained in emergency procedures. Provision should be made for the periodic testing and updating of these procedures by conducting periodic exercises. In the event of an unforeseen incident happening during remediation, the responsible parties should without delay notify the regulatory body.

SITE SECURITY

5.16. Appropriate means, commensurate with the associated hazards, for restricting access to the area should be maintained throughout the remediation activities. These measures should be described in the remediation plan.

QUALITY ASSURANCE

5.17. The organization conducting remediation activities should implement an appropriate quality assurance programme under its management system [10, 11]. Activities for remediation and waste management should be performed by properly trained individuals in accordance with approved work procedures. Work procedures should be prepared for each activity. In the development of the quality assurance programme, the need for the acquisition and retention of records and information relevant to the area being remediated should be emphasized.

5.18. A record should be maintained of each task carried out in the remediation operations. Accurate and complete information concerning the locations, configurations, types and amounts of radionuclides remaining in the area after remediation is essential and should be acquired and maintained. For the unrestricted release of the area, these records should be used to demonstrate that all the radioactive material that was present at the beginning of the activities has been properly accounted for and that its ultimate destinations and uses have been specified and confirmed.

ENSURING COMPLIANCE WITH REQUIREMENTS

5.19. The regulatory body should confirm that the remediation criteria were correctly chosen and applied by the responsible party. The regulatory body is required "To ensure compliance with the legal and regulatory requirements" (Ref. [1], para. 4.9(j)), and should verify that the remediation end criteria have been met.

5.20. The responsible party is required to submit to the regulatory body a final remediation report, including any necessary final confirmation survey (Ref. [1], para. 7.8) that shows that the remediation criteria have been met. The regulatory body will use the information in the remediation report to develop a confirmation plan and will implement this plan as an independent confirmation of the responsible party's survey data.

5.21. The regulatory body should compare the data presented in the results of the final confirmation survey with the information presented in the responsible party's final survey report, and should verify compliance with the requirements. If there is an assurance that the remediation end criteria have been met, the regulatory body should agree that remediation has been concluded. If it is determined that compliance with the requirements has not been achieved, the responsible party should evaluate how to proceed. The options to be considered should include further remedial work or the imposition of institutional controls. Again, preference should be given to meeting the original objectives. If revision of the remediation plan is envisaged, the process for a new consideration of possible options as discussed in Section 3 and illustrated in Fig. 1 should be followed.

5.22. Any quantitative recommendations will be difficult to implement unless there are agreed approaches to the estimation of exposures for the purpose of demonstrating compliance with the recommendations. Long term scenarios should be specified to characterize the individuals potentially exposed and the ways in which they may be exposed.

5.23. The quantification of uncertainties should be an integral part of the estimation of annual radiation doses. Methods for estimating uncertainties vary significantly, ranging from qualitative judgements about variability to more rigorous approaches that include a statistical analysis of distributions for a range of input values that have a bearing on the dose estimate. Uncertainty analysis is evolving rapidly, and techniques for estimating dosimetric uncertainties are still being developed. Whenever possible and appropriate,

annual doses should be assessed as a distribution of possible values rather than as single point values.

5.24. Radioactive residues are usually unevenly distributed in space, creating heterogeneous situations of prolonged exposure. These should be addressed on a case by case basis by making realistic assumptions about the patterns of individual exposures. The selection of methods for evaluating heterogeneous exposure will depend on the situation and on the objectives of the evaluation.

5.25. Annual doses in exposure situations involving long lived radionuclides should be estimated on the basis of the assumption of unrestricted use of the site under remediation. This assumption implies that all exposure pathways that could realistically apply at any time in the future should be taken into account. However, the outcome of the optimization process may be restrictions on area use. Restrictions on use may preclude certain pathways and thus may reduce exposures, thereby achieving some advantages while introducing the disadvantage of having the restriction imposed. Scenarios describing restricted use following remediation of a site will be case specific. Furthermore, decisions about possible restricted uses may vary significantly within and between different Member States. Restricted use will usually involve some form of ongoing institutional control such as by means of a land use registry. The possibility of the failure of this institutional control should be taken into account in the estimation of exposures. For areas that are contaminated with long lived radionuclides, consideration should be given to the fact that most restrictions and institutional controls have a limited time period of implementation, and sometimes this period is not commensurate with the half-life of the radionuclide.

