

IAEA Safety Standards

for protecting people and the environment

Environmental and Source Monitoring for Purposes of Radiation Protection

Safety Guide
No. RS-G-1.8



IAEA

International Atomic Energy Agency

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

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Safety standards are coded according to their coverage: nuclear safety (NS), radiation safety (RS), transport safety (TS), waste safety (WS) and general safety (GS).

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All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by e-mail to Official.Mail@iaea.org.

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Reports on safety and protection in nuclear activities are issued in other publications series, in particular the **Safety Reports Series**. Safety Reports provide practical examples and detailed methods that can be used in support of the safety standards. Other IAEA series of safety related publications are the **Provision for the Application of Safety Standards Series**, the **Radiological Assessment Reports Series** and the International Nuclear Safety Group's **INSAG Series**. The IAEA also issues reports on radiological accidents and other special publications.

Safety related publications are also issued in the **Technical Reports Series**, the **IAEA-TECDOC Series**, the **Training Course Series** and the **IAEA Services Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. Security related publications are issued in the **IAEA Nuclear Security Series**.

ENVIRONMENTAL AND SOURCE MONITORING FOR PURPOSES OF RADIATION PROTECTION

Safety standards survey

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

IAEA SAFETY STANDARDS SERIES No. RS-G-1.8

ENVIRONMENTAL AND SOURCE MONITORING FOR PURPOSES OF RADIATION PROTECTION

SAFETY GUIDE

IAEA SAFETY STANDARDS SERIES No. RS-G-1.8

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2005

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FOREWORD

by Mohamed ElBaradei
Director General

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

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

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

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

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

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IAEA SAFETY STANDARDS

SAFETY THROUGH INTERNATIONAL STANDARDS

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

The standards also provide support for States in meeting their international obligations. One general international obligation is that a State must not pursue activities that cause damage in another State. More specific obligations on Contracting States are set out in international safety related conventions. The internationally agreed IAEA safety standards provide the basis for States to demonstrate that they are meeting these obligations.

THE IAEA STANDARDS

The IAEA safety standards have a status derived from the IAEA's Statute, which authorizes the Agency to establish standards of safety for nuclear and radiation related facilities and activities and to provide for their application.

The safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment.

They are issued in the IAEA Safety Standards Series, which has three categories:

Safety Fundamentals

- Presenting the objectives, concepts and principles of protection and safety and providing the basis for the safety requirements.

Safety Requirements

- Establishing the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements, which are expressed as 'shall' statements, are governed by the objectives, concepts and principles of the Safety Fundamentals. If they are not met, measures must be taken to reach or restore the required level of safety. The Safety Requirements use regulatory language to enable them to be incorporated into national laws and regulations.

Safety Guides

- Providing recommendations and guidance on how to comply with the Safety Requirements. Recommendations in the Safety Guides are expressed as 'should' statements. It is recommended to take the measures stated or equivalent alternative measures. The Safety Guides present international good practices and increasingly they reflect best practices to

help users striving to achieve high levels of safety. Each Safety Requirements publication is supplemented by a number of Safety Guides, which can be used in developing national regulatory guides.

The IAEA safety standards need to be complemented by industry standards and must be implemented within appropriate national regulatory infrastructures to be fully effective. The IAEA produces a wide range of technical publications to help States in developing these national standards and infrastructures.

MAIN USERS OF THE STANDARDS

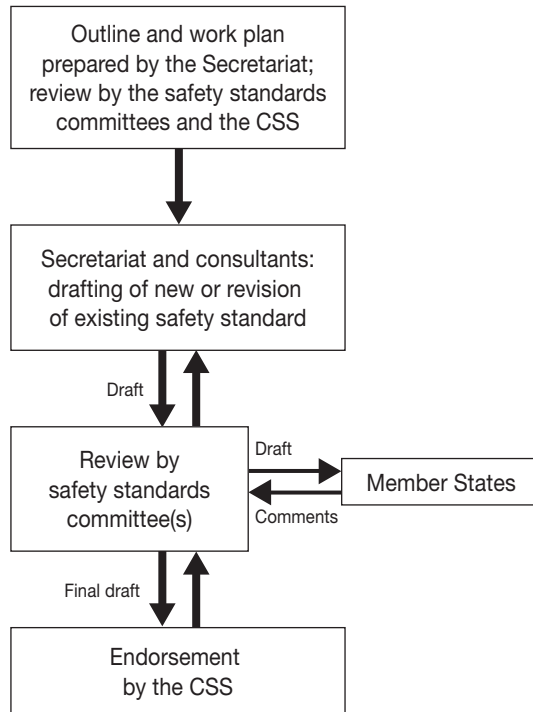
As well as by regulatory bodies and governmental departments, authorities and agencies, the standards are used by authorities and operating organizations in the nuclear industry; by organizations that design, manufacture and apply nuclear and radiation related technologies, including operating organizations of facilities of various types; by users and others involved with radiation and radioactive material in medicine, industry, agriculture, research and education; and by engineers, scientists, technicians and other specialists. The standards are used by the IAEA itself in its safety reviews and for developing education and training courses.

DEVELOPMENT PROCESS FOR THE STANDARDS

The preparation and review of safety standards involves the IAEA Secretariat and four safety standards committees for safety in the areas of nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS), which oversees the entire safety standards programme. All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the CSS is appointed by the Director General and includes senior government officials having responsibility for establishing national standards.

For Safety Fundamentals and Safety Requirements, the drafts endorsed by the Commission are submitted to the IAEA Board of Governors for approval for publication. Safety Guides are published on the approval of the Director General.

Through this process the standards come to represent a consensus view of the IAEA's Member States. The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the standards. Some standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the International



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

Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

The safety standards are kept up to date: five years after publication they are reviewed to determine whether revision is necessary.

APPLICATION AND SCOPE OF THE STANDARDS

The IAEA Statute makes the safety standards binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA concerning any form of Agency assistance is required to comply with the requirements of the safety standards that pertain to the activities covered by the agreement.

