DS505

~~2023-10-30~~

2024-08-01

Draft

IAEA SAFETY STANDARDS

for protecting people and the environment

Status: Step ~~7~~11

~~First review~~ Second Review of the ~~draft publication~~Draft Publication by the Review Committees

~~Radiological~~ Monitoring for Protection of the Public and the Environment

DRAFT SAFETY GUIDE

DS505

Revision of RS-G-1.8

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IAEA
International Atomic Energy Agency

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1. INTRODUCTION

BACKGROUND

1.1. ~~Radiological monitoring~~Monitoring for protection of the public and the environment includes monitoring at the source (source monitoring, see para. 3.11), monitoring in the environment (environmental monitoring, see para. 3.12) and, as necessary, monitoring of members of the public (individual monitoring, see para. 3.13).

~~1.1.~~1.2. Monitoring programmes are required to verify compliance with the safety requirements related to the control and assessment of public exposure (see para. 3.127(f) of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1]). Governments, regulatory bodies, operating organizations in charge of facilities and activities, organizations in charge of preparedness and response to a nuclear or radiological emergency, technical support organizations and other agencies ~~that may be~~ involved in such ~~radiological~~ monitoring have different responsibilities, ranging from the definition of the policies to the implementation of such programmes.

~~1.2. Monitoring for protection of the public and the environment includes monitoring at the source (source monitoring), monitoring in the environment (environmental monitoring) and, as necessary, monitoring of members of the public (individual monitoring, see also paras 3.11–3.13).~~

1.3. Facilities and activities that discharge radionuclides to the environment are required to prospectively evaluate the radiological impact on the public and the environment (see ~~Requirement 31~~para. 3.132 of GSR Part 3 [1]). Recommendations on implementing these requirements are provided in IAEA Safety Standards Series ~~No.~~Nos GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [2~~1~~,] and GSG-9, Regulatory Control of Radioactive Discharges to the Environment [3].

1.4. ~~-~~The regulatory body may establish requirements for monitoring the impact of discharges using a graded approach, commensurate with the ~~radiation risk.~~level of radiation risk associated with the source based on the likelihood of exposure and possible radiological consequences to the public. In some facilities or activities, routine monitoring — both at the source of the discharge and in the receiving environment — is an important and essential element in the process of control of the discharges and verification of compliance with discharge authorization conditions. Recommendations on ~~including~~applying a graded approach

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within the licensing process are provided in IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment [4].

1.5. Despite measures to prevent accidents and mitigate harmful consequences, uncontrolled releases of radionuclides to the environment might still occur. Monitoring of an accidental release at its source, and of the resulting radioactive contamination[1] in the environment is necessary for the assessment and implementation of actions for protection of the public and the environment. In some cases, individual monitoring of members of the public may be appropriate. The requirements for ~~radiation~~ monitoring in emergency exposure situations are established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [6]. ~~In some cases, individual monitoring of members of the public may be appropriate.~~

1.6. In areas contaminated with ~~long lived~~ radionuclides from past activities that were not subject to appropriate regulatory control, or as a result of a nuclear or radiological emergency after its termination, monitoring may be needed to aid decisions on the protection of the public and the environment, including for implementing practical measures to reduce the exposures to the population~~.~~, including remedial actions, where justified.

1.7. Although the IAEA safety standards contain general provisions for the protection of the environment from the harmful effects of radiation, GSR Part 3 [1] does not ~~have~~establish specific requirements for the explicit assessment of the exposure (and hence the level of protection) of flora and fauna. Nevertheless, GSR Part 3 [1] identifies the protection of the environment as an issue usually necessitating assessment, while allowing for flexibility in incorporating into decision making processes the results of environmental assessments that are commensurate with the radiation risks. The usual environmental monitoring programmes for the protection of the public, as described in this Safety Guide, are generally sufficient to validate the assessment of the level of protection of the populations of other species.

1.8. This Safety Guide supersedes IAEA Safety Standard Series No. RS-G-1.8[2], Environmental and Source Monitoring for Purposes of Radiation Protection, which was published in 2005. This Safety Guide improves consistency with IAEA Safety Standards published after 2005, ~~namely~~ in particular IAEA Safety Standards Series No. SF-1, Safety

[1] Contamination is defined as radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable, or the process giving rise to their presence in such places [5].

[2] IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection, IAEA, Vienna (2005).

Fundamentals [7~~] and the associated safety requirements, in particular in~~], GSR Part 3 [1] and GSR Part 7 [6].

~~OBJECTIVE~~

OBJECTIVE

1.9. The objective of this Safety Guide is to provide recommendations on implementing the requirements established in GSR Part 3 [1], GSR Part 7 [6] and ~~to provide recommendations and guidance to help in the implementation of~~ other IAEA Safety Requirements publications ~~[~~(see para. 2.8~~ 12]~~) relevant for source, environmental and individual monitoring for the protection of the public and the environment. This includes planned exposure situations, emergency exposure situations, and existing exposure situations.

1.10. This Safety Guide provides recommendations for governments, regulatory bodies~~,~~ and other relevant authorities responsible for developing the legal and regulatory frameworks for source and environmental monitoring and, where applicable, individual monitoring of members of the public. This Safety Guide also provides recommendations for those responsible for developing and implementing monitoring strategies and programmes.

1.11. This Safety Guide provides recommendations on confirmatory monitoring programmes conducted by the regulatory body (or by ~~other organizations~~another organization on ~~their~~ behalf of the regulatory body) in relation to the operation and decommissioning of facilities and the conduct of activities, and in cases where a responsible operating organization cannot be identified.

1.12. This Safety Guide also provides recommendations on the interpretation of monitoring results, including for use in dose assessment, as well as recommendations ~~for~~on data management, recording and reporting for ~~providing~~the provision of information to interested parties, including the ~~general~~ public.

~~SCOPE~~

SCOPE

1.13. This Safety Guide applies to all exposure situations for which, in accordance with their radiological characteristics and the applicable national regulations or international agreements, monitoring is required to verify the level of radiological protection of the public and the

environment. It applies to source monitoring, environmental monitoring and individual monitoring, as relevant.

1.14. This Safety Guide applies to monitoring relating to the control of discharges to the environment from authorized facilities and activities in planned exposure situations. It ~~considers the~~takes into account changes in ~~the~~ monitoring requirements over the different stages ~~of~~in the lifetime of a facility, as appropriate.

1.15. General aspects of monitoring for nuclear installations are provided in this Safety Guide. Specific ~~guidance~~recommendations on the monitoring of radioactivity in the environment for nuclear installations is given in IAEA Safety Standards Series No. DS529, Investigation of Site Characteristics and Evaluation of Radiation Risks to the Public and the Environment in Site Evaluation for Nuclear Installations [~~13~~38].

1.16. This Safety Guide applies to ~~the~~ nuclear fuel cycle facilities, including facilities for the mining and processing ~~activities~~of uranium and thorium ores. This Safety Guide does not cover monitoring in other industries that process materials with elevated concentrations of natural radioactivity, including the mining and milling of metalliferous and non-metallic ores, the production of coal, oil and gas, the extraction and purification of water, the generation of geothermal energy, and the production of industrial minerals, including phosphate, clay and building materials. However, certain technical aspects of this ~~safety guide~~Safety Guide may be helpful for ~~radiological~~ monitoring in such industries.

1.17. General aspects of monitoring performed in all phases of a nuclear or radiological emergency are ~~also~~ considered in this Safety Guide. More detailed ~~guidance~~recommendations on monitoring during a nuclear or radiological emergency are provided in IAEA Safety Standards Series Nos GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [~~14~~9], GSG-11, Arrangements for the Termination of a Nuclear or Radiological Emergency [~~15~~10], and SSG-65, Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material [~~16~~11]. This Safety Guide only addresses ~~the~~ source and environmental monitoring for facilities and activities in emergency situations where an off-site release has occurred or is foreseen to occur.

1.18. This Safety Guide ~~also~~ addresses general aspects of monitoring associated with existing exposure situations related to residual radioactive materials dispersed in the environment following a nuclear or radiological emergency, as a result of activities that were never subject to regulatory control or that were subject to regulatory control but not in accordance with the requirements of the current IAEA Safety Standards~~.~~ (see para. 5.1 of GSR Part 3 [1]). More

detailed recommendations on monitoring related to the remediation processes and to the management of residual material generated during remediation are provided in IAEA Safety Standards Series No. GSG-15, Remediation Strategy and Process for Areas Affected by Past Activities or Events [17~~12~~].

1.19. This Safety Guide considers the analysis of the content of radionuclides in food and drinking water only where ~~they are~~this food and water is considered environmental media (see para. 3.~~12~~) relevant to public exposures, as part of environmental monitoring programmes. Monitoring for control of exposures to the general population due to radionuclides in commodities, such as construction and building materials, food and feed, and drinking water, or for the purpose of quality control for international trade is out of the scope of this Safety Guide. Practical guidance on the regulatory control of building and construction materials is provided in Ref. [18~~13~~], and information in relation to the management of food in various circumstances where radionuclides are, or could be, present, excluding any nuclear or radiological emergency, is provided in Ref. [19~~14~~] and [15].

1.20. Monitoring explicitly related ~~specifically~~ to the assessment of exposures to flora and fauna is not ~~addressed~~covered in this Safety Guide. ~~If deemed necessary, a generic methodology as described and in Ref. [2] can be used for assessing exposures of flora and fauna[3].~~The monitoring programmes for members of the public ~~would generally be~~ are usually sufficient to ~~validate the~~conduct generic ~~assessment~~assessments for radiological protection of flora and fauna. ~~For specific cases, for example when dealing with endangered species or in protected areas, the~~The government or the regulatory body ~~could decide whether~~should determine the need for specific monitoring requirements for protection of flora and fauna based on regulatory objectives and/or the outcomes of a generic assessment. The decision to implement specific monitoring ~~for a~~ could be influenced by factors such as the presence of endangered and threatened species, protected areas, particular flora ~~or~~and fauna ~~would be necessary.~~that might be at high risk, or the need to provide public assurance. If deemed necessary, a generic methodology as described in Annex I of GSG-10 [2] can be used for assessing exposures of flora and fauna.

1.21. This ~~safety~~Safety Guide does not cover the protection of workers against radon which is addressed in IAEA Safety Standards Series No. ~~DS519~~SSG-91, Protection of

~~[3] The IAEA generic methodology is based on a reference approach for protection of the environment as described in ICRP 108 [19].~~

Workers Against Exposure Due to Radon [~~21~~16]. In addition, it does not cover the protection of the public against exposure indoors due to radon~~. Recommendations,~~ recommendations on ~~exposure indoors to radon and other natural sources of radiation~~which are provided in IAEA Safety Standards Series No. SSG-32, Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation [~~22~~17].

1.22. This Safety Guide does not provide recommendations on monitoring for the purpose of assessing exposures from the transport of radioactive material. This is addressed in IAEA Safety Standards Series No. SSG-86, Radiation Protection Programmes for the Transport of Radioactive Material [~~23~~18].

1.23. This Safety Guide does not address the monitoring of radioactive waste disposal facilities, as this is addressed in ~~in~~ IAEA Safety Standards Series No. SSG-31, Monitoring and Surveillance of Radioactive Waste Disposal Facilities [~~24~~19].

1.24. This Safety Guide does not address the monitoring of workers or the workplace~~. Recommendations, recommendations~~ on ~~monitoring of workers and workplaces~~which are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [~~25~~20] and in ~~Ref. [21~~SSG-91 [16].

1.25. The Safety Guide does not address monitoring for nuclear security or safeguards purposes.

1.26. This Safety Guide does not address the monitoring of non-radiological contaminants or physical stressors (e.g. temperature~~); however,~~), even though the chemical and physical properties relevant for the assessment of radiological impacts ~~should~~do need to be considered in a monitoring programme for radiological protection of the public and the environment.

STRUCTURE

1.27. Section 2 of this Safety Guide sets out the IAEA safety requirements for monitoring in different exposure situations. Section 3 presents basic concepts relevant to monitoring for the protection of the public and the environment. Section 4 provides recommendations on the responsibilities of ~~governments~~the government, regulatory body, operating organizations (i.e. registrants, licensees~~), regulatory bodies)~~ and other ~~relevant authorities~~parties with regard to monitoring. Sections 5, 6 and 7 provide recommendations on monitoring programmes for planned exposure situations, emergency exposure situations, and existing exposure situations, respectively. Specific responsibilities, objectives, monitoring procedures and considerations on dose assessment, interpretation and reporting of monitoring results which are applicable

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for each type of exposure situation are addressed. Section 8 provides recommendations on a systematic process for the development of a monitoring ~~programmes~~programme and technical considerations for sampling and measurements. Section 9 provides recommendations on data management, analysis, interpretation and reporting of monitoring results, including recommendations on the use of monitoring results for dose assessment and consideration ~~on~~of uncertainties.

1.28. Additional supporting information is provided in the annex, which addresses technical considerations for sampling and measurements for routine discharges in planned exposure situations.

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2. ~~SAFETY OBJECTIVES AND REQUIREMENTS RELEVANT TO RADIOLOGICAL~~SAFETY OBJECTIVES AND REQUIREMENTS RELEVANT TO MONITORING

~~GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK~~

GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK

2.1. SF-1 [7] establishes principles to be applied to achieve the fundamental safety objective of protecting the public and the environment, now and in the future, from harmful effects of ionizing radiation. This safety objective has to be achieved without unduly limiting the operation of facilities and the conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities conducted so as to achieve the highest standards of safety[4] that can reasonably be achieved, measures have to be taken, among others, to control the radiation exposure of people and the release of radioactive material to the environment.

2.2. IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [~~26~~21] establishes requirements on ~~the governmental, legal, and regulatory framework for safety. These requirements include~~ the need to establish a national policy and strategy for safety and to promulgate the necessary laws and statutes. Paragraph 2.5(5) of GSR Part 1 (Rev. 1) [21] states that the legal and regulatory framework is required to include "Provision for the involvement of interested parties and for their input to decision making". In addition, Requirement 13 states that: "**The government shall make provision, where necessary, for technical services in relation to safety, such as services for personal dosimetry, environmental monitoring and the calibration of equipment**."

2.3. GSR Part 3 [1] establishes requirements for the protection of people and the environment from harmful effects of ionizing radiation and for the safety of radiation sources, including monitoring for radiological protection purposes. GSR Part 3 [1] also establishes requirements relevant to the various interested parties (e.g. the government, the regulatory body, the operating organization) with responsibilities related to monitoring. Requirements for ~~radiation~~the monitoring in emergency exposure situations are established in GSR Part 7 [6].

~~2.4. Requirements for monitoring in the evaluation of sites for nuclear installations are established in IAEA Standards Series No. SSR-1, Site Evaluation for Nuclear Installations~~

[4] In the context of the IAEA safety standards 'safety' and 'nuclear safety' are interchangeable according to Ref. [5].

~~[8]. Requirements for monitoring in relation to the predisposal management of radioactive waste, including the discharge of radionuclides, are established in IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [9]. Requirements for monitoring in relation to the disposal of radioactive waste are established in IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [27]. Requirements for monitoring in relation to the design and operation of nuclear power plants are established in IAEA Standards Series Nos SSR-2/1 (Rev. 1) Safety of Nuclear Power Plants: Design [10], and SSR-2/2 (Rev.1) Safety of Nuclear Power Plants: Operation [11]. Requirements for monitoring in relation to all stages of the life cycle of fuel cycle facilities are established in IAEA Standards Series No. SSR-4 Safety of Nuclear Fuel Cycle Facilities [12].~~

~~2.5.~~2.4. Paragraph 2.23 of GSR Part 3 [1] states that:

> "The government shall ensure that arrangements are in place for the provision of technical services relating to protection and safety, such as services for personal dosimetry, environmental monitoring and the calibration of monitoring and measuring equipment."

~~Paragraph 2.5(5) of GSR Part 1 (Rev.1) [26] states that "The government shall establish a legal and regulatory framework that includes "Provision for the involvement of interested parties and for their input in decision making".~~

~~2.7.~~2.5. Paragraph 1.20 of GSR Part 3 [1] distinguishes between three different exposure situations: planned exposure situations, emergency exposure situations and existing exposure situations. ~~Paragraph 1.20 of GSR Part 3~~The paragraph states[5]:

> "(a) A *planned exposure situation* is a situation of exposure that arises from the planned operation of a source or from a planned activity that results in an exposure due to a source. Since provision for protection and safety can be made before embarking on the activity concerned, the associated exposures and their likelihood of occurrence can be restricted from the outset. The primary means of controlling exposure in planned exposure situations is by good design of facilities, equipment and operating procedures, and by training. In planned exposure situations, exposure at some level

[5] The term 'practice' is defined in GSR Part 3 [1] as "Any human activity that introduces additional sources of exposure or additional exposure pathways, or that 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." In accordance with the IAEA Nuclear Safety and Security Glossary [5], the term 'activities' is intended to provide an alternative to the terminology of practices (or interventions) to refer to general categories of situations. Terms such as 'authorized practice', 'controlled practice' and 'regulated practice' are used to distinguish those practices that are subject to regulatory control from other activities that meet the definition of a practice but do not need or are not amenable to control.

can be expected to occur. If exposure is not expected to occur with certainty, but could result from an accident or from an event or a sequence of events that may occur but is not certain to occur, this is referred to as 'potential exposure'.

(b) An *emergency exposure situation* is a situation of exposure that arises as a result of an accident, a malicious act or any other unexpected event, and requires prompt action in order to avoid or to reduce adverse consequences. Preventive measures and mitigatory actions have to be considered before an emergency exposure situation arises. However, once an emergency exposure situation actually arises, exposures can be reduced only by implementing protective actions.

(c) An *existing exposure situation* is a situation of exposure that already exists when a decision on the need for control needs to be taken. Existing exposure situations include situations of exposure to natural background radiation. They also include situations of exposure due to residual radioactive material that derives from past practices[6] that were not subject to regulatory control or that remains after an emergency exposure situation."

~~2.8.~~2.6. The responsibilities and requirements for monitoring ~~varies~~vary depending on the exposure situation. ~~Responsibilities~~Recommendations on the responsibilities specific to each of the three exposure situations ~~identified~~indicated in ~~GSR Part 3 (planned exposure situations, emergency exposure situations and existing exposure situations)~~para. 2.6 are ~~discussed~~provided in ~~detail in Section~~Sections 5, 6 and 7 of this Safety Guide.

~~REQUIREMENTS FOR MONITORING IN PLANNED EXPOSURE SITUATIONS~~

REQUIREMENTS FOR MONITORING IN PLANNED EXPOSURE SITUATIONS

2.7. Requirements for monitoring in the evaluation of sites for nuclear installations are established in IAEA Standards Series No. SSR-1, Site Evaluation for Nuclear Installations [22]. Requirements for monitoring in relation to the predisposal management of radioactive waste, including the discharge of radionuclides, are established in IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [23]. Requirements for monitoring in relation to the disposal of radioactive waste are established in IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [24]. Requirements for

~~[6] The term 'activities' is an alternative terminology of 'practices' to refer to general categories of situations [5].~~

monitoring in relation to the design and operation of nuclear power plants are established in IAEA Standards Series Nos SSR-2/1 (Rev. 1) Safety of Nuclear Power Plants: Design [25], and SSR-2/2 (Rev.1) Safety of Nuclear Power Plants: Commissioning and Operation [26]. Requirements for monitoring in relation to all stages of the life cycle of fuel cycle facilities are established in IAEA Standards Series No. SSR-4 Safety of Nuclear Fuel Cycle Facilities [27].

~~2.9.~~2.8. Requirement 14 of GSR Part 3 [1] states that: "**Registrants and licensees and employers shall conduct monitoring to verify compliance with the requirements for protection and safety.**"

~~2.10.~~2.9. Paragraph 3.37 of GSR Part 3 [1] states:

> "The regulatory body shall establish requirements that monitoring and measurements be performed to verify compliance with the requirements for protection and safety. The regulatory body shall be responsible for review and approval of the monitoring and measurement programmes of registrants and licensees."

~~2.11.~~2.10. Paragraph 3.38 of GSR Part 3 [1] states ~~that~~:

> "Registrants and licensees and employers shall ensure that:
>
> (a) Monitoring and measurements of parameters are performed as necessary for verification of compliance with the requirements of ~~these Standards;~~[GSR Part 3];
>
> (b) Suitable equipment is provided and procedures for verification are implemented;
>
> (c) Equipment is properly maintained, tested and calibrated at appropriate intervals with reference to standards traceable to national or international standard;
>
> (d) Records are maintained of the results of monitoring and verification of compliance, as required by the regulatory body, including records of the tests and calibrations performed in accordance with ~~these Standards;~~[GSR Part 3];
>
> (e) The results of monitoring and verification of compliance are shared with the regulatory body as required."

~~2.12.~~2.11. Requirement 30 of GSR Part 3 [1] establishes the responsibilities of relevant parties related to public exposure in planned exposure situations. ~~In this regard,~~ Paragraph 3.127 states:

> "Registrants and licensees, for sources under their responsibility, shall establish, implement and maintain:

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……

(f) Provision for appropriate monitoring equipment, monitoring programmes and methods for assessing public exposure.

(g) Adequate records of monitoring programmes."

~~2.13.~~2.12. Requirement 32 of GSR Part 3 [1] states:

"**The regulatory body and relevant parties shall ensure that programmes for source monitoring and environmental monitoring are in place and that the results from the monitoring are recorded and are made available.**"

~~2.14.~~2.13. Paragraphs 3.135–3.137 of GSR Part 3 [1] establish the responsibilities for monitoring programmes for planned exposure situations. Paragraph 3.135 of GSR Part 3 [1] states:

"The regulatory body shall be responsible, as appropriate, for:

(a) Review and approval of monitoring programmes of registrants and licensees, which shall be sufficient for:

(i) Verifying compliance with the requirements of these Standards in respect of public exposure in planned exposure situations;

(ii) Assessing doses from public exposure.

(b) Review of periodic reports on public exposure (including results of monitoring programmes and dose assessments) submitted by registrants and licensees.

(c) Making provision for an independent monitoring programme.

(d) Assessment of the total public exposure due to authorized sources and practices in the State on the basis of monitoring data provided by registrants and licensees and with the use of data from independent monitoring and assessments.

(e) Making provision for maintaining records of discharges, results of monitoring programmes and results of assessments of public exposure.

