

IAEA Safety Standards

for protecting people and the environment

Management of Residues Containing Naturally Occurring Radioactive Material from Uranium Production and Other Activities

Specific Safety Guide

No. SSG-60



IAEA

International Atomic Energy Agency



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IAEA SAFETY STANDARDS

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

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

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

<https://www.iaea.org/resources/safety-standards>

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

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

RELATED PUBLICATIONS

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

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

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

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

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

MANAGEMENT OF
RESIDUES CONTAINING
NATURALLY OCCURRING
RADIOACTIVE MATERIAL
FROM URANIUM PRODUCTION
AND OTHER ACTIVITIES



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

IAEA SAFETY STANDARDS SERIES No. SSG-60

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SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2021

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1400 Vienna, Austria
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email: sales.publications@iaea.org
www.iaea.org/publications

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Printed by the IAEA in Austria
August 2021
STI/PUB/1883

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.

Title: Management of residues containing naturally occurring radioactive material from uranium production and other activities / International Atomic Energy Agency.

Description: Vienna : International Atomic Energy Agency, 2021. | Series: IAEA safety standards series, ISSN 1020-525X ; no. SSG-60 | Includes bibliographical references.

Identifiers: IAEAL 21-01394 | ISBN 978-92-0-106219-2 (paperback : alk. paper) | ISBN 978-92-0-104821-9 (pdf) | ISBN 978-92-0-104921-6 (epub)

Subjects: LCSH: Radiation, Background. | Radioactive substances. | Radioisotopes — Safety measures. | Uranium.

Classification: UDC 546.79 | STI/PUB/1883

FOREWORD

by Rafael Mariano Grossi
Director General

The IAEA's Statute authorizes it to "establish...standards of safety for protection of health and minimization of danger to life and property". These are standards that the IAEA must apply to its own operations, and that States can apply through their national regulations.

The IAEA started its safety standards programme in 1958 and there have been many developments since. As Director General, I am committed to ensuring that the IAEA maintains and improves upon this integrated, comprehensive and consistent set of up to date, user friendly and fit for purpose safety standards of high quality. Their proper application in the use of nuclear science and technology should offer a high level of protection for people and the environment across the world and provide the confidence necessary to allow for the ongoing use of nuclear technology for the benefit of all.

Safety is a national responsibility underpinned by a number of international conventions. The IAEA safety standards form a basis for these legal instruments and serve as a global reference to help parties meet their obligations. While safety standards are not legally binding on Member States, they are widely applied. They have become an indispensable reference point and a common denominator for the vast majority of Member States that have adopted these standards for use in national regulations to enhance safety in nuclear power generation, research reactors and fuel cycle facilities as well as in nuclear applications in medicine, industry, agriculture and research.

The IAEA safety standards are based on the practical experience of its Member States and produced through international consensus. The involvement of the members of the Safety Standards Committees, the Nuclear Security Guidance Committee and the Commission on Safety Standards is particularly important, and I am grateful to all those who contribute their knowledge and expertise to this endeavour.

The IAEA also uses these safety standards when it assists Member States through its review missions and advisory services. This helps Member States in the application of the standards and enables valuable experience and insight to be shared. Feedback from these missions and services, and lessons identified from events and experience in the use and application of the safety standards, are taken into account during their periodic revision.

I believe the IAEA safety standards and their application make an invaluable contribution to ensuring a high level of safety in the use of nuclear technology.

I encourage all Member States to promote and apply these standards, and to work with the IAEA to uphold their quality now and in the future.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

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

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

Safety measures and security measures¹ have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

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

Safety Fundamentals

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

Safety Requirements

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

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it

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

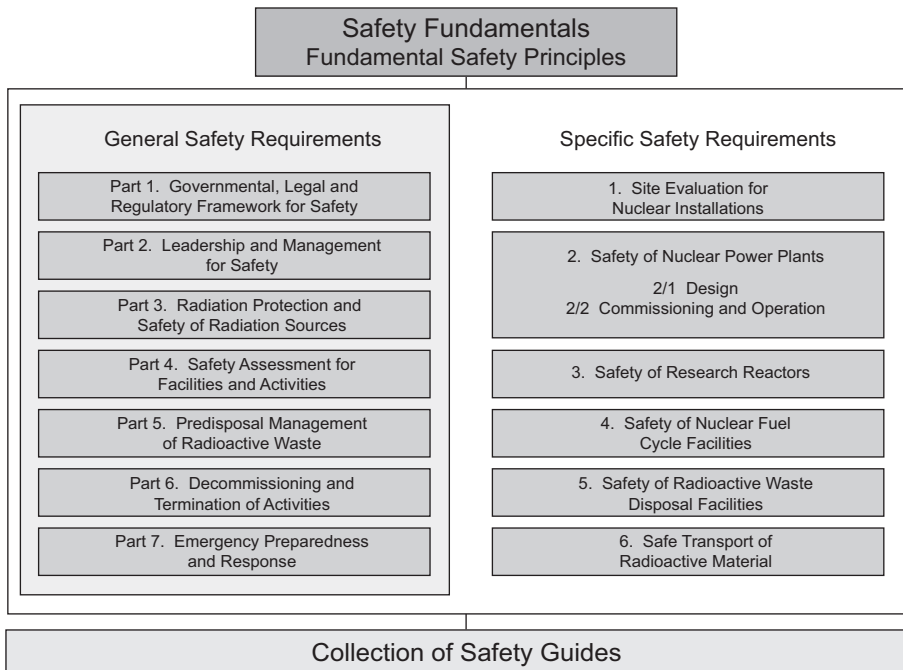


FIG. 1. The long term structure of the IAEA Safety Standards Series.

is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

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

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be

used by States as a reference for their national regulations in respect of facilities and activities.

