

IAEA SAFETY STANDARDS SERIES No. SSG-87

RADIATION SAFETY IN THE USE OF RADIATION SOURCES IN RESEARCH AND EDUCATION

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY

VIENNA, 2024

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1. INTRODUCTION

BACKGROUND

1.1. IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1], specifies the basic requirements for the protection of people and the environment from harmful effects of ionizing radiation and for the safety of radiation sources. The implementation of these requirements and all other relevant safety requirements established by the IAEA helps to ensure that the likelihood and magnitude of exposures and the number of individuals exposed are kept as low as reasonably achievable, with economic, societal and environmental factors taken into account. It also helps to prevent accidents involving radiation sources and, if such accidents occur, to mitigate their consequences. This Safety Guide provides recommendations for implementing the requirements in GSR Part 3 [1] with regard to the use of radiation sources ~~that are used~~ in research and education ~~facilities~~.

1.2. ~~There are many~~ Many types of radiation ~~source~~ source are used in research and education. The sources include: ~~particle accelerators;~~ sealed radioactive sources, such as low activity check sources and high activity sealed radioactive sources in irradiators; unsealed radioactive sources ~~that are~~ used as tracers in field work and in laboratory work; naturally occurring radioactive material; and X ray generators such as diffraction apparatus and fluorescence analysers.

1.3. The users of radiation sources include secondary school students, undergraduate students, graduate students, technical staff, research staff and academic staff. The graduate students, research staff and academic staff often work on more than one campus and may also undertake research work in other countries.

1.4. The use of radioactive sources can lead to the generation of radioactive waste that needs to be managed by the ~~education~~ educational or research facility or activity. Radioactive material and radioactive waste may need to be transported between laboratories on a campus, ~~and or~~ between campuses. Some radioactive waste needs to be stored to allow it to decay before being transferred to a waste management organization for treatment and disposal.

1.5. This Safety Guide is part of a set of ~~Specific~~ Safety Guides that cover the use of radiation sources in industrial irradiators, industrial radiography, inspection and non-medical imaging, well logging, nuclear gauges, and accelerator based isotope production facilities ~~Refs~~ [2–7].

1.6. Detailed recommendations on occupational radiation protection can be found in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [8]. Recommendations on the protection of the public and the environment are provided in IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment [9]. Requirements and recommendations for radiation protection in emergency exposure situations are in provided in ~~Refs~~ IAEA Safety Standards Series Nos GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [10–]; GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [11]; GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [12]; and GSG-11, Arrangements for the Termination of a Nuclear or Radiological Emergency [13].

1.7. It is assumed in this Safety Guide that the State has an effective governmental, legal and

regulatory infrastructure for radiation safety that covers the use of radiation sources in research and educational facilities and activities. Requirements for such infrastructure are established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [14], and recommendations on the implementation of these requirements are provided in Refs [15–17].

OBJECTIVE

1.8. The objective of this Safety Guide is to provide recommendations on how to meet the relevant requirements of GSR Part 3 [1] in the use of radiation sources in research and education. ~~It provides guidance~~ This includes recommendations on the control of occupational exposure and of public exposure, for planned exposure situations and, where appropriate, emergency exposure situations ~~and as well as on the specific~~ and as well as on the specific safety measures ~~specific to this practice~~.

1.9. The recommendations in this ~~publication~~ Safety Guide are aimed primarily at operating organizations such as educational and research establishments, including schools, colleges, universities and technical institutes, that are authorized to use radiation sources in academic programmes, as well as their employees, students, teachers and radiation protection officers. The ~~guidance~~ recommendations will also be of interest to regulatory bodies and to other relevant organizations involved in the design, manufacture, supply and service of radiation sources and associated equipment for research and education.

SCOPE

1.10. This Safety Guide addresses the radiation protection and safety aspects of the use of radioactive sources and radiation generators ~~that are used~~ in research and education.

1.11. This Safety Guide addresses the exposure of students and workers using radiation sources in research and education. It also covers the exposure of members of the public who might be inadvertently exposed during the use of such sources.

1.12. The exposure of volunteers for the purposes of biomedical research is considered ~~to be~~ a medical exposure. Recommendations on such exposures are provided in IAEA Safety Standards Series No. SSG-46, Radiation Protection and Safety in Medical Uses of Ionizing Radiation [18].

1.13. Requirements relating to the protection of students and research workers carrying out research or studies at research reactors are established in IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [19], and related recommendations are provided in IAEA Safety Standards Series No. ~~DS509~~ FSSG-85, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [20]. Such facilities and activities are outside the scope of this Safety Guide.

1.14. ~~The~~ This Safety Guide also provides information on the need for appropriate nuclear security measures and on their interface with safety measures but does not provide specific guidance on such nuclear security aspects. Additional security guidance can be found in the IAEA Nuclear Security Series.

STRUCTURE

1.15. Section 2 describes the basic principles of radiation protection and their application in the protection of students, research workers and members of the public in research and education. The types of radiation ~~source~~source used in research and education are described in Section 3. Recommendations on the duties and responsibilities of the operating organization, radiation safety committee, radiation protection officer and qualified ~~expert~~experts, and on the content of a radiation protection programme, are provided in Section 4. Recommendations on the preparation of a safety assessment are provided in Section 5. Section 6 provides recommendations on the design of facilities, laboratories, equipment and sources. Section 7 provides recommendations on arrangements for occupational radiation protection, including classification of areas, local rules, monitoring of the workplace, assessment of occupational exposure, health surveillance and training. Section 8 provides recommendations on the discharge of radioactive material from laboratories, and on the management of radioactive waste and decommissioning. Section 9 provides recommendations on protection of members of the public. Section 10 provides recommendations on the movement of radioactive material within a site, and on the transport of radioactive material to and from different sites. Section 11 provides recommendations on the arrangements for prevention of accidents and mitigation of their consequences, and ~~for~~on the preparation of ~~an~~ emergency ~~plan~~plans and procedures.

1.16. Annex I provides practical guidance on the use of naturally occurring radioactive material (NORM) in research and education. The use of radiation sources in secondary schools raises specific issues, for example in relation to the age of students; therefore, Annex II provides practical guidance on the use of radiation sources in secondary schools. Annex III provides case studies and practical guidance on the radiation protection of students in medical and paramedical education. Annex IV gives information on the safe use of specific types of radiation ~~source~~source in research and education. Annex V provides examples of specific on-site actions to ~~consider~~be considered in ~~the~~ emergency ~~plan~~plans and procedures for certain emergencies ~~related~~relating to the use of sources in research and education.

2. RADIATION PROTECTION PRINCIPLES FOR SOURCES USED IN RESEARCH AND EDUCATION

2.1. Requirement 1 of GSR Part 3 [1] specifies that those responsible for protection and safety in facilities handling radiation sources are required to ensure that the principles of radiation protection are applied. These principles are: justification of practices, optimization of protection and safety, and dose limitation, as stipulated in Requirements 10, ~~11 and~~ 12 of GSR Part 3 [1].

JUSTIFICATION OF THE USE OF SOURCES IN RESEARCH AND EDUCATION

2.2. Paragraph 3.16 of GSR Part 3 [1] states: (footnotes omitted):

”“The government or the regulatory body, as appropriate, shall ensure that provision is made for the justification of any type of practice and for review of the justification, as necessary, and shall ensure that only justified practices are authorized.”

This means that no practice is to be authorized unless the practice produces sufficient benefit to the exposed individuals or to society to offset any harm that the exposure to radiation might cause.

2.3. The process of determining ~~if~~whether a practice is justified involves a full characterization of the radiation sources that will be used, and the measures that will be taken to ensure safety, and an assessment of the radiation detriment in terms of the expected exposures from normal use of the sources and the magnitude and likelihood of potential exposures from accidents. The assumption is made in this Safety Guide that the process of justification has already taken place. The justification process should have specified the types of source and the type of practice, for example the type and activities of radiation sources that are permitted to be used in secondary schools. The justification of practices and sources should be reviewed, as necessary.

2.4. Recommendations on the application of the principle of justification are provided in IAEA Safety Standards Series No. GSG-5, Justification of Practices, ~~including~~Including ~~Non-Medical~~medical Human Imaging [21]. For research organizations developing new technologies involving the use of radiation sources, GSG-5 [21] sets out the elements that should be considered and the process that should be applied in determining whether the introduction of a particular type of practice is justified.

OPTIMIZATION OF PROTECTION AND SAFETY IN RESEARCH AND EDUCATION

2.5. Paragraph 3.23 of GSR Part 3 [1] states that “Registrants and licensees shall ensure that protection and safety is optimized.” This means that the process of optimization of protection and safety has been applied and the result of that process has been implemented. Guidance on the application of the principle of optimization of protection and safety in the control of occupational exposure can be found in Ref. [22]. The intended outcome of the optimization of protection and safety is that all exposures are controlled to levels that are as low as reasonably achievable, economic, societal and environmental factors being taken into account.

2.6. Optimization of protection and safety needs to be considered at all stages ~~of~~in the ~~life~~lifetime of facilities and activities, in relation to both exposures from normal operations and potential exposures. Therefore, all situations — from design, through operation to decommissioning, transport and waste management — should be considered in the optimization process.

2.7. In practice, the optimization of protection and safety for sources used in research and education calls for an approach that should include the following:

- (a) ~~All~~Consideration of all possible actions by workers and students involving the ~~source(s)~~are considered~~sources.~~
- (b) ~~A~~Implementation of a ‘management by objective’ process ~~is implemented~~ with the following sequence: planning, setting objectives, monitoring, measuring performance, evaluating and analysing performance to define corrective actions, record keeping and setting new objectives.
- (c) ~~The approach can~~Ability to be adapted to take into account any significant changes in technology or techniques, ~~and the prevailing social context.~~
- (d) Accountability, such that all parties adopt a responsible attitude to the process of eliminating unnecessary exposures.

2.8. The process of optimization of protection and safety should take into account the following:

- (a) The resources available for protection and safety;
- (b) The distribution of individual and collective exposure among different groups of workers and students;
- (c) The probability and magnitude of potential exposures;
- (d) The potential impact of protection actions on the level of other (non-radiological) risks to workers or members of the public;
- (e) Good practices in relevant sectors;
- (f) Societal and economic aspects.

2.9. The optimization of protection and safety for radiation sources used in research and education should be considered at the design stage of equipment and facilities, such as laboratories, when some degree of flexibility is still available and a graded approach that is commensurate with the radiation risk can be applied. The use of engineered controls should be examined carefully at this stage when defining the protection options. Decisions made at the design stage include the design of shielding, ~~the design~~ of ventilation/fume cupboards, ~~the design~~ of laboratories and ~~the design~~ of instrumentation including safety systems.

2.10. The content and scale of the optimization process will depend on the type and nature of the facilities and activities involving radiation sources. For example, for low activity sealed radioactive sources or with X ray equipment fitted with effective engineered controls, the optimization process can be quite straightforward, involving local rules and appropriate training of the users. For laboratories using complex equipment, or for activities involving complicated source handling procedures, a structured approach should be applied including, where appropriate, the use of decision aiding techniques.

2.11. Some of the options considered in the optimization of the protection and safety of workers might lead to increased exposure of other persons, such as students, the general staff working in the facility and visitors. Such effects should be taken into account in the optimization process, especially when considering the establishment of administrative controls and the use of personal protective equipment.

2.12. In general, the incremental benefits to be obtained in terms of dose reduction decrease progressively as the associated expenditure increases. Even the cost of considering the ways in which exposures may be reduced can become significant compared with the benefit to be achieved. At some stage, ~~for those~~ sources used in research and education that pose a low radiation risk, the effort might not be worthwhile.