International conventions also contain similar requirements to those in the safety standards, and make them binding on contracting parties. The Safety Fundamentals were used as the basis for the development of the Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The Safety

Requirements on Preparedness and Response for a Nuclear or Radiological Emergency reflect the obligations on States under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

The safety standards, incorporated into national legislation and regulations and supplemented by international conventions and detailed national requirements, establish a basis for protecting people and the environment. However, there will also be special aspects of safety that need to be assessed case by case at the national level. For example, many of the safety standards, particularly those addressing planning or design aspects of safety, are intended to apply primarily to new facilities and activities. The requirements and recommendations specified in the IAEA safety standards might not be fully met at some facilities built to earlier standards. The way in which the safety standards are to be applied to such facilities is a decision for individual States.

INTERPRETATION OF THE TEXT

The safety standards use the form ‘shall’ in establishing international consensus requirements, responsibilities and obligations. Many requirements are not addressed to a specific party, the implication being that the appropriate party or parties should be responsible for fulfilling them. Recommendations are expressed as ‘should’ statements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures) for complying with the requirements.

Safety related terms are to be interpreted as stated in the IAEA Safety Glossary (<http://www-ns.iaea.org/standards/safety-glossary.htm>). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard within the Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the main text (e.g. material that is subsidiary to or separate from the main text, is included in support of statements in the main text, or describes methods of calculation, experimental procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the standard. Material in an appendix has the same status as the main text and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. An annex is not an integral part of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material published in standards that is under other authorship may be presented in annexes. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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1. INTRODUCTION

BACKGROUND

1.1. The controlled release of radionuclides to the atmospheric and aquatic environments is a legitimate waste management practice in the nuclear industry and its related facilities [1]. Typically, controlled discharges of gaseous and particulate material containing radionuclides are made through stacks, although for small facilities they may be made through discharge vents or working hoods, for example. Controlled liquid discharges are typically made via pipelines into rivers, lakes or the sea, but they may also be made via the normal sewer systems from small establishments. An important and essential element in the control of the discharges is regular monitoring — both at the source of the discharge and in the receiving environment — to ensure the protection of the public and the environment.

1.2. The uncontrolled release of radionuclides to the atmospheric, aquatic and terrestrial environments may occur as a result of a nuclear or radiological accident. Monitoring of the accidental release at its source, and especially the direct monitoring of the environmental contamination with radionuclides, is necessary for the assessment and execution of actions for public protection and longer term countermeasures as well as of emergency occupational radiation protection. In such cases individual monitoring may be justified. In areas historically contaminated with long lived radionuclides, monitoring is essential for the protection of the public and as a basis for restoration activities.

1.3. In 1995, the IAEA published a Safety Fundamentals publication on The Principles of Radioactive Waste Management [1]. This establishes principles, concepts and objectives for measures for the protection of human health and the environment, since the improper management of radioactive waste could lead to adverse effects on human health or the environment both in the short term and in the future.

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1.4. In 1996, the IAEA, jointly with five other international sponsoring organizations,¹ published the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (hereinafter referred to as the Basic Safety Standards (BSS)) [2]. The BSS establish the requirements for protection against the risks associated with exposure to ionizing radiation and, in particular, they establish requirements for radiation monitoring in the context of discharge control to check for compliance with the authorized limits on discharges and to permit the estimation of the exposure of critical groups. The BSS also establish requirements for radiation monitoring and assessment in emergency exposure conditions, which are elaborated on in a separate Safety Requirements publication [3].

1.5. The safety requirements for the predisposal management of radioactive waste, including the discharge of radionuclides, are established in another safety standard [4]. The Safety Requirements on Near Surface Disposal of Radioactive Waste [5] include requirements for radiation monitoring for the purpose of demonstrating compliance with safety standards.

1.6. This Safety Guide elaborates on relevant requirements established in Refs [2–5]. It also takes account of the guidance of the International Commission on Radiological Protection on the issue of radiation monitoring [6]. It accompanies the Safety Guide on Regulatory Control of Radioactive Discharges to the Environment [7], which is mainly concerned with the considerations and the procedures to be followed in establishing authorizations for the discharge of radioactive material. The present Safety Guide supersedes two earlier Safety Guides.²

¹ The five other sponsoring organizations were the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organisation (ILO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO).

² INTERNATIONAL ATOMIC ENERGY AGENCY, Objectives and Design of Environmental Monitoring Programmes for Radioactive Contaminants, Safety Series No. 41, IAEA, Vienna (1975); Monitoring of Airborne and Liquid Radioactive Releases from Nuclear Facilities to the Environment, Safety Series No. 46, IAEA, Vienna (1978).

OBJECTIVE

1.7. The purpose of this Safety Guide is to provide international guidance, coherent with contemporary radiation protection principles and accounting for experience gained since the previous publication of guidance (see footnote 2), on the strategy of monitoring in relation to: (a) the control of radionuclide discharges under the conditions of practices, and (b) situations requiring intervention, such as a nuclear or radiological emergency or the past contamination of areas with long lived radionuclides.³ Three categories of monitoring are discussed: monitoring at the source of the discharge (hereinafter called ‘source monitoring’), monitoring in the environment (‘environmental monitoring’) and monitoring of individual exposure (‘individual monitoring’).

1.8. The Safety Guide also provides general guidance on the assessment of the doses to critical groups of the population due to the presence of radioactive material or due to radiation fields in the environment, which may arise both from the normal operation of nuclear and other related facilities (practices) or from a nuclear or radiological emergency or the past contamination of areas with long lived radionuclides (interventions). The dose assessment is based on the results of source monitoring, environmental monitoring or individual monitoring or on combinations of these.

1.9. This Safety Guide is primarily intended for use by national regulatory bodies that have responsibilities for regulating the introduction and conduct of any practice involving sources of radiation and for appropriate radiation monitoring procedures. It will also be valuable to other agencies involved in national systems for radiation monitoring as well as to operators of nuclear installations and other facilities in which natural or human made radionuclides are treated and monitored.

³ In the context of this Safety Guide, which concerns the radiation protection of the public against both present and future exposure, the term ‘long lived radionuclide’ is applied to radionuclides with half-lives of 30 years or more (e.g. ¹³⁷Cs), in contrast to the usual terminology in waste safety, where this term is usually used for radionuclides with half-lives of 1000 years or more.