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

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

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

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

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five Safety Standards Committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the Safety Standards Committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards.

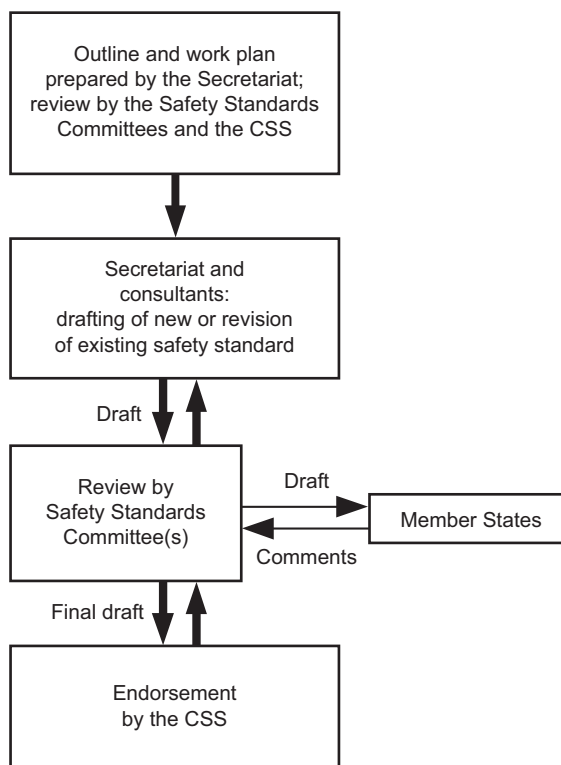


FIG. 2. The process for developing a new safety standard or revising an existing standard.

It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

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

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

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

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

CONTENTS

1.	INTRODUCTION.....	1
	Background (1.1–1.9).....	1
	Objective (1.10)	3
	Scope (1.11–1.18).....	4
	Structure (1.19, 1.20)	5
2.	OVERVIEW OF NORM ACTIVITIES AND NORM RESIDUES (2.1–2.8).....	6
3.	GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK FOR SAFETY.....	12
	Responsibilities of the government (3.1–3.11).....	12
	Responsibilities of the regulatory body (3.12–3.22)	15
	Responsibilities of the operating organization (3.23–3.30)	16
4.	PROTECTION OF PEOPLE AND THE ENVIRONMENT	18
	General (4.1–4.6)	18
	Planned exposure situations (4.7–4.16)	19
	Emergency exposure situations (4.17–4.20).....	21
	Existing exposure situations (4.21–4.23)	22
	Protection of the environment (4.24, 4.25).....	23
	Non-radiological considerations (4.26, 4.27).....	24
5.	SYSTEM FOR REGULATORY CONTROL	25
	General (5.1, 5.2)	25
	Inventory of NORM facilities and activities for regulatory consideration (5.3–5.6)	25
	Graded approach to regulation (5.7–5.40)	26
	Financial provisions (5.41–5.45)	35
	Interested parties (5.46–5.49)	36
	Management system (5.50–5.57)	37
6.	STRATEGIES FOR NORM RESIDUE MANAGEMENT	40

General (6.1–6.8)	40
Development and implementation of a residue management plan (6.9–6.14)	42
Control of residue generation (6.15–6.17)	43
Processing (6.18–6.27)	44
Reuse and recycling (6.28, 6.29)	46
Storage and retrieval of residues (6.30, 6.31)	46
Options for long term management of NORM residues (6.32–6.39) ..	47
 7. THE SAFETY CASE AND SAFETY ASSESSMENT FOR NORM RESIDUE MANAGEMENT	 49
General (7.1–7.13)	49
Scope of the safety assessment (7.14–7.16)	51
Conducting a safety assessment (7.17–7.25)	53
Graded approach to safety assessment (7.26–7.31)	56
Documentation of the safety case and the safety assessment (7.32–7.34)	57
Periodic safety reviews (7.35)	58
 8. SAFETY CONSIDERATIONS FOR LONG TERM MANAGEMENT OF NORM RESIDUES	 58
General (8.1–8.5)	58
Siting (8.6–8.8)	59
Design and construction (8.9–8.14)	60
Operation (8.15–8.20)	63
Decommissioning of facilities and closure of facilities (8.21–8.36) ..	64
Long term management and institutional controls (8.37–8.44)	68
Monitoring and surveillance (8.45–8.54)	69
 APPENDIX I: SPECIAL CONSIDERATIONS FOR RESIDUES FROM URANIUM PRODUCTION	 73
 APPENDIX II: RESIDUE MANAGEMENT PLAN FOR URANIUM PRODUCTION	 81
 APPENDIX III: CLOSURE PLAN FOR A TAILINGS MANAGEMENT FACILITY AT A URANIUM PRODUCTION SITE	 83