2.13. Even if protection has been optimized at the design stage, there is still a need to optimize protection and safety during the operation of a facility or the conduct of an activity. Optimization of protection and safety in operation is a process that begins at the planning stage and continues through the stages of scheduling, preparation, implementation and feedback. This process of optimization through work management should be applied ~~in order~~ to keep exposures under review and to ensure that they are as low as reasonably achievable. The establishment of a radiation protection programme (see paras 4.17–4.22) is an essential element of work management.

2.14. The operating organization should record information on the way in which optimization of protection and safety is being implemented for the radiation sources used in research and

education and should disseminate this information where appropriate. This information could include the following:

- (a) The rationale for the proposed operating, maintenance and administrative procedures, including for the purchase, transport, storage and disposal of sources, together with other options ~~that have been~~ considered and the reason for their rejection;
- (b) Periodic reviews of and analysis of trends in the exposure of individuals, and other performance indicators;
- (c) The results of internal audits and peer reviews;
- (d) Incident reports and lessons learned.

Dose constraints

2.15. Dose constraints are required to be used for the optimization of protection and safety: see ~~paras~~ 1.22 and 3.25 of GSR Part 3 [1]. Dose constraints are applied to occupational exposure and to public exposure in planned exposure situations. For occupational exposures, a dose constraint is a source related value of individual dose used to limit the range of options considered in the process of optimization and will always be a fraction of the dose limit. Dose constraints are set separately for each source under control and serve as boundary conditions in defining the range of options for the purposes of optimization. Dose constraints are not dose limits; exceeding a dose constraint does not represent non-compliance with regulatory requirements, but it could result in follow-up actions.

2.16. While the objectives of the use of dose constraints for controlling occupational exposure and public exposure are similar, the dose constraints are applied in different ways. For occupational exposure, the dose constraint is a tool to be established and used by the licensee responsible for radiation sources in the optimization of protection and safety. The setting of dose constraints needs to be considered in conjunction with other health and safety provisions and the technology available. For public exposure, the relevant dose constraint is a source related value established or approved by the government or the regulatory body, with account taken of the doses from planned operations of all sources under control. The dose constraint for ~~each particular source~~ individual sources is intended, among other things, to ensure that the sum of doses from planned operations for all sources under control remains within the dose limit (see footnote 25 ~~of~~ GSR Part 3 [1]).

2.17. The objective of a dose constraint is to place a ceiling on values of individual dose — from a source, a set of sources in a facility, a practice, a task or a group of operations in a specific type of industry — that could be considered acceptable in the process of optimization of protection for those sources, practices or tasks. Depending on the situation, the constraint can be expressed as a single dose or as a dose over a given time period. The setting of dose constraints should be such that dose limits for occupational exposure are complied with when workers incur exposures from multiple sources or tasks.

2.18. To apply the optimization principle, individual doses should be estimated at the design and planning stage, and it is these predicted individual doses for the various options that should be compared with the appropriate dose constraint. Options predicted to give doses below the dose constraint should be considered further; those predicted to give doses above the dose constraint would normally be rejected. Dose constraints should be used prospectively in optimizing radiation protection in planning and executing activities, and in designing facilities or equipment. ~~They~~ Dose constraints should, therefore, be set on a case-by-case basis in accordance with the specific characteristics of the source of exposure.

2.19. Since dose constraints are source related, the source to which they relate should be specified. Dose constraints should be set in consultation with those involved in the facility or activity. For students, the dose constraint should take account of the number of hours ~~that~~ the students will be using radiation sources. For research workers, the dose constraint would need to take account of the time ~~that~~ they spend using radiation sources at their ‘home’ campus, and of the time ~~spent~~they spend using other sources in other facilities.

2.20. For members of the public, the dose constraint is a fraction of the public dose limit, and is to be used in ~~the design of~~ designing shielding (e.g. for radiation sources and associated equipment, laboratories, and stores for radioactive sources and ~~for~~ radioactive waste) and in determining discharge limits.

2.21. Dose constraints should not be used retrospectively to check compliance with the requirements for protection and safety. However, para. 1.23 of GSR Part 3 [1] states:

“After exposures have occurred, the dose constraint may be used as a benchmark for assessing the suitability of the optimized strategy for protection and safety (referred to as the protection strategy) that has been implemented and for making adjustments as necessary.”

DOSE LIMITS

2.22. The dose limits for planned exposure situations are specified in ~~Schedules~~schedule III of GSR Part 3 [1] and, for convenience, are reproduced in paras 2.23–2.26 of this Safety Guide. Associated requirements are specified in paras 3.26–3.28 of GSR Part 3 [1].

2.23. For occupational exposure of workers over the age of 18 years, the dose limits are as follows:

- (a) An effective dose of 20 mSv per year averaged over five consecutive years (100 mSv in ~~5~~five years) and of 50 mSv in any single year;
- (b) An equivalent dose to the lens of the eye of 20 mSv per year averaged over ~~5~~five consecutive years (100 mSv in ~~5~~five years) and of 50 mSv in any single year;
- (c) An equivalent dose to the extremities (hands and feet) or to the skin of 500 mSv in a year.

Additional restrictions apply to occupational exposure for a ~~female~~ worker who has notified ~~pregnancy~~their employer that they are pregnant or ~~who is~~ breastfeeding (see para. 3.114 of GSR Part 3 [1] and paras 6.2–6.20 of GSG-7 [8]).

2.24. For occupational exposure of apprentices of 16 ~~to~~ 18 years of age who are being trained for employment involving radiation and for exposure of students of ~~age~~ 16 ~~to~~ 18 years of age who use sources in the course of their studies, the dose limits are as follows:

- (a) An effective dose of 6 mSv in a year;
- (b) An equivalent dose to the lens of the eye of 20 mSv in a year;
- (c) An equivalent dose to the extremities (hands and feet) or to the skin of 150 mSv in a year.

2.25. For public exposure, the dose limits are as follows:

- (a) An effective dose of 1 mSv in a year.

- (b) In special circumstances, a higher value of effective dose in a single year could apply, provided that the average effective dose over five consecutive years does not exceed 1 mSv per year.
- (c) An equivalent dose to the lens of the eye of 15 mSv in a year.
- (d) An equivalent dose to the skin of 50 mSv in a year.

2.26. The equivalent dose limits for the skin specified in paras 2.23–2.25 apply to the average dose over 1 cm² of the most highly irradiated area of the skin. The dose to the skin also contributes to the effective dose, this contribution being the average dose to the entire skin multiplied by the tissue weighting factor for the skin.

2.27. The dose limits apply to all users of radiation sources, including short term contractors, research workers, and students. Notwithstanding the dose limits specified for students in para. 2.24, ideally secondary school students (typically up to the age of 17 or 18 years) and undergraduate students (typically up to the age of 21 or 22 years) should receive the same level of protection and safety as members of the public. There is a general expectation that a high level of protection will be provided for younger students. Compliance with the dose limits for public exposure is normally straightforward, as these students are likely to be using radiation sources for only a few hours per year.

2.28. Graduate and postgraduate students (typically above the age of 22 years) conducting ~~continuous~~ research or studies using radiation sources for long duration should be afforded the same level of protection and safety as workers. Registrants and licensees should establish a system to ensure that the total annual radiation exposure of research workers and graduate students, including any exposure received by them when they are using radiation sources at other research organizations, does not exceed the dose limits for occupational exposure. In addition, registrants and licensees should make arrangements for pregnant or breastfeeding research workers or graduate students to meet the requirements of para. 3.114 of GSR Part 3 [1].

3. TYPES OF RADIATION SOURCE USED IN RESEARCH AND EDUCATION

3.1. A wide variety of radiation sources are used in research and education. These sources include sealed radioactive sources, unsealed radioactive materials, and radiation generators such as X ray units, accelerators and neutron generators. Radioactive sources may be used in teaching basic science principles in secondary schools or used in the teaching of undergraduate students ~~in~~ at universities. The sources can be used to test radiation monitoring instruments (e.g. as used in research laboratories and secondary schools for demonstrations). Radiation sources in research activities can be used by undergraduate students, graduate research students and research scientists.

SEALED SOURCES USED IN RESEARCH AND EDUCATION

3.2. A large variety of sealed sources are used in research and education. A sealed source is a radioactive source in which the radioactive material is (a) permanently sealed in a capsule or (b) closely bonded and in a solid form [23]. In research and education, sealed sources are generally longer half-life radioactive materials firmly contained or bound within a suitable capsule or housing. As such, sealed sources represent a possible external radiation hazard: such

sources only present a risk of internal radiation exposure (i.e. due to contamination) if they have been breached or are leaking. The radionuclides and activities of such sources vary depending on the application; sealed sources may be used as sample irradiators or calibration sources, or used in scientific equipment.

3.3. Sealed sources should meet the following criteria:

- (a) Sealed sources should be designed, manufactured and tested to meet the requirements of the appropriate ~~ISO~~ International Organization for Standardization (ISO) standard [24] or an equivalent national standard. These standards set out the normal operating conditions and accident conditions that a sealed source should withstand.
- (b) Sealed sources should be periodically leak tested in accordance with the appropriate ISO standard [25] or an equivalent national standard and should be issued with a valid leak test certificate that is traceable to a standards laboratory.
- (c) Where appropriate, sealed sources should be certified as meeting the requirements for 'special form radioactive material' as established in IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [26].

3.4. A categorization system for ranking radioactive sources in terms of their potential to cause harm to human health, and for grouping sources and the practices in which they are used, is provided in IAEA Safety Standards Series, No. RS-G-1.9, Categorization of Radioactive Sources [27]. This categorization can assist in establishing regulatory requirements to ensure an appropriate level of safety and security control for each authorized source.

3.5. Sealed sources may be used to calibrate radiation measurement equipment (e.g. area radiation monitors, spectrometers, contamination measuring instruments, analytical radiation measuring equipment). Depending on the instrument to be calibrated, a wide range of radionuclides (e.g. ^{60}Co , ^{137}Cs , $^{241}\text{Am-Be}$, ^{210}Po , ^{90}Sr) that emit alpha, beta, gamma or neutron radiation may be used. The activity of the source is dependent on the application, and ranges from a few ~~kBq~~ kilobecquerels for check sources to several ~~TBq~~ terabecquerels for some sources used in calibrations. It is possible for some check sources to be exempted from regulatory authorization ~~due owing to~~ their low activity. However, even with these small sources, best ~~practices~~ practice guidelines for radiation protection should be employed to minimize the risk of exposure to workers, students, the public and the environment. Calibration sources (e.g. ^{68}Ge , ^{57}Co , ^{22}Na) are also commonly used to test equipment used in microPET (~~Positron Emission Tomography~~ micro positron emission tomography) and microSPECT (~~Single Photon Emission Computed Tomography~~ micro single photon emission computed tomography) imaging techniques.

3.6. Sample irradiators are used to irradiate different types of sample, such as metals, plastics, cells, tissue samples, plants or small animals, to study the effects of radiation exposure. The radionuclides usually employed are gamma ray emitters (e.g. ^{60}Co , ^{137}Cs). However, some sample irradiators are specifically designed to expose materials to alpha or beta radiation using plated or laminated sources: ~~such~~. Such sources should be handled with special care to minimize the risk of causing a release of the radioactive material (see also para. 3.17). The activity of sources used in irradiators ranges from a few ~~kBq~~ kilobecquerels to several ~~TBq~~ terabecquerels.