SCOPE

1.10. This Safety Guide is primarily concerned with source monitoring and environmental monitoring of discharges from authorized (registered or licensed) practices under normal operating conditions and during the decommissioning of facilities. The practices considered in this Safety Guide include the operation of nuclear power plants and research reactors, reprocessing plants and nuclear fuel production plants, uranium and thorium mining and milling facilities, near surface disposal facilities for radioactive waste, and facilities of other types where natural or human made radionuclides are used (medical, radiopharmaceutical, research, educational and others).

1.11. The guidance presented here applies for planning monitoring during waste emplacement in surface (uranium and thorium ore mining and milling sites) or near surface (for low and intermediate level waste) disposal facilities and for borehole and deep underground (geological) waste disposal facilities, and specifically for post-closure monitoring — although radionuclide releases would not be expected from such facilities under normal circumstances.

1.12. General issues of emergency monitoring in the aftermath of a radiation accident are also considered in this publication. More detailed information on monitoring during emergencies is presented in Refs [8–12].⁴

1.13. This Safety Guide also addresses general aspects of monitoring for long lived radionuclides widely dispersed in the environment following a radiation accident, or as residual waste from past practices. This includes monitoring of the content of natural and human made radionuclides in commodities, especially in foodstuffs and drinking water.

1.14. This Safety Guide does not address the monitoring of workers and the workplace, although its recommendations and guidance may be useful for the occupational protection of emergency workers in the event of an accident

⁴ The references cited supersede the following IAEA safety standards: Techniques and Decision Making in the Assessment of Off-site Consequences of an Accident in a Nuclear Facility, Safety Series No. 86, IAEA, Vienna (1987); Response to a Radioactive Materials Release Having a Transboundary Impact, Safety Series No. 94, IAEA, Vienna (1989); Emergency Planning and Preparedness for Accidents Involving Radioactive Materials Used in Medicine, Industry, Research and Teaching, Safety Series No. 91, IAEA, Vienna (1989).

accompanied by the release of radionuclides to the environment. More detailed guidance on the occupational monitoring of workers and the workplace is provided in Refs [13–16]. Neither does the Safety Guide address monitoring for research purposes, which is not for the purposes of radiation protection, or monitoring of the global fallout of radionuclides released during past nuclear weapon tests, which are unamenable to control.

1.15. A general surveillance and monitoring programme for the release to, or the presence of toxic chemicals in, the environment is not addressed in this Safety Guide, which is devoted to the monitoring of radionuclides only. However, operators and other responsible organizations may find it convenient to combine chemical and radiological monitoring programmes.

STRUCTURE

1.16. Section 2 discusses some general international guidance for monitoring radionuclides in the environment. Section 3 outlines the responsibilities of registrants, licensees and regulatory bodies with regard to monitoring. Most generic aspects of monitoring programmes are discussed in Section 4, and detailed objectives and different types of design of monitoring programmes for practices and interventions are presented in Section 5. Section 6 addresses some specific technical features of monitoring procedures. In Section 7 dose assessment methods as they relate to different types of monitoring programmes are discussed. Section 8 contains guidance on the interpretation of monitoring results. Section 9 describes the appropriate quality assurance programme. Section 10 is devoted to the recording of monitoring results and Section 11 specifies requirements for education and training.

2. MEETING REGULATORY REQUIREMENTS FOR MONITORING IN PRACTICES AND INTERVENTIONS

LEGAL CONTEXT

2.1. Exposures of members of the public from a controlled discharge in a practice, an uncontrolled release or past area contamination may arise from the direct emission of radiation at the source of the discharge or from the dispersal

of radionuclides in the environment. For the latter case the more likely pathways are external exposure due to radionuclides in a plume and on the ground as well as the ingestion of contaminated food. The inhalation of airborne radionuclides in a plume or from the resuspension of ground deposits may also be of importance. In the case of practices, the monitoring of radiation dose rates around the source, of discharge levels and of the levels of radionuclides in the environment is necessary to verify compliance with authorized limits on discharges and to facilitate the assessment of radiation dose to members of the public. In case of interventions, monitoring of a release source and of environmental contamination is necessary for decision making on protective actions and longer term countermeasures in an emergency, or on remedial actions in areas contaminated with long lived radionuclides.

2.2. The concepts underlying the requirements for monitoring are set out in Refs [2, 3, 5, 7, 17].

2.3. With regard to the monitoring of controlled discharges in practices, the BSS require that “Registrants and licensees shall be responsible... for the establishment, implementation, and maintenance of appropriate monitoring equipment and surveillance programmes to assess public exposure to the satisfaction of the [regulatory body]” (Ref. [2], para. III.2(f)). In particular, according to the Basic Safety Standards (Ref. [2], para. III.13), “Registrants and licensees shall, if appropriate:

- “(a) establish and carry out a monitoring programme sufficient to ensure that the requirements of the Standards regarding public exposure to sources of external irradiation be satisfied and to assess such exposure;
- “(b) establish and carry out a monitoring programme sufficient to ensure that the requirements of the Standards for discharges of radioactive substances to the environment and the requirements established by the [regulatory body] in granting the discharge authorization be satisfied and that the conditions assumed in deriving the authorized discharge limits remain valid and sufficient to enable the exposures to critical groups to be estimated;
- “(c) keep appropriate records of the results of the monitoring programmes;
- “(d) report a summary of the monitoring results to the [regulatory body] at approved intervals;
- “(e) report promptly to the [regulatory body] any significant increase in environmental radiation fields or contamination that could be attributed to the radiation or radioactive discharges emitted by sources under their responsibility;

- “(f) establish and maintain a capability to carry out emergency monitoring, in case of unexpected increases in radiation fields or radioactive contamination due to accidental or other unusual events affecting sources under their responsibility; and
- “(g) verify the adequacy of the assumptions made for the prior assessment of radiological consequences of the discharges.”

2.4. With regard to assessment and monitoring in emergency exposure situations the BSS (Ref. [2], paras V.23–V.25) require that:

“V.23. All reasonable steps shall be taken to assess exposure incurred by members of the public as a consequence of an accident, and the results of the assessments shall be made publicly available.

“V.24. The assessments shall be based on the best available information, and shall be promptly updated in the light of any information that would produce substantially more accurate results.