REFERENCES..... 85

BIBLIOGRAPHY 89

ANNEX I: EXAMPLES OF NORM RESIDUES
 TO BE ASSESSED FOR POSSIBLE
 REGULATORY CONTROL 91

ANNEX II: SAMPLING NORM RESIDUES AND
 DETERMINING RADIONUCLIDE ACTIVITY
 CONCENTRATIONS 93

ANNEX III: EXAMPLE OF APPLICATION OF THE
 GRADED APPROACH IN THE MANAGEMENT
 OF NORM RESIDUES..... 99

ANNEX IV: REUSE AND RECYCLING OF
 NORM RESIDUES 103

CONTRIBUTORS TO DRAFTING AND REVIEW 107

1. INTRODUCTION

BACKGROUND

1.1. Radionuclides of natural origin are ubiquitous in the environment and in some geological formations have become sufficiently concentrated to be exploited for the purpose of uranium production. Uranium production, including mining, processing and management of radioactive residues, as either primary or secondary minerals, has long been recognized as needing regulatory control. However, significant concentrations of radionuclides of natural origin also occur in facilities and activities involving the processing of other minerals. These natural radionuclides can be present in the raw materials and in the residues from the processing of those other minerals.

1.2. Radioactive material is defined as material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity [1]. Naturally occurring radioactive material (NORM) is defined as radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides; the exact definition of ‘significant amounts’ would be a regulatory decision [1]. Material in which the activity concentrations of the naturally occurring radionuclides have been changed by a process is also considered NORM [1]. A NORM residue is defined as material that remains from a process and comprises or is contaminated by NORM. NORM waste is defined as NORM for which no further use is foreseen [1]. For the purpose of this Safety Guide, NORM residues and NORM waste can be in solid or liquid form and might emit radioactive gases. The term ‘NORM activity’ is used in this Safety Guide to describe those facilities and activities that involve management of NORM residues.

1.3. NORM residues can have a radiological impact on workers, the public and the environment. The fundamental safety objective established in IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [2], is “**to protect people and the environment from harmful effects of ionizing radiation.**” Consequently, a governmental, legal and regulatory framework, as described in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [3], for control of NORM residues might be necessary.

1.4. Uranium production activities have typically been subject to regulatory control, generally as part of the nuclear fuel cycle. Unlike uranium production,

the residues arising from other NORM activities (which may have been recycled, used in other applications or disposed of as waste) have not always been subject to appropriate regulatory control in the past, even though they might have contained radionuclides at levels that would now raise radiation safety concerns.

1.5. NORM residues, particularly those generated in mining and mineral processing, differ from radioactive residues generated at, for example, nuclear power plants or medical facilities. Such NORM residues can be generated in very large volumes but tend to contain radionuclides at relatively low activity concentrations. This has important implications for the management of NORM residues, including siting and engineering options. In some cases, NORM residues contain radionuclides at higher activity concentrations, but normally in smaller volumes¹.

1.6. Various IAEA Safety Standards Series publications have some relevance to NORM and to NORM residues, including the following:

- (a) IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [3];
- (b) IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [4];
- (c) IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [5];
- (d) IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [6];
- (e) IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [7];
- (f) IAEA Safety Standards Series No. SSR-5, Disposal of Radioactive Waste [8];
- (g) IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [9];
- (h) IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [10];
- (i) IAEA Safety Standards Series No. RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance [11];
- (j) IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [12];

¹ The volume of NORM residues can range from less than one cubic metre up to millions of cubic metres.

- (k) IAEA Safety Standards Series No. GSG-9, Regulatory Control of Radioactive Discharges to the Environment [13];
- (l) IAEA Safety Standards Series No. GSG-15, Remediation Strategy and Process for Areas Affected by Past Activities or Events [14];
- (m) IAEA Safety Standards Series No. SSG-32, Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation [15];
- (n) IAEA Safety Standards Series No. SSG-31, Monitoring and Surveillance of Radioactive Waste Disposal Facilities [16].

1.7. A number of Safety Reports containing practical information on NORM residues from specific industries (work involving minerals and raw materials, oil and gas, zircon and zirconia, rare earth processing, titanium dioxide and related industries, and the phosphate industry) have also been published [17–22]. Further publications that are relevant to the management of NORM residues are listed in the bibliography.

1.8. This Safety Guide supersedes IAEA Safety Standards Series No. WS-G-1.2, Management of Radioactive Waste from the Mining and Milling of Ores, issued in 2002².

1.9. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [1].

OBJECTIVE

1.10. The objective of this Safety Guide is to provide recommendations to regulatory bodies, operating organizations, technical support organizations and other interested parties on approaches for the safe management of NORM residues arising from uranium production and other NORM activities, in accordance with a graded approach. These recommendations are aimed at meeting the relevant requirements established in GSR Part 3 [4] for the protection of people and the environment, both now and in the future.

² INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Radioactive Waste from the Mining and Milling of Ores, IAEA Safety Standards Series No. WS-G-1.2, IAEA, Vienna (2002).

SCOPE

1.11. This Safety Guide addresses the management of the radiological hazards and risks associated with various types of NORM residue. It addresses radioactive residues arising from uranium production and from other NORM activities that generate very large quantities of NORM residues, such as tailings from mining and mineral processing. This Safety Guide also addresses activities that generate comparatively small volumes of NORM residues such as sludge and scales. Though the fundamental principles of managing these hazards and risks are similar, the options for the management of this broad range of materials are necessarily quite different.

1.12. This Safety Guide covers the entire lifetime of a NORM residue management facility, including siting, construction, operation, decommissioning, closure, post-closure and a period of institutional control, as appropriate to the facility. A NORM residue management facility can be a facility for the processing, storage and/or long term management of NORM residues, including the permanent disposal of NORM waste.