(f) Verification of compliance of an authorized practice with the requirements of ~~these Standards~~[GSR Part 3] for the control of public exposure."

~~2.15.~~2.14. Paragraph 3.136 of GSR Part 3 [1] states ~~that~~:

"The regulatory body shall publish or shall make available on request, as appropriate, results from source monitoring and environmental monitoring programmes and assessments of doses from public exposure."[7]

~~2.16.~~2.15. Paragraph 3.137 of GSR Part 3 [1] states ~~that~~:

"Registrants and licensees shall, as appropriate:

(a) Establish and implement monitoring programmes to ensure that public exposure due to sources under their responsibility is adequately assessed and that the assessment is sufficient to verify and demonstrate compliance with the authorization. These programmes shall include monitoring of the following, as appropriate:

(i) External exposure due to such sources;

(ii) Discharges;

(iii) Radioactivity in the environment;

(iv) Other parameters important for the assessment of public exposure.

(b) Maintain appropriate records of the results of the monitoring programmes and estimated doses to members of the public.

(c) Report or make available to the regulatory body the results of the monitoring programme at approved intervals, including, as applicable, the levels and composition of discharges, dose rates at the site boundary and in premises open to members of the public, results of environmental monitoring and retrospective assessments of doses to the representative person.

(d) Report promptly to the regulatory body any levels exceeding the operational limits and conditions relating to public exposure, including authorized limits on discharges, in accordance with reporting criteria established by the regulatory body.

(e) Report promptly to the regulatory body any significant increase in dose rate or concentrations of radionuclides in the environment that could be attributed to the

[7] In ~~addition~~support of this requirement, para. 4.30 of IAEA Safety Standards Series No. GSG-6, Communication and Consultation with Interested Parties by the Regulatory Body [28] states that: "A communication strategy should include a logical, coherent and efficient process for communicating and consulting with interested parties. This process should allow the regulatory body to, inter alia...~~[p]ublish~~...publish or make available on request, as appropriate, results from source monitoring and environmental monitoring programmes and assessments of doses from public exposure."

authorized practice, in accordance with reporting criteria established by the regulatory body.

(…)

…….

(g) Verify the adequacy of the assumptions made for the assessment of public exposure and the assessment for radiological environmental impacts.

(h) Publish or make available on request, as appropriate, results from source monitoring and environmental monitoring programmes and assessment of doses from public exposure."

REQUIREMENTS FOR MONITORING IN EMERGENCY EXPOSURE SITUATIONS

REQUIREMENTS FOR MONITORING IN EMERGENCY EXPOSURE SITUATIONS

2.17. Paragraph 3.13743 of GSR Part 3 [1] states that:

"Registrants and licensees shall, as appropriate:

(…)

(f) Establish and maintain a capability to conduct monitoring in an emergency in the event of unexpected increases in radiation levels or in concentrations of radionuclides in the environment due to an accident or other unusual event attributed to the authorized source or facility."

Requirement 43 of GSR Part 3 [1] states that "**The government shall ensure that an integrated and coordinated emergency management system is established and maintained.**" Related to this requirement, paragraph 4.5 of GSR Part 3 [1] states that "The emergency management system shall provide for essential elements at the scene, and at the local, national and international level, as appropriate, including the following:

……

(k) Provision for individual monitoring and environmental monitoring and for dose assessment."

2.19.2.16. Paragraph 3.43 of GSR Part 3 [1] states (citation(reference omitted):

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"If the safety assessment indicates that there is a reasonable likelihood of an emergency affecting either workers or members of the public, the registrant or licensee shall prepare an emergency plan for the protection of people and the environment. As part of this emergency plan, the registrant or licensee shall include arrangements for the prompt identification of an emergency, and for determining the appropriate level of the emergency response. In relation to the arrangements for the emergency response at the scene by the registrant or licensee, the emergency plan shall include, in particular:

(a) Provision for individual monitoring and area monitoring, and arrangements for medical treatment;

(b) Arrangements for assessing and mitigating any consequences of an emergency."

2.17. ~~GSR Part 7 [6] establishes a series of requirements on the monitoring needs in response to a nuclear or radiological emergency.~~ Paragraph 3.137 of GSR Part 3 [1] states:

"Registrants and licensees shall, as appropriate:

…….

(f) Establish and maintain a capability to conduct monitoring in an emergency in the event of unexpected increases in radiation levels or in concentrations of radionuclides in the environment due to an accident or other unusual event attributed to the authorized source or facility."

2.18. Requirement 43 of GSR Part 3 [1] states that "**The government shall ensure that an integrated and coordinated emergency management system is established and maintained.**" Related to this requirement, para. 4.5 of GSR Part 3 [1] states:

"The emergency management system shall provide for essential elements at the scene, and at the local, national and international level, as appropriate, including the following:

~~2.20.1.1. Requirements 7, 9 ,14, 16, 18, 24 and 26 address monitoring aspects for protecting the public and the environment.~~

…….

(k) Provision for individual monitoring and environmental monitoring and for dose assessment".

~~2.21.~~ Requirement 5 of GSR Part 7 [6] states~~:~~

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~~2.22.~~2.19. that: "**The government shall ensure that protection strategies are developed, justified and optimized at the preparedness stage for taking protective actions and other response actions effectively in a nuclear or radiological emergency.**"

2.20. In addition, GSR Part 7 establishes a series of requirements on the monitoring needs in response to a nuclear or radiological emergency. Requirements 7, 9 ,14, 16, 18, 24 and 26 address monitoring aspects for protecting the public and the environment.

~~2.23.~~2.21. Paragraph 6.24 of GSR Part 7 [6] states:

> "Emergency response facilities or locations to support an emergency response under the full range of postulated hazardous conditions shall be designated and shall be assigned the following functions, as appropriate:
>
> .....
>
> .....
>
> (g) Coordination of monitoring, sampling and analysis."

~~2.24.~~2.22. Paragraph 5.40 of GSR Part 7 [6] states:

> "Within emergency planning zones and emergency planning distances, arrangements shall be made for the timely monitoring and assessment of contamination, radioactive releases and exposures for the purpose of deciding on or adjusting the protective actions and other response actions that have to be taken or that are being taken."

~~2.25.~~2.23. Once the emergency is terminated, monitoring is ~~required to be~~ subject to the requirements for planned exposure situations or existing exposure situations, as appropriate (see para. 5.101 of GSR Part 7 [6]).

~~REQUIREMENTS FOR MONITORING IN EXISTING EXPOSURE SITUATIONS~~

REQUIREMENTS FOR MONITORING IN EXISTING EXPOSURE SITUATIONS

~~2.26.~~2.24. The requirements in GSR Part 3 [1] for monitoring in existing exposure situations are only established within the context of remediation. Nevertheless, monitoring could provide essential data to satisfy a number of other requirements for existing exposure situations, as ~~they are mentioned later in this section.~~presented in paras 2.26–2.35.

~~2.27.~~2.25. Requirement 47 of GSR Part 3 [1] states~~:~~:

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"**The government shall ensure that existing exposure situations that have been identified are evaluated to determine which occupational exposures and public exposures are of concern from the point of view of radiation protection.**"

~~2.28.~~2.26. Requirement 48 of GSR Part 3 [1] states that "**The government and the regulatory body or other relevant authority shall ensure that remedial actions and protective actions are justified and that protection and safety is optimized.**"

~~2.29.~~2.27. Paragraph 5.8 of GSR Part 3 [1] states:

"All reasonable steps shall be taken to prevent doses from remaining above the reference levels. Reference levels shall typically be expressed as an annual effective dose to the representative person in the range of 1–20 mSv or other corresponding quantity, the actual value depending on the feasibility of controlling the situation and on experience in managing similar situations in the past."

~~2.30.~~2.28. Requirement 49 of GSR Part 3 [1] establishes the responsibilities for remediation of areas with residual radioactive material. ~~Paragraphs~~Related to this requirement, paras 5.10, 5.12, 5.13, 5.16 and 5.17 ~~state~~of GSR Part 3 [1] establish the responsibilities for monitoring before~~,~~ and during remediation, for post-remediation and monitoring for public information.

~~2.31.~~2.29. Paragraph 5.10~~(d)~~ of GSR Part 3 [1] states:

"For the remediation of areas with residual radioactive material deriving from past activities or from a nuclear or radiological emergency ~~(para. 5.1(a)),~~…, the government shall ensure that provision is made in the framework for protection and safety for:

…

…….

(d) An appropriate system for maintaining, retrieval and amendment of records that cover the nature and the extent of contamination; the decisions made before, during and after remediation; and information on verification of the results of remedial actions, including the results of all monitoring programmes after completion of the remedial actions."

~~2.32.~~2.30. Paragraph 5.12 of GSR Part 3 [1] states:

"The persons or organizations responsible for the planning, implementation and verification of remedial actions shall, as appropriate, ensure that:

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…

(e) A mechanism for public information is in place and interested parties are involved in the planning, implementation and verification of the remedial actions, including any monitoring following remediation.

(f) A monitoring programme is established and implemented."

2.31. Paragraph 5.13 of GSR Part 3 [1] states ~~that~~ :

"The regulatory body … or other relevant authority shall take responsibility, in particular for:

…

…….

(c) Review of work procedures, monitoring programmes and records~~""~~".

~~2.34.~~2.32. Paragraph 5.14 of GSR Part 3 [1] states:

"The person or organization responsible for carrying out the remedial actions:

…

…….

(c) Shall monitor the area regularly during the remediation so as to verify levels of contamination, to verify compliance with the requirements for radioactive waste management, and to enable any unexpected levels of radiation to be detected and the remedial action plan to be modified accordingly, subject to approval by the regulatory body or other relevant authority".

~~2.35.~~2.33. Paragraph 5.16 of GSR Part 3 [1] states:

"The person or organization responsible for post-remediation control measures shall establish and maintain, for as long as required by the regulatory body or other relevant authority, an appropriate programme, including any necessary provision for monitoring, to verify the long term effectiveness of the completed remedial actions for areas in which controls are required after remediation."

~~2.36.~~2.34. Paragraph 5.17 of GSR Part 3 [1] states:

"For those areas with long lasting residual radioactive material, in which the government has decided to allow habitation and the resumption of social and economic activities,

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the government, in consultation with interested parties, shall ensure that arrangements are in place, as necessary, for the continuing control of exposure with the aim of establishing conditions for sustainable living, including:

…

…….

(b) Establishment of an infrastructure to support continuing 'self-help protective actions' in the affected areas, such as by the provision of information and advice, and by monitoring."

~~TRANSBOUNDARY IMPACTS~~

TRANSBOUNDARY IMPACTS

~~2.37.~~2.35. There are no specific ~~provision~~provisions covering monitoring associated with transboundary impacts in GSR Part 3 [1] ~~and~~or GSR Part 7 [6], but there are requirements for transboundary impacts that are relevant to monitoring. For example, para. 3.124 of GSR Part 3 [1] states:

~~"the~~"[T]he government or the regulatory body:

(a) Shall ensure that the assessment for radiological impacts includes those impacts outside the territory or other area under the jurisdiction or control of the State;

…

…….

(c) Shall arrange with the affected State the means for the exchange of information and consultations, as appropriate."

~~2.38.~~2.36. Requirement 22 of GSR Part 7 [6] states:

"**The government shall ensure that arrangements are in place for the coordination of preparedness and response for a nuclear or radiological emergency between the operating organization and authorities at the local, regional and national levels, and, where appropriate, at the international level**".

~~2.39.~~2.37. Paragraph 6.13 of GSR Part 7 [6], states:

"When several different organizations of the State or of other States are expected to have or to develop tools, procedures or criteria for use in the response to an emergency,

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arrangements for coordination shall be established to improve the consistency of the assessments of the situation, including assessments of contamination, doses and radiation induced health effects and any other relevant assessments made in a nuclear or radiological emergency, so as not to give rise to confusion."

~~GRADED APPROACH~~

GRADED APPROACH

~~2.40.~~2.38. GSR Part 1 (Rev. 1) [~~26~~21], GSR Part 3 [1] and IAEA Safety Standards Series No. GSR Part 4~~,~~ (Rev. 1), Safety Assessment for Facilities and Activities [29] establish specific requirements for the implementation of a graded approach[8]. Regarding monitoring for the protection of the public and the environment, the ~~graded approach should reflect that the~~ type of monitoring programme, as well as its scale and extent, should ~~be commensurate with~~take into account the characteristics of the practice or the source and be commensurate with the magnitude of the radiation risk and the extent to which the exposure is amenable to control~~.~~, consistent with the graded approach.

[8] For a system of control, such as a regulatory system or a safety system, graded approach is a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control [5].

3. CONCEPTS AND TERMS RELEVANT ~~FOR~~TO MONITORING

3.1. This section provides an explanation of some of the concepts and terms used in this Safety Guide. Unless otherwise mentioned, concepts or terms are to be understood as defined in GSR Part 3 [1] or in the IAEA Nuclear Safety and Security Glossary [5].

~~ENVIRONMENTAL MEDIA~~

~~3.2. 'Environmental media' is used in this Safety Guide to refer to the environmental compartments from which samples are collected and analysed as part of the environmental monitoring programmes. This includes environmental samples relevant to human exposure, such as air, surface and underground water, soils, sediments, drinking water, crops, animals and vegetables in the human food chain and other foodstuffs, as well as bioindicator organisms[9].~~

~~ENVIRONMENTAL RELEASES AND DISCHARGES~~

DISCHARGES AND ENVIRONMENTAL RELEASES

~~3.3.~~3.2. A discharge is a planned and controlled release of ~~(usually gaseous or liquid)~~ radioactive substances to the environment [5]. More specifically, in this Safety Guide, 'discharges' refers to releases arising from sources within facilities and activities in planned exposure situations. The release of radioactive material to the environment in an emergency ~~or~~and the migration of radioactive material through the environment in an existing exposure situation are referred to as a 'release' or 'environmental release'~~, respectively.~~. Discharges and releases may include gases, aerosols, liquids ~~or~~and solids.

~~EXPOSURE AND EXPOSURE PATHWAYS~~

ENVIRONMENTAL MEDIA

3.3. 'Environmental media' is used in this Safety Guide to refer to the environmental compartments from which samples are collected and analysed as part of the environmental monitoring programmes. This includes environmental samples relevant to human or, in specific cases, to non-human species exposures, such as air; surface water and groundwater; soil;

~~[9] Bioindicator organisms are biota that might not be significant in relation to pathways of human exposure and are therefore not used for dose assessment purposes, but that c can be utilized as sensitive indicators for assessing trends in environmental radiation levels and activity concentrations of radionuclides in the environment.~~

sediments; drinking water; crops; animals and vegetables in the human food chain and other foodstuffs; as well as bioindicators[10].

EXPOSURE AND EXPOSURE PATHWAYS

3.4. GSR Part 3 [1] defines exposure as "the state or condition of being subject to irradiation." External exposure is defined as "exposure to radiation from a source outside the body", and internal exposure as "exposure to radiation from a source within the body" [1]. ~~Exposure~~

~~3.4.~~3.5. An exposure pathway is defined in GSR Part 3 [1] as "a route by which radiation or radionuclides can reach humans and cause exposure~~" [1].~~". Typical pathways for external exposures are irradiation from radionuclides in an atmospheric plume or deposited on different surfaces such as the ~~ground or on sediments.~~soil water bodies, crops and forests. Typical pathways for internal exposures are inhalation~~,~~ and ingestion of food and drinking water~~.~~ (see Fig. 1).

~~3.5.~~3.6. ~~An~~In the context of this Safety Guide, an exposure pathway ~~defines routes~~can be described more specifically as a route from a source of radionuclides or radiation to a target receptor or population through media in the environment. Transport and migration over different time periods are considered. ~~One important purpose of monitoring is to provide data that can be used in the assessment of doses to the public and of exposures to flora and fauna, when required (see paragraphs 1.7, 1.20 and 5.13), or to confirm that models used to predict doses are adequate.~~

~~MEMBER OF THE PUBLIC AND THE REPRESENTATIVE PERSON~~

~~FOR THE PROTECTION~~ MEMBER OF THE PUBLIC ~~IN PLANNED, EXISTING AND EMERGENCY EXPOSURE SITUATIONS, IT IS NECESSARY TO DEFINE A~~ AND THE REPRESENTATIVE PERSON ~~WHOSE DOSE CAN BE USED~~

~~3.6.~~3.7. GSR Part 3 [1] defines a member of the public, for ~~determining~~the purposes of protection and safety, as "any individual in the population except when they are subject to occupational exposures or medical exposure". For the purpose of verifying compliance with dose constraints ~~and,~~ dose limits~~,~~ and reference levels, as relevant~~. This is called~~ in planned,

[10] Bioindicators are organisms that may not be significant in relation to pathways of human exposure and are therefore not used for dose assessment purposes, but can be utilized as sensitive indicators for assessing trends in environmental radiation levels and activity concentrations of radionuclides in the environment.

existing and emergency exposure situations, it is necessary to identify the 'representative person' ~~[30],~~ who is ~~a person assumed to receive~~an individual receiving a dose that is representative of the doses to the more highly exposed individuals in the population~~.~~ [5]. The representative person is generally a hypothetical construct and not an actual individual. Factors~~,~~ such as the relevant exposure pathways, spatial distribution of radionuclides in the environment, ~~the location~~use of local resources, age, diet, and habits of the population group to which the representative person belongs, as relevant, should be considered when identifying the representative person and estimating the dose received. More information on assessing the dose of the representative person for the purpose of radiation protection is provided in Ref. [30].

~~3.7.~~3.8. The concept of 'representative person' ~~also~~ applies not only to planned exposure situations, but also to existing exposure situations and emergency exposure situations [30]. However, the particular characteristics of the representative person in each situation, such as ~~his or her~~ location, habits and age group, may be different. For emergencies, the operational criteria[11] (~~i.~~e.g. operational intervention levels) need to be derived for a representative person with account taken of those members of the public that are most vulnerable to radiation exposure ~~(i.e. ,~~ in particular children and pregnant women ~~and children) [6].~~

~~MONITORING STRATEGY AND MONITORING PROGRAMME~~

MONITORING STRATEGY AND MONITORING PROGRAMME

~~3.8.~~3.9. 'Monitoring strategy' in the context of this Safety Guide refers to the national approach to establish the responsibilities of and interactions among the organizations that will conduct activities related to monitoring~~.~~[12] ~~[6].~~.

~~3.9.~~3.10. 'Monitoring programme' in the context of this Safety Guide refers to the means (including resources, tools and techniques) designed to observe and characterize the source or environment and to assess the radiological impact on the public and environment. ~~It~~The monitoring programme includes, for example, sampling locations and frequency, types of

[11] GSR Part 7 [6] defines operational criteria as ~~values~~"Values of measurable quantities or observable conditions (i.e. observables) to be used in the response to a nuclear or radiological emergency in order to determine the need for appropriate protective actions and other response actions~~.~~". Operational criteria include operational intervention levels ~~(OILs)~~ and emergency action levels ~~(EALs).~~

[12] For emergency exposure situations, the monitoring strategy is related to the monitoring arrangements ~~as~~that form part of the protection strategy~~, this is further discussed in~~ (see Section 6~~. Protection~~). Paragraph 4.27 of GSR Part 7 [6] states that: "protection strategies are developed … at the preparedness stage for taking protective actions and other response actions effectively in a nuclear or radiological emergency ~~[6].~~".

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environmental ~~matrix~~media, sampling and measurement techniques and the interpretation of the data obtained.

SOURCE~~SOURCE~~

~~3.10.~~3.11. A source is anything that may cause radiation exposure — such as by emitting ionizing radiation or by releasing radioactive substances or radioactive material — and can be treated as a single entity for purposes of protection and safety [5]. If a facility or ~~an~~ activity, releases radioactive substances into the environment, ~~the~~that facility or ~~the~~ activity as a whole may be regarded as a source; if radioactive substances are already dispersed in the environment, such as those resulting from past practices that were not subject to regulatory control or that remain after an emergency exposure situation, the portion of ~~them~~ the radioactive substances to which people are exposed to may be considered a source.

~~TYPES OF RADIATION MONITORING~~

TYPES OF MONITORING

~~3.11.~~3.12. ‘Source monitoring’ refers to the measurement of activity ~~in~~of radionuclides being released to the environment or ~~of~~ external dose rates due to sources within a facility or activity [5].

~~3.12.~~3.13. ‘Environmental monitoring’ refers to the measurement of external dose rates due to sources in the environment or of radionuclide concentrations in environmental media [5]. Environmental monitoring is ~~considered as~~ the monitoring conducted outside ~~the~~a site ~~giving~~that gives rise to ~~the~~ exposure. ~~Environmental~~An environmental monitoring ~~programmes include~~programme includes measurements of radiation fields and radionuclide activity concentrations in environmental media relevant to human exposure~~,~~ (primarily ~~in~~ air, drinking water, sediments, soils, agricultural produce and foodstuffs, and aquatic foods~~,~~), as well as in bioindicators (e.g. lichen ~~and~~, seaweed) that can provide a measure of trends in activity levels. ~~Environmental~~An environmental monitoring ~~programmes~~programme may also include ~~other~~ descriptions of the physical, chemical and biological ~~factors~~features of the environment that ~~can~~might affect the behaviour of radionuclides in the environment~~.~~ (see para. 8.10).

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~~3.13.~~3.14. ‘Individual monitoring’[13] refers to monitoring using measurements by equipment worn by individuals, or measurements of quantities of radioactive substances in or on, or taken into, the bodies of individuals, or measurements of quantities of radioactive substances excreted from the body by individuals [5]. Individual monitoring for members of the public ~~would be~~is necessary for certain emergency exposure situations (see ~~paragraphs~~paras 6.21–6.24), and existing exposure situations resulting from emergencies in which health follow-up was recommended (see paras 7.23–7.24).