3.7. Sealed sources may be used in scientific or measurement equipment such as liquid scintillation counters. In the academic and research environment, these sources may be

commercial sealed sources or specially constructed sources ~~that are~~ integrated into commercially available instruments or other equipment, depending on the application. The radiation exposure of users of commercial instruments is generally very low; it should be ensured that instruments that have been designed 'in-house' achieve a similar level of protection and safety. The main risks of exposure from these sources are due to improper handling, loss of source integrity, or ~~the~~ loss or uncontrolled release of the source or the instrument incorporating the source. Some of these sources might be exempted from regulation ~~due~~ owing to ~~the~~ low activity. Nevertheless, the instrument and the source should be marked with the radiation symbol (trefoil) [28], the word 'RADIOACTIVE' and a description of the source, including the serial number.

3.8. Neutron sources are used ~~for~~ in the calibration of instruments, ~~to create~~ in the creation of fission reactions in experimental reactors, in nuclear physics research ~~such as (e.g. neutron logging and neutron diffraction analysis, to demonstrate), in the demonstration of~~ physics principles, and ~~for~~ in neutron activation analysis. ~~The common~~ Common nuclides in neutron sources are ^{252}Cf (spontaneous fission), $^{241}\text{Am-Be}$ (α, n reaction) ~~or~~ and $^{124}\text{Sb-Be}$ (γ, n reaction). The safety of neutron sources normally involves shielding against both neutron and photon radiations.

UNSEALED SOURCES USED IN RESEARCH AND EDUCATION

3.9. Unsealed sources are radioactive materials that are not permanently sealed within a container. These materials are extensively used in research and education. Applications include ~~physics experiments,~~ tracers in biomedical or environmental studies, ~~physics experiments,~~ and various uses in radiochemistry laboratories. The radioactive material may be in different physical forms, such as a liquid for environmental transfer studies, ~~or~~ a gas for atmospheric research or an activated solid sample in physics research. A variety of radionuclides with a very wide range of activities are used in research facilities. For example, the activity of radioactive liquids used in laboratories can range from a few ~~Bq~~ becquerels to multiple ~~GBq~~ gigabecquerels with a high specific activity that is often diluted for further use in the laboratory. Research work involving the use of unsealed sources in animal experiments may also be conducted.

3.10. The use of unsealed sources can give rise to both internal exposure and external exposure during experiments or laboratory work, or due to events that lead to dispersal of the radioactivity resulting in contamination of persons, the workplace, equipment or the environment. Depending on the physical characteristics of the unsealed source and the activities involved, the radioactivity could be released as a gas, liquid or solid. As a result, the nature, spread and magnitude of the contamination risk ~~depends~~ depend on the ~~radionuclide(s)~~ radionuclides and activity, the chemical and physical forms of the material involved, and the dispersal method.

3.11. Unsealed alpha emitters (e.g. natural uranium, natural thorium, ^{239}Pu , ^{241}Am) are used in radioecological or radiation protection studies, environmental monitoring such as radon measurements, basic science research, and biomedical and medical research. Such sources may be used in a particulate or liquid form. The activity used is often very small (a few ~~Bq~~ becquerels to ~~MBq~~ megabecquerels); however, there is still potential for significant internal exposure from ingestion and (especially) inhalation. Alpha emitters are difficult to detect unless the source also emits a more readily measured radiation such as gamma rays. In artificial sources, the radioactive material may be present as a liquid or powder; natural sources may include radon and thoron gas.

3.12. Beta emitters (e.g. ^3H , ^{14}C , ^{32}P) are often used as molecular ~~labels~~ or tracers in biological or environmental studies. The activities used vary from a few ~~kBq~~ kilobecquerels to ~~MBq~~ megabecquerels. Beta emitters are generally grouped into two categories: low energy ($E_{\text{max}} < 150 \text{ keV}$) and high energy ($E_{\text{max}} > 150 \text{ keV}$). Generally, the radiation risk associated with beta emitters is lower than for alpha emitters, but care should be taken to protect the skin and the lens of the eye against external exposure from high energy beta emitters. For low energy beta emitters (e.g. ^3H , ^{14}C), higher activities are often used in experiments. As a result, exposure to these low-energy beta emitters is controlled by minimizing the spread of contamination and by ~~the use of personnel using personal~~ protective equipment. Tritium (^3H) is widely used in research and is present as a contaminant in accelerator environments; it can also enter the body by skin absorption, for example due to skin contamination or ~~from~~ to contact with contaminated materials such as metals and plastics.

3.13. Unsealed gamma emitters (e.g. ^{125}I , ^{131}I , ^{133}Xe , ^{60}Co , ^{137}Cs) may be used in environmental research applications and are widely used in laboratories undertaking biological and medical research ~~including involving~~ positron emitters (e.g. ^{18}F , ^{11}C). In nuclear medicine applications, it is desirable to use radionuclides with short half-lives. However, some research work may be performed using radionuclides with long half-lives to study the material's biological properties. Unsealed gamma emitters may also present an external exposure risk. It may be necessary to consider both whole body and hand exposure when materials are handled, for example in flasks or syringes.

3.14. Environmental research may involve the use of unsealed radioactive sources in the form of radiotracers to study processes and interactions such as sediment transport, water currents, or effluent distribution. Such studies involve the deliberate and controlled release of unsealed sources ~~into~~ to the environment. A detailed safety assessment (see Section 5), including a prospective environmental impact assessment, is necessary.

3.15. ~~Naturally occurring radioactive materials (NORM)¹ are~~ is used in educational and research establishments. ~~The, including the display or use of NORM includes~~ minerals containing NORM ~~on display or used~~ in class demonstrations in secondary schools, and research projects involving NORM in universities or research centres. ~~Examples of laboratory~~ Laboratory activities that may involve NORM include: ~~the~~ analysis of raw materials, products and residues; process related research; research for the recycling or reuse of NORM residues, waste conditioning and management, and decontamination of processing facilities and equipment; and the construction and operation of pilot plants. In many cases, research using NORM is part of the industrial activity and may be performed in a specific laboratory at an industrial site, or in a separate off-site laboratory ~~offsite~~. Research may also be undertaken at university laboratories, or at technical support organizations. Further information on laboratories using NORM is provided in Annex-I.

3.16. Laboratories that provide calibration and equipment testing services for the measurement of radon contain radon chambers of various sizes, from ~~less~~ smaller than 1 m^3 to tens of ~~m³~~ cubic metres. These chambers contain a source of radon gas.

¹ NORM is defined as a radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides. Material in which the activity concentrations of the naturally occurring radionuclides have been changed by a process is included in naturally occurring radioactive material (NORM) [23].

ELECTRODEPOSITED SOURCES USED IN RESEARCH AND EDUCATION

3.17. Plated radioactive sources where a thin layer of radioactivity is electrodeposited on a non-radioactive surface are also used in some applications in research and education. They present a greater potential contamination hazard than the same amount of material as a sealed source but less than the same amount of material in unsealed form. Electrodeposited sources (e.g. ^3H , ^{90}Sr , ^{63}Ni , ^{226}Ra , ^{57}Co) are used in electron capture detectors in gas chromatography units and in the efficiency determination of some alpha scintillation detection instruments.

RADIATION GENERATORS USED IN RESEARCH AND EDUCATION

3.18. Low energy X rays are used in diffraction and spectroscopy applications to investigate the structure of materials. While the energy of these beams means that shielding can readily be provided, there is a significant hazard if access to the beam is possible. Care should be taken during experiments involving access to such X ray beams to avoid extremity doses.

3.19. X rays can also be produced by apparatus in which high speed electrons strike a target in a (partial) vacuum. Some examples, such as Crookes tubes and other cold cathode discharge tubes, are described in Annex II. In electron microscopy, any X rays ~~that are~~ produced are generally well shielded by the microscope and associated housings.

3.20. ~~Hand held~~Handheld X ray devices are used to identify materials ~~based on~~ the basis of their characteristic X rays. These ~~hand held~~handheld devices can produce very intense but narrow X ray beams. If the user modifies the shielding or places a part of the body into the beam, significant exposures might result.

3.21. X rays are also used in research and education to generate an image (e.g. of materials, objects, people or animals). The devices used range from ~~hand held~~handheld X ray generators to fixed devices in shielded cabinets or rooms that incorporate shielding and safety systems to protect users and other persons. Computed tomography uses a narrow high intensity X ray beam to produce cross-sectional and ~~3D~~3-D images; it is used in applications such as biomedical research, materials analysis and anthropology. Fluoroscopy uses X rays to produce real-time images; it is used in research to view the movement and functioning of the system under investigation. Annex III provides examples of measures for radiation protection of students in medical and paramedical education programmes.

3.22. X rays are also used to irradiate materials and other objects, for example to deliberately create radiation damage for research purposes. High levels of radiation are needed, and the X-ray beam is generated in a shielded cabinet or room that incorporates shielding and safety systems to protect users and other persons.

3.23. Accelerators may be used for medical purposes as well as for physics and materials science research. The radiation hazards associated with these devices include the primary and secondary ~~radiations~~radiation (e.g. X rays, electrons, neutrons) produced during operation. Shielding materials with low atomic numbers should be used to minimize the production of secondary X-rays (bremsstrahlung). Many of these facilities produce radiation fields of sufficient energy to make the structural components of the accelerator radioactive, and access to the area around the device may need to be controlled both during and after operation. The potential for release of radioactive material into the air, and for activation of air and/or components of the facility, should be considered. The arrangements for managing activated

components and for decommissioning of the facility should also be considered. Specific recommendations on accelerator based isotope production facilities are provided in IAEA Safety Standards Series No. SSG-59, Radiation Safety of Accelerator ~~based~~Based Radioisotope Production Facilities [7].

4. ORGANIZATIONAL ARRANGEMENTS FOR RADIATION SOURCES USED IN RESEARCH AND EDUCATION

4.1. GSR Part 3 [1] establishes requirements on duties and responsibilities ~~related~~relating to the use of radiation sources. This section provides recommendations on the duties and responsibilities of relevant parties in relation to the use of radiation sources in research and education.

4.2. The use of radiation sources in research and education will take place within a legal and regulatory framework within the State. The government will have established a legal framework that includes the establishment of a regulatory body. The responsibilities of the regulatory body include the development of regulations and user guides, the exemption or authorization of practices, the review and assessment of applications for authorization, the inspection of facilities and activities, and the enforcement of the regulations and law relating to radiation safety.

GRADED APPROACH TO RADIATION SAFETY IN THE USE OF SOURCES IN RESEARCH AND EDUCATION

4.3. Paragraph 2.12 of GSR Part 3 [1] states that “The application of the requirements for the system of protection and safety shall be commensurate with the radiation risks associated with the exposure situation.”

4.4. GSR Part 3 [1] places responsibilities for a graded approach on the government, the regulatory body, registrants and licensees, and employers. The government and the regulatory body are required to use the graded approach in establishing and enforcing regulatory requirements, such as the processes for justification and for authorization:- (see paras 2.18 and 2.31 of GSR Part 3 [1]).

4.5. Registrants and licensees, and employers are required to use the graded approach in the measures they take for protection and safety:- (see Requirement 6 of GSR Part 3 [1].) For example, university departments with accelerators or research irradiators, and laboratories using unsealed radioactive material that generates radioactive waste, would be expected to have a more detailed safety assessment (see Section 5 of this Safety Guide) and more extensive local rules (see paras 7.12–7.19) ~~compared to~~than a department with a few check sources or a secondary school that has a very limited number of low activity radioactive sources.