1.13. This Safety Guide identifies organizational and regulatory requirements (including for exemption and clearance and for reuse and recycling). It includes recommendations on the conduct of screening assessments and, where necessary, safety assessments for facilities and activities involving NORM residues, including those facilities and activities for which a formal safety case is appropriate (e.g. the management of uranium production tailings).

1.14. This Safety Guide provides recommendations for regulatory bodies to determine which facilities and activities carrying out NORM residue management should be considered for regulatory control.

1.15. This Safety Guide is principally directed towards the management of NORM residues as a planned exposure situation (i.e. including the generation, reuse and recycling, long term management, and disposal of residues). It also applies to residues arising from the decommissioning of NORM facilities.

1.16. This Safety Guide does not address the remediation of areas contaminated by residual radioactive materials arising from past practices. The requirements for the remediation of such areas are established in GSR Part 3 [4], and further recommendations are provided in GSG-15 [14].

1.17. This Safety Guide is intended to address new facilities; however, it is also relevant to the review and upgrade of existing facilities. It might not be practical to apply all the recommendations to existing facilities; in such cases, the regulatory body should decide to what extent these recommendations should be applied. In accordance with national policies, appropriate steps should be taken to review existing facilities and, where reasonably practicable, to upgrade the provisions for protection and safety in accordance with the recommendations provided in this Safety Guide.

1.18. The radionuclides contained in NORM residues are not the only potential hazard. The chemical constituents within many NORM residues are also capable of causing harm to people and the environment, and it might be necessary to apply controls through environmental regulations or occupational health and safety regulations. These chemical constituents include heavy metals, inorganic elements (e.g. arsenic), acids and various organic compounds. The potential for such substances to cause harmful effects needs to be considered when planning the management of NORM residues. Although outside the scope of this Safety Guide, there is a particular need for regulatory bodies to take account of non-radiological hazards, which in many cases represent the primary risk to people and the environment. Achieving a consistent regulatory and integrated approach to protect against these different hazards is a challenge for regulatory bodies.

STRUCTURE

1.19. Section 2 provides an overview of NORM activities and NORM residues. Recommendations on the governmental, legal and regulatory framework for the safe management of NORM residues are provided in Section 3, and recommendations on the protection of people and the environment are provided in Section 4. Recommendations on the regulatory control process are provided in Section 5, while Section 6 provides recommendations on strategies for NORM residue management. Section 7 provides recommendations on the development of a safety case and supporting safety assessment. Section 8 addresses the full lifetime of facilities for the long term management of NORM residues, from siting through to long term institutional controls.

1.20. Three appendices and four supporting annexes complete the publication. Appendix I provides information on special considerations for managing residues from uranium production. Appendix II recommends a residue management plan for uranium production. Recommendations for a closure plan for a tailings management facility at a uranium production site are provided in Appendix III.

Annex I provides examples of NORM residues to be assessed for possible regulatory control. Annex II provides information on sampling NORM residues and determining radionuclide activity concentrations. An example of the application of the graded approach in the management of NORM residues is provided in Annex III. Annex IV provides information on the reuse and recycling of NORM residues. In addition, the bibliography provides a list of publications that are relevant to the management of NORM residues.

2. OVERVIEW OF NORM ACTIVITIES AND NORM RESIDUES

2.1. Paragraph 3.4 of GSR Part 3 [4] states (footnote omitted):

“Exposure due to natural sources is, in general, considered an existing exposure situation and is subject to the requirements [for existing exposure situations]. However, the relevant requirements...for planned exposure situations apply to:

- (a) Exposure due to material in any practice...where the activity concentration in the material of any radionuclide in the uranium decay chain or the thorium decay chain is greater than 1 Bq/g or the activity concentration of ^{40}K is greater than 10 Bq/g;
- (b) Public exposure due to discharges or due to the management of radioactive waste arising from a practice involving material as specified in (a) above”.³

2.2. The requirement stated in para. 2.1 does not apply to NORM residues in fertilizers, soil amendments or construction materials (or components of such) or to NORM residues that exist as residual radioactive material in the environment. In all such cases, the requirements for existing exposure situations apply, irrespective of the activity concentrations (see para. 5.1 of GSR Part 3 [4]). However, in terms of planning an activity for recycling NORM residues (including recycling residues into construction materials), the optimum protection strategy might include treating this as a planned exposure situation.

³ The criteria in para. 3.4(a) of GSR Part 3 [4] represent (in order of magnitude terms) the upper bounds of the activity concentrations in normal soil.

2.3. In addition to uranium production, other NORM activities also generate residues that might be of regulatory concern. This includes the following industry sectors⁴ [17]:

- (1) Extraction of rare earth elements;
- (2) Production and use of thorium and its compounds;
- (3) Production of tantalum, niobium and ferro-niobium;
- (4) Mining of ores other than uranium ore;
- (5) Production of oil and gas;
- (6) Manufacture of titanium dioxide pigments;
- (7) The phosphate industry;
- (8) The zircon and zirconia industries;
- (9) Production of tin, copper, aluminium, zinc, lead, and iron and steel;
- (10) Combustion of coal;
- (11) Water treatment.