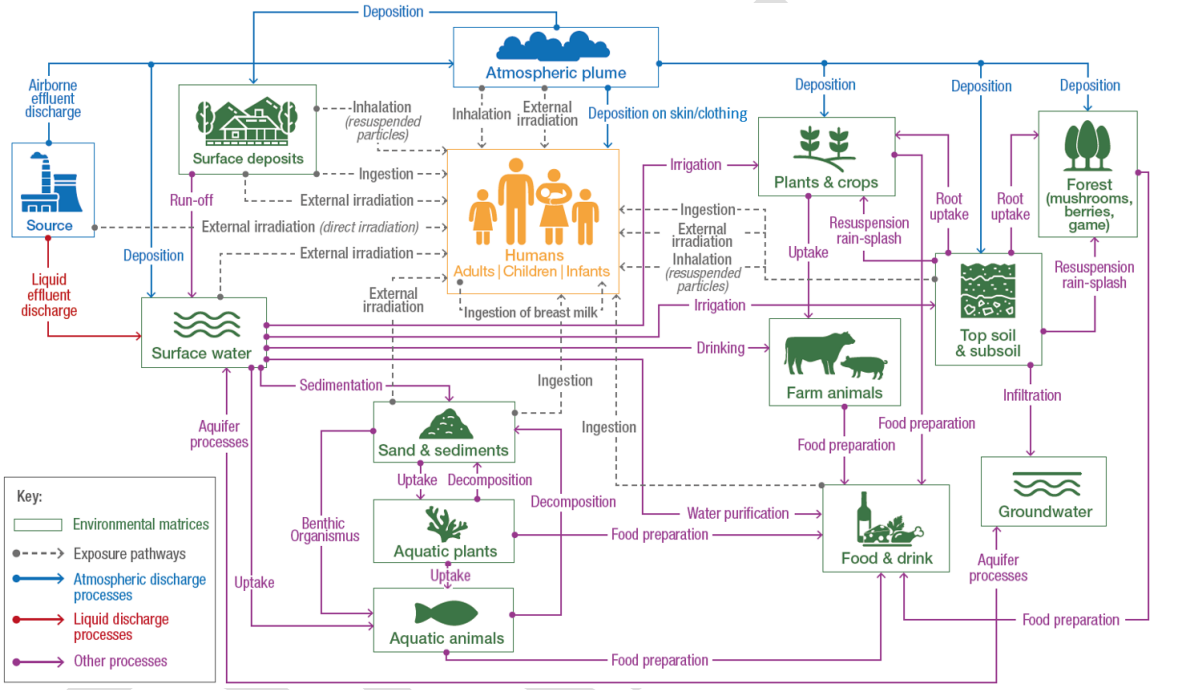

FIG. 1.

[13] Individual monitoring can be performed for workers, patients, or members of the public.

~~4. RESPONSIBILITIES FOR MONITORING~~

Possible exposure pathways for members of the public as a result of releases of radioactive material to the environment.

~~5.~~4. RESPONSIBILITIES ~~OF THE GOVERNMENT, REGULATORY BODY, OPERATING ORGANIZATIONS, AND OTHER PARTIES~~FOR MONITORING

4. ~~The~~RESPONSIBILITIES OF THE GOVERNMENT, REGULATORY BODY, OPERATING ORGANIZATIONS AND OTHER PARTIES

4.1. In certain situations, the government or the regulatory body ~~should~~is expected to make specific provisions in the regulatory framework to ensure that appropriate monitoring strategies and programmes are in place, and that responsibilities are clearly assigned, to provide an appropriate level of protection of the public and the environment. The government is required to ensure that arrangements are in place for prompt monitoring and assessment in a nuclear or radiological emergency (see para. 5.76(b) of GSR Part 7 [~~5~~6]).

4.2. ~~-~~States might have legislative obligations to conduct environmental monitoring to protect people and the environment from non-radioactive pollutants. The framework for ~~radiological~~ monitoring should be compatible and consistent with such obligations.

4.3. With regard to planned exposure situations, the regulatory body is required to review and approve, as appropriate, monitoring programmes and review periodic reports on monitoring data and public exposures, make provisions for an independent environmental monitoring programme, and assess the cumulative radiological impact of multiple sources (see para. 3.135 of GSR Part 3 [1]). The regulatory body, or other relevant body, as appropriate, should assist in the coordination of environmental monitoring and individual monitoring in an emergency.

4.4. The government or the regulatory body might delegate specific ~~activities~~tasks related to monitoring to other parties. These parties should possess sufficient technical ~~capacity~~capability and should remain independent of any parties 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 facilities or activities being regulated. The government might delegate

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authority for these ~~responsibilities~~tasks directly, or through the regulatory body. The ~~delegated responsibilities~~tasks might include the following:

(a) Selection of appropriate monitoring equipment;

~~(a)~~(b) Testing and calibration of monitoring equipment;

~~(b)~~(c) Review of quality management systems;

~~(c)~~(d) Design and ~~regular~~ performance of environmental monitoring or source monitoring to verify the quality of the results provided by the operating organization;

~~(d)~~(e) Verification of the assessment of ~~the~~ doses to members of the public made by the operating organization;

~~(e)~~(f) Implementation of the environmental monitoring programme to assess the cumulative radiological impact of multiple facilities on the public and on the environment;

~~(f)~~(g) Environmental monitoring and individual monitoring (see paras 3.13 and 3.14, respectively) and dose assessment in emergency exposure situations or existing exposure situations ~~(see 3.13),~~, as appropriate;

~~(g)~~(h) Collection and retention of monitoring data and related dose assessments provided by operating organizations, government agencies and international bodies;

~~(h)~~(i) ~~Nationwide~~Countrywide environmental monitoring.

4.5. The operating organization or ~~other~~ another party[14] responsible ~~party~~[15] for monitoring of a facility, activity~~,~~ or site, as established in the legal or regulatory framework, should define the objectives of the monitoring programme(s) in accordance with the prevailing radiological characteristics and regulatory requirements.

4.6. The responsibilities of the government, regulatory body, operating organization, ~~regulatory body,~~ and other parties (e.g. response organizations ~~and government~~) may differ depending on the exposure situation. Table 1 presents an indication of ~~such~~the main responsibilities. Detailed recommendations on the responsibilities for planned exposure

[14] Other parties with a role in monitoring might include technical support organizations, non-governmental organizations, food safety authorities, water authorities, public health authorities, and emergency preparedness and response organizations.

[15] ~~The other parties with a role in monitoring might include technical support organizations (TSOs), non-governmental organizations, food authorities, water authorities, public health authorities, and emergency preparedness and response organizations.~~

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situations, emergency exposure situations and existing exposure situations are provided in Sections 5, 6 and 7, respectively.

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TABLE 1. RESPONSIBILITIES FOR SOURCE, ENVIRONMENTAL AND INDIVIDUAL MONITORING AND DOSE ASSESSMENT

Exposure Situation		Operating organization[a]	Regulatory body	Government
Planned	Exempted, cleared and notified ~~practices/sources~~practice or source	No monitoring required	~~Not applicable~~No monitoring required	~~Not applicable~~No monitoring required
	Registered practice~~/~~ or source	~~Source~~Conduct source monitoring[b]	Review and approve monitoring programmes of registrants and licensees, as appropriate Review periodic reports on public exposure including dose assessments, as appropriate[c] Conduct limited confirmatory environmental monitoring, as appropriate[c,d]	Ensure arrangements are in place for monitoring
	Licensed practice~~/~~ or source	~~Source~~Conduct source and environmental monitoring~~,~~ and dose assessment		
	Multiple sources	~~Source~~Conduct source monitoring of its own facility, site specific environmental[c] monitoring, and dose assessment for its own facility[c]	Review monitoring data and prepare dose assessments cumulative over the relevant period, as appropriate Conduct environmental monitoring to assess cumulative radiological impact[d]	Ensure arrangements are in place for management of ~~nationwide~~countrywide surveys
Emergency	–	~~Source~~Conduct source monitoring~~,~~ and site specific environmental monitoring[c]	Coordinate large scale and~~-~~/or local environmental ~~monitoring[d]~~monitoring, as appropriate[d,e] Coordinate individual monitoring of the public, as appropriate[d,e]	Ensure resources and capabilities are available to respond to emergencies Ensure arrangements are in place for management of ~~nationwide~~countrywide monitoring networks Assign responsibilities to the regulatory body or other response organizations depending on the national arrangements
Existing	Areas with residual radioactive material	~~Source~~Conduct source monitoring, site specific environmental monitoring~~,~~ and dose ~~assessment[e]~~assessment[f]	Review monitoring data and dose assessments Conduct local environmental monitoring, as appropriate Coordinate individual monitoring of the public, as appropriate[d,fg]	~~To screen~~Screen areas where the radiological impact is of potential concern and a radiological survey is considered necessary Decide on the need for ~~control/~~monitoring Ensure arrangements are in place for management of existing exposure sites, including monitoring, as ~~they arise~~the sites are identified

[a] The operating organization can delegate the monitoring to another party, but should maintain the responsibility.

[b] For registered practices, the regulatory body might require source monitoring to be performed. ~~[c] Only for licensed practices/sources (see Table 2).~~

[c] Only for licensed practices or sources (see Table 2 in Section 8).

[d] The regulatory body can perform ~~itself or delegate the execution of some~~ activities related to monitoring itself or delegate their implementation (see para. 4.4).

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[e]~~In~~ The government can assign this responsibility to other response organizations rather than the regulatory body, depending on the national arrangements.

[f]In the cases in which remediation ~~have~~has been determined to be justified, the operating organization is the responsible party authorized to conduct remediation ~~[17].~~(see GSG-15) [12]). If the operating organization is not present, the government should assign a responsible body.

[fg] For existing exposure situations ~~resulting from emergencies~~ in which health follow-up was recommended.

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~~5. MONITORING IN A PLANNED EXPOSURE SITUATION~~

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5. MONITORING IN A PLANNED EXPOSURE SITUATION

5.1. The need for monitoring in a planned exposure situation should be determined by the regulatory requirements that apply to the facility or activity.

5.2. Monitoring is not required for sources that give rise to exposures that are deemed to be not amenable to control and therefore are excluded from the scope of GSR Part 3 [1]. Examples of excluded exposures are provided in IAEA Safety Standards Series No. GSG-17, Application of the Concept of Exemption [31] and include exposures from ^{40}K in the human body or cosmic radiation at the surface of the Earth, unmodified concentrations of radionuclides of natural origin in soil, including those in high natural background radiation areas, other primordial radionuclides (e.g. ^{87}Rb,^{138}La,^{147}Sm,^{176}Lu) present in unmodified activity concentrations, and fallout resulting from past atmospheric nuclear weapon tests.

5.3. Monitoring is not required for exempted practices or sources (see Schedule I of GSR Part 3 [1]). An example of an exempted practice is a laboratory that utilizes small amounts of radionuclides for which either the total activity or the activity concentration is below the exemption levels specified in Table I.1 of GSR Part 3 [1]. For practices[16] for which notification alone is sufficient, there is no requirement for monitoring in(see GSR Part 3 [1].]).

5.4. Material that meetsin which activity concentrations are below the clearance levels[17] is no longer considered radioactive material and can be used, recycled or disposed of without further regulatory consideration regarding the radiological aspects [32].. Hence, once a material has been cleared there is no requirement for monitoring. The processes and procedures leading to clearance should be well defined in the national regulatory framework and in the authorization conditions for the facility or activity.

5.5. For authorized practices[18] [1], routine monitoring programmes are required (see para. 3.127(f) of GSR Part 3 [1]). Nuclear installations, large research establishments and radioisotope

[16] Practice is defined in ref [5] as 'any human activity that introduces additional sources of exposure or additional exposure pathways, or that 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." The term 'activities' is intended to provide an alternative to the terminology of practices (or interventions) to refer to general categories of situations. Terms such as 'authorized practice', 'controlled practice' and 'regulated practice' are used to distinguish those practices that are subject to regulatory control from other activities that meet the definition of a practice but do not need or are not amenable to control [5].

[17] Radioactive material or radioactive objects within notified or authorized practices can be cleared of regulatory control. IAEA Safety Standards Series No. GSG-18, Application of the Concept of Clearance [32] provides guidance [31]recommendations on the application of the concept of clearance of materials, objects and buildings that are to be released from regulatory control in the framework of planned exposure situations.

[18] Sources or practices for which neither exclusion nor exemption is appropriate are required to be notified or authorized by the regulatory body (see GSR Part 3 [1]. The authorization]). Authorization can take the form of either a registration or a

production facilities typically have specific ~~license~~licence conditions and are expected to have in place source and environmental monitoring programmes in support of verification of regulatory compliance. These monitoring programmes might also contribute to ~~maintain~~maintaining competences for emergency monitoring and provide a baseline for assessing the ~~assessment of~~ radiological impact of emergencies, although not all facilities and activities will need full emergency monitoring capability.

5.6. For registered practices, the regulatory body might require source monitoring to be performed, but routine environmental monitoring is usually not necessary. The regulatory body should consider requiring a single confirmatory source and environmental monitoring campaign, for example at the time of ~~giving the~~granting authorization[19]. The regulatory body should provide guidance on how to conduct this monitoring, involving, as necessary, the technical support organizations.

5.7. During the authorization process, the conditions of the operation of facilities that are likely to discharge radioactivity to the environment, which are related to the management of gaseous, airborne and liquid effluents, should be defined by the regulatory body. In general, the following data should be established as part of the authorization process[20] ~~[3]~~::

(a) The total inventory of radionuclides in the facility or activity;

(b) The total activity of radionuclides expected to be discharged during a defined period in different operational states;

(c) The exposure pathways that contribute to the doses to the public;

(d) The expected doses to the public due to discharges;

(e) The discharge limits, specified for different radionuclides, or groups of radionuclides.

RESPONSIBILITIES FOR MONITORING IN A PLANNED EXPOSURE ~~SITUATIONS~~SITUATION

5.8. Operating organizations have primary responsibility for ~~carrying out~~performing source monitoring to demonstrate compliance with operational limits, including the authorized limits for

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~~license~~licensing. Examples of licensed practices are the operations of nuclear power plants and of other fuel cycle installations. Examples of registered practices are those conducted at small research institutes and small hospitals, where the usage of short lived radionuclides and the corresponding discharges to the environment are low.

[19] In addition to fulfilling a regulatory obligation, this ~~measurement~~measure would provide reassurance for the neighboring populations.

[20] GSG-9 [3] provides recommendations ~~for~~on the establishment and authorization of discharge limits and the related operational conditions.

discharges. Source monitoring for a specific facility or activity should be performed by the operating organization ~~in~~at all applicable stages in the lifetime of the facility or activity. The operating organization should establish, implement and maintain the appropriate equipment and programmes to monitor discharges. The operating organization should also be responsible for conducting environmental monitoring and performing dose assessment ~~according to~~in accordance with the regulatory requirements (see Table 1 and ~~paragraphs~~paras 5.5~~ and~~ –5.6).

5.9. The regulatory body is responsible for ensuring that the operating organization complies with regulatory requirements for source and environmental monitoring. The regulatory body should establish technical requirements for such monitoring and should regularly review them. The regulatory body should check the monitoring data provided by the operating ~~organizations~~organization and publish (or make available on request) evidence that authorized facilities and activities are being suitably monitored and controlled.

5.10. The regulatory body is required, as appropriate, to make arrangements for an independent monitoring programme to verify the quality of results provided by the operating organization and to confirm that the doses to members of the public are below the dose limits (see para. 3.135(c) of GSR Part 3 [1~~].~~]). The regulatory body may implement this independent programme itself or delegate ~~through agreements the~~ implementation ~~of this independent programme~~ to other parties, such as technical support organizations with adequate technical resources; however, the responsibility for such a programme remains with the regulatory body.

5.11. The regulatory body is required, as appropriate, to assess the total radiological impact based on the results of monitoring conducted by operating organizations and other parties (see para. 3.135(d) of GSR Part 3 [1]). For the assessment of the total public exposure due to multiple authorized sources and practices that might have impact on the same population groups, the cumulative radiological impact should be ~~considered~~addressed.

~~OBJECTIVES FOR MONITORING IN PLANNED EXPOSURE SITUATIONS~~

OBJECTIVES OF MONITORING IN A PLANNED EXPOSURE SITUATION

5.12. The objectives of a monitoring programme for the protection of the public and the environment in a planned exposure situation, should be as follows:

(a) To demonstrate compliance of the facility or activity with the authorized discharge limits, ~~radiation~~ dose limits and constraints, and operational conditions ~~concerning~~, with regard to the impact on the public and the environment;

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(b) To provide information and data for the radiological environmental impact assessment (see GSG-10 [2~~],~~]), including the evaluation of doses to the representative person;

(c) To check the conditions of operation and verify the adequacy of controls on discharges from a source and to provide an early warning of anticipated operational occurrences[21], which might trigger the need ~~of~~for additional monitoring, mitigation and corrective actions ~~on~~for the facility or activity;

(d) To provide input to the periodic safety reviews, including the ~~re-assessment~~reassessment of the radiological environmental impact and, if necessary, the review of the discharge limits;

(e) To detect unexpected or unauthorized ~~discharge~~releases;

(f) To detect any unexpected increase in radionuclide concentrations in the environment;

(g) To assess the buildup of activity concentrations in the environment arising from discharges;

(h) To verify ~~or validate environmental models used~~the dose assessed in the prospective radiological environmental impact assessment;

(i) To provide information for interested parties[22];

(j) To evaluate long term trends.

5.13. ~~If required in the national regulations, dose~~Dose rates to the reference animals and plants may also be evaluated with a methodology as described in annex I of GSG-10 [2], based on the ICRP approach for the protection of the environment [20]. To the extent possible, monitoring programmes for environmental protection should be integrated to fulfill dose assessment objectives for the protection of people and flora and fauna. The environmental media and locations sampled to support human dose assessment might also be useful for the dose assessment of flora and fauna as radionuclide activity concentrations in biota are likely to be

[21] Examples of anticipated operational occurrences are loss of normal electrical power and faults such as a turbine trip, malfunction of individual items of a normally running plant, failure to function of individual items of control equipment, and loss of power to the main coolant pump [5].

[22] GSR Part 3 [1] uses the term 'interested party' to mean, in a broad sense, a person or group having an interest in the performance of an organization. Interested parties have typically included customers, owners, operators, employees, suppliers, partners and trade unions; the regulated industry or professionals; scientific bodies; ~~and~~ governmental agencies or regulatory bodies~~.~~; the media; the public (individuals, community groups and interested groups). The term could also include other States (e.g. neighboring States ~~concerned with~~for which there are possible transboundary impacts).

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estimated from activity concentrations measured in environmental media (~~e.g. water, soil, sediments~~see para. 3.2) taking account of relevant exposure pathways.

~~MONITORING OVER THE DIFFERENT STAGES IN THE LIFETIME OF FACILITIES~~MONITORING AT THE DIFFERENT STAGES IN THE LIFETIME OF A FACILITY

5.14. For certain facilities, for example, nuclear power plants and other nuclear installations, there are generally a number of stages throughout the lifetime of the facility ~~[33].~~(see IAEA Safety Standards Series No. SSG-12, Licensing Process for Nuclear Installations) [34]. For such facilities, the nature of the monitoring programme should be appropriate for the characteristics of these different stages, and ~~consider, for example,~~aspects such as the extension, scope and frequency of the sampling and the type of environmental media to be monitored should be taken into consideration to reflect ~~the~~any changes in the facility~~.~~ at the different stages. The allocation of resources ~~devoted to the~~for monitoring programmes ~~in~~at each of these stages should be optimized on the basis of previous results.

5.15. In the early stages of the operation of a facility, more frequent and detailed environmental measurements ~~should~~are often needed to characterize the local spatial and temporal variation in environmental concentrations of radionuclides. These measurements can be ~~conducted~~used to ~~confirm~~verify the predictions of environmental models used to ~~simulate~~estimate the transfer of radioactivity through the environment~~. Subsequently, when~~ and refine the assumptions and parameters considered in the prospective assessment of the impact of radioactive discharges. When more information and experience ~~are~~has been gained~~, it might be appropriate to reduce~~ from such characterization, the scale and extent of both source and environmental monitoring~~. Nevertheless, any~~ can be reduced. Any decision to reduce the frequency of sampling or the scope of the environmental monitoring programme should be justified and documented. Account should be taken of potential changes in the discharge regimes or unexpected releases, as well as any concerns raised by the public.

5.16. Monitoring programmes should be reassessed with the frequency established by the regulatory body or ~~when~~in the following cases:

(a) When changes are anticipated in ~~operations~~the operation of the facility or conduct of the activity, which affect the radionuclides composition or magnitude of the discharges~~, leading~~ and might lead, for example, to a modification of the discharge authorization~~, or when~~;

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(b) When significant changes in the demographics, local environment or ~~in the~~ habits of the local population are observed.

It is advisable to communicate the changes in the monitoring programmes to the public, as appropriate.

Pre-operational stage

5.17. ~~Pre-operational studies for those~~For facilities and activities for which a site evaluation is part of the authorization process, pre-operational studies should be performed in planned exposure situations to establish baseline environmental radiation levels and activity concentrations for the purpose of subsequently determining the radiological impact of the source. The results from the baseline characterization studies should be used for ~~future evaluation of~~evaluating the impact of ~~the~~ facility operation on the site and the surrounding area ~~from its operation~~, determining the acceptability of ~~proposes~~proposed decommissioning options ~~and~~, establishing end state criteria and ~~demonstrate~~demonstrating compliance with the proposed end state ~~[34~~ (see IAEA Safety Standards Series Nos GSR Part 6, Decommissioning of Facilities [35], SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities [36~~].~~] and SSG-49, Decommissioning of Medical, Industrial and Research Facilities [37]). Pre-operational ~~assessments~~studies should also provide information for use in the prospective assessment of doses to the public (see GSG-10 [2~~],~~]), such as information on the expected inventories of radionuclides during normal operation of a facility, the possible discharge ~~pathways~~routes and the likely amounts that will be discharged to the environment, with ~~due~~ consideration of the effluent treatment systems that will be installed. Pre-operational studies should include the monitoring of ~~the~~ environmental media ~~explained~~ in ~~para. 3.1 in this Safety Guide such that~~ order to provide accurate baseline values for the measurements ~~that are contemplated to occur~~to be taken during the operational stage ~~are provided with accurate baseline values.~~. The prospective assessment of doses to the public should be ~~considered~~evaluated by the regulatory body before issuing an authorization for discharges to the environment (see GSG-9 [3~~].~~]).

5.18. The pre-operational monitoring programme should ~~evaluate~~include an evaluation of the need to identify suitable ~~bioindicator organisms~~bioindicators or inert indicator materials (e.g. water catchment soils, marine and riverine sediments) for particular radionuclides. The pre-operational monitoring programme should also serve to train staff ~~and to~~, test ~~the~~

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~~instruments~~instrumentation, and ensure effective organization of the monitoring programmes for the operational stage.