5.26. For areas where there is more than one site giving exposures at high levels, the necessary degree of remediation should be determined by taking account of the annual doses arising from all the high exposure sites as well as those arising from the area as a whole. When there are sites giving high exposure levels within a larger area where exposure has been prolonged, remediation of these sites giving high exposure levels may be governed by local regulations for decontamination.

6. POST-REMEDIATION MANAGEMENT

RELEASE OF AREAS

6.1. There are several possible end points for the remediation process:

(a) Use of the area may be unrestricted;
(b) Use of the area may need to be restricted in some or all parts and control may need to be exercised, for example, through a system of planning consents;
(c) Access to the area may need to be restricted and measures may need to be put into place to enforce this.

6.2. In each case, further surveillance and monitoring may be required to confirm the long term effectiveness of the programme of remediation, and additional controls may need to be imposed on the basis of the monitoring results.

6.3. The "degree, extent and duration of control, if any (ranging from monitoring and surveillance to restriction of access) shall be reviewed and formalized with due consideration of the residual risk" (Ref. [1], para. 7.2). In implementing this requirement, the recommendations made in this section apply.

Unrestricted use

6.4. If the chosen remediation process involved the removal of contamination itself, and if the area meets the required remediation end criteria, the area may be released without restrictions. In this situation, the prevailing conditions are considered to be the residual background conditions for a new practice or for use of the land for habitation.

6.5. The remediation of the site for any new practice should be conducted on the basis of the guidance presented in Ref. [2], which means that the contribution to individual doses from the eventual remediation of the new practice should not exceed an additional dose of 300 μSv/a over the new background level that resulted from any previous remediation activities following any previous practices. However, the sum of all possible combinations of doses to members of the public due to exposures from all

subsequent practices should not exceed an additional dose of 1 mSv/a over the original background level before the first practice began.

Restricted use

6.6. The term 'restricted use' means that some types of use are allowed while others are not; for example, in certain cases the use of an area for forestry may be possible but its use for agriculture may be prohibited. Where a significant part of the exposure due to residual contamination arises from the food chain, the use of agricultural countermeasures should be considered. Similarly, the use of an area for recreational, industrial or certain agricultural purposes may be appropriate, but its residential use may not be. Impacts of the residual contamination on aquifers should also be considered in this evaluation.

6.7. In cases where all reasonable remediation options are insufficiently protective or in cases where the optimized remediation options do not include removal of the contamination itself, specific restrictions on the future uses of the contaminated areas are required to be imposed. Specific restrictions are also required to be established for controlling the removal of material from such areas or the use of such material (Ref. [1], para. 7.3).

Restricted access

6.8. Restriction of access to contaminated areas is required to be maintained in cases of serious residual contamination (Ref. [1], para. 7.3(b)). The degree of any such restrictions should be determined by the regulatory body. Depending on the type and levels of residual contamination, access control measures may vary from the placing of warning signs to fencing of various types and guarded control stations. Area control personnel should have the legal authority to deny access to the area, if required.

Removal of restrictions

6.9. If the monitoring and surveillance programme has verified the long term effectiveness of the remedial measures in eliminating unacceptable risks to human health and the environment, consideration should be given to removing any restrictions applied to the area and ending or reducing the extent of the monitoring and surveillance. If the option of ending or reducing these services is considered, the value of the monitoring and surveillance in promoting and maintaining public confidence should be taken into account. In considering the long term effectiveness of remedial measures, the environmental influence of

physical, chemical, geological and other factors should be evaluated. In particular, contamination of groundwater may not become apparent for some time and may do so at some distance from the source of the contamination. Such considerations should be documented in the remediation plan.