2.4. Table 1 provides a general overview of the NORM residues arising from uranium production and other industrial activities. Annex I provides more details of the typical characteristics of the NORM residues that might be of regulatory concern. Residues of different origins can vary significantly with respect to their radiological, chemical and physical characteristics. The information in Table 1 and Annex I includes the majority of industry sectors and NORM residues that need to be considered; however, NORM residues might also occur in other industrial activities that are yet to be identified.

2.5. Of the different residues generated by NORM activities, those residues that are generated in bulk amounts (of the order of millions of tonnes) represent the greatest challenge in terms of safe management. Although such residues contain radionuclides at relatively low activity concentrations, they are generated in very large volumes and contain long lived radionuclides and (often) other hazardous substances, such as heavy metals. Such bulk residues include waste rock from uranium mining, mineral process tailings, phosphogypsum, red mud from alumina processing, and fly ash.

⁴ The list is not exhaustive. NORM residues that might be of regulatory concern can also arise from other sectors, such as the potash industry, geothermal energy use, use of deep water with a high mineral content, limestone processing and shale gas production.

TABLE 1. TYPES OF NORM RESIDUE ARISING FROM DIFFERENT INDUSTRIAL ACTIVITIES

Industrial activity	Bulk amounts of residues					Moderate to small amounts of residues		
	Tailings	Waste rock	Liquids	Slags	Scale	Sludge/ filter	Precipitator dust	Intermediate products
Conventional uranium production	X	X	X		X	X	X	
Heap leaching for uranium	X	X	X		X	X		
In situ leaching for uranium			X		X	X		
Extraction of rare earth elements	X		X		X	X	X	
Production and use of thorium and its components	X				X	X		Thorium compound and concentrate
Production of tantalum, niobium and ferro-niobium	X			X		X	X	Pyrochlore concentrate

TABLE 1. TYPES OF NORM RESIDUE ARISING FROM DIFFERENT INDUSTRIAL ACTIVITIES (cont.)

Industrial activity	Bulk amounts of residues				Moderate to small amounts of residues			
	Tailings	Waste rock	Liquids	Slags	Scale	Sludge/ filter	Precipitator dust	Intermediate products
Mining of ores other than uranium ore	X	X	X		X	X		
Production of oil and gas			X		X	X		
Manufacture of titanium dioxide pigments	X		X		X	X		
Phosphate and potash industries	Phosphogypsum			Thermal production	X	X	X	
Zircon and zirconia industries							X	Fused zirconia
Production of tin, copper, aluminium, zinc, lead, iron and steel	Red mud			Tin and copper smelting		X	X	

TABLE 1. TYPES OF NORM RESIDUE ARISING FROM DIFFERENT INDUSTRIAL ACTIVITIES (cont.)

Industrial activity	Bulk amounts of residues				Moderate to small amounts of residues			
	Tailings	Waste rock	Liquids	Slags	Scale	Sludge/ filter	Precipitator dust	Intermediate products
Combustion of coal	Fly ash				X			
Water treatment and geothermal energy use					X	X		

2.6. Some residues might be of a relatively small volume but have a relatively high activity concentration, for example the following:

- (a) Scales and sludge that accumulate in pipes or process vessels in oil and gas production, coal production with radium-rich inflow water, geothermal energy use and rare earth production;
- (b) Anode slimes from electrowinning processes;
- (c) Precipitated smelting dusts;
- (d) Rare earth extraction residues (e.g. thorium hydroxide);
- (e) Residues from decontamination processes;
- (f) Contaminated equipment and process filters.

2.7. Plant and equipment, such as pipes, valves, process vessels, pumps and machinery, used for the handling or processing of material containing NORM can become contaminated with NORM residues, which can be a concern during the operation, and particularly during the decommissioning, of relevant facilities. These residues are often associated with scrap metals, which also require appropriate management (see Annex IV).

2.8. Liquid residues of various origin are also generated, in some cases in large volumes, including the following:

- (a) Process water;
- (b) Leaching fluids;
- (c) Rainfall runoff (from the process plant area, residue management area, and residue and ore stockpiles);
- (d) Seepage from process tailings, stockpiles and waste rock management areas;
- (e) Mine water (e.g. groundwater that has entered open pits or underground mines).

3. GOVERNMENTAL, LEGAL AND REGULATORY FRAMEWORK FOR SAFETY

RESPONSIBILITIES OF THE GOVERNMENT

3.1. Requirement 1 of GSR Part 1 (Rev. 1) [3] states:

“The government shall establish a national policy and strategy for safety, the implementation of which shall be subject to a graded approach in accordance with national circumstances and with the radiation risks associated with facilities and activities, to achieve the fundamental safety objective and to apply the fundamental safety principles established in the Safety Fundamentals.”

3.2. For the safe management of NORM residues, the government should establish a policy and strategy that is appropriate to the national situation. The policy and strategy should acknowledge existing governmental, legal and regulatory frameworks; promote a graded approach to regulation; identify further industries that might need oversight; and coordinate the overall approach to the management of NORM residues. The policy and strategy should reflect, and be consistent with, the principles as set out in SF-1 [2] and the recommendations provided in Sections 4–8 of this Safety Guide.

3.3. The policy and strategy for the management of NORM residues should be consistent with the national policy and strategy for the development of activities that generate NORM residues. Together, these policies and strategies should address controls on the generation of NORM residues and encourage the reuse and recycling of NORM residues, where it is safe and appropriate to do so. Reuse and recycling of NORM residues are described further in Section 6 (i.e. as options for residue management), and more information on the application of these options is given in Annex IV.