5.19. The pre-operational monitoring programme should be initiated ~~in sufficient time~~sufficiently before the start of operation[23] to be able to study the possible effect of the annual variability in the local environment on the measurements and the results obtained. For nuclear power plants a pre-operational environmental monitoring programme should be implemented two to three years before the planned commissioning of the plant. This pre-operational programme should provide for the measurement of background radiation levels in the vicinity of the site and their variation over and between the seasons. It should also provide the basis for the operational programme of environmental monitoring and should include the routine collection and radionuclide analyses of various samples, such as samples of air, soil, water, sediments, foodstuff and environmental media collected from several fixed and identified locations outside the site. The results of this pre-operational monitoring should be used as an input to the development of the monitoring programme for the operational stage.

5.20. At the pre-operational stage, one or more areas that can be assumed ~~as not being impacted~~ to be unaffected by the facility or activity should be identified. If such areas are not already ~~covered~~included in ~~national~~existing environmental monitoring programmes, pre-operational monitoring should also be ~~undertaken~~conducted in these areas ~~as~~to provide control measurements for comparison with impacted areas.

Operational stage

Source monitoring at the operational stage

5.21. The design and implementation of ~~the~~a source monitoring programme in the operational stage should enable ~~the~~ verification of compliance with the authorized discharge limits and operational conditions ~~of discharges~~ specified by the regulatory body. For licensed facilities, particularly for nuclear installations, periodic monitoring of the direct radiation in the

~~[23] For nuclear power plants a pre-operational environmental monitoring programme should be implemented two to three years before the planned commissioning of the plant. This pre-operational programme should provide for the measurement of background radiation levels in the vicinity of the plant and their variation over and between the seasons. It should also provide the basis for the operational programme of environmental monitoring and should include the routine collection and radionuclide analyses of various samples, such as samples of vegetation, air, milk, water, sediment, fish, and environmental media collected from several fixed and identified locations off the site.~~

immediate ~~environment~~vicinty of the facility and monitoring of discharges should be considered.

5.22. Direct radiation from the source should usually be measured at the boundaries of the controlled~~,~~ and supervised areas and at the boundaries of the facility. The monitoring of direct radiation can be performed using off-line integrating passive devices (such as thermoluminescent dosimeters), by periodic surveys using portable radiation meters or through an on-line network of dose rate meters. In ~~the~~ cases in which the implementation of an on-line network is justified, some dose meters can be placed ~~close to the~~in nearby ~~villages or cities.~~populated areas. The on-line network might also ~~can~~ be useful to detect an unplanned significant increase ~~of the~~in direct radiation from the source or an unplanned release of radioactive material ~~[43].~~(see Ref. [38]).

5.23. The monitoring of radioactive discharges may entail measurements ~~for~~of specific radionuclides or total activity measurements, as appropriate. If the discharge limits are given in terms of total alpha activity and/or total beta activity, and not for specific radionuclides, radionuclide specific measurements on a routine basis might not be necessary. However, a full determination of the radionuclide composition in the discharges should be performed at least once, or at the intervals approved by the regulatory body, and ~~when~~whenever there might be changes in the radionuclide composition of releases ~~could be conceived~~.

5.24. Monitoring of discharges should normally be performed before dilution occurs or at the point of discharge (e.g. at the stack for atmospheric discharges or at the pipeline for a liquid discharge). In the case of batch discharges, the ~~material due to be discharged~~effluents should be adequately characterized by the volume of the batch and the radionuclide composition either of a sample taken from ~~either~~ the homogenized batch prior to discharge~~;~~, or of a ~~flow~~ proportional flow sample taken during ~~the~~ discharge ~~process~~. For continuous discharges, time integrated or continuous measurements should be used to ensure ~~that~~ a correct assessment of the release ~~has occurred~~.

5.25. ~~The choice of~~In selecting the sampling and measurement procedures ~~should consider~~, the following should be taken into consideration:

(a) The characteristics and amounts of discharged radionuclides and the sensitivity of the measurement system;

(b) The expected variation ~~with~~over time in the discharge rates, in the composition of radionuclides and in the volume of effluent involved;

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(c) The likelihood of abnormal or unexpected releases ~~requiring~~needing prompt detection~~,~~ and notification, and possible mitigation.

5.26. Regardless of the type of sampling and measurement, provisions should be made for the accurate determination of the volume of material discharged as a function of time so that the total activity discharged over a given time can be computed from measurements of activity concentration. To calculate the radiation dose to the representative person, relevant meteorological and hydrological dispersion data should also be collected. ~~For properly evaluating~~To assess the radiological impact of the discharges, other physical and chemical parameters should also be considered.[24]~~.~~

5.27. In selecting the instrumentation for source monitoring, possible abnormal releases should also be considered to ensure that the measurement range is sufficient and that alarm levels are adequately set. ~~It should be also considered~~In designing the monitoring system, there should be sufficient flexibility of response for accidental releases, taking into consideration that the radionuclide composition and physical and chemical characteristics of an accidental release are likely to be different from the discharges in normal operation~~, to ensure that sufficient flexibility of response in designing the monitoring system for accidental releases is achieved [37].~~ (see Ref. [39]).

Environmental monitoring at the operational stage

5.28. Measurements should be made, and sampling performed, at appropriate locations outside the boundary of the facility. ~~This~~ The measurements should include, as appropriate, ~~measurements of~~ external radiation levels and ~~of~~ radionuclide activity concentrations in all relevant environmental media~~, including food products and drinking water.~~. The locations ~~for~~where measurements and sampling are to be performed should be determined on a site specific basis, with the aim of assessing radiation doses to the representative person and identifying the areas with the highest levels of radiation. Additionally, environmental sampling ~~could~~should be ~~conducted regularly~~considered in nearby ~~population centres~~populated areas, as appropriate, for ~~reassurance~~public assurance, as well as in unaffected areas ~~for control measurements~~ for comparison.

[24] ~~Such as,~~ These parameters include the physical and chemical form and solubility of the radionuclide(s) discharged; the particle size distribution in the case of airborne discharges; the pH in the case of water based liquid discharges; the temperature of the effluent; and the volatility of the substances in the discharges.

5.29. In addition to measurements that directly relate to exposure pathways to humans, the measurement of activity concentrations in ~~'indicator' organisms~~bioindicators or inert indicator materials should be considered. This ~~includes measurements on seaweeds~~could include measurement of seaweed, lichen or suspended particulate matter ~~which~~that are not direct parts of the food chain~~, to~~ but can provide data on trends and the buildup of radionuclides in the environment.

5.30. When environmental monitoring is performed to assess the impact of a particular facility or activity ~~it~~, measurement points and sampling points should ~~enable~~be selected and analytical methods should be applied that allow the ~~verification~~detection of radiation and radioactive contamination arising from the ~~results of~~ source ~~monitoring. It should also enable the assessment of the doses to members of the public.~~under consideration.

5.31. Where there are several facilities or activities giving exposure to the same group of individuals, there ~~could~~may be a need to select sampling locations ~~from which~~where the aggregate effect of all discharges can be assessed. ~~For~~In designing the ~~proper design of such a~~ monitoring programme in this case, information on the direct irradiation and the radionuclides discharged from each of the contributing sources ~~may be~~is needed, as well as the chemical and physical form of the radionuclides and the intervals at which discharges are made, so that appropriate collection and measurement techniques can be employed.

~~**Facility decommissioning**~~

Decommissioning stage

5.32. During decommissioning, the monitoring programme should reflect changes in the characteristics of the discharges (e.g. radionuclide composition, magnitude of discharge ~~rates~~, release rate). As decommissioning proceeds, the impact on the public from direct irradiation and changes in the discharged radionuclides compared to the impact during the operational stage should be considered.[25] ~~.~~ The monitoring programme for the source and the environment that were in place during operation of the facility should be re-evaluated whenever dynamic

[25] Radioactive discharges in liquid and airborne form ~~will be~~are likely to change as a result of the decommissioning process and will eventually ~~be eliminated.~~cease. However, the decontamination and dismantling activities integral to decommissioning ~~may~~might result in increased radioactive releases through the creation, suspension and resuspension of contaminated aerosols. For a nuclear power plant, once reactor operations have ceased, ~~there are no more~~ short lived fission products in the discharges rapidly decline; however, the occurrence and ~~re-suspension~~resuspension of aerosols might increase the discharges of activation products. In addition, as decommissioning progresses, area sources ~~are~~become more likely to occur, whereas the potential for large emergency releases becomes ~~unlikely [35~~less likely [36].

changes in the site occur to determine whether they remain appropriate. Any ~~new~~changes in the arrangements for source and environmental monitoring should be documented in the decommissioning plan and implemented, as appropriate.

Source monitoring at the decommissioning stage

5.33. The objectives of source monitoring at the decommissioning stage should be essentially the same as ~~for~~those at the operational stage. When ~~defining the~~designing a source monitoring ~~programmes during~~programme for the decommissioning~~, the~~ stage, possible changes ~~of~~in the quantities, ~~radionuclides~~radionuclide composition and physicochemical characteristics of the releases should be considered, as well as ~~the~~ changes in the external radiation fields around the facility. As the facility undergoes ~~the~~ transition to decommissioning, the monitoring programme should be reviewed and adapted to ensure that it still enables verification of compliance with the authorized discharge limits and criteria for external radiation levels as specified or approved by the regulatory body.

5.34. During decommissioning, the selection of the sampling procedures and the characteristics of measurement instruments, such as sensitivity, should be adapted based on the characteristics of the possible new discharges and the likelihood of unplanned releases that ~~would require~~need prompt detection and notification.

Environmental monitoring at the decommissioning stage

5.35. ~~Environmental~~The environmental monitoring programme during the decommissioning of a facility might be initially similar to that for the operational stage but should be modified to take account of changes in the source term ~~(e.g. radionuclides composition, magnitude of discharge, release rate),~~ the exposure pathways and the representative ~~persons~~person. The necessary changes for the measurement of external dose rates and radionuclide activity concentrations in the environment should be considered and incorporated in the updated environmental monitoring programme~~.~~ and reviewed as decommissioning progresses.

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Release from regulatory control

5.36. Prior to the release of sources or sites from regulatory control, monitoring should be conducted to verify compliance with the authorized end state criteria[26]. Recommendations for monitoring ~~in~~at this stage are provided in IAEA Safety Standards Series DS 542, Release of Sites from Regulatory Control on Termination of Practices [~~38~~40].

~~PUBLIC DOSE ASSESSMENT FOR A PLANNED EXPOSURE SITUATION~~

PUBLIC DOSE ASSESSMENT FOR A PLANNED EXPOSURE SITUATION

5.37. The results of source monitoring and environmental monitoring should be used to confirm that the dose to the public during normal operation and decommissioning comply with the appropriate dose limits and dose constraints.

5.38. When sufficient results of measurements of the activity concentration of radionuclides in air, water and ~~foods~~food are available, the calculation of doses on the basis of these ~~measurements~~measurement results ~~should be~~is preferable ~~used~~ to ~~avoid~~modelled assessments, which may contain significant statistical uncertainties. In many cases, only some of the ~~discharged~~ radionuclides in the discharges can be measured ~~above the detection limits~~[27] in the relevant environmental media~~.~~ above the detection limits.[28] The calculation of doses from the results of environmental monitoring should therefore be complemented with calculations made on the basis of the results of annual discharges derived from source monitoring combined with environmental models.

5.39. ~~When possible, the models used for the prospective radiological impact assessment should be validated through a comparison of the results predicted by environmental models with the actual data from measurements.~~ Data from environmental monitoring ~~for~~at the

[26] End state criteria ~~is~~are predetermined criteria defining the point ~~in~~at which a specific task or process is to be considered completed. ~~Used~~These criteria are used in relation to decommissioning activities as the final state of decommissioning of a facility [5].

[27] ~~Both measurement results above the detection limit and measurement results below the detection limits could be used for dose assessment purposes. However, it should be noted that, in the cases when measurements are below the detection limits, the use of detection limits as substitutive values might substantially overestimate the estimated dose. Alternatively, radionuclides concentrations that cannot be measured above the detection limits can be computed through scaling factors. It is an accepted practice to derive the activities from a fraction of the detection limit to refrain to add up to result in unrealistic estimation.~~

[28] Both measurement results above the detection limits and measurement results below the detection limits can be used for dose assessment purposes. However, it should be noted that, in cases when measurements are below the detection limits, the use of detection limits as substitutive values might lead to a substantial overestimate in the estimated dose. Radionuclide concentrations that cannot be measured above the detection limits can be computed using scaling factors. It is an accepted practice to derive the activities from a fraction of the detection limit to avoid unrealistic dose estimation.

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operational stage of a facility or during the conduct of an activity can be used as an input to verify compliance with ~~dose limits and dose constraints,~~any applicable derived limits on the radionuclide concentration in the environment and ~~also to confirm that the environmental models, assumptions, and parameters used in the prospective assessment are adequate~~dose limits and constraints (see GSG-10 [2~~].~~]).

5.40. Doses from external exposures should include, as relevant, the external irradiation from ~~the source(s)~~sources within the facility and the external irradiation from radionuclides in an atmospheric plume or deposited on ~~the ground~~surfaces. The assessment of doses from external irradiation from ~~the~~a source within the facility using direct dose rate measurements is straightforward~~, at least in principle. The~~ : the radiation ~~fields~~field in ~~its~~the vicinity of the source may be measured or calculated using simple radiation detectors. The results of source monitoring within a facility can be extrapolated to provide estimations on locations outside the facility. Additional recommendations on retrospective dose assessment from monitoring results are provided in ~~Section~~para. 9.13.

~~INTERPRETATION, REPORTING AND COMMUNICATION~~INTERPRETATION, REPORTING AND COMMUNICATION OF MONITORING RESULTS FOR A PLANNED EXPOSURE SITUATION

5.41. For planned exposure situations, source and environmental monitoring results should be used to verify compliance of the actual radiation conditions with regulatory limits and constraints by comparison with one or ~~some~~several of the following criteria:

(a) Discharge limits for the facility or activity;

(b) Environmental limits ~~(~~, as appropriate ~~—~~(see para. 5.~~42~~44);

(c) Dose constraints for the facility, activity or site~~;~~[29]~~;~~

(d) Dose limits for members of the public.

5.42. Discharge limits in authorizations granted to operating organizations are usually expressed as annual discharge limits; however, discharge limits for shorter periods may also be included. Reports from source monitoring programmes should include the discharge data in the

[29] ~~Dose~~Recommendations on dose constraints for sites with multiple facilities or for facilities and activities ~~in an area~~ where more than one source is present ~~that~~, which could contribute to the exposure of the representative person ~~is discussed~~, are provided in ~~ref~~GSG-9 [3].

periods specified to demonstrate that the discharges were within the respective authorized limits.

5.43. Discharge limits ~~generally~~should include a margin of flexibility to provide for operational variability and for anticipated operational occurrences ~~[3].~~(see para. 5.67 of GSG-9 [3]).

5.44. Authorizations may also include environmental limits, such as radiation levels at the site boundary or limits on the concentrations of radionuclides or categories of radionuclides in specific environmental ~~compartments~~media. Data from environmental monitoring should be used to ensure that actual radiation levels and radionuclide concentrations are below these limits.

5.45. The operating organization ~~should~~is required to report promptly to the regulatory body whenever discharge limits have been exceeded (see para. 3.137(d) of GSR Part 3 [1]). The report should include the circumstances of the release, the results of any additional monitoring and estimation of doses to the public from the ~~event~~release. Operating organizations should also report promptly to the regulatory body a significant unexpected increase in environmental radiation fields or activity concentrations, or an unplanned release of a significant quantity of radionuclides. The report should include a description of the investigation that has been initiated, the preliminary results, the immediate actions that have been taken in relation to discharge operations (e.g. stopping ~~batch~~or reducing the level of discharges) and the actions that are anticipated for the immediate future ~~(e.g. resuming discharge operations).~~, including corrective actions and plans for the resumption of discharges.

5.46. The operating organization is required to report the results of the monitoring programme for a facility or activity to the regulatory body at ~~a minimum once a year~~approved intervals (see para. 3.137(c) of GSR Part 3 [1]). This should include, as applicable, the results of dose assessments derived from the source monitoring or the environmental monitoring data and other data~~, such as~~ (e.g. meteorological~~,~~) that are relevant to the dose assessment. A comparison with dose limits and dose constraints should also be presented. The analysis should ~~discuss~~present any trends observed ~~by~~in comparison with previous results.

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6. MONITORING IN AN EMERGENCY EXPOSURE SITUATION

6.1. Monitoring during a nuclear or radiological emergency is a key tool to assess the impact on the public of a release of radioactive material and assist in ~~the~~ decision making on, or adjustment of, protective actions to prevent or minimize the radiological consequences. For a nuclear or radiological emergency, the government is required to ensure the clear allocation of responsibilities (see Requirement 2 of GSR Part 7 [6]). ~~This~~These should include the responsibilities for monitoring in accordance with the possible radiological consequences of the emergency.

6.2. Depending on the severity of a nuclear or radiological emergency, all three types of monitoring (i.e. source monitoring, environmental monitoring and individual monitoring) should be performed, in accordance with a graded approach.

~~6.2.~~6.3. Monitoring during an emergency may be undertaken by several different organizations (e.g. ~~the~~ operating organization, ~~the~~ regulatory body, ~~the~~ technical support organizations ~~or the~~, response organizations~~-~~). The coordination between these ~~organisations~~organizations in relation to monitoring should be established by the government to make the best use of resources available to deliver the most effective response. The different organizations with responsibilities for monitoring should establish mechanisms to ensure the sharing of monitoring data collected during the emergency.

~~6.3.~~6.4. The monitoring strategy for an emergency exposure situation should be developed at the preparedness stage, as part of the protection strategy to protect the public, emergency workers[30] and helpers~~, and to~~. The protection strategy should provide information necessary to make decisions on protective actions[31] and other response actions~~, which need to~~ (see GSR Part 7 [6], GS-G-2.1 [9] and IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [41]), and should either be included in the emergency plan, or issued as a standalone document, as appropriate ~~[6, 14, 39]~~. The monitoring strategy should be established on the basis of the hazard assessment, and should follow a graded approach, as requested by the government (see Requirement 4 of GSR

[30] An emergency worker is a person having specified duties as a worker in response to an emergency. Emergency workers may or may not be designated as such in advance of an emergency. Emergency workers not designated as such in advance of an emergency are not necessarily workers prior to the emergency [5].

[31] Protective actions may include on~~-the-~~site and off~~-the-~~site urgent protective actions, early protective actions and other response actions. Most of these actions are taken as a matter of urgency. Some of the actions involve more detailed assessment ~~primary~~, primarily based on monitoring, and can be taken within days or weeks ~~[15]. For details on the requirements and recommendations on~~(see GSG-11 [10]). The emergency planning and response ~~see Refs~~requirements are established in GSR Part 7 [6~~, 15, 40, 41~~], and detailed recommendations are provided in GSG-11 [10] and refs [42, 43].

~~part~~Part 7 [6]) and should be adjusted on the basis of the prevailing circumstances during the emergency.

~~6.4. Depending on the severity of a nuclear or radiological emergency, all three types of radiation monitoring — source monitoring, environmental monitoring and individual monitoring — should be performed, in accordance with a graded approach.~~

6.5. The monitoring strategy for an emergency exposure situation should take into account both national and transboundary impacts. States should establish national strategies to respond to a nuclear or radiological emergency that may occur in other States. Arrangements should be in place between potentially affected States to ensure appropriate exchange of information and, where necessary, coordination in ~~the~~ monitoring activities. For those States that do not need extensive emergency monitoring capability, monitoring to provide a baseline for assessing the radiological impact of emergencies in neighbouring countries should be considered. This monitoring might also contribute to maintaining competences for emergency monitoring in the event of an emergency that has transboundary consequences. The national monitoring strategy ~~for monitoring should consider~~could include the establishment of a network of monitoring stations for early warning and to follow the evolution of ~~the~~ environmental conditions at the regional scale.

RESPONSIBILITIES FOR MONITORING IN AN EMERGENCY EXPOSURE SITUATION

6.6. ~~The government should ensure that a monitoring strategy is developed at the preparedness stage~~ In preparation for any emergency, as part of the protection strategy~~,~~ based on the hazards identified~~.~~, the government should ensure that a monitoring strategy is developed. The monitoring strategy should take account of the type of emergency~~,~~ and the resources ~~required~~needed to undertake monitoring, and should stipulate priorities for the different phases of the emergency[32], in accordance with the protection strategy.

6.7. The regulatory body or other competent authorities[33] should ensure that arrangements for monitoring on the site and in its vicinity during an emergency are established by the

[32] GSG-11 [~~15~~10] proposes a sequence of ~~various~~ phases of a nuclear or radiological emergency, as follows: ~~Urgent~~the urgent response phase, with a typical duration of hours to days ~~after~~from the onset of the emergency~~ onset; Early~~; the early response phase, with a typical duration of days to weeks ~~after~~from the onset of the emergency~~ onset; Transition~~; and the transition phase, with a typical duration of days to a year ~~after~~from the onset of the emergency~~ onset~~.

[33] ~~Competent authority is "any body or authority designated or otherwise recognized as such for any purpose in connection with regulation".~~ Although the term 'competent authority' is generally ~~applicable~~used in the context of transport

operating organization and are routinely tested. This should include ensuring the capacity and capability for rapid monitoring during an emergency.

6.8. The operating organization should establish and maintain an adequate capability to ~~carry out~~conduct monitoring on the site and ~~its~~in the vicinity of a practice or source for which ~~a license is issued~~authorization has been granted, in accordance with an emergency plan approved by the regulatory body.

6.9. The government is required to ensure that there is coordination between all the organizations involved in emergency preparedness and response (see Requirement 22 of GSR Part 7 [6]). This should include establishing a coordinating mechanism to identify responsible organizations and coordinate all the monitoring activities involved in emergency preparedness and response.

6.10. The government should ensure that in the event of an emergency resulting in long term exposures due to residual radioactive material in the environment, where necessary, monitoring of the existing exposure situation will be maintained after the emergency has been declared terminated (see GSG-11 [~~15~~10]). The government is required to ensure that responsibilities for monitoring in the transition from the emergency exposure situation to the existing exposure situation are clearly assigned (see Requirement 46 of GSR Part 3 [1]).