“V.25. Comprehensive records shall be maintained of assessments and their updates, and of monitoring results for workers, the public and the environment.”

2.5. For the purpose of assessment and monitoring in emergency exposure situations, the Safety Requirements on Preparedness and Response for a Nuclear or Radiological Emergency [3] further require that:

- (a) In response to the initial phase of the emergency, “Radiation monitoring and environmental sampling and assessment shall be carried out in order to identify new hazards promptly and to refine the strategy for response.” (Ref. [3], para. 4.67.)
- (b) To ensure preparedness to respond to the initial phase of the emergency, “arrangements shall be made for promptly assessing any radioactive contamination, releases of radioactive material and doses for the purpose of deciding on or adapting the urgent protective actions to be taken following a release.” (Ref. [3], para. 4.71.)
- (c) To ensure preparedness to take agricultural countermeasures and longer term protective actions, “arrangements shall include... timely monitoring for ground contamination in the field; the sampling and analysis of food and water.” (Ref. [3], para. 4.89.)

2.6. In order to ensure proper monitoring and assessment during the operation of near surface waste disposal facilities and after their closure, the Safety Requirements publication on Near Surface Disposal of Radioactive Waste [5] requires that:

- “(a) The design of a near surface repository shall allow for implementation of a monitoring programme to verify the containment capability of the disposal system during operation and, as necessary, after closure of the repository. Arrangements for monitoring shall not compromise the long term performance of the disposal system.” (Ref. [5], para. 7.5.)
- “(b) The regulatory body shall provide guidance necessary to establish an environmental monitoring programme, including monitoring of releases and external exposure, and to assess the environmental impact of operations.” (Ref. [5], para. 9.3.)
- “(c) The operator shall be responsible for ensuring the provision and maintenance of adequate monitoring to measure radioactive releases during repository operation, and shall take necessary actions to ensure that the requirements established by national authorities are met.” (Ref. [5], para. 9.12.)
- “(d) The responsible organization shall implement an appropriate post-closure monitoring programme, which shall be approved by the regulatory body. This programme shall deal with radiological and other monitoring of the repository and its surrounding area in order to verify the absence of unacceptable radiological impacts (for example, with respect to the leachate limits, if appropriate), and to confirm, as far as possible, the assumptions made in the safety assessment.” (Ref. [5], para. 11.8.)

2.7. The Safety Requirements publication on Safety of Nuclear Power Plants: Design [18] specifically requires that at the stage of nuclear power plant design, “arrangements shall also be made to determine radiological impacts, if any, in the vicinity of the plant, with particular reference to:

- “(1) pathways to the human population, including the food-chain;
- “(2) the radiological impact, if any, on local ecosystems;
- “(3) the possible accumulation of radioactive materials in the physical environment; and
- “(4) the possibility of any unauthorized discharge routes.” (Ref. [18], para. 6.106.)

2.8. For the stage of nuclear power plant operation, the Safety Requirements publication on Safety of Nuclear Power Plants: Operation [19] specifically requires that:

- “(a) The operating organization shall establish and implement procedures for monitoring and controlling discharges of radioactive effluents. A copy of these procedures shall be made available to the regulatory body.
- “(b) If required by the regulatory body, the operating organization shall establish and implement a programme for monitoring the environment in the vicinity of the plant in order to assess the radiological impacts of radioactive releases on the environment.” (Ref. [19], paras 8.11 and 8.12.)

GENERAL CONDITIONS FOR MONITORING

2.9. The type of monitoring programme, as well as its scale and extent, should be commensurate with the source characteristics at the expected or current discharge rates, the radionuclide composition, the comparative significance of different exposure pathways, and the magnitudes of expected and potential doses to individuals. Some practices and sources (e.g. hospitals or research institutes using short lived radionuclides) may not require a monitoring programme for the environment; some (e.g. small nuclear installations or nuclear medicine departments using radionuclides for diagnostic purposes) may require routine monitoring at the source but only occasional checks on environmental levels; and others (e.g. most nuclear installations, large nuclear medicine departments) require continuous and comprehensive monitoring of both source and environment. Every facility should be prepared to conduct emergency monitoring at an appropriate level.

Conditions for monitoring in practices

2.10. The requirements for the monitoring of discharges in a practice should be directly related to the regulatory situation applying to the sources in question. The international requirements as they relate to monitoring actions are described in the following paragraphs.

2.11. Monitoring is not required at the source or in the environment for sources that give rise to exposures that are ‘excluded’ from regulatory control because their magnitude or likelihood is essentially unamenable to control through the requirements of the BSS [2]. A relevant example in the context of this

publication is the gaseous discharge through a building ventilation system of radon and its decay products arising from the underlying soil.

2.12. Practices and sources can be exempted or materials cleared from the requirements for regulatory control if the associated radiation risks to individuals and populations are low enough to be of no regulatory concern and the exempted practices or sources are inherently safe [2]. For exempted practices and sources or cleared materials that include discharges, there is no requirement for monitoring. An example of exemption is a small laboratory that utilizes amounts of radionuclides for which either the total activity of a given radionuclide or the activity concentration is below the exemption level [2].

2.13. Sources or practices for which neither exclusion nor exemption is possible are required to be authorized by the regulatory body [2, 7]. The authorization takes the form of either a registration or a licence. Examples of registered practices are those at small research institutes and small hospitals, where the usage of short lived radionuclides and the corresponding discharges to the environment are low. Monitoring in the environment for registered practices of these types is usually not required by the regulatory body, while some degree of monitoring at the source may be required.

2.14. Finally, there are several types of source for which routine monitoring programmes are required. Most installations in the nuclear fuel cycle, some large research establishments and radioisotope production facilities fall under this category. Installations of this type are licensed by the regulatory body, have specific safety related requirements and conditions with which the licensee must comply, and are always subject to monitoring, both at the source and in the environment, as well as to public dose assessment. The routine monitoring programme may also form the basis for the emergency monitoring programme at facilities of these types, although not all of them require a full emergency monitoring capability. Table 1 summarizes a relationship between the types of source and the necessary types of monitoring.