MONITORING AND SURVEILLANCE PLAN

6.10. A monitoring and surveillance plan is required to be prepared for any remediated areas where restrictions are maintained after remediation has been completed. The plan is subject to periodical review and to approval by the regulatory body (Ref. [1], para. 7.6).

6.11. The extent of such monitoring and surveillance plans should be based on the residual risks and their degrees of uncertainty and on the need to verify the long term stability of the radiological conditions. Monitoring and surveillance programmes should include, as necessary, environmental monitoring (of dose rates, activity concentrations in soil, water and air, biological indicator species and foodstuffs), whole body monitoring (if applicable) and dose assessment.

6.12. Decisions regarding the routine maintenance of such monitoring and surveillance programmes should be documented in the remediation plan. The results of the monitoring and surveillance programmes are required to be documented and made readily available to interested parties to assist in maintaining public confidence. An invitation to interested parties to participate in the decision making is required also in the post-remediation phase (Ref. [1], para. 7.7).

RECORDS

6.13. Records are required to be kept to document the remediation programme and any lessons learned and changes made during its implementation (Ref. [1], para. 7.9). Such records should include: descriptions of activities performed; data from the monitoring and surveillance programmes; occupational health and safety records for the remediation workers; records of the types and quantities of waste produced and of their management and disposition; data from environmental monitoring; records of financial expenditures; records of the involvement of interested parties; records of any continuing responsibilities for the site; identification of locations that were remediated and those with residual levels of contamination remaining;

specifications of any areas that remain restricted and the restrictions that apply; statements of any zoning and covenant restrictions or conditions; and statements of lessons learned.

6.14. Failures in the implementation of remedial measures can arise from a lack of consensus among interested parties, often in the negotiations during the decision making process regarding the implementation of the remediation plan. While some conflicts between interested parties are apparent at the outset of the decision making process, others may arise much later, for example during discussions in which the actual implications of alternative decisions are made explicit. All conflicts and their resolution in the decision making process should be documented.

6.15. The organization responsible for maintaining and updating the permanent records is required to be clearly designated (Ref. [1], para. 7.9), and the provision of the necessary resources and notification of the regulatory body should be considered.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Remediation of Areas Contaminated by Past Activities and Accidents, IAEA Safety Standards Series No. WS-R-3, IAEA, Vienna (2003).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Release of Sites from Regulatory Control on Termination of Practices, IAEA Safety Standards Series No. WS-G-5.1, IAEA, Vienna (2006).

[3] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety, IAEA Safety Standards Series No. GS-R-1, IAEA, Vienna (2000).

[5] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Protection of the Public in Situations of Prolonged Radiation Exposures, Publication No. 82, Pergamon Press, Oxford and New York (2000).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Near Surface Disposal of Radioactive Waste, IAEA Safety Standards Series No. WS-R-1, IAEA, Vienna (1999).
[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste, Including Decommissioning, IAEA Safety Standards Series No. WS-R-2, IAEA, Vienna (2000).
[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).
[9] 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 CO-ORDINATION 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).
[10] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006).
[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

CONTRIBUTORS TO DRAFTING AND REVIEW

Batandjieva, B.	International Atomic Energy Agency
Clark, M.	Environmental Protection Agency, United States of America
Cooper, J.	National Radiological Protection Board, United Kingdom
Cooper, M.	Australian Radiation Protection and Nuclear Safety Agency, Australia
Delattre, D.	International Atomic Energy Agency
Doumenc, A.	Direction de la sûreté des installations nucléaires, France
Gnugnoli, G.	Nuclear Regulatory Commission, United States of America
Golubev, V.	Ministry for Environmental Protection and Nuclear Safety, Ukraine
Hedeman Jensen, P.	Risø National Laboratory, Denmark
Hubert, P.	Institut de protection et de sûreté nucléaire, France
Kraus, W.	Bundesamt für Strahlenschutz, Germany
Liland, A.	Norwegian Radiation Protection Authority, Norway
Lokan, K.H.	Private consultant, Australia
Przyborowski, S.	Bundesamt für Strahlenschutz, Germany
Reisenweaver, D.	International Atomic Energy Agency
Wilson, C.	Department of the Environment, Transport and the Regions, United Kingdom
Zgola, B.	Canadian Nuclear Safety Commission, Canada

BODIES FOR THE ENDORSEMENT OF IAEA SAFETY STANDARDS

An asterisk denotes a corresponding member. Corresponding members receive drafts for comment and other documentation but they do not generally participate in meetings.