~~OBJECTIVES FOR MONITORING IN EMERGENCY EXPOSURE SITUATIONS~~

OBJECTIVES OF MONITORING IN AN EMERGENCY EXPOSURE SITUATION

6.11. The objectives of monitoring for the protection of the public and the environment in an emergency exposure situation are as follows:

(a) ~~Guide~~To guide decision makers on the need to take protective actions and other response actions (e.g. see Refs [~~40–~~42–44]);

(b) ~~Contribute~~To contribute to dose assessment and provide information for the protection of the public, emergency workers and helpers;

(c) ~~Provide~~To provide information on the radiological, physical and chemical characteristics of the radiological hazard;

~~regulations,~~and nuclear security [5], it is used ~~here~~in this Safety Guide to ~~indicate that~~refer to any body or authority designated by the government as having responsibility in an emergency situation ~~the responsible could be any competent organization indicated by the government [5].~~

(d) ~~Provide~~To provide information on the efficacy of the protection strategy;

(e) ~~Assist~~To assist to identify individuals needing specialized medical care, health screening or longer term medical follow-up;

(f) ~~Provide~~To provide technically correct information ~~required~~ to keep the public informed and maintain public trust;

(g) ~~Facilitate~~To facilitate the coordination and consistency of national emergency arrangements with ~~the relevant~~ international emergency ~~arrangements~~agreements under the relevant instruments.

~~SOURCE, ENVIRONMENTAL AND INDIVIDUAL MONITORING IN AN EMERGENCY EXPOSURE SITUATION~~

SOURCE, ENVIRONMENTAL AND INDIVIDUAL MONITORING IN AN EMERGENCY EXPOSURE SITUATION

Source monitoring in an emergency exposure situation

6.12. Decisions regarding the urgent protective actions to be taken in the event of a nuclear or radiological emergency depend on the prevailing conditions at the facility or on the results of environmental monitoring. Source monitoring should be conducted to provide information for emergency classification[34] and to facilitate the assessment of the magnitude of the radiological hazard and the possible development of conditions throughout a nuclear or radiological emergency ~~in order to promptly initiate~~ . This will allow the prompt initiation of an effective response and ~~revise~~, where apppropiate, revision of the protection strategy~~, as appropriate [14].~~ (see GS-G-2.1 [9]). Source monitoring can be used to obtain information for the estimation of the accident source term and to assist in the implementation of environmental monitoring.

6.13. For facilities that might experience an accidental release that ~~could require~~requires urgent protective actions, early protective actions or other response actions, a continuous or batch monitoring system~~, able to~~ that can measure the potential range of activity concentrations~~,~~ should be established at all potential release points~~, such as~~ (e.g. stacks and discharge points of

[34] ~~When monitoring data is used to emergency classification, emergency action levels (EALs) are the basis.~~ Emergency action levels are predefined criteria for the classification of an emergency. In the case of an emergency at a nuclear facility, they are on-site observables that can relate to abnormal conditions, security related concerns, releases of radioactive material, environmental monitoring, and other observable indications (see GSG-2 [41]).

radioactive liquid effluents.). Additional technical information about source monitoring in emergency exposure situations is provided in Ref. [4338].

6.14. The arrangements for source monitoring should consider that for certain accidents, further releases maymight occur through different locations (e.g. due to building leaks). For such cases, the source monitoring arrangements should include means to urgently deploy special monitoring equipment. In such cases, information related to source terms can also be derived from other measurement devices on site or at the boundaries of the facility.

Environmental monitoring in an emergency exposure situation

6.15. Environmental monitoring in an emergency exposure situation should provide information on the need and extent of protective actions and other response actions, and should facilitate the following:

(a) Identification of areas in which urgent or early protective actions or other response actions need to be implemented;

(b) Confirmation of whether the urgent and early protective actions implemented, such as (e.g. evacuation, sheltering, relocation, iodine thyroid blocking,) are appropriate;

(c) CalculationEstimation of the accident source term;

(d) Assessment of doses to members of the public, emergency workers and helpers;

(e) ProvideProvision of information to identify needsany need for individual monitoring;

6.16. Depending on the duration of the release[35], environmental monitoring may include measurements of dose rates and the sampling of radionuclides from the plume to compare with operational criteria for emergency preparedness and response (see ref.GSR Part 7 [6]). Once the release has stopped and the radioactive plume has passed, monitoring should be directed to the measurement of deposited radionuclides (including dose rates from the ground) and food contamination, taking into account the pathways of radiation exposure. and the protection and safety of the individuals taking the measurements. Additional technical information about environmental monitoring during and after the passage of the plume is provided in Ref. [4338].

[35] In many cases the significant release will be over by the time the results of environmental measurements are available; and it couldmight also be difficult to take samples and analyzeanalyse air concentrations in a sample in a timely manner [4042].

6.17. During and immediately after the onset of a nuclear or radiological emergency, the available monitoring resources ~~could~~might be insufficient to ~~cover~~meet all the monitoring ~~needs~~requirements, particularly in a severe nuclear accident. The available resources should be utilized as effectively and efficiently as possible, ~~in a timely manner,~~ by setting priorities ~~considering characteristics~~that take into account aspects such as the population distribution and land use in the emergency planning zones, the distances involved ~~and~~, the available infrastructure, ~~on the bases of~~ and the prevailing meterorological conditions. It might be necessary to request support from other organizations including those ~~for which monitoring is~~that do not ~~their normal~~normally have responsibility~~.~~ for monitoring; in this case, it should be ensured that the monitoring capabilities of these organizations are adequate and that their personnel are capable of performing the necessary monitoring tasks. The monitoring strategy should anticipate such situations ~~and, when necessary, include pre-signed~~, including the signing of agreements and provision of training in advance of an emergency.

6.18. The effects of a protracted release of radioactive material on the available resources for emergency monitoring should be considered when developing the monitoring strategy. ~~The environmental monitoring strategy should, as necessary, include arrangements for assistance from other organizations and other States, if deemed necessary.~~

6.19. For facilities that ~~should~~could warrant urgent protective actions or early protective actions and other response actions~~,~~ (see table 1 of GSR Part 7 [6]), environmental monitoring systems, consisting of fixed remote stations at designated locations and mobile resources for environmental monitoring under emergency conditions, should be established and deployed in accordance with the provisions included in the emergency plan.

6.20. The arrangements for environmental monitoring should take into account that~~,~~ a large ~~amounts~~volume of monitoring data ~~— for example,~~(including dose rates, activity concentrations and deposition of radionuclides in relevant media ~~— will need~~over large areas) needs to be collected ~~in an~~ and made available in a timely manner to reflect the evolving situation~~, often over a large area.~~. The arrangements should also ~~consider that environmental monitoring~~allow for comparison of these data ~~should be made available in a timely manner in order to compare them to~~ with the operational criteria and ~~to estimate~~ for the fast estimation of doses ~~to make~~so that prompt decisions can be made about the implementation of appropriate protective actions ~~[40].~~(see Ref. [42]).

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Individual monitoring in an emergency exposure situation

6.21. Individual monitoring of members of the public may be ~~considered~~ appropriate in the context of an emergency exposure situation~~: if so, such~~. Such monitoring should be appropriately justified and implemented effectively ~~and,~~ efficiently~~,~~ and in a timely manner, by setting priorities. Permission should be sought from each person before performing individual ~~measurements~~monitoring, and the nature and purpose of the measurements, and the planned use and protection of the information obtained, should be explained to the persons ~~that are~~being monitored.

6.22. Monitoring should focus on individuals that could have received doses close to or exceeding the generic criteria for protective actions and other response actions to avoid or minimize severe deterministic effects or to reduce the risk of stochastic effects (see Appendix II of GSR Part 7 [6]). Individual monitoring should be conducted if deemed necessary to determine whether protective actions such as decontamination, medical care or follow-up is warranted. Individual monitoring may also be useful as a means of reassuring individuals and ~~to verify~~verifying the dose assessments that have been made ~~[43,44].~~(see Refs [38, 45]).

6.23. In establishing the individual monitoring strategy, it should be considered that the interpretation of measurements of external exposure ~~of members of~~for the ~~public may~~purpose of dose assessment might be ~~difficult~~limited as the dose ~~may~~might fall within the range of the ~~variation of the~~ natural ~~radiation~~ background radiation level. Therefore, individual monitoring of the external dose rate is only ~~effective~~of value if the dose rate in the area significantly exceeds the natural background level. Selected representative members of the public may be provided with individual dosimeters and receive instructions on their use.

6.24. Measurements of quantities of radionuclides incorporated ~~or deposited on~~into the bodies of individuals should provide input for the assessment of the committed dose and may help to reassure members of the public, for example, those who have been evacuated. The decision to conduct individual monitoring should be balanced against causing unnecessary alarm to the potentially affected population. Measurements of iodine isotopes in the thyroid, other gamma emitters (~~such as~~e.g. cobalt and caesium isotopes), beta ~~emiters (such as~~emitters (e.g. tritium and ~~strontium-90~~^{90}Sr) and alpha emitters (~~such as~~e.g. radium, uranium and plutonium isotopes)

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should be considered in accordance with the radiological characteristics of the emergency[36]. The arrangements for individual monitoring should take into account the urgency ~~needed to detect~~with which short lived radionuclides~~,~~ such as ^{131}I~~,~~ need to be measured in order to be detected in the body ~~[43,44].~~(see Refs [38, 45]).

~~PUBLIC DOSE ASSESSMENT IN AN EMERGENCY EXPOSURE SITUATION~~

PUBLIC DOSE ASSESSMENT IN AN EMERGENCY EXPOSURE SITUATION

6.25. The doses to the members of the public and emergency workers may be derived from source monitoring, environmental monitoring or individual monitoring data, or from a combination of these. Data from monitoring should be combined with supporting information ~~such as~~(e.g. data on meteorological and hydrological conditions~~ and~~, data on habits) appropriate assumptions, environmental dispersion and transfer models, and dose coefficients ~~[45,~~ (see Refs [46~~],~~, 47]), to assess doses to the representative person ~~of the public~~[37] and emergency workers. ~~Best available monitoring data should be considered when performing the dose assessment.~~

6.26. For identification of the representative person in emergency situations, different exposed population groups should be considered, depending on the characteristics of the emergency, ~~in accordance with,~~ for ~~instance,~~example the prevailing meteorological or hydrological conditions, possible temporary occupancy and seasonal variations in habits and in consumption of food products ~~[2].~~(see para. 5.63 of GSG-10 [2]).

6.27. During an emergency, careful consideration should be given to the methods and models selected to assess doses to members of the public. Models used for ~~dose~~ assessment of doses from discharges in planned exposure situations might not be appropriate to estimate doses ~~for~~in emergency exposure situations.[38]

[36] The measurement procedure ~~will depend~~depends on the emitter. Monitoring of radioiodine content in thyroid glands ~~should be~~is undertaken with an appropriately calibrated gamma detector. The direct measurement of other gamma emitting radionuclides may be ~~made by~~performed using whole body counters. The doses due to incorporated beta emitters are usually estimated by bioassay ~~[39, 42].~~(see GSG-2 [41] and Ref. [44]).

[37] The representative person identified for potential exposures may be different from the representative person for exposures in normal operation.

[38] Models ~~in~~for planned exposure situations are designed to deal with long term, steady state ~~long term~~ conditions rather than the variable short~~-~~ term dispersion that occurs in emergency situations.

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6.28. Monitoring data should be interpreted and presented to governmental organizations ~~in a way that facilitates well-informed~~ with responsibility in decision making in a form (e.g. using tables, maps, indications of time evolution, appropriate and consistent units~~).~~) that facilitates well-informed decisions. The monitoring results and related analysis ~~from~~by different organizations (at the local, national and international levels) conducting monitoring ~~are preferable to~~should be presented in a pre-arranged compatible format[39]. The regulatory body or other competent authority should establish the format, content and frequency of ~~reporting the results~~reports by organizations conducting source and environmental monitoring activities in an emergency exposure situation. Systems to collect, maintain and share this information with different users, in accordance with pre-established agreements on the level of access, should be developed, as appropriate.

6.29. The government is required to ensure that arrangements are in place to provide the public with information that is necessary for their protection (see ~~Requirement~~Requirements 10 and 13 of GSR ~~part~~Part 7 [6]). This should include arrangements for the regulatory body or other response organizations to promptly ~~provide~~communicate to the public ~~with~~ clear information, including in the languages spoken by the locals. The information communicated should be based on the results of monitoring and additional analysis and interpretation~~.~~ by specialists. The information should ~~include~~use understandable ~~interpretations in terms of~~ terminology to convey health risks and practical advice on protective actions and other response actions. Communication should assist in preventing the spread of misinformation. Further recommendations ~~on~~are provided in IAEA Safety Standards Series No. GSG-14, Arrangements for Public Communication in Preparedness and Response for a Nuclear or Radiological Emergency ~~are given in IAEA Safety Standards Series No. GSG-14 [48~~[49].

6.30. When the results of monitoring programmes indicate that ~~the~~some information is relevant outside national boundaries, this information should be shared with the States concerned in accordance with the Convention on Early Notification ~~Convention~~[40] ~~[6~~of a Nuclear Accident [50]. The State where the emergency occurred should provide such

[39] Information on the content and format of reports of measurement results for record keeping and information exchange is provided in Ref. [~~47~~48].

[40] ~~See the Early Notification Convention (https://www.iaea.org/topics/nuclear-safety-conventions/convention-early-notification-nuclear-accident).~~

information to the States concerned using the agreed means for exchange of information and consultations~~, as appropriate [47].~~ (see Ref. [48]).

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7. MONITORING IN AN EXISTING EXPOSURE SITUATION

7.1. ~~Monitoring~~The monitoring programmes for ~~the~~ existing exposure situations addressed in this Safety Guide include those for sites with residual radioactive material as a result of past activities that were not subject to effective regulatory control and areas with residual contamination as a consequence of a nuclear or radiological emergency.

7.2. Monitoring in existing exposure situations primarily relates to verifying the radiological conditions and comparing these conditions with reference levels for existing exposure situations. ~~The monitoring~~It can also be used to identify areas in which further, more detailed ~~radiation~~ monitoring is needed. In areas with residual contamination as a consequence of a nuclear or radiological emergency, the monitoring conducted, and the protective actions implemented, during the emergency response should be considered in the development of the monitoring programme for the existing exposure situation.

7.3. A monitoring programme for an existing exposure situation should be justified, and ~~the~~should follow a graded approach. The type and extent of the monitoring programme, including the monitoring frequency, should take into account the characteristics of the affected area or site, the nature of the contamination, the number of people exposed, and the access to the site or area, in order to focus efforts on the highest radiological ~~hazard~~risk.

7.4. Monitoring should be performed to identify areas ~~in which~~where remedial actions may be necessary and to aid decisions concerning the justification of any remedial actions. If a decision for remediation is made, monitoring should be performed to verify that remedial actions ~~or~~and protective actions have been optimized.

7.5. Monitoring should be undertaken prior to and during the remediation of an area, and ~~where~~when required by the regulatory body or other responsible authority, as part of post-remediation control. The concept of clearance ~~also~~ applies to the management of material originating from remediation activities[41], with the same qualitative and~~,~~ quantitative criteria as for the clearance of material in planned exposure situations (see para. 5.4~~),~~). Likewise, for cleared materials originating from remediation activities, there are no further requirements for monitoring. GSG-18 [32] provides recommendations on the application of the screening values

[41] ~~The same qualitative and quantitative criteria as for clearance of materials from planned exposure situations apply to the management of material originating from remediation activities. GSG-18 [32] provides recommendations on the application of the screening values for recycling or disposal of materials and waste generated during remediation actions after a nuclear or radiological emergency. GSG-15 provides [17] recommendations on the management of residual materials generated during remediation.~~

for recycling or disposal of materials and waste generated during remedial actions after a nuclear or radiological emergency. GSG-15 [12] provides recommendations on the management of residual materials generated during remediation.

7.6. For existing exposure situations resulting from emergencies or past activities in which health follow-up was recommended, the need ~~of~~for individual monitoring should be considered, as appropriate.

RESPONSIBILITIES FOR MONITORING IN AN EXISTING EXPOSURE ~~SITUATIONS~~SITUATION

7.7. The government is required to ensure that responsibilities to assess and manage existing exposure situations that have been identified are assigned (see para. 5.2 of GSR Part 3 [1]). This should include the responsibilities for monitoring. The identification of the responsible party in an existing exposure situation is not always straightforward.[42] ~~.~~ In cases where it is not possible to identify a responsible party, the responsibility should remain with the government.

7.8. ~~Where~~If the operating organization ~~from~~of a past practice ~~which~~that resulted in an existing exposure situation has been identified, this organization should have the responsibility to assess and manage that situation, including performing the appropriate monitoring. ~~Where~~If an existing exposure situation has been identified where there is no current responsible party, the government should assign a responsible body to ensure that the public and the environment are protected, including responsibilities for monitoring, as necessary.

7.9. In relation to monitoring of areas with residual radioactive material, the responsible party should ~~undertake~~take the following actions, as relevant:

(a) Obtain data and conclusions from preliminary studies, where available;

(b) Conduct ~~detailed~~appropriate monitoring ~~for~~to allow the radiological evaluation of the area[43].

In ~~the case where~~addition, if remedial actions have been justified, the responsible party should also take the following actions ~~should be undertaken by the responsible party~~:

[42] For example, for sites with residual radioactivity, the responsible party may be the organization with responsibility for planning and implementing the remediation ~~[17].~~(see GSG-15 [12]).

[43] This might include characterization of the local environment, including compilation of meteorological data for the area of interest, surveys of ambient radiation levels, and sampling and analysis of soil, groundwater, surface water and sediment, as appropriate ~~[17].~~(see GSG-15 [12]).

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(c) Conduct characterization and monitoring to provide basic information for the purposes of developing a remediation strategy, planning the remediation programme and identifying appropriate remedial actions~~.~~;

(d) Conduct monitoring throughout the implementation of the remediation plan.

And finally, once remedial actions have been completed, the responsible party should take the following actions:

(e) Conduct monitoring and verification of the effectiveness of the remediation by comparing source monitoring and environmental monitoring data with the results of the quantitative site model (see para 7.31(r) of GSG-15 [~~17]).~~12]);

(f) Keep records of all the results from the monitoring ~~programmes~~programme, including after the completion of the remedial actions.

7.10. The regulatory body ~~should~~ is required to review the monitoring ~~programmes~~programme (see para. 5.13(c) of GSR Part 3 [1]) and should perform confirmatory monitoring, as appropriate (see para ~~2.33(c) and~~. 2.34(j) of GSG-15 [~~17]~~.12]).

~~OBJECTIVES FOR MONITORING IN EXISTING EXPOSURE SITUATIONS~~

OBJECTIVES OF MONITORING IN AN EXISTING EXPOSURE SITUATION

7.11. The objectives of a monitoring programme ~~for the radiological protection of the public and the environment~~ in an existing exposure situation ~~related to~~involving areas with residual radioactive material should include the following:

(a) To evaluate the radiological conditions and to provide information for estimating doses to members of the public~~.~~;

(b) To assist in the establishment of reference levels;

~~(b)~~(c) To compare measurements with the reference levels and other radiological criteria and to identify areas where more detailed ~~radiation~~ monitoring is needed~~.~~;

~~(c)~~(d) To identify areas in which remedial actions or protective actions ~~are~~may be justified;

~~(d)~~(e) To support identification and justification of appropriate remedial actions~~,~~ and, as appropriate, other protective actions;

~~(e)~~(f) To evaluate and verify the effectiveness of remedial actions~~,~~ and, as relevant, other protective actions;

~~(f)~~(g) To detect changes and evaluate long term trends in radiological conditions in the environment as a result of natural processes and human activities, including remedial actions;

~~(g)~~(h) To provide information to build trust with and ~~for the~~provide reassurance ~~of~~to interested parties, including local communities and members of the public~~.~~;

~~(h)~~(i) To provide information to support decisions related to release of contaminated land from regulatory control and application of restrictions and institutional controls, as relevant[44].

The objectives of monitoring might be different at the various phases of remediation, as defined in GSG-15 [~~17~~12].

SOURCE, ENVIRONMENTAL AND INDIVIDUAL MONITORING IN AN EXISTING EXPOSURE SITUATION

Source monitoring in an existing exposure situation

7.12. In many existing exposure situations, the source is the radioactive contamination being evaluated and ~~can~~it might be spread across a large area that changes over time due to natural processes or disruptive events, which can be either natural or man-made. Source monitoring in such situations can be similar to environmental monitoring.

7.13. Monitoring should assist in the delineation of areas ~~requiring~~needing evaluation or remediation. Within the source area, the monitoring could include sampling and analysis to support the estimation of the migration of the contaminant outside the source area, as action might be needed to control such migration ~~[17].~~(see GSG-15 [12]).

Environmental monitoring in an existing exposure situation

7.14. Information on the radioactive contamination is essential to develop an environmental monitoring programme for areas with residual radioactive material. Where information is available on the source, the monitoring programme should ~~consider~~take that information~~.~~ into consideration. Where information about the source term is absent, ~~or such information is~~incomplete or insufficient and needs to be supplemented, historical records and local surveys

[44] ~~Considerations for~~ Recommendations on environmental survey, surveillance and monitoring related to the release of remediated areas from regulatory control ~~are provided in Ref. [17],~~ including conditions for restricted and unrestricted release~~.~~, are provided in GSG-15 [12].

could be ~~considered~~used to inform the design of an initial screening programme. Results of this initial screening could be compared to the background levels to identify and differentiate the radionuclides present in the environment due to the past activities or emergencies.

7.15. To develop an effective environmental monitoring programme for sites or areas with residual radioactive material, the most significant exposure pathways should be characterized and any likely changes in their significance in the future identified. Changes in the most significant exposure pathways, for example, in cases where remedial actions alter the distribution of radionuclides in the environment (e.g. tree removal, excavation, blasting, diversion of water courses) or where groundwater contamination reaches surface ~~waters~~water over a period of time, should be taken into account in the monitoring programmes. A periodic evaluation of the monitoring programme may be needed to verify that the exposure pathways and magnitude of the risks have not changed.

7.16. Areas with residual radioactive material ~~could involve~~might include sites with multiple contaminants (~~such as chemicals~~e.g. chemical and biological~~). In~~ contaminants). For these ~~cases~~sites, coordination with other ~~competent~~responsible authorities should be considered to obtain a common understanding of the situation and harmonize monitoring activities.