RESPONSIBILITIES OF OPERATING ORGANIZATIONS, REGISTRANTS AND LICENSEES IN RESEARCH AND EDUCATION

4.6. The operating organization is the organization that is applying for authorization or that is authorized to operate a facility and is responsible for its safety [23]. Authorization can take the form of either registration or licencing (see para. 3.8 of GSR Part 3 [1]). Consequently, the term

‘operating organization’ includes registrants and licensees, including individual persons where appropriate.

4.7. Requirement 4 of GSR Part 3 [1] states:

“The person or organization responsible for facilities and activities that givesgive rise to radiation risks shall have the prime responsibility for protection and safety. Other parties shall have specified responsibilities for protection and safety.”

4.8. Paragraph 2.39 of GSR Part 3 [1] states that “The person or organization responsible for any facility or activity that gives rise to radiation risks shall have the prime responsibility for protection and safety, which cannot be delegated.”

4.9. The principal parties responsible for protection and safety with regard to the use of radiation sources in research or education are as follows:

- (a) The educational or research entity ~~that is~~ responsible for the facility or activity in which the radiation sources are stored or used.
- (b) Employers and/or academic or research managers who have direct operational oversight of the radiation sources. For most academic and research staff, the employer is (or is part of) the operating organization. Some academic staff and researchers undertake research at more than one organization. Consequently, these persons may have one employer but use radiation sources owned by more than one operating organization. It is also common for researchers to receive assistance from students (i.e. who are not employed) during their education.

4.10. Other parties have specified responsibilities for protection and safety in support of the operating organization’s responsibilities: ~~(see para. 2.41 of GSR Part 3 [1+]).~~ With regard to the use of radiation sources in research or education, these parties include the following:

- (a) Radiation protection officers (see paras 4.27–4.31);
- (b) Qualified experts (see paras 4.32 and 4.33);
- (c) Users of radiation sources, such as academic staff, research workers and students;
- (d) External service providers, such as suppliers (e.g. of sealed sources, unsealed radioactive material and radiation generators), dosimetry services, and organizations providing support for the transport of radioactive material and the disposal of radioactive waste.

MANAGEMENT SYSTEM, ORGANIZATIONAL STRUCTURE AND POLICIES FOR RADIATION SAFETY IN RESEARCH AND EDUCATION

4.11. Requirement 5 of GSR Part 3 [1] states that **“The principal parties shall ensure that protection and safety are effectively integrated into the overall management system of the organizations for which they are responsible.”** Requirements for the management system are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [29].

4.12. Paragraph 2.47 of GSR Part 3 [1] states that: “The principal parties shall demonstrate commitment to protection and safety at the highest levels within the organizations for which they are responsible.”

4.13. Paragraph 2.48 of GSR Part 3 [1] states (footnote ~~removed~~omitted):

“The principal parties shall ensure that the management system is designed and applied to enhance protection and safety by:

- (a) Applying the requirements for protection and safety coherently with other requirements, including requirements for operational performance, and coherently with guidelines for security;
- (b) Describing the planned and systematic actions necessary to provide adequate confidence that the requirements for protection and safety are fulfilled;
- (c) Ensuring that protection and safety are not compromised by other requirements;
- (d) Providing for the regular assessment of performance for protection and safety, and the application of lessons learned from experience;
- (e) Promoting safety culture.”

4.14. Paragraph 2.50 of GSR Part 3 [1] states that: “The principal parties shall be able to demonstrate the effective fulfilment of the requirements for protection and safety in the management system.”

4.15. The management system is required to include a description of the organizational structure as it relates to radiation safety: ~~(see paras 4.11 and 4.16 of GSR Part 2 [29]-1).~~ This structure, which may be presented in the form of an organizational chart, should show the names of the relevant radiation protection ~~officer(s)~~officers or units (see paras 4.27–4.31 of this Safety Guide), the radiation safety committee (see paras 4.23–4.26) and its members, and interfaces with other relevant parties within the research or educational facility. The chart should clearly show the line of reporting. An example of an organizational chart for a large research or ~~education~~educational facility, with multiple departments and laboratories using radiation sources, which may be spread across more than one site, is shown in Fig. 1. For smaller research or educational facilities, the chart can be simpler but should still show the relevant responsible persons, for example a radiation protection officer and one or more qualified experts, as necessary.

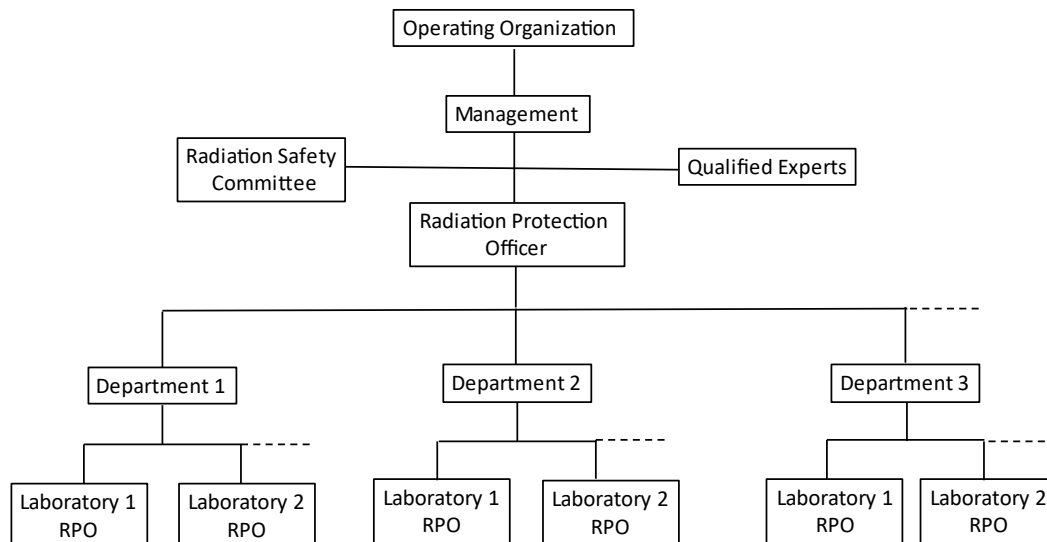


FIG. 1. Example of an organizational chart for radiation safety in a large research or educational facility. **RPO** — radiation protection officer.

4.16. In research organizations that use radiation sources, persons from multiple organizations may work together; equally, persons from one organization may use radiation sources at a number of different organizations. Under these conditions, the management system should clearly specify the persons responsible for the safety of workers and other persons at each location. If responsibilities are shared, **the division of responsibilities** should be defined in the management system. Examples of these extended organizations include the following cases:

- The operating organization has more than one location of operation.
- Several operating organizations **share** the same location of operation.
- The worker is employed by several different organizations.
- The worker is not employed **by** or affiliated with the operating organization.
- The worker is engaged in experiments that **involve** sources that are not under the control of the employer.

RADIATION PROTECTION PROGRAMME FOR SOURCES USED IN RESEARCH AND EDUCATION

4.17. Requirement 24 of GSR Part 3 [1] states:

“Employers, registrants and licensees shall establish and maintain organizational, procedural and technical arrangements for the designation of controlled areas and supervised areas, for local rules and for monitoring of the workplace, in a radiation protection programme for occupational exposure.”

4.18. The operating organization should ensure that in the implementation of the radiation protection programme the following are addressed:

- (a) The measures and resources necessary for achieving the objectives for protection and safety have been determined and are duly provided;
- (b) The programme is periodically reviewed to assess its effectiveness and its continued fitness for purpose by considering and incorporating feedback from operating experience and lessons learned;
- (c) Any failures or shortcomings in protection and safety are identified, and corrected, and steps are taken to prevent their recurrence;
- (d) Arrangements are made to consult with relevant interested parties;
- (e) Appropriate records are maintained.

4.19. The roles of the radiation protection officer and the radiation safety committee should be clearly defined in the radiation protection programme. The radiation protection officer and the radiation safety committee should oversee the effectiveness of the radiation protection programme and inform the management of the facility as appropriate.

4.20. The radiation protection programme should be customized and scaled to meet the needs of the operating organization. The programme should reflect the complexities and hazards associated with the radiation sources and the education and research activities to be conducted. The programme should be based on the operating organization's safety assessment (see Section 5), and it should address both normal use of the radiation sources and accidents.

4.21. Recommendations on the content of a radiation protection programme are provided in paras 3.49–3.158 of GSG-7 [8]. For sources used in research and education, the radiation protection programme should cover the main elements contributing to protection and safety, including the following:

- (a) Reference to the management system, including the management structure and policies and the assignment of individual responsibilities for radiation safety.
- (b) Reference to the results of the safety assessment (see Section 5).
- (c) Arrangements for control of radiation sources.
- (d) Arrangements for protection of workers and other persons (e.g. students) ~~that~~who might use the radiation sources. ~~These~~Such arrangements include; local rules; designation of controlled or supervised areas; arrangements for the monitoring of persons, the workplace and the environment; and, where appropriate, a health surveillance programme (see paras 7.52–7.57).
- (e) The education and training programme on the nature of the radiation hazards, the radionuclides involved, and the measures for protection and safety. This training should be adapted to the experiments and activities conducted and should be revised and repeated as often as necessary.
- (f) Arrangements for protection of the public. ~~These~~Such arrangements include the control of discharges of radioactive material to the environment, management of radioactive waste, and ~~demonstrating~~demonstration of compliance with dose limits and constraints for public exposure.
- (g) Arrangements for the prevention of accidents, and mitigation of their consequences, and for emergency preparedness and response.
- (h) Arrangements for periodically reviewing and auditing the performance of the radiation protection programme, and for implementing improvements where appropriate.

The key points should be summarized on a leaflet and given to workers and students who might be exposed to radiation sources and should be prominently displayed at important locations.

4.22. The elements of the radiation protection programme should be documented appropriately, taking into account the scale and complexity of operations. The radiation protection programme should include a commitment by the management to keep radiation doses as low as reasonably achievable and to foster a positive safety culture (see Requirements 2 and 12 of GSR Part 2 [29]).

RADIATION SAFETY COMMITTEE

4.23. In organizations where education or research involving a variety of radiation sources is conducted, it may be appropriate for the operating organization to establish a radiation safety committee to oversee the radiation protection programme. The operating organization should appoint to the radiation safety committee staff members (and, if appropriate, external experts) who have expertise in the radiation sources used. In addition, the radiation safety committee should include representatives of the senior management of the operating organization, the radiation protection officer(s); health, safety and environment officers; laboratory managers; and other relevant staff.

4.24. The main task of the radiation safety committee should be to regularly evaluate and review the operational structure and the effectiveness of the radiation protection programme (e.g. scope of radiation monitoring, training, application of engineered controls, administrative controls and personal protective equipment).

4.25. The radiation safety committee should be responsible for the following:

- (a) Establishing policies, approving procedures and making recommendations to improve the effectiveness of the radiation protection programme in compliance with regulatory requirements;
- (b) ~~Review~~ Reviewing and ~~approval of, where appropriate, approving~~ proposals for the use of radiation sources and their conditions of use, as recommended by the radiation protection officer;
- (c) ~~Regular reviews of~~ Regularly reviewing all aspects of the radiation protection programme. ~~This includes, including~~ programme documentation, guidance, training and related information;
- (d) Providing guidance on the performance of the radiation protection officer's duties;
- (e) Communicating to ~~relevant~~ staff and students about relevant radiation safety issues;
- (f) Providing guidance on the training programmes for workers and students;
- (g) Conducting audits of the radiation protection programme to comply with regulatory requirements and organizational policy;
- (h) Checking compliance with the radiation protection programme, including recommending actions to correct non-compliances;
- (i) Performing any role that has been assigned in the emergency plan;
- (j) Reviewing reports of abnormal events, incidents and accidents, and making recommendations to avoid their reoccurrence.