Commission on Safety Standards

Argentina: Oliveira, A.; *Australia*: Loy, J.; *Brazil*: Souza de Assis, A.; *Canada*: Pereira, J.K.; *China*: Li, G.; *Czech Republic*: Drábová, D.; *Denmark*: Ulbak, K.; *Egypt*: Abdel-Hamid, S.B.; *France*: Lacoste, A.-C. (Chairperson); *Germany*: Majer, D.; *India*: Sharma, S.K.; *Israel*: Levanon, I.; *Japan*: Abe, K.; *Korea, Republic of*: Eun, Y.-S.; *Pakistan*: Hashmi, J.; *Russian Federation*: Malyshev, A.B.; *South Africa*: Magugumela, M.T.; *Spain*: Azuara, J.A.; *Sweden*: Holm, L.-E.; *Switzerland*: Schmocker, U.; *United Kingdom*: Weightman, M.; *United States of America*: Virgilio, M.; *European Commission*: Waeterloos, C.; *IAEA*: Karbassioun, A. (Coordinator); *International Commission on Radiological Protection*: Holm, L.-E.; *OECD Nuclear Energy Agency*: Tanaka, T.

Nuclear Safety Standards Committee

Argentina: Sajaroff, P.; *Australia*: MacNab, D.; *Austria*: Sholly, S.; *Belgium*: Govaerts, P.; *Brazil*: de Queiroz Bogado Leite, S.; **Bulgaria*: Gladychev, Y.; *Canada*: Newland, D.; *China*: Wang, J.; *Croatia*: Valčić, I.; **Cyprus*: Demetriades, P.; *Czech Republic*: Böhm, K.; *Egypt*: Aly, A.I.M.; *Finland*: Reiman, L. (Chairperson); *France*: Saint Raymond, P.; *Germany*: Herttrich, M.; **Greece*: Camarinopoulos, L.; *Hungary*: Vöröss, L.; *India*: Kushwaha, H.S.; *Iran, Islamic Republic of*: Alidousti, A.; **Iraq*: Khalil Al-Kamil, A.-M.; *Ireland*: Hone, C.; *Israel*: Hirshfeld, H.; *Italy*: Bava, G.; *Japan*: Nakamura, K.; *Korea, Republic of*: Kim, H.-K.; *Lithuania*: Demčenko, M.; *Mexico*: González Mercado, V.; *Netherlands*: Jansen, R.; *Pakistan*: Habib, M.A.; *Paraguay*: Troche Figueredo, G.D.; **Peru*: Ramírez Quijada, R.; *Portugal*: Marques, J.J.G.; *Romania*: Biro, L.; *Russian Federation*: Shvetsov, Y.E.; *Slovakia*: Uhrik, P.; *Slovenia*: Levstek, M.F.; *South Africa*: Bester, P.J.; *Spain*: Zarzuela, J.; *Sweden*: Hallman, A.; *Switzerland*: Aeberli, W.; **Thailand*: Tanipanichskul, P.; *Turkey*: Bezdegumeli, U.; *Ukraine*: Bezsalyi, V.; *United Kingdom*: Vaughan, G.J.; *United States of America*: Mayfield, M.E.; *European Commission*: Vigne, S.; *IAEA*: Feige, G. (Coordinator); *International Organization for Standardization*:

Nigon, J.L.; *OECD Nuclear Energy Agency*: Reig, J.; **World Nuclear Association*: Saint-Pierre, S.