3.4. The policy and strategy for the management of NORM residues should also take into account the national policies and strategies for safety, for management of non-radioactive waste and for radioactive waste management. States may choose to integrate key elements of the strategy for NORM residue management into their national policy, legal framework and regulatory instruments. In such cases, a separate national strategy for NORM residue management might not be necessary.

3.5. The government should consider the need for, and the extent of, public involvement and coordination among relevant governmental organizations during the development and implementation of the policy and strategy, including the establishment of a system for regulatory control. Increasing consultation with the public is a feature of the authorization process in many States; however, the responsibility for regulatory decisions remains with the regulatory body.

3.6. To enable oversight of NORM activities, the government should first identify which industries within the State process NORM and/or generate NORM residues. The government should then identify the regulatory body, or other authorities appropriate to these industries, to oversee NORM activities. If there are multiple activities or industries, there might be more than one regulatory body or authority involved.

3.7. In accordance with Requirements 3 and 4 of GSR Part 1 (Rev. 1) [3], the government is required to establish and maintain a regulatory body that is effectively independent and has the authority and sufficient resources (staff and financial) to properly oversee the safety of facilities and activities. For regulatory bodies that historically have not been involved in regulating radiation sources, this is likely to involve cooperation with other agencies or organizations with relevant radiation protection expertise.

3.8. The government should coordinate the establishment of an appropriate national inventory of significant NORM residues arising from new and existing NORM activities. Where possible, residues identified from past practices (i.e. those that need to be considered as part of the national strategy for residue management) should also be included in the inventory.

3.9. The government should establish legislation that allows the regulatory body to maintain effective oversight of NORM activities, where such legislation does not already exist. Such legislation should address the relevant requirements of GSR Part 3 [4] and should include provision for the authorization of facilities and activities and for the establishment of financial resources by the operating organization, where these are required. Financial resources are explained in more detail in Section 5.

3.10. For activities such as uranium production, effective legislation will do the following:

- (a) Establish requirements and/or safety criteria for the management of residues, including for long term safety and the disposal of mill tailings and other residues as waste when no further use is foreseen;
- (b) Prohibit the generation or storage of residues and waste unless these activities have been licensed by the regulatory body;
- (c) Enable the regulatory body to specify conditions to be attached to licences;
- (d) Make the failure to comply with licence conditions an offence subject to enforcement action;
- (e) Require information and any associated fees to be provided with the licence application;
- (f) Require that the operating organization prepare plans for the management of residues and waste;
- (g) Require financial resources for the purposes of decommissioning, remediation, closure and institutional controls, as relevant;
- (h) Require regulatory approval for significant changes to operations;
- (i) Require regulatory approval before any licence is relinquished or is transferred to another party;
- (j) Grant the regulatory body access to the facility to undertake inspections and measurements, as necessary.

For other NORM activities, the legislation and the regulatory effort should be commensurate with the risks and should take into account existing legislation and systems of control. In some cases, existing regulations for workplace health and safety and for environmental protection may already provide adequate protection against radiation; hence, further legislation specific to radiation protection might not be necessary for such NORM activities.

3.11. Given the range of industries concerned, it is possible that several different parts of government will have responsibilities relating to NORM activities, and it is likely that several pieces of legislation will apply. For effective and efficient regulation, it is important that responsibilities be defined and formally coordinated through instruments such as administrative agreements or memorandums of understanding between different agencies. This coordination can be achieved by one regulatory body acting for the government to coordinate regulatory oversight across multiple industries. More commonly, there will be multiple regulatory bodies. In the case of multiple regulatory bodies, it should be ensured that regulatory requirements and any authorization conditions are suitably aligned.

RESPONSIBILITIES OF THE REGULATORY BODY

3.12. For planned exposure situations involving NORM, as stated in Requirement 12 of GSR Part 3 [4], **“The government or the regulatory body shall establish dose limits for occupational exposure and public exposure, and [operating organizations] shall apply these limits.”**

3.13. In addition, as stated in para. 3.22(c) of GSR Part 3 [4] (footnote omitted):

“The government or the regulatory body: ...Shall establish or approve constraints on dose and on risk, as appropriate, or shall establish or approve a process for establishing such constraints, to be used in the optimization of protection and safety.”

3.14. The regulatory body is also required to oversee compliance with conditions specified in licences and to review and assess the results of inspection and enforcement activities, as appropriate, in accordance with Requirements 25, 27 and 31 of GSR Part 1 (Rev. 1) [3].

3.15. The regulatory body should establish regulations or guides for the exemption of practices and sources, for the clearance of material and for the release of sites from regulatory control, and should establish end state criteria for such sites. The regulatory body should oversee the implementation of the operating organization’s plans for decommissioning, for the management of NORM residues and waste and, where appropriate, for closure (including any institutional controls or long term monitoring) to verify that progress to meet the end state criteria is being made.

3.16. The regulatory body is also responsible for establishing guidance on the implementation of regulatory requirements and on the authorization process (see paras 2.5(9) and 4.34 of GSR Part 1 (Rev. 1) [3]). The regulatory body should also establish guidance on regulatory review and assessment, operational oversight, and oversight of the closure or decommissioning of a facility. The process for making regulatory decisions should be transparent, independent and justifiable, such that if a decision is challenged the regulatory body can explain how it was reached.