4.26. Prior to the introduction of a new radiation source, approval should be obtained from the radiation safety committee. Prior to the use of a new source, the committee should undertake the following:

- (a) Review the case, concluding on the justification of this new source or practice;

- (b) Review the predicted exposure and potential exposure of workers, students and the public in normal use and in accident conditions, and consider the related monitoring aspects;
- (c) Review the design criteria and design features relating to each proposed new radiation source, and make recommendations and set conditions on the proposed work with the sources.

RADIATION PROTECTION OFFICERS IN RESEARCH AND EDUCATION

4.27. Paragraph 3.94(e) of GSR Part 3 [1] states:

“Employers, registrants and licensees, in consultation with workers, or through their representatives where appropriate...~~[s]hall~~...Shall designate, as appropriate, a radiation protection officer in accordance with criteria established by the regulatory body.”

4.28. The radiation protection officer is a person who is technically competent in radiation protection matters relevant for a given type of practice and who is designated by the registrant, licensee or employer to oversee the application of relevant requirements [23]. In the context of research and education, this person should also have a working knowledge of the laboratory practices, the general health, safety and environment principles, and the institutional culture as ~~it relates~~they relate to the operating organization’s activities. The radiation protection officer should have a strong working ~~relation~~relationship with other health, safety and security officials in the organization to implement an effective radiation protection programme in facilities and activities in which there are also, for example, biological, chemical and physical safety considerations.

4.29. The radiation protection officer should be granted sufficient authority, resources and organizational freedom to effectively oversee the radiation protection programme and, if necessary, ~~to~~ stop unsafe activities.

4.30. The appointment of the radiation protection officer should be in writing, and the duties should be integrated into a job description that assigns the radiation protection officer the organizational responsibilities and authority to effectively implement the radiation protection programme. The radiation protection officer should have the following responsibilities:

- (a) To oversee the application of and compliance with regulatory requirements.
- (b) To ensure that all workers and students using radiation sources are instructed in and comply with safe operating practices.
- (c) To identify and control access to controlled areas and supervised areas.
- (d) To evaluate proposals for the use of radiation sources and make recommendations to the radiation safety committee.
- (e) To optimize measures to control ~~the~~ exposures from radiation sources, including by having installed and properly maintained engineering features and other equipment that contribute to controlling the exposure of persons and the environment.
- (f) To conduct and periodically assess the radiation protection programme, including the monitoring and recording of individual doses, routine radiation surveys and environmental monitoring.
- (g) To maintain the radioactive source inventory and relevant training and safety records.
- (h) To arrange statutory tests for leakage of radioactive material from sealed sources, in accordance with Ref. [25].

- (i) To undertake periodic safety checks of safety systems and warning signals and alarms, and of general conditions at the facility.
- (j) To ensure the proper management of radioactive waste, including collection, packaging, storage and disposal.
- (k) To liaise with laboratory directors, faculty heads, laboratory managers, medical services, contractors, designers and suppliers with regard to radiation protection matters and significant changes to physical or operational aspects of the facility.
- (l) To ensure the adequacy of safety assessments, local rules, contingency plans, and the emergency plan and procedures, as appropriate.
- (m) To take part in the investigation and analysis of any accident or incident at the facility such as the following:
 - (i) Any operational parameters being out of the normal ranges established for normal operation;
 - (ii) Any equipment failures, operating errors, unusual events or circumstances that cause, or have the potential to cause, exposures in excess of dose constraints or dose limits (e.g. failure of a radioactive source to return to the shielded position).
- (n) To identify radiation protection problems associated with the use of radiation sources, and to recommend and initiate corrective actions.
- (o) To interrupt ~~an~~ unsafe or non-compliant activities to maintain radiation safety, and to inform other relevant departments, such as health, safety or security, as appropriate.

LABORATORY RADIATION PROTECTION OFFICERS IN RESEARCH AND EDUCATION

4.31. The laboratory radiation protection officer (or equivalent) is responsible for ensuring that the radiation protection programme is implemented on a day to day basis with regard to a specific laboratory. Each laboratory radiation protection officer (or equivalent) should work under the overall guidance of the designated radiation protection officer for the operating organization.

QUALIFIED EXPERTS

4.32. A qualified expert is an individual who, by virtue of certification by appropriate boards or societies, professional licence, or academic qualifications and experience, is duly recognized as having expertise in a relevant field of specialization, for example medical physics, radiation protection, occupational health, fire safety, quality management or any relevant engineering or safety speciality [23].

4.33. The operating organization should consult with one or more qualified experts on matters relevant to radiation safety where such expertise is needed. The intent of this consultation is to assist the organization in meeting regulatory requirements and developing or improving protection and safety.

WORKERS AND OTHER PERSONS USING RADIATION SOURCES IN RESEARCH AND EDUCATION

4.34. A worker is defined as any person who works, whether full time, part time or temporarily, for an employer and who has recognized rights and duties in relation to occupational radiation

protection [23]. In the context of this Safety Guide, the term ‘worker’ should be taken to include administrative, academic and research workers (e.g. postdoctoral research fellows) employed by the research or ~~education~~educational facility. It also includes contract cleaners, as well as visiting academic and research workers employed by other universities undertaking collaborative research. In addition to the ~~recognized~~-rights and duties recognized in relation to occupational radiation protection, Requirement 28 of GSR Part 3 [1] specifies special arrangements for the protection and safety of female workers and for persons under 18 years of age undergoing training.

4.35. The requirements ~~on~~for compliance by workers in respect of protection and safety are established in paras 3.83 and 3.84 of GSR Part 3 [1] and include following rules and procedures; using monitoring equipment and personal protective equipment; cooperating in programmes for workers’ health surveillance and programmes for dose assessment; and accepting instruction and training. Workers are also required to provide relevant information (e.g. to their employer) and to act in a responsible manner with regard to protection and safety.

4.36. The requirements for protection and safety of workers in emergency exposure situations are established in ~~Section~~section 4 of GSR Part 3 [1] and in GSR Part 7 [10]. Relevant recommendations on the protection of workers in a nuclear or radiological emergency are provided in ~~Section~~section 4 of GSG-7 [8].

Workers who are not employed by the operating organization

4.37. Operating organizations in which workers who are not ~~their~~the organization’s employees (e.g. academic appointees, research workers) use radiation sources should ensure that these workers have the same level of protection and safety as full-time employees. The relevant responsibilities of the operating organization and the employer of any such workers should be clearly specified in contractual arrangements.

4.38. When a worker is not employed by the operating organization, an agreement should be established to ensure that there is cooperation between the employer and the operating organization ~~to ensure~~on the following:

- (a) The protection and safety of workers who work with radiation sources but are employed by another organization ~~is,~~ which should be at least equivalent to that for employees of the operating organization;
- (b) Compliance with the radiation protection programme of the operating organization and ~~ensuring~~assurance that appropriate contact information (e.g. for the radiation protection officer) is provided.

Additional recommendations on itinerant workers are provided in paras 6.21–6.100 of GSG-7 [8].

4.39. Paragraph 3.87 of GSR Part 3 [1] states:

“As part of the cooperation between parties, the registrant or licensee responsible for the source or for the exposure as appropriate:

- (a) Shall obtain from the employers, including self-employed individuals, the previous occupational exposure history of workers as specified in para. 3.103 [of GSR Part 3 ~~+~~], and any other necessary information;

- (b) Shall provide appropriate information to the employer, including any available information relevant for compliance with the requirements of [GSR Part 3] that the employer requests;
- (c) Shall provide both the worker and the employer with the relevant exposure records.”

4.40. The operating organization should clarify with the employer of the worker the allocation of responsibilities for matters such as the following:

- (a) Local rules;
- (b) Workplace monitoring;
- (c) The provision of radiation protection equipment and personal protection equipment;
- (d) Individual dosimetry and dose record keeping;
- (e) Training on radiation safety, particularly when the radiation sources and associated equipment have not previously been used by the worker;
- (f) Health surveillance arrangements, if required (see paras 7.52–7.57).

4.41. The operating organization should verify that persons who use radioactive sources have the appropriate qualifications and have received adequate training in both radiation safety and source handling techniques. If necessary, the operating organization should provide specific training on the use of the radiation sources and on the associated radiation protection measures. The operating organization should verify that all procedures and other relevant documents are provided in a language known to the persons ~~that~~who use the radiation sources.

CONTROL OF RADIOACTIVE SOURCES IN RESEARCH AND EDUCATION

4.42. Operating organizations are required to ensure that radioactive sources are kept under proper control from the time they are first acquired until they are returned to their original supplier or disposed of as waste:– (see Requirement 17 of GSR Part 3 [17]). Recommendations on the safety and security of radioactive sources are given in the Code of Conduct on the Safety and Security of Radioactive Sources [30].

4.43. Operating organizations should ensure that they obtain radiation sources only from authorized suppliers. Specific attention should be paid to sources no longer in routine use. Disused sealed sources are required to be returned to the original supplier or transferred to another authorized body:– (see paras 3.55 and 3.60 of GSR Part 3 [17]). The import and export of radioactive sources should be consistent with the recommendations in the Code of Conduct on the Safety and Security of Radioactive Sources [30] and its supplementary guidance on import and export controls [31].

4.44. In the case of research and ~~education~~educational facilities where animal experiments are performed involving unsealed sources, the operating organization should ensure that animals containing radionuclides are not released without first making an appropriate safety assessment.

4.45. Operating organizations are required to maintain inventories of the radiation sources for which they are responsible, and to periodically check these inventories to confirm that sources are in their assigned locations:– (see paras 3.53 and 3.55(d) of GSR Part 3 [17]). Sources should only be removed from a source store and moved to another location by authorized and trained workers. For sealed sources and mobile radiation generators, the users should log their name, the date and time, the location the source or the generator was taken to, and the date and time it

was returned to safe storage. For unsealed radioactive material, the users should log their name, the date and time, and the quantity of the source withdrawn. When an unsealed source (or a part thereof) is no longer needed, it should be disposed of as radioactive waste and recorded as such. These records should be audited by the radiation protection officer at least once per month, to confirm that all radiation sources are under the control of the operating organization.

4.46. The joint use of radioactive sources by different research facilities should be justified, and the sources should be transported between facilities in compliance with the requirements established in SSR-6 (Rev. 1) [26]. It should be ensured that the authorization for any such sources permits this use. The transfer of responsibility for the sources between different facilities, and any associated conditions, should be documented.

4.47. Any suspected loss of control of a radioactive source should be promptly investigated by the operating organization. If loss, damage or theft of a radiation source is confirmed, the operating organization is required to promptly notify the regulatory body (see para. 3.55(b) of GSR Part 3 [1]).

Security of radioactive material and the interfaces with safety

4.48. The aim of nuclear security is to prevent, detect, delay and respond to any attempted or actual unauthorized access to radioactive material for malicious purposes. Some radioactive sources used for research and education can cause serious injuries, and there could be a significant impact if these sources were to be used for malicious purposes. The security issues that need to be addressed are covered in detail in the IAEA Nuclear Security Series publications. In particular, IAEA Nuclear Security Series No. 20, Objective and Essential Elements of a State's Nuclear Security Regime [32], sets out the objective and the essential elements of a State's nuclear security regime. IAEA Nuclear Security Series No. 14, Nuclear Security Recommendations on Radioactive Material and Associated Facilities [33], provides recommendations to States and competent authorities on how to develop, implement, and maintain a nuclear security regime for radioactive material, associated facilities, and associated activities. IAEA Nuclear Security Series No. 11-G (Rev. 1), Security of Radioactive Material in Use and Storage and of Associated Facilities [34], contains more specific guidance to assist States in the development of regulatory requirements for the security of radioactive sources. IAEA Nuclear Security Series No. 9-G (Rev. 1), Security of Radioactive Material in Transport [35], provides guidance on the security of radioactive material during transport.