7.17. In ~~those~~ areas where a remediation programme has been conducted, the effectiveness of the ~~remediation~~remedial actions should be verified ~~by~~through environmental monitoring, and a programme for monitoring and surveillance should continue after remediation has finished, as necessary.

External exposure

7.18. Where large areas ~~are required~~need to be evaluated, large- scale measurements of external dose rates should be considered. Ideally, different monitoring methods should be used in parallel, in accordance with the level of radiological contamination, to provide comprehensive information on the situation. For example, aerial monitoring can be used to cover wide areas in a short time; measurements at fixed locations or walking surveys can provide a more precise measurement of dose rates at specific locations. All the data obtained using different methods should be integrated to provide a complete picture of the contamination.

7.19. In areas where the contamination is uneven, dose rates can vary greatly from one location to another. The monitoring programme should take into account the non-uniform ~~distributions~~distribution of radionuclides across the area monitored, seasonal changes in the dose rate due to weather conditions (e.g. snow cover ~~or precipitations~~, precipitation) and the

reduction of dose rates in urban ~~environment~~environments due to paved areas and to shielding provided by the buildings.

Internal exposure

7.20. In areas with residual radioactive material, the inhalation of resuspended radionuclides from the ground ~~may~~might cause ~~a~~ significant exposure. In these cases, sampling and analysis of airborne radionuclides should be regularly performed. Measurements should also be taken to determine the amount of dust generated by wind or by human activities, such as agricultural activities or traffic. If measurement data are unavailable or insufficient, radionuclide concentrations in air can be estimated from concentrations in soil by using a resuspension model. In areas with significant existing contamination, the resuspension of radionuclides~~, such~~ (e.g. as ~~those due to~~a result of wild fires) should be considered. In the case of areas contaminated with ~~radon progeny~~natural radionuclides, such as naturally occurring radioactive material (NORM) legacy sites, public exposure due to radon indoors can be an exposure pathway of concern and should also be considered. ~~Ref. [22~~SSG-32 [17] addresses the protection of the public against exposure indoors due to radon.

7.21. If the radioactively contaminated area extends to agricultural land, samples of all major animal products and crops ~~grown~~(e.g. vegetables, milk, meat) produced in the area should be regularly ~~collected~~sampled and ~~analyzed~~analysed for their radionuclide concentrations ~~(e.g. vegetables and milk and meat).~~. The environmental monitoring should also include wild food products (e.g. game, mushrooms ~~and,~~ berries) ~~from the contaminated area, if~~where it is known ~~that these foods~~they are ~~typically~~ consumed. Drinking water should ~~also~~ be monitored if a source of drinking water is present in the contaminated area or could be contaminated by the migration of radionuclides. Further information on the assessment of public health risks from radionuclides in drinking water is provided in Ref. [~~49~~51]. Further ~~guidance~~information on the monitoring of radionuclides in the diet is given in ~~Ref. [19] and in Safety Reports Series No. 114, Exposure due to Radionuclides in Food Other Than During a Nuclear or Radiological Emergency. Part 1: Technical Material [50~~Refs [14, 15]. Activity concentrations of radionuclides in soil and sediments could also be monitored to estimate the migration and accumulation of radionuclides in these environmental media, which could be used to predict radionuclide concentrations in food products. The design of the environmental monitoring programme should ensure that important routes of radionuclide migration are considered, such as ~~migration of radioactivity~~ through ~~the~~ soil~~,~~ or groundwater, or into biomass.

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7.22. In areas with significant radioactive contamination, radionuclide activity concentrations in environmental media should be measured at an adequate sampling frequency to establish whether the activity concentrations comply with the reference levels established for the existing exposure situation (see paras 5.2, 5.4, 5.8 and 5.9 of GSR Part 3 [1]).

Individual monitoring in an existing exposure situation

7.23. Individual monitoring of the public may be considered appropriate in the context of an existing exposure situation resulting from an emergency or past activities: if so, such monitoring should be appropriately justified. Individual monitoring should be conducted if medical follow-up is ~~deemed~~ necessary and may also be useful as a means of reassuring individuals and ~~to verify~~verifying the dose assessments that have been made ~~[43].~~(see Ref. [38]).

7.24. Individual monitoring in an existing exposure ~~situations~~situation should consider the need ~~of~~for measurements of ~~individual~~internal and external ~~and internal~~ exposures ~~[44]~~of individuals (see Ref. [45]) and should provide input for ~~the assessment of~~assessing the committed dose. Individual monitoring should take into account the presence of long ~~lived~~lasting radionuclides and their possible build up in the environment.

PUBLIC DOSE ASSESSMENT ~~IN AN EXISTING EXPOSURE SITUATION~~IN AN EXISTING EXPOSURE SITUATION

7.25. For ~~normal~~routine discharges, the doses calculated for the representative ~~persons~~person as part of the authorization process are often conservative. In contrast, the doses calculated for the representative ~~persons~~person in existing exposure situations should be defined on the basis of 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 appropriate allocation of resources. In particular, where the purpose of the dose assessment is to determine if remedial actions are justified, the doses to the representative person should be estimated avoiding overconservative assumptions. In ~~sites with highly heterogeneous~~ areas where there is significant variation in the contamination~~, the dose assessment could also consider potential~~ distribution, exposures that are not certain to occur should be assessed, as appropriate. [45].

[45] ~~Sometimes, the estimated doses resulting from contaminated areas may be low when the decision to manage the situation is taken. Nevertheless, depending on the situation, potential transport and special characteristics of the source (for example,~~ In certain situations, (e.g. in cases of heterogeneous contamination, such as discrete radioactive particles) the transfer and characteristics of the source could potentially lead ~~in the future~~ to higher exposures. These exposures are not certain to

7.26. When transfer factors and concentration factors are selected, they should preferably be site specific and appropriate to the local food pathways and environmental conditions, including the soil type, soil chemistry, and the mineral content of fresh water ~~[51].~~(see Ref. [52]).

7.27. The local food consumption rates and fractions should preferably be obtained by means of site specific studies. The effects of water treatment and food processing on reducing radionuclide concentrations should be considered in estimating the dietary intakes. Additional recommendations on undertaking dose assessment from monitoring results are provided in Section 9.

~~INTERPRETATION, REPORTING AND COMMUNICATION~~INTERPRETATION, REPORTING AND COMMUNICATION OF MONITORING RESULTS FOR AN EXISTING EXPOSURE SITUATION

7.28. The monitoring results should be compared to relevant radiological criteria for the existing exposure situation. The estimated dose to the representative person should be compared to the reference level established for the existing exposure situation. In all such comparisons, uncertainties in sampling, measurements and calculations should be taken into account (see paras 9.20–9.22).

7.29. For practicality, derived criteria[46] that correspond to the relevant dose criteria and that can be easily measured (e.g. activity per unit area, per unit weight or per unit volume; gamma dose rates at 1 m height for a defined surface) may be established ~~when deemed~~as necessary ~~[17].~~(see para. 3.14 of GSG-15 [12]).

7.30. Reports of the results of the source monitoring and environmental monitoring programmes should be produced at periodic intervals, at least once per year, by the responsible party to monitor the evolution of radiological conditions and, in situations when remediation was justified and implemented, to verify the effectiveness of the ~~of~~ remedial actions. These reports should describe the monitoring results and the associated dose assessment to inform conclusions with respect to protective actions or remedial actions, as appropriate.

7.31. Estimated doses to the public after remediation has been completed should be compared to reference levels or other relevant end-point criteria in the approved remediation plan to

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occur, ~~so they are called 'potential exposures'. These potential exposures from contaminated areas should be assessed to define an appropriate remediation process.~~however. It is important in these ~~cases~~situations to identify the ~~potential~~ exposure pathways and to determine the probability of exposures that could occur, together with the magnitude of the detriment.

[46] The term 'derived criteria' is related to the concept of 'derived reference levels' ~~established~~, defined in Ref. ~~[52]. A derived reference level is "~~[53] as a numerical value expressed in an operational or measurable quantity, corresponding to the reference level set in dose~~".~~.

determine if additional actions to restrict public exposure are necessary, and ~~to demonstrate~~ if ~~land~~the area can be released from regulatory oversight.

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8. DESIGN AND IMPLEMENTATION OF A MONITORING PROGRAMME

~~DESIGN OF A MONITORING PROGRAMME~~

DESIGN OF A MONITORING PROGRAMME

8.1. A monitoring programme should be designed using a systematic approach. The characteristics of the exposure situation (planned, emergency or existing), and the aspects of relevance that may impact the monitoring activities, including prior knowledge of the site and background monitoring data[47], should be taken into account. Background monitoring includes the investigation done to establish baseline levels of radiation and/or radionuclide concentration to be compared against subsequent conditions.

8.2. The ~~radiation~~ monitoring programme should follow a graded approach and the types of monitoring should be appropriate to the expected level of anticipated risk associated with the source, based on the likelihood of exposure and possible radiological consequences ~~to~~for the public[48] ~~[2, 17]~~ and the environment. Table 2 summarizes the relationship between the types of exposure situation and the types of ~~radiation~~ monitoring ~~required~~recommended.

TABLE 2. TYPES OF MONITORING RECOMMENDED FOR DIFFERENT EXPOSURE SITUATIONS

Exposure situation		Type of monitoring		
		Source monitoring	Environmental monitoring	Individual monitoring[a]
Planned	Exempted, cleared and notified practices~~/~~ or sources	Not ~~required~~recommended	Not ~~required~~recommended	Not ~~required~~recommended
	Registered practices~~/~~ or sources	~~Required~~Recommended	Not ~~required~~recommended	Not ~~required~~recommended
	Licensed practices~~/~~ or sources	~~Required~~Recommended	~~Required~~Recommended	Not ~~required~~recommended
	Multiple sources	~~Required~~Recommended	~~Required~~Recommended	Not ~~required~~recommended
Emergency		~~Required~~Recommended	~~Required~~Recommended	As appropriate

~~[47] Background monitoring is the investigation done to establish baseline levels of radiations and/or radionuclides concentration to be compared against subsequent conditions.~~

[48] In all exposure situations, conceptual and quantitative site models need to be developed, as relevant, to provide an understanding of important radionuclides and pathways of exposure ~~[2, 17].~~(see GSG-10 [2] and GSG-15 [12]).

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Existing	Areas with residual radioactive material	~~Required~~Recommended	~~Required~~Recommended	As appropriate

[a]For members of the public.

8.3. Although the objectives of a monitoring programme are expected to vary between planned exposure situations, emergency exposure situations and existing exposure situations, in all cases, monitoring should provide information and data for assessing the radiological impact ~~to~~on the public and the environment. The following elements should be taken into account in the design of any monitoring programme:

(a) Radioactive inventory and radionuclide composition of the source~~.~~;

(b) Spatial and temporal characteristics of the radiation fields around the source~~.~~;

(c) Radionuclide activities being released per unit of time (i.e. release rates~~).~~);

(d) Exposure pathways[49]~~. Figure~~ (Fig. 1 illustrates the pathways by which an individual ~~may~~might be exposed following the discharge of radionuclides to the atmosphere ~~and the~~, surface water or groundwater~~, respectively.~~);

(e) Possible contributions from other surrounding facilities or activities to environmental radioactivity~~.~~;

(f) Geographic characteristics at the site, presence and characteristics of receptors (e.g. demography, living habits and conditions, flora and fauna), and the uses of the land;

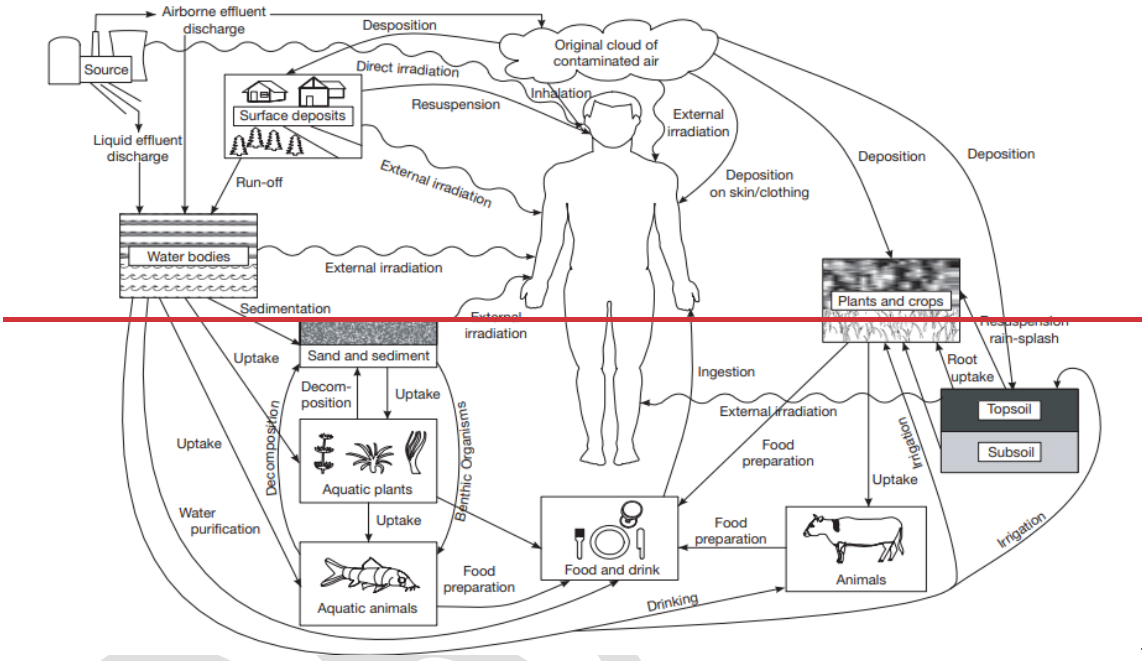
(g) Significance of the ~~calculated~~estimated dose~~(s)~~ to the representative person~~(s);~~;

(h) Longevity of the contamination creating radiological risks.

8.4. Information on the characteristics of the radioactive source(s) (in planned exposure situations), potential accidental radioactive releases (in emergency exposure situations), and historical information on the source (in existing exposure situations) should be obtained and considered in the design of monitoring programmes.

[49] Exposure pathways by which releases could give rise to exposure of members of the public are listed in GSG-10 [2]. Depending on the exposure scenarios and the site characteristics, not all the exposure pathways listed in GSG-10 [2] may need to be considered in the design of the monitoring programme. Therefore, some exposure pathways may be excluded from the design of the monitoring programme on the grounds that the doses associated with them are evaluated to be non-existent or negligible.

8.5. The scale and extent of monitoring programmes should take into account the information from safety assessments[50] (for planned exposure situations) and also from the radiological hazard assessment (for emergency exposure situations~~) which~~). This information can assist in defining the areas of the environment potentially impacted, the radionuclides involved, and the dose to the representative person in each area. This helps to ensure that the design of the monitoring programme is commensurate with the level of expected radiation risk.



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

8.6. ~~The characteristics~~design of the monitoring programme (~~for example, the~~e.g. frequency of ~~the~~sample collection ~~of samples~~) should ~~consider the~~take into consideration expected seasonal variations in the environmental media and the resulting variation in the associated exposure. Non-homogeneous distribution of radionuclides should also be considered. ~~Non-normal~~Reporting of any unusual distribution of monitoring data should trigger a review of the sampling frequency. Further recommendations on the design of monitoring programmes for

[50] The safety assessment can assist in defining the extent of the impacted area in which monitoring should be conducted in a planned exposure situation. For emergency exposure situations, the hazard assessment can provide information to define the area to be monitored. For existing exposure situations, the characterization can provide such information.

planned, emergency and existing exposure situations are presented in Sections 5, 6 and 7, respectively.

Design of source monitoring programmes

8.7. Source monitoring programmes should be designed to monitor ~~a~~ the direct radiation from a particular source ~~of radiation or~~and the release of radioactive material ~~arising from a facility or activity~~to the environment.

8.8. The characteristics of the source and the mode of any release into the environment should be considered in the design of a monitoring programme. For example, in planned exposure situations, airborne effluents are often discharged continuously; in contrast, liquid effluents might be stored and subsequently discharged from tanks in batches. In the case of emergency exposure situations, in which a loss of control of the source may result in an unplanned and uncontrolled release of radioactive material to the environment, direct monitoring of the source may be difficult (or even impossible) ~~and~~so the magnitude of the release may have to be estimated by using measurements in the environment. Source monitoring in areas with residual radioactive material should take into account that the source of radiation can either be a local source or be diffused over a large area in the environment, uniformly or heterogeneously.

8.9. Additional supporting information that should be considered in the design of a source monitoring programme includes information on the physical and chemical form (~~i.e.~~ which can affect the migration of radionuclides), temperature and flow rates of the release, as well as meteorological and hydrological data and information on the environment.

Design of environmental monitoring programmes

8.10. Environmental monitoring programmes should take into account the characteristics of the source and the mode of any release into the environment together with features of the environment to be monitored, such as the characteristics of the site that might affect the dispersion of radionuclides in the environment (e.g. geology, hydrology, meteorology, morphology, biophysical characteristics), as well as demography, living habits and conditions, land use and other activities, including agriculture, food production and other industries.

8.11. When monitoring ~~of~~ external radiation levels in inhabited areas ~~is performed~~, the dose rate should be measured in ~~typical areas~~the zones that are accessible to the public, such as close

to dwellings, public buildings, production areas, gardens and recreation areas (e.g. beaches, parks).

8.12. When designing the monitoring programme, the shielding provided by buildings[51] in the area contaminated with radioactivity should be taken into account and detailed data on dose rates in living environments should be considered, wherever possible, for the accurate assessment of the external dose to the public. This could be achieved by measuring dose rates both outside and inside dwellings, giving special attention to ~~those~~ individuals who~~,~~ might receive the highest dose because of their habits ~~may receive the highest dose.~~(e.g. farmers).

8.13. ~~The results of the environmental monitoring programme should enable the verification of the predicted doses to the public (and, as necessary, exposures to flora and fauna) using dispersion models and data from source monitoring. For this purpose, environmental~~Environmental samples should be taken, and measurements made of the radionuclides that are expected to provide significant contributions to doses ~~should be made~~ at a number of locations selected on the basis of the predicted dispersion pattern of the discharges and on the relevant exposure pathways. In addition, the sampling of food products should be ~~determined~~decided on the basis of knowledge of the habits and consumption patterns of the representative person.

Design of individual monitoring programmes for the public

8.14. Individual monitoring for members of the public may be appropriate in certain emergency exposure situations (see paras 6.~~22~~21–6.~~26~~24) and in existing exposure situations ~~resulting from emergencies~~ in which health follow-up is recommended (see paras 7.23–7.24). When properly justified, individual monitoring for internal exposure may include measurements of radionuclides in individual organs or in the whole body using in-vivo or in-vitro bioassay techniques and analysis~~.~~. Individual monitoring for external exposure should be based on measurements using individual dosimeters~~.~~ or external contamination monitoring. Individual monitoring programmes should be adapted to the situation, in particular to the size of the population to ~~control~~monitor.

[51] Shielding is relevant for radiation from anthropogenic sources, while the natural background can be different ~~in~~ indoors and outdoors. In some cases, for example, dose rates indoors due to building materials ~~may~~might become higher than outdoors.

~~INFORMATION TO SUPPORT THE DESIGN OF A MONITORING PROGRAMME~~

INFORMATION TO SUPPORT THE DESIGN OF A MONITORING PROGRAMME

8.15. Baseline monitoring data and data from control measurements, as appropriate, should be collected over a period ~~as~~ deemed necessary by the regulatory body or other relevant authority to enable the understanding of spatial and temporal trends (e.g. over at least two years). The ~~information~~data should be documented and should be updated as necessary if changes due to other sources affecting the area under consideration (e.g. other facilities and activities ~~or~~, accidental releases) are expected.

8.16. For planned exposure situations ~~(~~and existing exposure situations~~),~~, the hydrological characteristics[52] of the aquatic environment and the meteorological characteristics of the atmosphere into which radionuclides are expected to be released should be monitored in the pre-operational stage (or during characterization studies) and periodically verified in the operational stage and while the exposure situation remains. For emergency exposure situations, where possible, studies performed in the operational stage should be used to identify the general characteristics of the environment that might affect the fate of accidental releases and ~~which~~that should be considered in the monitoring programme.

8.17. The local water sources and water cycle ~~should be monitored:~~(including precipitation and evaporation, local surface ~~waters~~water and ~~groundwaters~~groundwater and their ~~connections, and inputs and outputs by main rivers.~~interconnections) should be monitored. Characteristics of soils such as texture, structure, porosity, chemistry and colour ~~should~~can also be studied to ~~predict~~ help evaluate any spatial and temporal changes in the radionuclide transfer and migration through the soil to groundwater or vegetation.

8.18. Environmental monitoring programmes should take account of the distribution and habits of the population in the vicinity of the site or area, and other factors that may be relevant to estimate doses, such as age, food consumption rates and the fractions locally obtained, location of drinking water sources, and human activities. Land and water use, such as local ~~practices of~~ agriculture~~,~~ and aquaculture practices should be considered. Particular attention should be paid to the characteristics of ethnic and cultural minorities and indigenous peoples that may reside in the area.

[52] Examples of hydrological characteristics that might be considered in monitoring programmes are water fluxes, water depths, turbulence and other features that affect the mixing of radioactive releases in the receiving environment, including seasonal and inter-annual variations.

8.19. In an emergency exposure situation, knowledge of the meteorological and, in some scenarios, the hydrological conditions that might be present during a radioactive release are essential to estimate or predict the dispersion of radionuclides. Parameters such as the wind speed, wind direction, stability of the mixing layer of the atmosphere and magnitude and extent of any precipitation should be measured in the event of an airborne release: this type of information is useful to predict the dispersion of radionuclides and to understand the extent of potential future impacts.

~~CONTENT OF~~ CONTENT OF A MONITORING PROGRAMME

A ~~MONITORING PROGRAMME~~

8.20. ~~Monitoring~~monitoring programmes should describe the basis for ~~their~~its design, including the rationale for the media to be sampled, sampling locations, sampling strategy and analytical methods. The following should be specified in a monitoring programme ~~should include the specification of the following~~:

(a) Parameters to be measured;

(b) Environmental media to be monitored (in case of environmental monitoring);

(c) Locations of in- situ measurements and sampling;

(d) Frequency and timing of ~~the~~ measurements or sample collections;

(e) Sampling procedures, sample preservation, sample ~~pre-treatment~~pretreatment and sample analysis techniques~~;~~, including reporting values.