Conditions for monitoring in intervention situations

2.15. Intervention situations requiring a response in order to reduce or avert exposures can be emergency exposure situations or situations of chronic (prolonged) exposure. Protective and remedial actions are not normally likely to be necessary unless intervention levels or action levels are or may be exceeded. The initial input for decision making with regard to protective or

TABLE 1. TYPES OF MONITORING AND DOSE ASSESSMENT REQUIRED FOR DIFFERENT TYPES OF SOURCE

Exposure category	Type of source	Type of monitoring			Dose assessment
		Source monitoring	Environmental monitoring	Individual monitoring	
Practice	Excluded, exempted or cleared	No monitoring required			
	Registered source	Required	Not required		
	Licensed source	Required		Not required	
	Multiple sources	Required		Not required	
Intervention	Emergency situation	Required			As appropriate
	Chronic (prolonged) exposure situation	As appropriate	Required	Not required	
					As appropriate

remedial actions is usually based on monitoring. An overall monitoring strategy for emergencies and remedial actions should therefore be established; such a strategy should be site specific and should be based on detailed consideration of the sources and of possible pathways of human exposure.

Emergency exposure situations

2.16. Radiation monitoring should be performed in the event of any nuclear or radiological emergency. The strategy for emergency monitoring should be determined in accordance with the possible radiological consequences of the accident. The intended uses of the monitoring results should guide the selection of priorities in monitoring and the technical details of the type of monitoring that is to be performed.

2.17. Emergency exposure situations range from a spill of small amounts of radioactive material in a laboratory to a major reactor accident with loss of confinement. The methods and extent of emergency monitoring, including source monitoring, environmental monitoring, individual monitoring and appropriate dose assessment (see Table 1), should depend on the severity of the emergency and its potential or actual consequences.

2.18. With regard to the timing, number and methods for radiation measurements and environmental sampling, to ensure the timely execution of protective and remedial actions, the monitoring strategy should be selected for the early detection of any exposures of the general public or of emergency workers that are approaching the intervention levels or action levels.

2.19. In the development of a national strategy for emergency monitoring, both national and international aspects should be considered. Emergency monitoring should be aimed at receiving data relevant to the possible transfer of accidentally released radioactive material to other States and international waters. The national monitoring system should also be able to monitor environmental radioactive contamination originating from accidental releases that occur in other States.

2.20. Emergency monitoring may be terminated when control over the accidental source is restored or when radioactive conditions are not deteriorating and levels of human exposure and environmental contamination are substantially below the respective generic intervention levels and action levels [2] or the appropriate national levels.

Situations of chronic (prolonged) exposure

2.21. Situations of chronic (prolonged) exposure include exposure to radioactive residues from past events, such as radioactive contamination caused by radiation accidents (post-emergency exposure situations), as well as from the past conduct of practices and the use of sources not under the system of regulatory control (sites contaminated with natural long lived radionuclides).

2.22. There is no standard of radiation protection that is universally applied in all States for intervention in situations of chronic (prolonged) radiation exposure of populations. Appropriate intervention levels or action levels are established by national authorities, depending on the circumstances and generally based on existing or averted doses, dose rates in air and radionuclide concentrations. According to the International Commission on Radiological Protection (ICRP), intervention (remedial actions) is not likely to be justifiable if the existing annual effective dose from all the environmental radioactive sources does not reach 10 mSv [20].

2.23. Monitoring of environmental contamination with long lived radionuclides would generally be justified if the annual dose due to this source comprised a substantial fraction (one tenth or more, i.e. 1 mSv or above) of the generic level as given in para. 2.22 or the appropriate national intervention or action levels.

2.24. Monitoring of food contamination with long lived radionuclides for the purpose of the substantiation of protective actions would generally be justified if the radionuclide levels in food comprised a substantial fraction of the generic action levels for radionuclides in foodstuffs [2] or the appropriate national intervention or action levels.

3. RESPONSIBILITIES FOR MONITORING

RESPONSIBILITIES OF THE OPERATOR

3.1. In relation to the control of discharge practices, operators should have the following general responsibilities:

- (a) To prevent any unacceptable radiation or contamination hazard to the public resulting from a discharge practice;
- (b) To comply with applicable regulatory requirements;
- (c) To report to the regulatory body any changes to the discharge practice.

3.2. With regard to specific responsibilities in the area of monitoring, operators:

- (a) Should perform all necessary pre-operational investigations (including, as appropriate, pre-operational monitoring);
- (b) Should provide means and perform adequate source and environmental monitoring programmes during and after operation that will permit unexpected releases to be detected promptly and will provide the data to demonstrate that doses to the public are below the dose criteria established by the regulatory body;
- (c) Should report to the regulatory body any significant changes in releases or increases in environmental radiation fields or contamination that could be attributed to releases from the sources under their responsibility.

3.3. On this basis, the responsibilities of operators for monitoring should be defined along the following lines⁵:

- (a) Source monitoring referred to a specific practice or source within a practice that is under the responsibility of the particular operator (licensee or registrant) should be carried out by that operator in all phases of the programme, including monitoring in operational and post-operational stages and in the event of an emergency. The operator should have the responsibility of establishing, carrying out and maintaining the

⁵ In some States, the main responsibility for environmental monitoring lies with the regulatory body or with other governmental agencies, in general agreement with IAEA guidance [21].

appropriate equipment and programmes for the monitoring of discharges.

- (b) Environmental monitoring referred to a given practice or source within a practice is only necessary for major practices and sources warranting a licence. The licensees should be generally responsible for such environmental monitoring in all its phases, including the pre-operational, operational and post-operational stages. The licensees should also establish and maintain an adequate capability to carry out environmental monitoring in emergency situations.
- (c) The licensees should periodically check the assumptions made for the prior assessment of the radiological impact of the discharges.

RESPONSIBILITIES OF THE REGULATORY BODY

3.4. In relation to the control of discharge practices, the regulatory body has the following general responsibilities:

- (a) Ensuring, by means of establishing and implementing appropriate regulations, that the public and the environment are protected;
- (b) Ensuring that the operator complies with the appropriate regulations and regulatory requirements, including those in respect of carrying out such source and environmental monitoring as may be necessary;
- (c) Providing assurance that judgements concerning the safety of the public are based upon valid information and sound methods.