4.49. Safety measures and security measures have the common aim of protecting human life, health and the environment. Safety measures and security measures should be designed and implemented in a coordinated manner so that security measures do not compromise safety and safety measures do not compromise security. Managers in the operating organization are required to advocate and support the exchange of ideas between, and the combination of, safety culture and security culture (see para. 5.2(h) of GSR Part 2 [29]).

4.50. To ensure that safety and security are implemented in a compatible manner, the government may have designated a responsible body for managing the interfaces between safety and security in relation to radioactive sources. This may be the regulatory body if that body has responsibility for both the safety and security of radioactive sources within the regulatory infrastructure.

4.51. There is an interface between security and safety measures with regard to access to information. For safety purposes, information on the locations and characteristics of radioactive

sources and the safety measures implemented may need to be readily accessible. However, this information may also be of potential value to an adversary and therefore security considerations may necessitate that the confidentiality of some sensitive information be protected. Guidance on the protection and confidentiality of sensitive information in nuclear security is provided in IAEA Nuclear Security Series No. 23-G, [Security of Nuclear Information](#) [36].

4.52. The primary security concerns in relation to radiation sources used in research and education ~~is~~are the possibility of unauthorized removal of radioactive sources or of sabotage. Effective security measures will also provide some inherent safety benefit by helping to prevent accidental loss of control of, or unauthorized use of, radiation sources. However, the element of intent involved in a malicious act means that additional considerations apply, especially for higher activity sources, and additional security measures may be needed to protect against unauthorized removal or sabotage.

4.53. The [IAEA](#) Nuclear Security Series provides guidance on how to implement measures for the security of radioactive sources using a graded approach, based on considerations of threat, the nature of the sources, and the relative attractiveness of the material for use in a malicious act. [IAEA](#) Nuclear Security Series No. 11-G (Rev. 1) [34] suggests using the system for categorization of radioactive sources described in RS-G-1.9 [27] ~~in order~~ to assign a particular security level to sources and to help define the necessary security measures. If the radioactive sources used for research and education purposes are in Categories 1, 2 or 3, then the security measures described in [IAEA](#) Nuclear Security Series 11-G (Rev. 1) [34] should be applied for those radioactive sources.

SAFETY CULTURE

4.54. Paragraph 2.51 of GSR Part 3 [1] states:

“The principal parties shall promote and maintain safety culture by:

- (a) Promoting individual and collective commitment to protection and safety at all levels of the organization;
- (b) Ensuring a common understanding of the key aspects of ~~the~~ safety culture within the organization;
- (c) Providing the means by which the organization supports individuals and teams in carrying out their tasks safely and successfully, with account taken of the interactions between individuals, technology and the organization;
- (d) Encouraging the participation of workers and their representatives and other relevant persons in the development and implementation of policies, rules and procedures dealing with protection and safety;
- (e) Ensuring accountability of the organization and of individuals at all levels ~~within the organization~~ for protection and safety;
- (f) Encouraging open communication with regard to protection and safety within the organization and with relevant parties, as appropriate;
- (g) Encouraging a questioning and learning attitude, and discouraging complacency, with regard to protection and safety;
- (h) Providing means by which the organization continually seeks to develop and strengthen its safety culture.”

4.55. Senior managers and other managers in the operating organization are required to promote and maintain a strong safety culture within the operating organization:– (see para. 5.2 of GSR Part 2 [29]). This should include promoting relevant safety expectations within the organization and the importance of compliance with regulatory requirements.

4.56. In accordance with the requirements established in GSR Part 2 [29], the management of safety also includes: ~~periodic evaluation of~~ periodically evaluating the rules and procedures for their effectiveness; engaging with relevant managers, workers and students on the overall efficacy of the arrangements for protection and safety; implementing adequate training programmes to follow the rules and procedures correctly; disseminating feedback from accidents and incidents to learn from their occurrence and to improve the safety culture; maintaining an environment where individuals feel free to raise concerns without fear of retaliation; and eliciting safety related proposals from individual workers and students through incentive systems.

HUMAN FACTORS

4.57. Paragraph 2.52 of GSR Part 3 [1] states:

“The principal parties and other parties having specified responsibilities in relation to protection and safety, as appropriate, shall take into account human factors and shall support good performance and good practices to prevent human and organizational failures”.

In accordance with para. 2.52 of GSR Part 3 [1], the operating organization is required to address these human factors through the design of equipment, the development of safe operating procedures and the use of safety systems to mitigate the consequences of human error.

PROCESS IMPROVEMENT

4.58. As an integral part of the operating organization’s management system, the radiation protection programme and its implementation should be assessed on a regular basis (see paras 3.157 and 3.158 of GSG-7 [8]). This periodic review should identify any problems in the implementation of the radiation protection programme; and propose modifications that could improve the effectiveness of the programme. The overall aim is to ensure that protection and safety is optimized in normal operation, anticipated operational occurrences and accident conditions.

4.59. A key part of this periodic review ~~are~~ is workplace audits. The operating organization should decide on the designation and qualifications of the persons who will conduct the audits, the frequency of the audits, the expectations of the audit team, the method of reporting ~~of~~ the results and their follow-up.

4.60. The use of radiation sources in research and education is required to be performed in accordance with the operating organization’s management system:– (see Requirement 5 of GSR Part 3 [1] and Requirements 6–8 of GSR Part 2 [29]). Paragraph 6.2 of GSR Part 2 [29] states that “All processes shall be regularly evaluated for their effectiveness and for their ability to ensure safety.” To ensure that the radiation protection programme meets changing

programmatic needs, a process improvement programme should be developed in collaboration with researchers and persons responsible for safety.

4.61. The management system should include processes designed to ensure that all equipment and safety systems are assessed for suitability and regularly checked and tested, that the correct operational procedures are being followed, and that any faults or deficiencies are brought to the attention of the management and ~~are~~ promptly remedied.

4.62. The management system is required to include a process for the collection, analysis and dissemination of data and information from incidents and accidents (including those reported by other relevant research and ~~education~~educational facilities) and for learning lessons to enhance safety:- (see para. 2.48(d) and Requirement 16 of GSR Part 3 [1~~7~~]).

5. SAFETY ASSESSMENT FOR RADIATION SOURCES USED IN RESEARCH AND EDUCATION

5.1. Requirement 13 of GSR Part 3 [1] states:

“The regulatory body shall establish and enforce requirements for safety assessment, and the person or organization responsible for a facility or activity that gives rise to radiation risks shall conduct an appropriate safety assessment of this facility or activity.”

Detailed requirements for safety assessment are established in IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [37].

5.2. The primary purpose of the safety assessment is to determine whether an adequate level of safety has been achieved for a facility or activity and whether the basic safety objectives and safety criteria established by the designer, the operating organization and the regulatory body have been fulfilled.

5.3. Paragraph 3.30 of GSR Part 3 [1] specifies two types of safety assessment: generic, or specific to the practice or source. Footnote 29 to GSR Part 3 [1] states:

“A generic safety assessment is usually sufficient for types of source with a high degree of uniformity in design. A specific safety assessment is usually required in other cases; however, the specific safety assessment need not include those aspects covered by a generic safety assessment, if a generic safety assessment has been conducted for the type of source.”

The safety assessments needed for radiation sources used in research and education will range in complexity, but even if the source itself is covered by a generic safety assessment, its use in the research and ~~education~~educational facility will ~~nearly~~almost always involve some form of specific safety assessment.

5.4. A graded approach is required to be used in determining the scope and level of detail of the safety assessment:- (see Requirement 1 of GSR Part 4 (Rev. 1) [37~~7~~]). The aim is to ensure that the application of safety requirements is commensurate with the characteristics of the facilities and activities or of the source, and with the magnitude and likelihood of the exposures [23]. As such, radioactive sources and radiation generators that only give rise to a low radiation

hazard ~~due~~owing to inherent safety features should have a straightforward safety assessment.

5.5. The operating organization should conduct and document a safety assessment for each type of radiation source used in research and education. The radiation risks arising from routine use of the radiation source together with the probability and magnitude of potential exposures are required to be taken into account:- (see para. 3.31(a) and (b) of GSR Part 3 [17]).

5.6. A safety assessment should be prepared and documented before a radiation source is received at the site or before it is used for the first time. The safety assessment should also consider any future modifications that could have implications for protection and safety. The operating organization should plan ahead, to ensure that there is sufficient time for any protection and safety control measures identified as necessary by the safety assessment to be implemented. A new safety assessment might not be necessary for the replacement of a source with an identical source for the same intended use.

5.7. In the event of a radiation source being used without a safety assessment, the operating organization should prepare and document a retrospective safety assessment as soon as possible. The retrospective safety assessment should either confirm that all the relevant control measures have already been implemented, or else identify additional control measures that need to be implemented. In addition, the operating organization should investigate reasons for not performing why a safety assessment was not performed before use and, if needed, update its management system or radiation protection programme.

5.8. The safety assessment for radiation protection purposes should be complemented with other related risk assessments (e.g. for biological, chemical, pharmacological or physical hazards) that could impact overall safety.

5.9. The safety assessment should be conducted in consultation with appropriate individuals, such as the lead scientist, radiation protection officer, qualified expert, faculty head, or head science teacher, and experts in other safety fields, as necessary.

METHODS OF SAFETY ASSESSMENT

5.10. The safety assessment is an assessment of all aspects of a practice that are relevant to protection and safety including, as appropriate, the siting, design and operation of the facility and the conduct of activities. A safety assessment for sources used in research and education should include the following:

- (a) A description of how and where the radiation source will be used, the conditions of use, and the design of the facility in which the source will be used;
- (b) A description of the provisions for defence in depth (i.e. physical barriers, systems to protect the barriers, and administrative procedures) that would have to fail or be bypassed before there could be radiological consequences for people or the environment;
- (c) A description of the ways in which structures, systems and components (including software) and procedures relating to protection and safety might fail (singly or in combination) or might otherwise give rise to exposures, and the consequences of such events;
- (d) A prior radiological evaluation that includes an assessment of the expected likelihood and magnitude of exposures (occupational and public) in normal operation and in the event of accidents, and the workplace monitoring and individual monitoring that is necessary;

- (e) A summary of the training and experience of the individuals responsible for the supervision and use of the radiation source;
- (f) An evaluation of the implications of any proposed modifications ~~into~~ the experiment or equipment design that might impact protection and safety;
- (g) An evaluation of the implications for protection and safety of any security measures associated with the source;
- (h) A description of the proposed arrangements for the management of radioactive waste generated, including any potential biological and chemical hazards associated with the radioactive waste;
- (i) An assessment of the impact on the environment of a planned release of radioactive material (e.g. a radiotracer study or radioactive effluent discharge).

OUTCOMES OF THE SAFETY ASSESSMENT

5.11. The outcomes of the safety assessment should provide a basis for making decisions on protection and safety ~~related~~relating to the source, facility or activity. ~~These should include,~~ such as decisions on the training of workers and relevant students, individual monitoring (external exposure and internal exposure), the designation of controlled areas and supervised areas, and ~~on~~ the protection of the public and environment. In addition, the assessment is required to consider engineering aspects (see Requirement 10 of GSR Part 4 (Rev. 1) [37]) and should provide specifications of any additional engineered control measures necessary for safety, such as shielding, ventilation, fume hoods and ~~glove boxes~~gloveboxes.