3.17. Through the implementation of regulatory criteria that are based on the established national policy, strategy and legislation, the regulatory body should identify those facilities or processes that require formal regulatory control and those for which guidance on best practice is more appropriate. A key role of the regulatory body is to identify which facilities and activities involving NORM or NORM residues are likely to be subject to the requirements of legislation and to

provide guidance to industry on the scope and application of regulations. This will then lead to the notification and assessment processes described in Section 5 of this Safety Guide. Uranium production facilities are likely to already be familiar with the regulatory framework, but for other NORM activities this guidance will be important.

3.18. The regulatory body should consider an outreach programme to communicate with operating organizations involved with NORM residues, to make these operating organizations aware of the potential need for regulation and radiation protection. The outreach programme should also encourage the sharing of data between the operating organization and the regulatory body and should include communications with workers and, where appropriate, the public.

3.19. The regulatory body should encourage the reuse and recycling of NORM residues in accordance with national laws and regulations, as appropriate (i.e. rather than these residues being managed as waste), where relevant safety criteria can be met and residues can be cleared from further regulatory control.

3.20. The regulatory body should ensure that it maintains the necessary technical expertise to evaluate processes and activities that generate and manage NORM residues.

3.21. The regulatory body should ensure that the operating organization keeps relevant records concerning any facility that generates, handles, processes or stores NORM residues, in particular where residues are held for long term management. The regulatory body should ensure that the operating organization provides it with access to the facility and to safety related information, in accordance with para. 2.13 of GSR Part 1 (Rev. 1) [3] and para. 2.45 of GSR Part 3 [4].

3.22. The regulatory body should assess the need for inspection, audit and periodic reassessment of the inventories of NORM residues and of environmental monitoring data.

RESPONSIBILITIES OF THE OPERATING ORGANIZATION

3.23. The operating organization is responsible for all aspects of safety of the NORM activity, including protection of workers, the public and the environment against any hazards associated with NORM residues throughout the lifetime of the NORM facility or activity, including decommissioning or closure.

3.24. The operating organization is required to notify the regulatory body of an intention to undertake a NORM activity, in accordance with Requirement 7 of GSR Part 3 [4]. As such, the operating organization is required to inform the regulatory body of any circumstances or changes that might increase occupational exposures or public exposures, in accordance with para. 3.14 of GSR Part 3 [4].

3.25. The operating organization is required to provide the regulatory body with access to the facility and to safety related information, in accordance with para. 2.13 of GSR Part 1 (Rev. 1) [3] and para. 2.45 of GSR Part 3 [4].

3.26. In accordance with Requirement 6 of GSR Part 1 (Rev. 1) [3], the operating organization is required to comply with all legal and regulatory requirements; for some facilities and activities that require a licence (see Section 5), these requirements will include collecting baseline data prior to site development and preparing a safety case and supporting safety assessment (see Section 7) associated with siting, design, construction, commissioning, operation, decommissioning or closure, and post-closure.

3.27. The operating organization is responsible for developing a plan for the management of NORM residues.

3.28. The operating organization is responsible for establishing and implementing an appropriate management system that incorporates radiation protection requirements to a degree that is commensurate with the complexity and risk of the facilities and activities relating to NORM residues. The management system should meet the requirements of IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [23].

3.29. By means of design measures, procedures and processes, the operating organization should identify and implement measures to minimize the amounts of NORM residues and the amount of NORM waste. This could be achieved, for example, by increasing the efficiency of processes, or through the reuse and recycling of NORM residues.

3.30. Where applicable, the operating organization should maintain up to date plans for residue management and the decommissioning or closure of facilities, as appropriate. These plans should take account of the financial provision throughout the lifetime of the facility, including how it will meet the end state criteria, which also will provide the basis for any financial resources mechanism that is necessary.

4. PROTECTION OF PEOPLE AND THE ENVIRONMENT

GENERAL

4.1. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation [2]; this is to be achieved through compliance with the requirements established in GSR Part 3 [4]. Given the broad spectrum of NORM residues arising from a wide range of NORM activities, it is important that a graded approach to protection and safety in the management of NORM residues be adopted. That is, the protection measures adopted should be commensurate with the magnitude and likelihood of exposures and level of risk.

4.2. The regulatory framework for NORM residue management is based on requirements laid out in GSR Part 3 [4]. Practices or sources may be exempted from some or all of the requirements of GSR Part 3 [4]. With regard to NORM, para. I.4 of GSR Part 3 [4] states (footnote omitted):

“For radionuclides of natural origin, exemption of bulk amounts of material is necessarily considered on a case by case basis by using a dose criterion of the order of 1 mSv in a year, commensurate with typical doses due to natural background levels of radiation.”

4.3. The management of NORM residues is an example of the management of facilities and activities, as defined in GSR Part 3 [4]. Radiation protection considerations are therefore governed by the principles of justification, optimization and (for planned exposure situations) dose limitation. The justification principle should be applied to proposed new NORM activities before making modifications to processes that would affect the generation of NORM residues and during licence renewal.

4.4. In the management of NORM residues, a safety culture that encourages continuous improvement and a questioning and learning attitude to protection and safety is required to be fostered and sustained (see Requirement 12 of GSR Part 2 [23]).

4.5. Radioactive discharges to the environment from NORM facilities and activities that are subject to authorization should be controlled in accordance with a licence issued by the regulatory body. Recommendations on the regulatory control of discharges are provided in GSG-9 [13].