Radiation Safety Standards Committee

Argentina: Rojkind, R.H.A.; *Australia*: Melbourne, A.; **Belarus*: Rydlevski, L.; *Belgium*: Smeesters, P.; *Brazil*: Rodriguez Rochedo, E.R.; **Bulgaria*: Katzarska, L.; *Canada*: Clement, C.; *China*: Yang, H.; *Costa Rica*: Pacheco Jimenez, R.; *Cuba*: Betancourt Hernandez, L.; **Cyprus*: Demetriades, P.; *Czech Republic*: Petrova, K.; *Denmark*: Ohlenschlager, M.; **Egypt*: Hassib, G.M; *Finland*: Markkanen, M.; *France*: Godet, J.; *Germany*: Landfermann, H.; **Greece*: Kamenopoulou, V.; *Hungary*: Koblinger, L.; *Iceland*: Magnusson, S. (Chairperson); *India*: Sharma, D.N.; *Indonesia*: Akhadi, M.; *Iran, Islamic Republic of*: Rastkhah, N.; **Iraq*: Khalil Al-Kamil, A.-M.; *Ireland*: Colgan, T.; *Israel*: Laichter, Y.; *Italy*: Bologna, L.; *Japan*: Yoda, N.; *Korea, Republic of*: Lee, B.; *Latvia*: Salmins, A.; *Malaysia*: Rehir, D.; *Mexico*: Maldonado Mercado, H.; *Morocco*: Tazi, S.; *Netherlands*: Zuur, C.; *Norway*: Saxebol, G.; *Pakistan*: Mehboob, A.E.; *Paraguay*: Idoyago Navarro, M.; *Philippines*: Valdezco, E.; *Portugal*: Dias de Oliviera, A.; *Romania*: Rodna, A.; *Russian Federation*: Savkin, M.; *Slovakia*: Jurina, V.; *Slovenia*: Sutej, T.; *South Africa*: Olivier, J.H.I.; *Spain*: Amor, I.; *Sweden*: Hofvander, P.; *Switzerland*: Pfeiffer, H.J.; **Thailand*: Wanitsuksombut, W.; *Turkey*: Okyar, H.; *Ukraine*: Holubiev, V.; *United Kingdom*: Robinson, I.; *United States of America*: Miller, C.; *European Commission*: Janssens, A.; *Food and Agriculture Organization of the United Nations*: Byron, D.; *IAEA*: Boal, T. (Coordinator); *International Commission on Radiological Protection*: Valentin, J.; *International Labour Office*: Niu, S.; *International Organization for Standardization*: Perrin, M.; *OECD Nuclear Energy Agency*: Lazo, T.; *Pan American Health Organization*: Jimenez, P.; *United Nations Scientific Committee on the Effects of Atomic Radiation*: Crick, M.; *World Health Organization*: Carr, Z.; *World Nuclear Association*: Saint-Pierre, S.

Transport Safety Standards Committee

Argentina: López Vietri, J.; *Australia*: Sarkar, S.; *Austria*: Kirchnawy, F.; *Belgium*: Cottens, E.; *Brazil*: Mezrahi, A.; *Bulgaria*: Bakalova, A.; *Canada*: Faille, S.; *China*: Qu, Z.; *Croatia*: Kubelka, D.; *Cuba*: Quevedo Garcia, J.R.; **Cyprus*: Demetriades, P.; *Czech Republic*: Ducháček, V.; *Denmark*: Breddan, K.; **Egypt*: El-Shinawy, R.M.K.; *Finland*: Tikkinen, J.; *France*: Aguilar, J.; *Germany*: Rein, H.; **Greece*: Vogiatzi, S.; *Hungary*: Sáfár, J.; *India*: Agarwal, S.P.; *Iran, Islamic Republic of*: Kardan, M.R.; **Iraq*: Khalil