REVIEW OF THE SAFETY ASSESSMENT

5.12. Paragraph 5.10 of GSR Part 4 (Rev. 1) [37] states:

“The safety assessment shall be periodically reviewed and updated at predefined intervals in accordance with regulatory requirements. Periodic review may need to be carried out more frequently to take into account:

- (a) Any changes that may significantly affect the safety of the facility or activity;
- (b) Significant developments in knowledge and understanding (such as developments arising from research or operating experience);
- (c) Emerging safety issues due to a regulatory concern or a significant incident;
- (d) Safety significant modifications to the computer codes, or changes in the input data used in the safety analysis.”

Changes that might significantly affect safety include modifications to facilities or procedures, or the acquisition of a new radiation source with different radiation characteristics (e.g. different source type, activity or radiation output). Any results of the analysis of failures or errors that indicate that current safety measures are invalid or are not fully effective should also be used to trigger a review of the safety assessment.

5.13. The periodic review of the safety assessment should ensure that current working practices are reflected, and that changes have not been overlooked. Operating organizations should consider a review frequency based on the nature of the radiation hazards and the dynamic nature of the research and education activities.

5.14. Requirement 21 of GSR Part 4 (Rev. 1) [37] states that “**The operating organization shall carry out an independent verification of the safety assessment before it is used by the operating organization or submitted to the regulatory body.**” The independent review of the safety assessment should be part of the operating organization’s management system. Revisions and modifications of the safety assessment should be subject to approval, for example by the qualified expert or the radiation safety committee, and, where required, submitted to the regulatory body.

RECORD OF THE SAFETY ASSESSMENT

5.15. The results of the safety assessment are required to be documented: ~~(see Requirement 20 of GSR Part 4 (Rev. 1) [37+1]).~~ The report of the safety assessment should form an integral part of the documentation of the radiation protection programme.

5.16. The report of the safety assessment is required to be kept until the facility has been fully decommissioned or the activity has been terminated and released from regulatory control: ~~(see para. 4.65 of GSR Part 4 (Rev. 1) [37+1]).~~ If the operating organization ceases to exist before this, the report should be handed over to the new operating organization.

6. DESIGN OF FACILITIES, EQUIPMENT AND RADIATION SOURCES IN RESEARCH AND EDUCATION

6.1. Paragraph 3.51 of GSR Part 3 [1] establishes requirements for choosing a location for using or storing radiation sources and the factors to be considered in the design of the storage facility.

6.2. Provisions for the incorporation of radiation safety features in facilities are best made at the design stage. The siting and layout should take into account the types of radiation source, the activity (or, for radiation generators, the output), the use and storage of the source, the frequency and the purpose of use, and the radiation levels around the equipment and in and around the facility, including any facilities for the storage of radioactive waste.

6.3. The three factors relevant to the control of external exposure — time, distance and shielding — should be combined in the design to optimize occupational radiation protection and radiation protection of the public.

6.4. The locations in which radiation sources are used for research and education are diverse. The radiation sources may be used in a facility to which access is specially controlled, in a laboratory that is simultaneously used by other workers or students, or in an open environment. In all cases, it is the responsibility of the operating organization to ensure that the facilities (e.g. laboratories), the equipment containing radiation sources, and the radiation sources are designed, manufactured, and used ~~to minimize~~ in a way that minimizes the exposure of workers and the public, as far as is reasonably achievable.

6.5. Information on the use of radiation sources in secondary schools is provided in Annex II.

DESIGN OF ~~FACILITY~~ LABORATORIES AND OTHER FACILITIES FOR ~~USING~~USE OF RADIATION SOURCES IN RESEARCH AND EDUCATION

General design requirements for research and ~~education~~educational facilities

6.6. The design of facilities where radiation sources are used in research and education should include the following:

- (a) The ~~room(s)~~rooms where sources are handled should preferably be located at one end of the building where the studies are to be performed. This area, which should be used exclusively for the purpose of the intended studies, should not be frequented by persons who are not concerned with the activities. This area should be located away from the main entrance to the premises.
- (b) Provisions should be made for adequate illumination and ventilation.
- (c) If personal dosimeters are used (see paras 7.32–7.36), a suitable location with a low background radiation level should be provided for storing the dosimeters when not in use.
- (d) Adequate space should be provided for working with the sources and for storing sources and related records (e.g. relating to the inventory of radioactive sources, leak test results, and commissioning tests). Adequate space should also be provided for the management of radioactive waste ~~or~~and effluent, for the storage and disposal of waste sources, ~~individual doses, for the~~ calibration of radiation monitors, for the servicing and maintenance of equipment, for routine radiation monitoring and control, as well as for storage of reports on incidents and emergencies, records of individual doses, and other relevant reports.
- (e) Shielding should be designed to meet regulatory requirements, taking into account the intended workload and the type of work to be undertaken. The adequacy of the shielding should be reviewed if any of the factors in the design change, for example, if the occupancy of adjacent rooms changes. For radiation sources ~~that are~~ capable of causing activation, shielding materials with a low activation cross-section should be preferred (e.g. in sealed source capsules, local shielding, and room construction).
- (f) If personal protective equipment such as laboratory coats or overalls, gloves, protective glasses and overshoes are used, a designated area should be provided for their storage and ~~change~~as a changing area.

6.7. The shielding of walls (and doors and windows), floors and ceilings needs to be designed to optimize the protection and safety of workers and the public. The necessary shielding depends on the source characteristics (i.e. type of radiation, radiation energy and intensity), the classification of areas within the facility, the nature of the work to be done, and the relevant dose constraints. It is better to provide local shielding around sources, rather than shielding the room or providing shielding through the use of personal protective equipment (e.g. lead aprons). Shielding measures should be implemented to the extent necessary, with due regard to other work safety aspects (e.g. proper accessibility).

6.8. Local shielding (e.g. lead bricks ~~or~~, lead pots) is needed for the storage of radioactive sources and for source handling operations. Packages used for the transport of radioactive material should be provided with sufficient shielding to ensure that the dose rate limits specified in SSR-6 (Rev. 1) [26] are complied with.

6.9. Care should be taken to avoid an accumulation of conservative assumptions that can result in excessively overestimating the shielding ~~that is~~ needed. For example, workload, source usage and occupancy factors are often overestimated. Therefore, a realistic approach needs to be

achieved to avoid overly conservative designs. The specification of the shielding, including calculations, should be performed by a qualified expert in radiation protection, in collaboration with the radiation protection officer, and should meet regulatory requirements.

6.10. The need for structural shielding in facilities depends ~~upon~~ factors such as the radiation levels on the exterior of equipment containing radiation sources, the occupancy of the areas around the equipment, and the duration of use of the equipment. In facilities where only very low activity radioactive sources or radiation generators that emit very low levels of radiation are used, structural shielding might not be necessary. This should be reconfirmed by measurement of the dose rates around the radiation sources.

Specific design requirements for research and ~~education~~educational facilities

6.11. The design of facilities where radioactive sources are handled should include the following:

- (a) Separate storage areas for the radioactive sources and for radioactive waste arising in the facility.
- (b) An area or areas designated for source handling.
- (c) ~~If~~Location for sensitive counting equipment ~~is, if~~ used, ~~it should be located~~ in a room free from radioactive contamination. The level of background radiation in the counting room should be low.
- (d) As necessary, facilities and equipment for personal decontamination, and installed systems for radiation monitoring and contamination monitoring.

6.12. Laboratories where unsealed sources are used should have ~~nonporous~~non-porous surfaces. Floors in areas of potential contamination need to be finished with an impermeable material, that is washable and ~~is~~ resistant to chemical damage. The floor surface should also be curved at all joints where the walls meet the floor, and should be sealed and glued to the floor. In some ~~ease~~cases, the use of a disposable floor covering designed to absorb spills may be considered. In addition, sticky mats can be used at entrances and exits to limit the spread of contamination on shoes. The walls should have a smooth and washable surface. Strippable paints may be used, so that if part of the surface gets contaminated, it can be easily removed and replaced with fresh paint. The removed layer of paint should be treated as radioactive waste and managed accordingly (see Section 8).

6.13. All surfaces where unsealed radioactive materials are used or stored, such as benches, tables, seats, doors and drawer handles, should be smooth and non-absorbent for ease of decontamination. Laboratories using unsealed sources should be provided with specific equipment, such as decontamination equipment and materials, and dedicated waste containers for contaminated objects.

6.14. Laboratories where unsealed sources are used should be provided with adequate ventilation. Provisions should be made for the control of volatile radioactive materials, such as radioiodine, which should be handled in fume hoods vented through an appropriate filter (e.g. activated charcoal for iodine) prior to discharge to the atmosphere.

6.15. Appropriate access controls should be provided in laboratories and other rooms where radiation sources are used for research and education. Radiation warning signs and the trefoil symbol [28] should be displayed at entrances to such rooms.

6.16. Radioactive sources used for research and education should be stored in a secure cabinet

or room that provides suitable shielding and access control for the sources. The storage location should have fire protection, should be located away from corrosive material and should be protected against chemical hazards. The storage facility should be constructed of materials that provide sufficient shielding to reduce dose rates on the external surface to below the relevant levels specified by the regulatory body. Where appropriate, the storage facility should be designated as a controlled area or a supervised area in accordance with Requirement 24 of GSR Part 3 [1]. The storage facility should be kept locked, and the keys should be held only by authorized personnel. Keys should be of specifia design that cannot be easily reproduced. Other security requirementrequirements, if any, should also be taken into account. A warning notice incorporating the radiation trefoil symbol [28] and information on the area designation should be displayed on the door.

6.17. A room or suitable storage location for the interim storage of radioactive waste needs to be made available in each facility in which unsealed radioactive sources are used. The storage facility should be locked, properly marked and ventilated. A warning notice incorporating the radiation trefoil symbol [28] should be displayed on the door to the room. Further recommendations on the management of radioactive waste are provided in Section 8.

DESIGN OF EQUIPMENT CONTAINING RADIATION SOURCES FOR USE IN RESEARCH AND EDUCATION

6.18. Dedicated irradiation facilities or self-shielded irradiators involve detailed design and operating considerations [2]. Self-shielded irradiators are normally designed to contain the radioactive source(s) during the entire operational lifetime of the equipment. The source housing should be designed by the manufacturer to appropriate standards [2]. Such sources and equipment should be obtained from an authorized manufacturer with an established quality management system, such as described in ISO 9001 [38], GSR Part 2 [29], or an equivalent national standard, to ensure that the design safety features are incorporated consistently.

6.19. Source containers should be designed to be robust, and it should be difficult to gain unauthorized access to the source.

6.20. The operating organization should ensure that information on the safe use of the equipment is provided by the manufacturer or supplier. The operating organization should also ensure that this information is made available to the users of the equipment in a language they understand.

6.21. Operating organizations should ensure that equipment is not modified without prior assessment of the safety implications of the proposed modification to the original design. The initial assessment should be reviewed by a qualified expert and/or by the supplier, to confirm that it is in compliance with regulatory requirements and to determine whether additional authorization or approval is needed.

6.22. The design of equipment containing sealed sources of Category 1, 2 or 3 [27] may include enhanced provisions for safety and security, as specified by the relevant authorities.

6.23. Information on the design of X ray analysis equipment and neutron generators is provided in Annex IV.

DESIGN OF SEALED RADIOACTIVE SOURCES

6.24. Sealed sources should be designed, manufactured and tested to ensure that they meet the requirements of ISO ~~Standard~~ 2919 [24] or an equivalent national standard.