4.6. Radon exposures associated with the management of NORM residues should be controlled in accordance with the requirements established in GSR Part 3 [4] (e.g. see para. 3.4(c) and (d) of GSR Part 3 [4]). Recommendations on the assessment of radon (and thoron) exposures in workplaces, and on the protection of workers from such exposures, are provided in GSG-7 [12].

PLANNED EXPOSURE SITUATIONS

Occupational exposure

4.7. In general, occupational radiation protection in the management of NORM residues involves the consideration of three main exposure pathways:

- (a) External exposure to radiation (primarily gamma radiation);
- (b) Intakes of radionuclides directly through dust inhalation and ingestion or indirectly through ingestion of contaminated water or food;
- (c) Exposure due to radon (and sometimes thoron) released from residues into the air.⁵

Workers might be exposed during the generation of NORM residues; during operations to process, reuse or recycle the residues; or during the long term management of such residues. Exposure might also occur during the handling of contaminated items (e.g. pipes, equipment) and during maintenance and cleaning of facilities.

4.8. Where NORM residues are subject to regulatory control, the operating organization is required to prepare and implement a radiation protection programme (see Requirement 24 of GSR Part 3 [4]). The radiation protection programme should describe the measures taken to ensure that the protection of workers is optimized. Recommendations on the scope and content of the radiation protection programme are provided in GSG-7 [12], which also includes special considerations for mineral processing involving NORM (see paras 9.66–9.72 of GSG-7 [12]).

4.9. Occupational radiation protection in the generation of NORM residues is usually managed as part of the radiation protection programme for the overall process that is generating the residues. For example, radiation protection in the

⁵ The terms ‘radon’ and ‘thoron’ include not only the parent radionuclides — ^{222}Rn and ^{220}Rn , respectively — but also their short lived progeny.

generation and handling of uranium mill tailings will be a part of the overall radiation protection programme for the mill. In other cases, a single NORM residue might be the only material in the whole process where the concentration of radionuclides is sufficient to lead to exposures that warrant control; in such cases, the radiation protection programme will be specific to the NORM residue. For example, for a rare earth facility, the main residue of interest might be thorium hydroxide, which presents a significant radiological risk that needs to be managed through the radiation protection programme. Another example is NORM scale in oil and gas production facilities.

4.10. The radiation protection programme is required to include arrangements for the designation of controlled and supervised areas (see paras 3.88–3.92 of GSR Part 3 [4]). Controlled areas are likely to be unnecessary where only materials with low activity concentrations are handled, as is the case in many industrial activities involving NORM (see para. 3.79 of GSG-7 [12]).

Public exposure

4.11. As naturally occurring radionuclides are present in the environment and contribute to natural background radiation, it is important to distinguish between exposures arising as a result of NORM activities and NORM residues, and those arising from natural background sources. Establishing baseline information on natural radiation levels⁶ is therefore important (see para. 8.50(d)).

4.12. For public exposure, the dose limit is an effective dose of 1 mSv in a year⁷ (schedule III of GSR Part 3 [4]). NORM activities are also subject to the radiation protection principle of optimization, for which (for planned exposure situations) the government or the regulatory body is required to establish or approve dose constraints (see para. 3.120 of GSR Part 3 [4]).

4.13. Dose limits and dose constraints for public exposure apply both during operations involving NORM residues — such as generation, reuse or recycling, storage, or disposal of NORM residues — and after the cessation of such operations. During operation, public exposure can be assessed by monitoring

⁶ For facilities and sites where NORM industries have been operating for a long time, the monitoring programme for establishing natural radiation levels may need to focus on representative locations away from the immediate vicinity of the site.

⁷ In special circumstances, a higher value of effective dose could apply in a single year, providing that the average effective dose over five consecutive years does not exceed 1 mSv in a year.

the radionuclides in ambient air or foodstuffs, or by monitoring the discharges and then modelling the transfer of radionuclides through the environment to estimate the subsequent intakes and doses to the public. After the cessation of operations, the end state criteria — in conjunction with institutional control, where appropriate — should ensure that public exposures are below the established dose constraint.

4.14. If several facilities and activities are located on the same site, the dose constraints for public exposure should apply to all sources of planned exposure to which a representative member of the public could be exposed, leaving an appropriate margin for foreseeable future activities at the site that could give rise to additional exposure. As described in para. 4.12, the regulatory body is required to either establish dose constraints or approve dose constraints, for example those that have been proposed by the operating organizations of the facilities and activities on the site.

4.15. There should be reasonable assurance by the operating organization that any control measures implemented will remain effective for a specified period agreed with the regulatory body and that during this period the dose constraint established or approved by the regulatory body will continue to be met.

4.16. The potential for public exposures in excess of the dose constraint due to possible future redevelopment of, or unplanned intrusion into, closed facilities for NORM residue management should be considered in the planning and design as well as in the safety assessment, and appropriate institutional controls should be planned and implemented.

EMERGENCY EXPOSURE SITUATIONS

4.17. For the management of NORM residues, there are very few, if any, credible accident scenarios⁸ that could lead to an emergency exposure situation. Consequently, arrangements for emergency preparedness and response, as described in GSR Part 7 [10], are unlikely to be required.

4.18. Engineering controls (e.g. the surface cover of a tailings dam) could fail because of natural processes (e.g. erosion), or other incidents might occur that result in the release of increased amounts of radionuclides to the environment. Such scenarios might have some radiation exposure implications; however, other

⁸ 'Scenario' is defined as a postulated or assumed set of conditions or events [1].