(f) Equipment used;

(g) ~~The personnel~~Personnel responsible for each task;

~~(g)~~(h) Investigation levels to detect unusual values in the monitoring data;

~~(h)~~(i) Quality assurance procedures.

8.21. The monitoring programme should also provide information on procedures for managing and interpreting the data, assessing data quality~~,~~ and reporting the results, including uncertainties. It should include a process for ongoing programme evaluation, a process ~~to revise~~for revising and ~~modify~~modifying the ~~monitoring~~ programme as needed, and a process for ensuring appropriate qualifications and training of personnel undertaking the monitoring.

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~~TECHNICAL CONDITIONS FOR MONITORING PROCEDURES~~

TECHNICAL CONDITIONS FOR MONITORING PROCEDURES

Sample collection

8.22. Source monitoring and environmental monitoring should be aimed at obtaining representative values. Representativeness in this context means that the sample should reflect the conditions of the source or the environment from which it is taken. In general, activity levels in discharges or in the environment are subject to spatial and temporal variability and the sampling procedures should be formulated to consider such variabilities ~~[53].~~(see, e.g., Ref. [54]).

8.23. The sampling frequency should be established ~~based~~ on the basis of the quantity ~~that is~~ to be measured, the precision ~~that is~~ needed, the time dependence and the variability of the quantity ~~to be measured~~[53]. In general, sampling should be more frequent ~~for monitoring with increasing~~the higher the spatial and temporal variability~~, for~~. For example ~~the~~, more frequent sampling is needed for monitoring ~~for~~ radionuclides with short half-lives and ~~monitoring of~~ food ~~with~~ for which there is a short time ~~lapse~~period between harvesting and consumption.

8.24. To ~~provide for~~enable representative sampling in the environment, various methods ~~could~~and statistical schemes can be used. Specific procedures are suggested in Ref. [~~54~~55]. Although these procedures might not eliminate the uncertainty associated with activity levels in environmental samples, they may reduce the uncertainty and enable it to be quantified by statistical ~~means~~analysis. Table 3 summarizes the main sampling approaches ~~[54]~~ and their features.

8.25. Sampling procedures should be developed to ensure that each sample is representative of the sampled medium, collected samples are spatially independent, the sampling procedure is reproducible, and ~~that~~ sample integrity is maintained. Procedures should be ~~included~~in place for ~~addressing the~~ quality assurance in sampling and the analysis of uncertainties ~~originated~~originating from sampling in reported results (e.g. split samples, field replicates, field blanks), and for proper sample tracking through a ‘chain-of-custody’ process. Technical

[53] Data on variability in the discharges from planned exposure situations can be obtained from the facility safety assessment report or operating information~~, data~~. Data on environmental variability can be obtained from prior studies, including ~~pre-operational~~preoperational and early operational monitoring.

considerations for sampling that might apply to facilities in planned exposure situations are presented in the ~~annex~~Annex.

TABLE 3. SAMPLING APPROACHES FOR ENVIRONMENTAL MONITORING [~~54~~55]

Sampling ~~Approach~~approach	Description	Comment
Judgmental sampling	Sample is taken based on the understanding of the environment and exposure pathways	Increased probability of biased sampling; representativeness cannot be quantified
Simple random sampling	Any sample has the same probability of being included	Provides samples that are representative of the sampling area; problems might arise if the area is not homogeneous
Stratified sampling	The sampling area is divided into parts (strata) that are known to be more homogeneous; simple random sampling is then applied to the strata	Requires knowledge of the inhomogeneity of the sampling area; might lead to bias if the strata are not properly estimated
Systematic sampling	Starting from a randomly selected point, sampling follows a strict predefined sampling grid	In comparison with random sampling, easier to implement in practice; spatial pattern, spatial trends or correlation ranges of contamination data might be unnoticed

Measurements

8.26. As part of monitoring programmes, measurements may be performed at the source, in the environment and in laboratories. Monitoring at the source can be performed through on-line monitoring or sampling and laboratory measurements. On-line monitoring should provide a continuous indication of the activity of radionuclides in the discharge in real time or near real time and typically involves the ~~measurements~~measurement of dose rate or gross activity. Continuous flow measurement should be performed to estimate the release rates of significant radionuclides. Procedures for continuous measurement systems should include a regular schedule for instrument calibration and maintenance, as well as performance checks on the analysis systems.

8.27. Field measurements may include measurements performed in~~-~~ situ by gamma spectrometry; measurements of aerosols or gases at fixed monitoring stations with or without gamma spectrometry capabilities; measurements with alpha and beta monitors; measurements of dose rates; and measurements of surface contamination. Field measurement procedures

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should be established and validated to ensure that they are reproducible and representative of conditions at the time of sampling~~.~~ and deliver the necessary accuracy and precision.

8.28. Measurements of samples in laboratories should be used to characterize the activity concentration of radionuclides in the source and the environment. For the assessment of individual doses, dosimetry laboratories should ~~assess~~use measurements from individual dosimeters and/or bioassay samples (see Table 4).

8.29. If monitoring data are used to verify compliance with a dose limit or a dose constraint, or are compared to an operational limit or reference level, the detection limit of the analytical procedure and equipment should be selected so as to enable measurements to be made at levels that are ~~substantially~~ lower than the limits or levels against which the results are to be compared. This could involve, for example, ~~involve use of~~using more sensitive equipment, collecting a statistically significant number of samples, improving measurement statistics and~~/or~~ increasing counting times. The contribution of multiple radionuclides to the total dose to the public should also be considered in the determination of a fit-for-purpose detection limit.

8.30. The equipment to be used for measurements should be selected taking into account the purpose for which it is to be used. In particular, it should take into account the specific radionuclides that ~~may~~might be present, both in normal operation and in accident conditions. For example, nuclear power plants ~~may~~might discharge a large number of radionuclides with half-lives ranging from seconds to thousands of years, whereas fuel fabrication facilities discharge a much narrower range of radionuclides with no short lived radionuclides.

8.31. Table 4 presents examples of monitoring parameters and their respective sampling and measurement techniques that should be considered for different types of monitoring. Technical considerations for measurements that might apply to facilities in normal operation are presented in the ~~annex~~Annex.

TABLE 4. EXAMPLES OF MONITORING PARAMETERS AND APPROACHES TO SAMPLING OR MEASUREMENT

Monitoring ~~Parameter~~parameter	**Sampling/~~Measurement~~measurement approach**
Source monitoring	~~*Source monitoring*~~
External dose rate at the source [a]	Stationary on-line equipment, continuous measurement
Radionuclide activity concentrations of gases in released air	Stationary on-line equipment, continuous measurement
Radionuclide activity concentrations of aerosols in released ~~air~~ [b]air[b]	Stationary on-line equipment and/or aerosol filter sampling; continuous measurement and analysis for specific radionuclides and/or total alpha or total beta activity
Radionuclide activity concentrations	Stationary on-line equipment and/or sampling; continuous

Monitoring ~~Parameter~~parameter	Sampling/~~Measurement~~measurement approach
in released water [b]	measurement and analysis for specific radionuclides and/or total alpha or total beta activity
Environmental monitoring	~~*Environmental monitoring*~~
External dose rate ~~over ground~~[c]above ground[c]	Mobile or stationary equipment; discrete or continuous measurement
Radionuclide activity concentrations of aerosols in air above ground	Discrete or continuous air filter sampling; analysis for specific radionuclides
Radioiodine activity concentration in air	Discrete or continuous air filter sampling; activated charcoal filters
Radionuclide activity concentrations in dry~~/~~ or wet deposition	Planchette sampling; discrete or continuous sampling[d]; collector for dry~~/~~ or wet deposition; analysis for specific radionuclides
Radionuclide activity concentrations in soil	Surface soil sampling; analysis for specific radionuclides and/or in~~-~~ situ gamma spectrometry Vertical soil sampling at specified depths; analysis for specific radionuclides
Radionuclide activity concentrations in food and feed, biota, water~~,~~ (surface water, groundwater and drinking water) and sediment	Field sampling; analysis for specific radionuclides
Surface contamination	Mobile equipment; discrete measurements by surface contamination monitors and/or in-situ gamma spectrometry
Individual monitoring	~~*Individual monitoring*~~
Radionuclide activity concentrations in human organ or body	In~~-~~ vivo or in~~-~~ vitro bioassay; analysis for specific radionuclides
External dose	Individual dosimeters

[a] External dose could result from different penetrating radiations, such as photons, neutrons and high-energy charged particles.
[b] If discharge limits are for gross alpha/beta activity, then routine analysis for specific radionuclides might not be necessary.
[c] Typically measured 1 m above ground

~~QUALITY ASSURANCE~~

[d] For discrete samples, the sampling interval is determined on a case-by-case basis.

QUALITY ASSURANCE

8.32. A quality assurance programme as part of the management system ~~[55]~~(see IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [56]) should be an integral part of a monitoring ~~programmes~~programme for protection of the public and the environment. Quality assurance should be used to provide for a consistent approach to all activities affecting quality, including, where appropriate, verification that each task has met its objectives and that any necessary corrective actions have been implemented.

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8.33. ~~An adequate~~A quality assurance programme should ~~be designed to satisfy,~~ as a minimum, meet the ~~general~~ requirements established by the regulatory body or other relevant authority for quality assurance in the field of radiation protection. ~~Generally, the~~The quality assurance programme should be designed to ensure that:

(a) The organizational structure, functional responsibilities, levels of authority and interfaces for those managing, performing and assessing the adequacy of work are defined;

(b) All measures to manage the monitoring programme, including planning, scheduling and resource considerations, are implemented;

(c) Work processes and procedures are established and understood;

(d) Regulatory requirements relating to source monitoring, environmental monitoring and individual monitoring are met;

(e) Appropriate methods of sampling and measurement are used;

(f) ~~Selection of~~Appropriate environmental media, ~~the~~ locations for sampling and measurement and ~~the associated~~ sampling frequency are ~~appropriate~~selected;

(g) Interlaboratory comparisons of methods and instruments are conducted at the national or international level ~~for methods and instruments are in place~~;

(h) Quality control mechanisms and procedures for reviewing and assessing the overall effectiveness of the monitoring programme are in place.

8.34. The quality assurance programme should cover the following:

(a) ~~The design~~Design and implementation of monitoring programmes, including the selection of suitable equipment~~;~~ and of sampling locations and procedures, and ~~their~~the documentation~~;~~ of the selection process;

(b) ~~The maintenance~~Maintenance, testing and calibration of equipment and instruments;

(c) ~~The uncertainty~~Uncertainty analysis;

(d) ~~The requirements for record~~Record keeping;

(e) ~~Robust chain~~Chain of custody;

(f) ~~Description of the information~~Data management system;

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~~(e) The qualification~~(g) Qualification and training of personnel, including the necessary theoretical knowledge, the relevant legislation and regulations, and the appropriate technological tools to perform tasks related to the monitoring programme.

8.35. Analytical laboratories performing sample measurements should be qualified to ~~make~~perform the measurements assigned and have the ~~capacity~~capability to report ~~the~~accurate results ~~within the specified time and budget~~.

Data quality

8.36. Data should be of sufficient quality to meet the objectives of the monitoring programme and the specific purpose of the measurement. Data quality should be evaluated against predefined data quality objectives[54], as specified in the programme design. These objectives might include targets for detection limits, or limits on precision and accuracy ~~as determined from results for associated quality~~of measurement (see Ref. [54]). Quality control samples ~~such as~~(e.g. blanks, duplicates, certified reference materials, ~~if available,~~ and matrix spikes) and external quality control (e.g. intercomparison, participation in proficiency tests) should be included in the monitoring programme and used to access whether the data meet the pre-determined data quality objectives.

~~PROGRAMME EVALUATION AND REVIEW~~

MONITORING PROGRAMME EVALUATION AND REVIEW

8.37. Monitoring programmes should be evaluated and reviewed regularly, with the frequency established by the regulatory body or, in the case of planned exposure situations, when changes are anticipated in the operations of the facility or conduct of the activity, which affect the ~~radionuclides~~radionuclide composition or magnitude of the discharges~~, to ensure~~. This evaluation and review should ensures that ~~they are~~the monitoring programme is producing data that are sufficient to meet the objectives of the programme and that no significant routes of discharge or environmental transfer ~~or~~, and no significant exposure pathways, have been

[54] Data quality objectives are a set of programme performance or data acceptance criteria used to evaluate the quality of a set of data or of individual data values. ~~Data quality objectives might include targets for detection limits, precision, and accuracy of measurement [53]. Quality control samples (such as blanks, duplicates and matrix spikes) and external quality control (such as intercomparison, participation in proficiency tests) should be included in the monitoring programme and used to assess whether the data meet pre-determined data quality objectives.~~

overlooked. If ~~this is~~they have, the~~ case,~~ causes should be identified, and changes in the monitoring programme should be implemented.

8.38. The monitoring objectives may change over the lifetime of a facility in planned exposure situations or as an emergency exposure situation or an existing exposure situation evolves, and the monitoring programmes should also ~~change~~be updated to reflect these ~~modifications~~changes.

8.39. If there are significant changes ~~occur~~ in the operational conditions, environmental conditions~~,~~ or regulatory requirements, which may have an impact on the monitoring ~~programmes, these changes should trigger their reevaluation and review.~~programme, the programme should be reviewed. Any ~~changes made~~decision to make a change to the monitoring programme should be documented ~~to provide a record of decisions and~~, along with evidence ~~it~~that the programme continues to be fit for purpose.

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9. DATA MANAGEMENT, ANALYSIS, AND INTERPRETATION, AND REPORTING OF MONITORING RESULTS

~~DATA MANAGEMENT FOR MONITORING PROGRAMMES~~

DATA MANAGEMENT FOR MONITORING PROGRAMMES

9.1. A data management system should be established to ensure the integrity of the monitoring data, and to facilitate assessment of data quality, the interpretation of results and traceability of data over time (e.g see Ref. [~~56~~57]). Measured values should be recorded with their units, including an indication of fresh or dry weight for mass-based measurements.[55]~~.~~

9.2. Detailed records of the measurements of radiation dose rates, measurements of radionuclide activity concentrations in gaseous and liquid releases and measurements of other physical and chemical parameters or quantities that are correlated with the radionuclide measurements should be retained. Metadata to be recorded should be based on the specific requirements of the monitoring programme and should include locations and times of measurements and sampling~~;~~, discharge points, sampling periods, radioanalytical procedures and instruments used, instrument calibration data, and measurement uncertainties.

9.3. The data recorded should also include information on the data quality that are associated with the instruments and sample, such as: detection limits~~;~~; data for blanks, duplicates~~;~~ and matrix spikes~~;~~; instrument calibration data~~;~~; background counts for background correction; and results of intercomparisons.

9.4. ~~To allow auditing of~~The government or the regulatory body should specify a retention period for monitoring data~~;~~. Records, including records ~~should be kept~~ of all relevant ~~intermediate~~ observations in the course of the analysis and of the parameters used for the calculation of the data reported~~. Records~~ should ~~also~~ be kept ~~of any investigations concerning unusual environmental occurrences~~for the established period.

9.5. Results of individual monitoring and related information should be carefully managed since they contain personal and health related information.

[55] In bulk soil sediments, units are typically on a dry mass basis, whereas for food, units are typically on a fresh mass basis. For these media, moisture content is a useful measurement, which enables data conversion from one mass basis to another. In cases where samples are incinerated, the dry mass-to-ash mass conversion coefficient is also useful to convert data from one mass basis to another.

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~~DATA ANALYSIS~~DATA ANALYSIS AND ~~INTERPRETATION~~INTERPRETATION

9.6. Data analysis and interpretation should be consistent with the objectives that were specified in the programme design. ~~The data~~Data analysis might include, for example, comparison of individual results (or calculated ~~means~~mean values) with relevant criteria, comparison of mean values between affected areas and other areas (e.g. areas used for control measurements), or evaluation of trends for temporal and spatial variations. Unexpected results should be investigated to determine if any changes in the monitoring programme are needed.

9.7. A preliminary evaluation should be undertaken to ensure that the data are suitable for the planned data analysis. Graphical presentations of data are also useful for identification of outlier values. An investigation of the quality of data not meeting expectations should also be performed.[56] ~~.~~

Data interpretation

9.8. The results of a monitoring programme, whether for source, environmental ~~and/~~or individual monitoring, or a combination thereof, should be presented in terms of the following:

(a) Radiation levels at the source of the release, and activity concentrations of radionuclides in the release;

(b) Radiation levels in the environment and activity concentrations of radionuclides in environmental media;

(c) The doses received by the public derived from a dose assessment based on the measurement data, such as the annual doses received by the representative person living in the vicinity of a nuclear facility from routine discharges, or the projected doses received by individuals due to an accidental release.

9.9. The interpretation of the results of monitoring should be an integral part of the monitoring programme. The assumptions used in the processing and interpretation of the monitoring results, and the uncertainties in the results, should be part of the information collected and recorded. The description of the interpretation of the results should be

[56] ~~The~~A preliminary evaluation of the data can be helpful in ~~selection of~~selecting statistical tests that are appropriate to the data (e.g. parametric or non-parametric hypothesis testing) or in selecting appropriate data transformations to meet the assumptions of the statistical method.

documented in an open and transparent manner, including the assumptions used in interpreting the results.

9.10. For the interpretation of the measurements, correlation between different types of monitoring should be studied, for example:

~~(a)~~ Results of source monitoring ~~and,~~ of environmental monitoring~~;~~

~~(b)~~(a) ~~Results~~ and of individual monitoring, if applicable;

~~(c)~~(b) Measurements of radiation levels and of radionuclide concentrations;

~~(d)~~(c) Measurements of integrated parameters and of individual radionuclides;

~~(e)~~(d) In situ gamma surveys and sample measurements;

~~(f)~~(e) Routine and periodic measurements;

~~(g)~~(f) Measurements of other parameters relevant for dose assessment (e.g. meteorological and hydrological conditions).

9.11. When different types of monitoring (i.e. source, environmental ~~or~~and individual) are performed, there should be ~~an~~ effective ~~liaison~~coordination between the respective monitoring programmes~~,: information~~. Information obtained from one programme may contribute to a better understanding of the ~~other~~another.

Dose assessment from monitoring results

9.12. Information from monitoring programmes should be used to assess radiation doses to members of the public for comparison with criteria established by the regulatory body or other authority. Such criteria are usually specified in terms of annual dose limits or dose constraints (for planned exposure situations) or as reference levels (for emergency and existing exposure situations). ~~This~~These retrospective dose ~~assessment~~assessments should include a calculation of the dose to the representative person (see paras 3.~~6 and~~ 7–3.~~7~~8). GSG-10 [2] provides recommendations on the assessment of the dose to the representative person.

9.13. ~~Retrospective~~In some cases, retrospective assessment of the radiological impact ~~to~~on the public ~~due to~~from radioactive releases or residual radioactivity in the environment ~~can be done using~~cannot rely solely on the results of monitoring programmes. In such cases mathematical models ~~to convert~~can be used to calculate doses from data ~~of~~acquired from source or environmental monitoring (or ~~their~~a combination~~) into calculated doses.~~ of both). The results of such retrospective assessments should be used with careful consideration, taking into

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account both the cautious nature of models used for environmental dispersion and transfer~~;~~ and that the results of the measurements in the environment ~~may~~might be below detection limits~~;~~ or might ~~be~~ not be representative because of the limited frequency and spatial coverage inherent to the sampling technique.

9.14. The assessment of ~~the~~ dose to the representative person should ~~consider~~be based on the predominant exposure pathways ~~of exposure~~. External exposure (e.g. irradiation from radioactivity in the air, deposited on the ground or in water and sediments) and internal exposure (e.g. inhalation, ingestion of food and drinking water) should be considered. Where the dose ~~for~~to the representative person is of concern, ~~in principle,~~ dose calculations should initially be based on the results of environmental monitoring rather than ~~on~~source monitoring ~~at the source~~[57] ~~.~~.[58]

9.15. Doses from external exposures from radionuclides in the plume or deposited on the ground can be estimated either directly (using measurements of dose rates) or indirectly (using measurements of the activity deposited on the ground or the activity concentrations in air~~.~~). For direct measurements of dose rates, account should be taken of the natural background and the distance between where the measurement was taken and the location of the representative person. For indirect measurements, dose coefficients that relate the measured or estimated activity concentration to a dose rate should be used ~~[1, 44].~~(see Ref. [45]).

9.16. Dose assessment for internal exposure pathways may be based on measurements of activity concentrations of radionuclides in environmental media in combination with environmental transfer models and dosimetric models. The balance between measurements and models ~~should depend~~depends on several ~~criteria such as~~factors, including the following:

(a) The availability of environmental measurements directly relevant to the representative person;

(b) Whether the samples are representative;

(c) The accuracy and precision of the measurements;

~~[57] This approach has the advantage of minimizing the modelling uncertainties involved in the dose calculations and could provide a firmer indication of the actual doses incurred by the public. However, low levels of activity sometimes make environmental monitoring impracticable for dose assessment purposes.~~

[58] This approach has the advantage of minimizing the modelling uncertainties involved in the dose calculations and could provide a firmer indication of the actual doses incurred by the public. However, low levels of activity sometimes make environmental monitoring impracticable for dose assessment purposes.

(d) The number of measurements under the detection limit for radionuclides that are released from sources;

(e) The degree of validation of models for site specific calculations.

9.17. When environmental monitoring provides results on the radiation levels and activity concentrations of radionuclides in air, water and food, dose coefficients should be used for the purposes of dose assessment, in conjunction with habit data[59]. When only source monitoring results are available or when environmental monitoring does not provide sufficient data on radiation levels and activity concentrations in air, water and food, models[60] for dispersion and transfer of radionuclides through the environment and the food chains could be used to supplement the data.

9.18. When environmental monitoring data are used to estimate doses due to the ingestion of food and/or drinking water, account should be taken ~~for the~~of its origin~~,~~ and consumption rate, ~~and~~including seasonal variation in consumption. Data on radionuclide concentrations in locally produced agricultural foodstuffs and wild food, when appropriate, should be used to assess the annual intake of radionuclides and the associated dose.

9.19. The calculation of doses from the results of environmental monitoring ~~requires~~involves appropriate processing of the monitoring results. The background radiation, whether natural background radiation or that due to fallout from nuclear weapon tests, should be identified~~, generally~~ by means of comparison with results from monitoring in an area that has not been contaminated, and should be subtracted from the results. In emergency exposure situations and in some existing exposure situations, the background radiation ~~may~~might in some cases be negligible compared to the projected doses and may then be ignored in the calculations.