Al-Kamil, A.-M.; *Ireland*: Duffy, J. (Chairperson); *Israel*: Koch, J.; *Italy*: Trivelloni, S.; *Japan*: Amano, M.; *Korea, Republic of*: Kim, Y.-J.; *Malaysia*: Sobari, M.P.M.; *Netherlands*: Van Halem, H.; *New Zealand*: Ardouin, C.; *Norway*: Hornkjøl, S.; *Pakistan*: Rashid, M.; *Paraguay*: More Torres, L.E.; *Philippines*: Kinilitan-Parami, V.; *Portugal*: Buxo da Trindade, R.; *Romania*: Vieru, G.; *Russian Federation*: Ershov, V.N.; *South Africa*: Jutle, K.; *Spain*: Zamora Martin, F.; *Sweden*: Dahlin, G.; *Switzerland*: Knecht, B.; **Thailand*: Wanitsuksombut, W.; *Turkey*: Ertürk, K.; *Ukraine*: Sakalo, V.; *United Kingdom*: Young, C.N.; *United States of America*: Brach, W.E.; Boyle, R.; *European Commission*: Venchiarutti, J.-C.; *International Air Transport Association*: Abouchaar, J.; *IAEA*: Wangler, M.E. (Coordinator); *International Civil Aviation Organization*: Rooney, K.; *International Federation of Air Line Pilots' Associations*: Tisdall, A.; *International Maritime Organization*: Rahim, I.; *International Organization for Standardization*: Malesys, P.; *United Nations Economic Commission for Europe*: Kervella, O.; *Universal Postal Union*: Giroux, P.; *World Nuclear Transport Institute*: Green, L.

Waste Safety Standards Committee

Argentina: Siraky, G.; *Australia*: Williams, G.; *Austria*: Hohenberg, J.; *Belgium*: Baekelandt, L.; *Brazil*: Heilbron, P.; **Bulgaria*: Simeonov, G.; *Canada*: Lojk, R.; *China*: Fan, Z.; *Croatia*: Subasic, D.; *Cuba*: Salgado Mojena, M.; **Cyprus*: Demetriades, P.; **Czech Republic*: Lieteva, P.; *Denmark*: Nielsen, C.; **Egypt*: El-Adham, K.E.A.; *Finland*: Ruokola, E.; *France*: Cailleton, R.; *Hungary*: Czoch, I.; *India*: Raj, K.; *Indonesia*: Yatim, S.; *Iran, Islamic Republic of*: Ettehadian, M.; **Iraq*: Abass, H.; *Israel*: Dody, A.; *Italy*: Dionisi, M.; *Japan*: Ito, Y.; *Korea, Republic of*: Park, W.; **Latvia*: Salmins, A.; *Lithuania*: Paulikas, V.; *Mexico*: Aguirre Gómez, J.; *Morocco*: Soufi, I.; *Netherlands*: Selling, H.; **Norway*: Sorlie, A.; *Pakistan*: Rehman, R.; *Paraguay*: Facetti Fernandez, J.; *Portugal*: Flausino de Paiva, M.; *Romania*: Tuturici, I.; *Russian Federation*: Poluektov, P.P.; *Slovakia*: Konečný, L.; *Slovenia*: Mele, I.; *South Africa*: Pather, T. (Chairperson); *Spain*: Sanz, M.; *Sweden*: Wingefors, S.; *Switzerland*: Zurkinden, A.; *Turkey*: Özdemir, T.; *Ukraine*: Iievlev, S.; *United Kingdom*: Wilson, C.; *United States of America*: Camper, L.; *European Commission*: Hilden, W.; *IAEA*: Hioki, K. (Coordinator); *International Organization for Standardization*: Hutson, G.; *OECD Nuclear Energy Agency*: Riotte, H.; *World Nuclear Association*: Saint-Pierre, S.

Safety through international standards

"The IAEA's standards have become a key element of the global safety regime for the beneficial uses of nuclear and radiation related technologies.

"IAEA safety standards are being applied in nuclear power generation as well as in medicine, industry, agriculture, research and education to ensure the proper protection of people and the environment."

Mohamed ElBaradei
IAEA Director General

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 92–0–113306–5
ISSN 1020–525X