3.5. With regard to specific responsibilities in the area of monitoring, the regulatory body:

- (a) Should establish technical requirements for monitoring arrangements, including arrangements for emergency monitoring and quality assurance, and should regularly review them;
- (b) Should check the monitoring data provided by operators;
- (c) Should provide evidence that can satisfy the public that authorized sources of exposure are being suitably monitored and controlled.

3.6. On this basis, the allocation of responsibilities for the regulatory body should be along the following lines:

- (a) Although the licensees should be generally responsible for source and environmental monitoring, in some cases (such as major practices or

sources) the regulatory body may carry out a limited confirmatory programme of environmental measurements to verify the quality of the results provided by the licensee and to confirm that the doses to members of the public are maintained below the constraints established in the licence [21].

- (b) When several sources may have an impact on the same areas and population groups, an environmental monitoring programme should be carried out in order to assess the cumulative radiological impacts of these different sources. As it may be difficult for individual registrants or licensees to undertake such monitoring, since they may not have information about the radionuclide composition of materials discharged by other operators, this monitoring may be arranged or carried out by the regulatory body.
- (c) If the potential exists for a large scale accident, the regulatory body must ensure that emergency preparedness arrangements are in place and are routinely tested. This should include the ability for rapid, large scale monitoring under emergency conditions, which may be performed by a designated responsible organization with the requisite capability or by the regulatory body itself. The required monitoring may include both environmental monitoring and individual monitoring.

3.7. In rare circumstances, if the assessed annual dose to the average individual member of the critical group arising from all relevant practices, estimated on the basis of environmental monitoring, is approaching the dose limit, a reassessment of the doses to the critical group should first be made by the registrant or licensee and then validated by the regulatory body. Table 2 outlines the major areas of responsibility for registrants, licensees and the regulatory body concerning the different types of monitoring.

RESPONSIBILITIES OF OTHER AGENCIES

3.8. The government or the regulatory body may delegate specific responsibilities relevant to environmental monitoring to other agencies. The government may control this delegation through the regulatory body or directly. The delegation of authority may concern:

- (a) Review, testing and calibration of monitoring equipment;
- (b) Review of the quality assurance programme;

TABLE 2. RESPONSIBILITIES FOR ENVIRONMENTAL AND SOURCE MONITORING

Exposure category	Type of source	Responsible body		
		Registrant	Licensee	Regulatory body or designated organization
Practice	Excluded, exempted or cleared	No monitoring required		
	Registered sources	Source monitoring	<i>Not applicable</i>	Control measurements and review/verify dose assessments, as appropriate
	Licensed sources	<i>Not applicable</i>	Source and environmental monitoring; dose assessment	
	Multiple sources	Source monitoring	Source and local environmental monitoring	
Intervention	Emergency situations	Source monitoring	Source monitoring, near field environmental monitoring and individual monitoring of workers	Large scale and near field environmental monitoring; individual monitoring of the public as appropriate
	Chronic (prolonged) exposure situations	<i>Not applicable</i>	Source and local environmental monitoring	Large scale and near field environmental monitoring; dose assessment as appropriate

- (c) The design and regular performance of the confirmatory programmes of environmental measurements or release measurements to verify the quality of the results provided by the licensee;
- (d) The confirmatory assessment of the doses to members of the public to warrant that they are maintained below the limits established in licences;
- (e) The environmental monitoring programme carried out in order to assess the cumulative radiological impact of multiple sources when they have an impact on the same areas and the same population groups;
- (f) Emergency response.

3.9. Other agencies may also be responsible for other domains relating to monitoring, such as:

- (a) Collection and retention of data provided by operators, governmental or international agencies;
- (b) Nationwide environmental monitoring;
- (c) Establishing standards.

3.10. In deciding on the delegation of specific monitoring responsibilities to other agencies or companies, the regulatory body should pay due attention to the availability in these organizations of appropriate analytical techniques, equipment and qualified personnel, and of a quality assurance system.

3.11. As a general principle, the regulatory body, as well as any other agencies to which responsibilities have been delegated by the regulatory body, should remain independent of any government department and of any agencies that are responsible for the promotion and development of the practices being regulated, as well as of any registrant, licensee, designer or constructor of the radiation facilities used in the practices being regulated.

REPORTING OF MONITORING RESULTS

3.12. In accordance with the BSS, “Registrants and licensees shall, if appropriate:

- “(d) report a summary of the monitoring results to the [regulatory body] at approved intervals;
- “(e) report promptly to the [regulatory body] any significant increase in environmental radiation fields or contamination that could be attributed

to the radiation or radioactive discharges emitted by sources under their responsibility” (Ref. [2], para. III.13).

3.13. In addition, registrants and licensees should promptly report any discharges exceeding the authorized limits on discharges in accordance with criteria established by the regulatory body.

3.14. The periodic summary report of the monitoring results should include the results of both the source monitoring programme and the environmental monitoring programme. In all cases, results should be reported in a way that allows the verification of compliance with the limits on discharges authorized by the regulatory body. The way in which results are reported should be related to the objectives of the monitoring programme as defined by the regulatory body. In some circumstances it may be adequate to compare measured dose rates or activity concentrations with appropriate derived levels; in other cases, it may be necessary to evaluate the doses to critical groups. As specified by the regulatory body, these doses should be compared with the dose constraints attached to discharge authorizations; the results of the comparison and their interpretation should be reported to the regulatory body.

3.15. The periodic summary report should also include an interpretation of the results and an adequate explanation of their significance (e.g. with reference to appropriate models or standards or to the uncertainty of the results), especially for results that show significant variations in the releases or in the contamination of the environment. The summary should also include other useful information such as the weather conditions during the reported period and the net electrical energy production (for nuclear power plants) or the quantities of fuel produced (for a fuel fabrication facility) or reprocessed (for a fuel reprocessing plant) in the period concerned.

3.16. The registrant or licensee should present source and environmental monitoring data to the regulatory body at least annually, but other factors may necessitate more frequent reports. These factors could include the type of operation (e.g. registered or licensed sources or practices) and the time variability of the quantities and rates of the discharge. Licensed practices such as nuclear fuel cycle facilities should specify in their reporting the quantities of radionuclides discharged to the environment in accordance with the authorized limits established by the regulatory body.