Consideration of uncertainties in monitoring data and dose assessment

9.20. Monitoring data have associated uncertainties that arise from technical uncertainties, the non-uniformity of samples and/or measurements, and human errors. When ~~interpretating~~interpreting monitoring data, ~~particularly~~in particular when estimating public

[59] Habit data ~~includes~~include the time spent in different exposure conditions by ~~individuals~~members of the public and their consumption rates of ~~foodstuffs~~food and ~~beverages~~drink water. Shielding factors from structures might affect the exposure conditions of the population.

[60] The IAEA issued a Safety Report on methods and models that can be used to assess the impact of releases of radioactive material to the environment [58] and Technical Reports relating to environmental transfer parameters [52, 59]. A revision of Safety Reports Series No. 19 [58] is in preparation and will cover screening assessments of public exposure, generic models and parameters for use in assessing the impact of radioactive discharges, and generic models and parameters for assessing exposures of flora and fauna due to radioactive discharges from facilities and activities.

doses that are used in the decision making process to protect the public and/or the environment (e.g. decisions about implementation of protective actions or remedial actions), uncertainties in the monitoring data ~~alongside those~~and in any environmental and dosimetric models being used, should be considered.

9.21. The uncertainties in monitoring results should be estimated taking into account any uncertainties in sampling and measurement procedures, including~~, the~~ uncertainties in sample processing and equipment calibration. Uncertainties should be reported together with the monitoring results. Additional technical information about estimation and control of uncertainties ~~could~~can be found in ~~ref [43~~Ref. [38].

9.22. The acceptable level of uncertainty should be commensurate with the magnitude of the quantity being measured and the relevant criteria for making decisions. For example, high uncertainty may be acceptable where measured concentrations result in trivial doses, whereas more precise measurements are needed for doses of significance. Uncertainties cannot be eliminated but they should be reduced and controlled by use of appropriate standard procedures in the field and in the laboratory, and by use of a quality assurance programme to verify that these procedures are followed. Uncertainties in monitoring data can also be reduced through using appropriately calibrated instruments, performing regular intercomparison measurements amongst organizations involved in monitoring, and participating in proficiency tests.

~~REPORTING~~

REPORTING OF MONITORING RESULTS

9.23. Results from the monitoring programmes should be reported to the regulatory body, or other ~~competent~~relevant authority, at ~~a~~the frequency required by the regulatory body or other ~~competent~~relevant authority, in accordance with the approved monitoring programme.

9.24. Monitoring results should be reported in a way that allows ~~the~~their comparison with the relevant criteria, such as the following:

(a) For planned ~~exposures~~exposure situations, limits on discharges or other criteria for operation specified in authorizations issued by the regulatory body, the dose constraint for the facility, the public dose limits~~,~~ and, where specified, any derived levels for flora and fauna ~~[20];~~(see Ref. [33]);

(b) For emergency ~~exposures~~exposure situations, operational intervention levels or emergency action levels~~,~~;

(c) For existing ~~exposures~~exposure situations, dose reference levels, screening criteria[61] for remedial actions~~,~~ or end state criteria[62];

9.25. Monitoring reports should present the data obtained for the monitoring period, along with an interpretation of the data that addresses the objectives of the monitoring programme.

9.26. Monitoring reports should also contain an adequate interpretation of the radiological significance of monitoring data with reference to relevant standards or criteria. Particular attention should be given to monitoring data that show significant ~~increase,~~increases or trends~~,~~ in ~~the~~ releases or in the contamination of the environment.

9.27. Monitoring reports should also ~~include a discussion of the uncertainty~~indicate uncertainties in the monitoring data~~,~~ and, to the extent possible, ~~of the uncertainty~~uncertainties in the calculated doses.

9.28. The regulatory body is required to publish or make available on request, as appropriate, results from monitoring programmes and ~~related dose assessment~~assessments of doses to the public (see para. 3.136 of GSR Part 3 [1]). The regulatory body should define the content and characteristics of the reports on source and environmental monitoring to be made available to the ~~general~~ public and other interested parties. The basis for such reports should be the results ~~on~~of the monitoring programme by the operating organization, and the independent monitoring by the regulatory body or the delegated party (see para. 4.4). The regulatory body should provide well documented and transparent information, taking into account that some interested parties might not have high specialized expertise. Information should be made available in an appropriate, understandable form and include the key findings in a language (or languages) accessible for all the interested parties. The regulatory body might consider the need to include general information on aspects of radiation protection of the public of the environment, as a complement ~~of~~to the technical data.

[61] Screening criteria are used to indicate if remediation could be justified. ~~The~~This can be done by comparing the projected ~~doses~~dose prior to remediation ~~should be compared against~~with the relevant screening criterion (e.g. the lower level of the reference level range, as established in the national strategy for remediation) that has been approved by the regulatory body, in order to determine whether or not remediation might be justified ~~[17].~~ (see GSG-15 [12]).

[62] ~~End~~The end state is a predetermined criterion defining the point at which a specific task or process is to be considered completed. It is used in relation to remediation as the final status of a site at the end of the activities for remediation [5].

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Annex
TECHNICAL CONSIDERATIONS FOR SAMPLING AND MEASUREMENTS FOR ROUTINE DISCHARGES IN OPERATIONAL STATES OF FACILITIES

A–1. The technical considerations presented in this Annex might not be applicable in all situations and might therefore need to be adapted, as appropriate, to the facility or activity under consideration.

SOURCE MONITORING IN OPERATIONAL STATES OF FACILITIES

A–2. Most ~~of the~~ data on the discharge of radionuclides are ~~generally~~ obtained by means of on-line (real time) measurements of the dose rate, measurements of activity concentration or total activity at the discharge point, or by effluent sampling in tanks before discharges, with subsequent laboratory analysis. Sampling and subsequent ~~monitoring~~analysis of the ~~air~~airborne and ~~water released~~liquid releases, whether continuous or ~~discontinuous~~discrete, are used mainly to determine the radionuclide composition of a discharge.

A–3. If the activity concentrations in the discharged effluents are very low, on-line measurements might be insufficiently sensitive ~~and sampling with~~, making subsequent laboratory analysis ~~may become~~ necessary. Continuous sampling is preferred when discharges are continuous. When discharges are made from tanks, samples of the effluent in each tank or composite samples of several tanks are obtained~~,~~ after ~~an efficient mixing~~homogenization of the effluents in the tanks, in order to ensure samples are representative of the whole volume of the tanks.

A–4. When the radionuclide composition of the discharges is known and does not vary significantly, measurements of gross alpha, gross beta or gross gamma activity may be sufficient to characterize the radioactive discharges. When the radionuclide composition may vary, spectrometric measurements are needed; in this case, pure beta emitters need special consideration as chemical preparation is necessary. When discharges include radionuclides with short half-lives, prompt analysis is needed to avoid losses from rapid decay of the nuclides in the samples.

A–5. As appropriate, on-line measurements are complemented with an alarm ~~which~~that warns the operating organization when a predefined threshold is exceeded, and with automatic devices ~~which~~that stop the current discharges from tanks. For large facilities, the main monitoring systems might be equipped with alarms to warn the operating organization of any

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malfunctioning of ~~the~~a device; the main monitoring systems might also be duplicated in order to avoid any lack of monitoring during maintenance or failure of the systems.

A–6. As ~~generally~~ the concentrations of radionuclides are generally measured in the discharged effluents, an accurate measurement of the volume of discharged effluent is needed to derive the radionuclide quantities discharged into the environment.

A–7. ~~The diffuse~~Diffuse discharges might be assessed from various parameter measurements, including parameters of the industrial processes, or from environmental measurements in the vicinity of the facility. The procedure to estimate diffuse discharges ~~will~~is normally ~~be~~ specified or approved by the regulatory body.

A–8. Diffuse sources might not be amenable to on-line monitoring. For example, radon gas (^{222}Rn) is released from some mining operations through multiple mine vents, and from tailings and waste rock storage areas. While continuous radon monitors are available to measure radon concentrations, on-line systems are not practical for large source areas. ~~Retrospective~~Integrating detectors~~, such as~~ (e.g. alpha track detectors~~,~~) that are periodically collected for measurement and replaced ~~periodically~~, might be more practical. In either case, monitoring is expected to cover all seasons in order to reflect the seasonality of radon emanation. Estimates of radon discharge can be made from measured concentrations and air flow or wind data. Recommendations on suitable monitoring methods are provided in ~~Ref.~~IAEA Safety Standards Series No. SSG-32, Protection of the Public Against Exposure Indoors due to Radon and Other Natural Sources of Radiation [A–1].

ENVIRONMENTAL MONITORING IN OPERATIONAL STATES OF FACILITIES

A–9. The main objectives of environmental monitoring during ~~normal operation~~operational states are the verification of compliance of measured values with environmental limits, ~~or~~and the comparison of measured values with predicted values of dose rates or radionuclide concentrations in environmental samples. Sampling locations are therefore selected close to points where the maximum exposure or deposition is expected for airborne discharges, or downstream from the release point for aquatic discharges, where the representative person lives or gets food, ~~, or~~or at the site boundary (for direct radiation from the source) ~~at the site boundary.~~(see Ref. [A-3]). In special cases when ~~a~~the specific monitoring of endangered species or ~~in~~ protected areas is ~~required~~needed, samples can also be taken in or close to ~~this protected~~the relevant area ~~or where the endangered species have been identified.~~(s). Since atmospheric dispersion and ~~water~~aquatic dispersion might vary significantly from year to year,

~~a part~~some of the monitoring measurements ~~needs~~need to be performed at the same location for the year~~ -~~by~~ -~~year comparison of ~~the~~ results.

A–10. Additional environmental sampling and/or measurements need to be conducted regularly in areas used for control measurements to compare the results with those in potentially affected areas.

A–11. Continuously produced agricultural food products ~~such as~~(e.g. leafy vegetables ~~or~~, milk) are normally sampled several times a year, or more frequently in the case of releases of radionuclides~~,~~ such as ~~radioiodines that~~radioiodine, which do not persist long in the produce, or ~~such as~~ tritium ~~that~~, is highly mobile, resulting in the possibility for rapid changes in activity concentrations in the environment. Sediment, soil and products with one harvest per year are monitored once a year, at the time of harvest (see Ref. [A–2~~].~~]).

A–12. ~~Typical constituents~~The typical aspects monitored, the frequencies and locations of sampling, and the measurements taken on the samples for different types of discharges are presented in Tables A-1, A-2 and A-3. ~~This is~~These tables provide a generic framework; ~~the~~a site specific monitoring programme is expected to be established ~~in~~, taking into consideration ~~of~~ the radionuclides involved, site specific considerations and the magnitude of discharges. The choice of foodstuffs ~~will depend~~depends on local agricultural practices and the food related habits of the local population (see Ref. [A–2~~].~~]).

A–13. For large facilities, site characterization work to support the monitoring programme might include on-site automated weather ~~observing~~observation systems (e.g. to monitor wind speed and direction, atmospheric stability and precipitation) and river flow or lake current monitoring systems.

A–14. The analysis systems for measurement of low-level environmental samples ~~is~~are expected to be physically separated from the systems for measurement of higher level effluent samples, to avoid cross contamination. It is advisable to have separate laboratories for performing low-level measurements and effluent analyses. When possible, it is advisable to allocate the laboratory for low-level measurements outside of the facility.

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TABLE A–1. ~~EXAMPLE~~EXAMPLES OF ~~TYPICAL~~ ENVIRONMENTAL MONITORING FOR AN AIRBORNE DISCHARGE

~~Monitored constituent~~Monitoring	Frequency of monitoring	Monitoring ~~location~~location[a,b]	Measurement (as appropriate to the source)
External radiation			
External radiation	Continuously On-line, as appropriate	Several ~~azimuths~~locations (e.g. ~~4~~four) and several distances (e.g. ~~fence,~~at the site boundary, at 1 km, ~~5km,~~5 km and 10 km) around the facility	Gamma dose rate Neutron dose rate ~~at fence~~ (if neutron radiation is foreseen)
External radiation – integrated	Monthly to ~~twice a year~~semiannually	Several locations (e.g. ten) at the ~~fence (e.g. 10)~~site boundary	Gamma dose rate Neutron dose rate (if neutron radiation is foreseen)
Air and deposition			
Air: -~~aerosols~~ Aerosols ~~- gases including noble gases, tritium and iodine~~- Gases - Moisture condensate	~~Continuous collection~~Continuously	Several ~~azimuths~~locations (e.g. ~~4~~four) including downwind of the prevailing wind direction -Near areas with ~~endangered species or protected areas~~receptors of concern	~~Daily to monthly measurements:~~ -Gamma ~~and alpha~~ spectrometry -Gross ~~beta~~ ~~- Gross~~ alpha ~~- Tritium~~, gross beta[c] Tritium[d]
Rain	~~Continuous collection~~Continuously	Downwind of the ~~wet~~ prevailing wind direction Near areas with receptors of concern	~~Monthly measurements:~~ ~~- Tritium~~ ~~- Gross beta~~ -Tritium[d] Gross alpha, gross beta[c]
Deposition	~~Continuous collection~~Continuously	-Downwind of the prevailing wind direction -Near areas with ~~endangered species or protected areas~~receptors of concern	~~Daily to monthly measurements:~~ -Gamma ~~and alpha~~ spectrometry -Gross ~~beta~~ ~~- Gross~~ alpha, gross beta[c]
Soil	Annually	-Downwind of the prevailing wind direction -Near areas with ~~endangered species or protected areas~~receptors of concern	-Gamma ~~and alpha~~ spectrometry
Groundwater	Monthly to annually	Several locations around the facility where groundwater is present	~~- Tritium~~ ~~- Gross beta (+ potassium)~~ -Tritium[d] Gross alpha, gross beta[c]
Food and drinking ~~water~~water[e]			
Leafy vegetables	Monthly during growing season	Downwind of the prevailing wind direction Near areas with receptors of concern	~~- Tritium (HTO and OBT as appropriate)~~ -Tritium[d] Gamma spectrometry

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~~Monitored constituent~~Monitoring	Frequency of monitoring	Monitoring ~~location~~location[a,b]	Measurement (as appropriate to the source)
Other vegetables and fruits	At harvest	Downwind of the prevailing wind direction Near areas with receptors of concern	~~Tritium (HTO and OBT as appropriate)~~ Tritium[d] Gamma spectrometry
Grain	At harvest	Downwind of the prevailing wind direction Near areas with receptors of concern	~~Tritium (HTO and OBT as appropriate)~~ Tritium[d] Gamma spectrometry
Milk	Monthly to annually~~, when cows on pasture~~	~~Pasture downwind the prevailing wind~~ Local farms	~~Tritium (HTO and OBT as appropriate)~~ Tritium[d] Gamma spectrometry ~~-~~Carbon-~~14~~ 14[d] Strontium-90
Meat	Annually	~~Animals on pasture downwind the prevailing wind~~ Local farms	~~-~~Gamma spectrometry Carbon-14[d]
Drinking water	Quarterly to annually	~~Tap water~~Public and private ~~wells~~water suppliers near the facility	~~Tritium~~ Tritium[d] Gamma spectrometry ~~-~~Gross alpha, gross beta[c]
Terrestrial pathways			
Grass	Monthly	~~Pasture~~Pastures downwind of the prevailing wind direction	~~Tritium (HTO)~~ Tritium[c] Gamma spectrometry ~~Alpha spectrometry~~
Lichen, mosses, mushrooms	Annually	Selected samples downwind of the prevailing wind direction	~~-~~Gamma spectrometry

~~Notes:~~

~~1. Tritium, carbon-14 and alpha emitters are to be measured only when these radionuclides are discharged from the facility.~~

~~2. Alpha spectrometry for the aerosols might be performed on a grouping~~

[a]In addition to the locations indicated in the table, sampling and analyses in unaffected areas is advisable for comparison purposes.

[b]Sampling in areas with endangered species or protected areas is only applicable if specific monitoring for this purpose is required by the regulatory body.

[c]If measurements of ~~filters~~gross alpha or gross beta exceed the established screening levels, specific radionuclide analysis to ~~enhance detection capability.~~

~~3.~~identify the radionuclides is advisable. Potassium~~ can be measured in order to derive the potassium-40 content. Alternatively, K-~~40 can be measured directly by gamma spectrometry to be subtracted from gross beta measurements.

[d]Tritium, carbon-14 and alpha emitters are to be measured only when they are present in the radioactive inventory and are authorized to be released.

[e]Large volume samples (e.g. 20 L) may be needed to reach reasonable detection limits for radionuclides in water.

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TABLE A–2. EXAMPLES OF ENVIRONMENTAL MONITORING FOR A LIQUID DISCHARGE TO FRESHWATER

Monitoring	**Frequency of monitoring**	**Monitoring location[a,b]**	**Measurement (as appropriate to the source)**
Aquatic dispersion			
Surface waters[c]	Continuous or discrete sampling	Downstream[d]	Tritium[e] Gross alpha, gross beta[f] Gamma spectrometry
Sediment	Annually	Downstream[d]	Gamma spectrometry
Aquatic foodstuffs			
~~4. Large~~			
Fish	Annually	Downstream[d]	Tritium[e] Carbon-14[e] Gamma spectrometry Gross alpha, gross beta[f]
Bioindicators			
Aquatic organisms	Annually	Downstream[d]	Gamma spectrometry

[a]In addition to the locations indicated in the table, sampling and analyses in unaffected areas is advisable for comparison purposes.

[b]Sampling in areas with endangered species or protected areas is only applicable if specific monitoring for this purpose is required by the regulatory body.

[c]Large volume samples (e.g. 20 L) may be needed to reach reasonable detection limits for radionuclides in water.

[d]When other discharges occur upstream, surface water and sediment should be also collected upstream of the point of discharge.

[e]Tritium, carbon-14 and alpha emitters are to be measured only when they are present in the radioactive inventory and are authorized to be released.

[f]If gross alpha or gross beta exceed the established screening levels, specific radionuclides analysis to identify the radionuclides is advisable. Potassium-40 can be measured directly by gamma spectrometry to be subtracted from gross beta measurements.

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TABLE A–3. EXAMPLES OF ENVIRONMENTAL MONITORING FOR A LIQUID DISCHARGE TO SEAWATER

Monitoring	**Frequency of monitoring**	**Monitoring location[a,b]**	**Measurement (as appropriate to the source)**
Aquatic dispersion			
Surface water[c]	Continuous or discrete sampling	Downstream[d]	Tritium[e] Gross alpha, gross beta[f] Gamma spectrometry
Sediment	Annually	Downstream[d]	Gamma spectrometry
Aquatic foodstuffs			
~~5. Sampling near~~			
Fish	Annually	Selected samples downstream[d]	Tritium[e] Carbon-14[e] Gamma spectrometry Strontium-90
Molluscs	Annually	Selected samples downstream[d]	Tritium[e] Carbon-14[e] Gamma spectrometry Strontium-90
Crustaceans	Annually	Selected samples downstream[d]	Tritium[e] Gamma spectrometry Strontium-90
Bioindicators			
Seaweed	Annually	Downstream[d]	Gamma spectrometry

[a]In addition to the locations indicated in the table, sampling and analyses in unaffected areas is advisable for comparison purposes.

[b]Sampling in areas with endangered species or protected areas is only applicable if specific monitoring for this purpose is required~~.~~ by the regulatory body.

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TABLE A-2. EXAMPLE OF TYPICAL ENVIRONMENTAL MONITORING FOR A LIQUID DISCHARGE TO FRESHWATER

Monitored constituent	Frequency of monitoring	Monitoring location	Measurement (as appropriate to the source)
Aquatic dispersion [A-3]			
Surface water	Continuous or spot sampling	Downstream	Monthly measurement: - Tritium - Gross beta (+potassium) - Gross alpha - Gamma spectrometry - Alpha spectrometry - Strontium-90 - Uranium
Sediment	Annually	Downstream	- Gamma spectrometry - Alpha spectrometry - Uranium
[c]Large volume samples (e.g. 20 L) may***Aquatic foodstuffs***			
Fish	Annually	Selected samples downstream	- Tritium (OBT) - Carbon-14 - Gamma spectrometry
Aquatic pathways			
Aquatic flora	Annually	Downstream	- Gamma spectrometry

Notes:

1. Tritium, carbon-14, strontium-90, uranium and other alpha emitters are to be measured only when theseneeded to reach reasonable detection limits for radionuclides are discharged from the facility.

2. Potassium can be is measured in order to derive the potassium-40 content. Alternatively, K-40 can be measured directly by gamma spectrometry to be subtracted from gross beta measurementswater.

3. When[d]When other discharges occur upstream, surface water and sediment should be also collected upstream of the point of discharge, as a baseline prior to discharge and during facility operation.

[e]Tritium

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TABLE A–3. TYPICAL ENVIRONMENTAL MONITORING FOR A LIQUID DISCHARGE TO SEAWATER

Monitored constituent	Frequency of monitoring	Monitoring location	Measurement (as appropriate to the source)
Aquatic dispersion [A–3]			
Surface water	Continuous or spot sampling	Downstream	Monthly measurement: - Tritium - Gross beta (+potassium) - Gross alpha - Gamma spectrometry - Alpha spectrometry - Strontium-90
Sediment	Annually	Downstream	- Gamma spectrometry - Alpha spectrometry - Strontium-90
Aquatic foodstuffs			
Fish	Annually	Selected samples downstream	- Tritium (OBT) - Carbon-14 - Gamma spectrometry
Molluscs	Annually	Selected samples downstream	- Tritium (OBT) - Carbon-14 - Gamma spectrometry
Crustacean	Annually	Selected samples downstream	- Tritium (OBT) - Gamma spectrometry
Aquatic pathways			
Seaweed	Annually	Downstream	- Gamma spectrometry

Note:
1. Tritium, carbon-14, strontium-90 and alpha emitters are to be measured only when thesethey are present in the radioactive inventory and are authorized to be released.

[f]If measurements of gross alpha or gross beta exceed the established screening levels, specific radionuclides are discharged fromanalysis to identify the facility.

2.radionuclides is advisable. Potassium can be measured in order to derive the Potassium-40 content. Alternatively, K-40 can be measured directly by gamma spectrometry to be subtracted from gross beta measurements.

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