3.17. The prompt report of a significant unplanned increase in environmental radiation fields or contamination should include a description of the

investigation that has been set up, its preliminary results if available, the immediate actions that have been taken in relation to discharge operations (e.g. stopping batch discharges) and the actions that are foreseen for the immediate future (e.g. resuming discharge operations).

3.18. In view of the increasing public awareness of environmental issues, the regulatory body together with the licensees and registrants should make available to the public summary information on environmental monitoring with an adequate explanation of its significance (e.g. with reference to standards or to the uncertainty of the results).

4. GENERIC ASPECTS OF MONITORING PROGRAMMES

GENERAL

4.1. The general objectives of any monitoring programme for the protection of the public and the environment, as considered in this Safety Guide, are [6, 7]:

- (a) To verify compliance with authorized discharge limits and any other regulatory requirements concerning the impact on the public and the environment due to the normal operation of a practice or a source within a practice;
- (b) To provide information and data for dose assessment purposes and to assess the exposure or potential exposure of critical groups and populations due to the presence of radioactive materials or radiation fields in the environment from the normal operation of a practice or a source within a practice and from accidents or past activities;
- (c) To check the conditions of operation and the adequacy of controls on discharges from the source and to provide a warning of unusual or unforeseen conditions and, where appropriate, to trigger a special environmental monitoring programme.

4.2. Some subsidiary objectives, which should usually be fulfilled by a monitoring programme, are [6, 7]:

- (a) To provide information for the public;

- (b) To maintain a continuing record of the impacts of an installation or a practice on environmental radionuclide levels;
- (c) To check the predictions of environmental models so as to modify them as appropriate in order to reduce uncertainties in the dose assessment.

4.3. In accordance with general and subsidiary objectives, the monitoring programmes should include radiation measurements and the collection of relevant supporting information as well as the assessment of doses to critical groups and populations due to the presence of radioactive material in the environment from a practice or intervention and a demonstration of compliance with authorized limits on discharges within a practice.

HUMAN EXPOSURE PATHWAYS

4.4. One important purpose of monitoring is to provide data that permit the analysis and evaluation of human radiation exposure. For this purpose, programmes for monitoring radionuclides in the environment should focus on pathways of human exposure. An exposure pathway defines routes from a source of radionuclides and/or radiation to a target individual or a population through media in the environment. There are two main categories of exposure pathway: external exposure pathways (the source of exposure remains outside the body) and internal exposure pathways (the source of exposure is incorporated into the body).

4.5. The main external exposure pathways considered in this Safety Guide are:

- (a) *Source of radiation → human*: direct exposure from a source of ionizing radiation;
- (b) *Source of radionuclides → atmosphere or water body → human*: exposure due to the plume of radionuclides in the atmosphere ('cloud shine') or water;
- (c) *Source of radionuclides → atmosphere or water body → human skin*: contact exposure from radionuclides on the skin;
- (d) *Source of radionuclides → atmosphere or water body → soil or sediment or building surface or vegetation → human*: exposure from the radionuclides deposited on the ground or on sediments (on the shores of rivers, lakes or the sea) or building surfaces (walls, roofs and floors) or vegetation (trees, bushes and grass).

4.6. The main internal exposure pathways considered in this Safety Guide are:

- (a) *Source of radionuclides → atmosphere → human*: inhalation of radionuclides in the plume;
- (b) *Source of radionuclides → atmosphere or water body → (soil or sediment) → vegetation and/or meat, milk, eggs or marine food → human*: ingestion of radionuclides in food or beverages;
- (c) *Source of tritium → atmosphere → human*: for tritium oxide in the plume, absorption through the skin;
- (d) *Soil or sediment → human*: inhalation of resuspended radionuclides.

4.7. Figure 1 illustrates the pathways by which an individual may be exposed following the discharge of radionuclides to the atmosphere and the surface water or groundwater, respectively.

4.8. The importance of the various exposure pathways depends on:

- (a) The radiological properties of the material released (e.g. gamma emitters, beta emitters or alpha emitters; physical half-life);
- (b) The physical (e.g. gas, liquid or solid) and chemical (e.g. organic or inorganic form, oxidation state, speciation, etc.) properties of the material and its migration characteristics;
- (c) The dispersal mechanism and factors affecting it (e.g. stack height, meteorological conditions, etc.) and environmental characteristics (e.g. climate, type of biota, agricultural production, etc.);
- (d) The locations, ages, diets and habits of the exposed individuals or population.

4.9. Under conditions of normal discharges the exposure pathways are usually permanent and well defined. In the case of emergency releases, the contributions via different pathways to the doses received by workers and the public may be different from the normal and transient. These differences should be considered when establishing the emergency monitoring programme. In order to protect the public and workers from deterministic health effects following major accidents, different radiological criteria may be applied in emergencies from those applied under conditions of normal discharges and, therefore, the collection of additional monitoring data may be necessary.

4.10. At different stages of an accident the exposure pathways may change and different monitoring data may be necessary to support decision making on protective actions. Thus, at an early stage of an accidental atmospheric release,

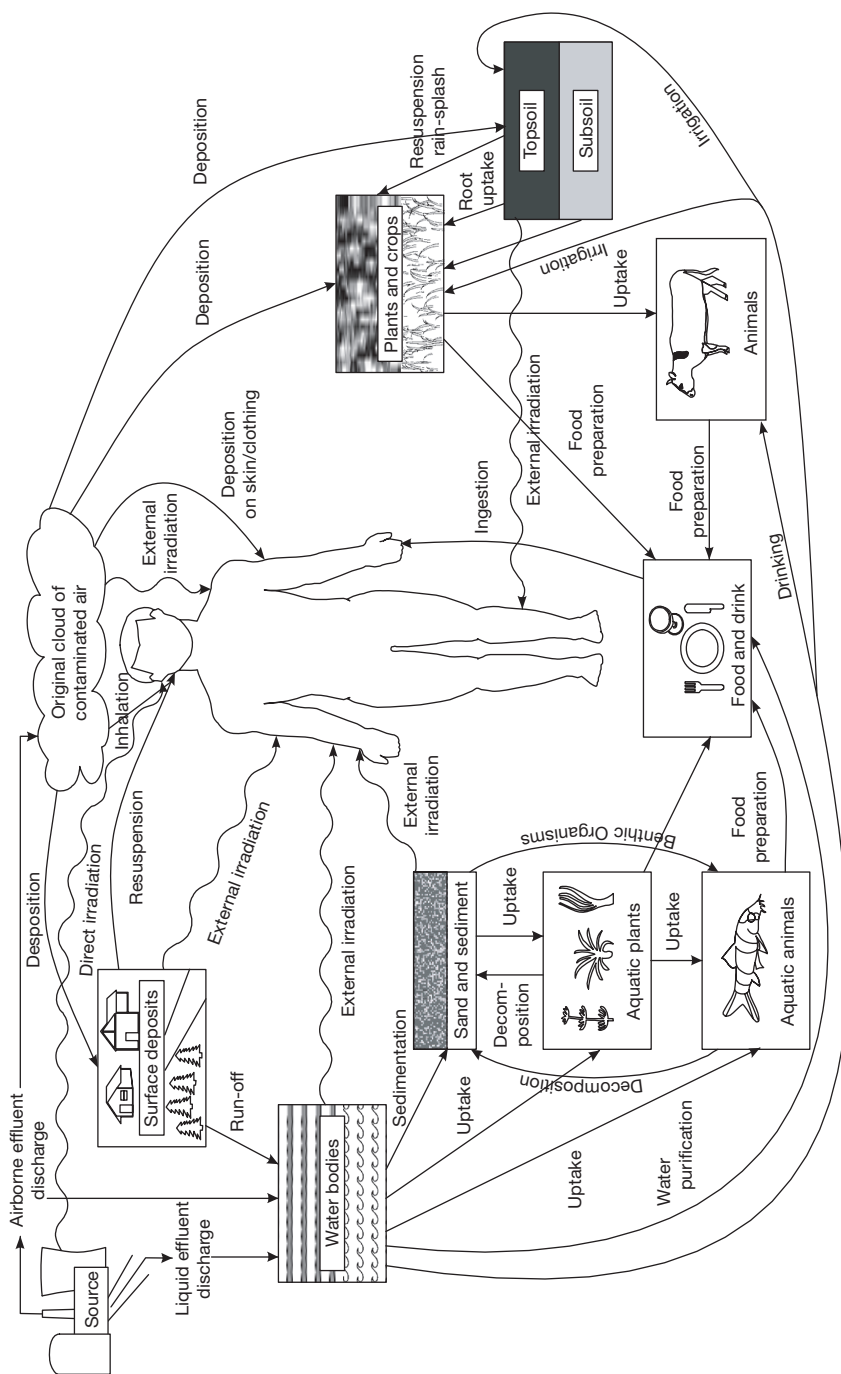


FIG. 1. The possible pathways of exposure for members of the public as a result of discharges of radioactive material to the environment.

the monitoring should be focused on measurements of cloud shine and on the sampling of radionuclides from the plume to assess the contributions of external exposure and inhalation to doses. Once the release has been terminated and the radioactive cloud has passed, monitoring should be refocused on 'ground shine' and food contamination to take into account the contributions of external exposure and ingestion to doses.

4.11. In situations of chronic (prolonged) exposure, exposure pathways are usually well defined and not likely to change rapidly. External exposure is determined by the radiation from radionuclides deposited on the ground or sediments, building surfaces or vegetation and not by cloud shine. The ingestion of agricultural and/or natural foodstuffs containing radionuclides may contribute substantially to doses. Because of the gradual penetration of long lived radionuclides into soil, the importance of resuspension and, therefore, of the inhalation pathway decreases with time.

EXPOSURE GROUPS

4.12. One of the primary purposes of monitoring in the context of normal discharges is to provide information and data for assessing the exposure of members of the public and for verifying the doses anticipated at the licensing stage to occur as a consequence of discharges to the environment during normal operation.

4.13. An important concept for this purpose is that of the 'critical group'. The critical group is defined as a group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) from the given source because of their location, age, diet or habits [2]. Dose constraints or, in some circumstances, dose limits established by the regulatory body generally apply to the mean dose to this critical group. The ICRP has provided guidance to assist in the determination of critical groups [6]. This issue is discussed in more detail in Ref. [7].

4.14. The critical group for a particular set of circumstances should be selected carefully. Adequate attention should be paid to the habits of ethnic and cultural minorities as well as those of indigenous people where applicable. Their living patterns and habits of consumption of food and water could give rise to pathways and elevated exposure levels that are unanticipated by conventional analysis.

4.15. One of the major aspects of the selection is the size of the critical group, which is strongly influenced by the above mentioned requirement for homogeneity. In extreme cases, it may be convenient to define the critical group in terms of a single hypothetical individual. However, the critical group will not usually consist of a single individual, although it will rarely be a large group because homogeneity could then be lost. In practice, the size of the critical group is generally of the order of a few tens of individuals, except in cases in which a large population is homogeneously exposed, for example, through the ingestion of widely distributed foodstuffs or of drinking water from a large reservoir.

4.16. There may be different groups of the most exposed for different exposure pathways and some individuals may be members of more than one such group. In this situation, the critical group should be defined on the basis of the calculated sum of doses via all exposure pathways, which should be compared with the dose constraints or dose limits (e.g. in the case of multiple sources). Some population distributions or land use patterns near a facility may change with time, creating a new critical group or changing the relative importance of some exposure pathways.

4.17. Whereas in the case of normal discharges the doses calculated for the exposure groups are often conservative, the doses for exposure groups during emergencies and situations of chronic (prolonged) exposure should be defined according to realistic habits so as to provide realistic dose assessments that can be used as a basis for making decisions on protective actions and remedial actions and to ensure an adequate allocation of resources. The exposure groups defined should be oriented on real individuals and on assumptions of real patterns of deposition and contamination of the environment and of the foodstuffs and feedstuffs that are produced and used by the population in the affected areas.

TYPES OF RADIATION MONITORING

4.18. Monitoring for radiation protection of the public can be divided into three types: monitoring at the source (source monitoring), monitoring in the environment (environmental monitoring) and, in very rare cases, individual monitoring of members of the public. Source monitoring includes measurements of radiation levels and radionuclides from a particular source of radiation or from a practice, environmental monitoring is conducted outside