6.25. Each radioactive source should be permanently and clearly marked with the following details:

- (a) The trefoil symbol [28];
- (b) The word 'RADIOACTIVE';
- (c) The chemical ~~symbol(s)~~symbols and mass number of the ~~radionuclide(s)~~radionuclides (e.g. ^{137}Cs , ^{241}Am);
- (d) The activity of each radionuclide and the reference date;
- (e) The identification of the sealed source (model and serial number) and the manufacturer.

For some types of source, ~~due~~owing to the small size of the source capsule, it might not always be practicable to include all the above information, in which case it should be included on the source container.

6.26. Source storage containers should be provided for the safe storage of sealed sources when not in use. Although there are no specific standards for storage containers, when possible, they should meet the applicable sections of ISO 3999 [39] or IEC 62598 [40], or equivalent national standards, with regard to labelling and the dose rates outside ~~of~~ the equipment. Source storage containers should include a lock or should have an outer locked container designed to prevent unauthorized or accidental removal of the sealed source from its shielded position.

6.27. Some manufacturers specify a recommended working life for a sealed source. The recommended working life is based on a number of factors, including the half-life of the radioisotope, the construction of the source encapsulation and the environmental conditions during the source life. ~~It~~The working life is an indication of the period of time over which the source should retain its design integrity. Sealed sources should be replaced at the end of the manufacturer's recommended working life. Alternatively, a physical assessment of the condition of the source by a suitably experienced body or expert may be performed to support its continued use. The regulatory body may recommend certain tests for the extension of use of a source after it reaches its recommended working life, such as an increased frequency of leak tests or an assessment by a qualified expert with access to appropriate facilities.

6.28. Certificates for special form radioactive material (see paras 803 and 804 of SSR-6 (Rev. 1) [26]) should be retained by the operating organization. ~~Special~~The special form certificate expiration date should be kept under review by the radiation protection officer, and replacements should be obtained, as necessary.

~~THE~~ USE OF RADIATION SOURCES IN TEMPORARY LOCATIONS

6.29. The use of radiation sources in temporary locations, including outdoor locations, should be performed in accordance with the safety assessment and relevant provisions of the management system. Such use should only be undertaken by authorized users under the supervision of the radiation protection officer, with due ~~account~~consideration of security requirements. Appropriate signs and boundary markings should be put in place to warn individuals and to control access to the area. Local rules should be followed throughout the

handling of the radiation ~~source(s)~~sources.

7. OCCUPATIONAL RADIATION PROTECTION IN THE USE OF SOURCES IN RESEARCH AND EDUCATION

7.1. Paragraphs 3.68–3.116 of GSR Part 3 [1] establish requirements in relation to occupational exposure, including responsibilities for protection of workers;; compliance by workers;; monitoring and recording of occupational exposure,~~co-operation~~; cooperation between employers and licensees;; arrangements under the radiation protection programme;; assessment of occupational exposure;; workers health surveillance;; information, instruction and training;; conditions of service;; and special arrangements for workers who are pregnant or breastfeeding and for persons under 18 years of age undergoing training. Recommendations on occupational radiation protection are provided in GSG-7 [8]. This section focuses on the protection and safety of workers in the use of sources in research and ~~education~~educational facilities and activities. Some elements of the radiation protection programme for ~~the~~ protection of workers also provide protection ~~offer~~ for the public (e.g. designation of controlled and supervised areas, and ~~the~~ access to such areas~~;~~).

DESIGNATION OF CONTROLLED AREAS AND SUPERVISED AREAS IN RESEARCH AND EDUCATION

7.2. Various laboratories, rooms and areas within rooms in education and research facilities may need to be designated as controlled areas or supervised areas, in accordance with paras 3.88–3.92 of GSR Part 3 [1]. Once designated, these areas are required to meet paras 3.~~898~~–3.90 (for controlled areas) and paras 3.91–and 3.92 (for supervised areas) of GSR Part 3 [1], including requirements for delineation of areas;; warning signs;; measures for protection and safety;; control of access;; and provision of personal protective equipment, equipment for individual monitoring and workplace monitoring, equipment for monitoring for contamination, and personal decontamination facilities.

7.3. All other laboratories, rooms and areas ~~that are~~ not designated as controlled areas or supervised areas should be considered to be in the public domain~~,~~ and the levels of radiation in these areas should be within the range of local natural background radiation levels.

7.4. The classification of areas within research and ~~education~~educational facilities should be based on the advice of a qualified expert in radiation protection or the radiation protection officer.

7.5. Paragraph 3.89 of GSR Part 3 [1] states:

“In defining the boundaries of any controlled area, registrants and licensees shall take account of the ~~magnitudes~~magnitude of the exposures expected in normal operation, the likelihood and magnitude of exposures in anticipated operational occurrences and in accident conditions, and the type and extent of the procedures required for protection and safety.”

To avoid uncertainties about the extent of controlled areas or supervised areas, the boundaries of such areas should, when possible, be walls and doors or other physical barriers, clearly marked or identified with warning signs.

7.6. The designation of controlled areas should be based on the safety assessment. Examples of facilities that will normally be designated as controlled areas are accelerator facilities, facilities where Category 1, 2 or 3 sealed sources are used, and laboratories that use significant activities of unsealed radioactive material and where care is needed to prevent contamination.

7.7. The radiation protection programme should describe how controlled areas are designated for research and education activities, what signs are to be posted, and how the areas are to be monitored. To limit the extent of the controlled area, shielding should be used where practicable around radiation generators and radioactive sources. Additional local shielding (e.g. lead sheets) should ~~also~~ be provided, if appropriate. There should be access control to prevent unauthorized entry to controlled areas.

7.8. The radiation protection programme should describe the rules for accessing controlled areas and supervised areas, including the need for monitoring, the use of personal protective equipment and any specific instructions.

7.9. Paragraph 3.91 of GSR Part 3 [1] states:

²²“Registrants and ~~licensees~~ shall designate as a supervised area ~~as~~ any area not already designated as a controlled area but for which occupational exposure conditions need to be kept under review, even though specific measures for protection and safety are not normally needed.”

Much of the research work involving low levels of radioactive material may be performed in a supervised area.

7.10. It is important to consider all hazards when establishing the boundaries of designated areas. It may be possible that other hazards in the facility present a greater risk, and involve more stringent controls, than the radiation ~~source(s)-sources~~.

7.11. For the use of low levels of radioactive material that do not present an exposure hazard to users, the teaching or research activities may be performed in rooms or areas that are not designated as controlled areas or as supervised areas. Alternatively, these activities may be performed in areas that are temporarily designated as such for the duration of the teaching or research activity.

LOCAL RULES FOR THE USE OF RADIATION SOURCES IN RESEARCH AND EDUCATION

7.12. Paragraph 3.94 of GSR Part 3 [1] states:

“Employers, registrants and licensees, in consultation with workers, or through their representatives where appropriate:

- (a) Shall establish in writing local rules and procedures that are necessary for protection and safety for workers and other persons;
- (b) Shall include in the local rules and procedures any relevant investigation level or authorized level, and the procedures to be followed in the event that any such level is exceeded;
- (c) Shall make the local rules and procedures and the measures for protection and safety known to those workers to whom they apply and to other persons who ~~might~~may be

- affected by them;
- (d) Shall ensure that any work in which workers are or could be subject to occupational exposure is adequately supervised and shall take all reasonable steps to ensure that the rules, procedures, and measures for protection and safety are observed;
 - (e) Shall designate, as appropriate, a radiation protection officer in accordance with criteria established by the regulatory body.”

7.13. Local rules should describe the specific procedures for working with radiation sources in a designated area. Local rules and procedures should include sufficient information and guidance for workers to perform their duties safely and in compliance with regulatory requirements and should cover all situations where there is the potential for radiation exposure, including routine operation, waste management, emergency response, and transport and movement. Further recommendations on local rules are provided in paras 3.87–3.92 of GSG-7 [8].

Local rules for unsealed radioactive material

7.14. In many cases in research and education, the protective measures used to prevent intake of radioactive materials are similar to those used in the handling of other hazardous chemicals and are consistent with good laboratory practice (see for example Ref. [41]). Typical local rules for the safe handling of unsealed sources in research and education may include the following instructions:

- (a) Unsealed radioactive sources should be used in a specifically designated area that is away from areas frequented by other persons. The area used should be appropriate for the radioactive material used, and should be determined on the basis of the safety assessment. Appropriate radiation warning signs should be posted, and the radioactive material containers should be clearly labelled.
- (b) Users should make use of shielding materials and other protective devices ~~that are~~ provided.
- (c) Personal protective equipment, such as laboratory coats, gloves (~~i.e. that are~~ appropriate for the radiological, biological and chemical hazards associated with the materials being used), protective glasses and closed-toed shoes, should be worn when handling unsealed radioactive materials.
- (d) Appropriate radiation monitors should be used to monitor the area where unsealed sources are being used. Individual dosimeters should be worn by users when indicated by the safety assessment.
- (e) Unsealed sources with the potential for release of vapours, gases or aerosols should be handled in a fume hood. If airborne dust can be generated, the material may need to be handled in a ~~glove box~~ glovebox approved for protection against airborne releases and spread of contamination.
- (f) Remote handling tools should be used, where appropriate.
- (g) Before leaving the area, persons should check the work area and themselves for the presence of radioactive contamination using an appropriate instrument.
- (h) Persons should remove personal protective equipment and wash their hands before leaving the work area.
- (i) Persons should refrain from smoking, drinking, storing food, eating, chewing (e.g. gum), applying cosmetics (including medical or barrier creams), touching ~~the~~their face (mouth, nose and eyes), licking labels, or any other action that can increase the risk of transferring radioactive materials to the body during work with unsealed radioactive material.
- (j) Mouth pipetting should not be performed.

- (k) Good housekeeping practices should be maintained.
- (l) Containers for unsealed radioactive material or samples should be kept closed when not in use.
- (m) The generation of radioactive waste should be minimized to the extent possible, and any waste that is generated should be stored in suitable, clearly labelled containers.
- (n) Radioactive waste management should be documented to ensure adequate control of the waste (solid, liquid or gaseous) until safe discharge or disposal. Liquid radioactive waste should be disposed of only in designated approved sinks and in accordance with an authorization issued by the regulatory body. Such disposals should be recorded.
- (o) All work should be planned in advance and executed as planned. If the work plan changes, the corresponding radiation safety and protection measures should be adjusted appropriately.
- (p) Any observed abnormal conditions should be immediately reported to the supervisor and the radiation protection officer.

7.15. Graduate, ~~post-graduate~~postgraduate and other students should also follow local rules, where these are provided for their protection.

7.16. Information on the safe handling of NORM in research and ~~education~~educational facilities is provided in Annex I.

Local rules for sealed sources

7.17. Typical local rules for the safe handling of sealed sources in research and education may include the following instructions:

- (a) Appropriate shielding should be used. For neutron sources, shielding may be needed to protect against exposure to both neutron and photon radiations.
- (b) Appropriate radiation monitors should be used to monitor the area when sealed sources are being used. Individual dosimeters should be worn by users when indicated by the safety assessment.
- (c) Persons should remain at a sufficient distance from the ~~source(s)~~sources, noting that the radiation level decreases inversely as the square of the distance.
- (d) Remote handling tools should be used.
- (e) The amount of time persons are exposed to ~~the~~a source should be minimized.
- (f) Sources should not be left unattended.
- (g) All work should be planned in advance and executed as planned. If the work plan changes, the corresponding radiation safety and protection measures should be adjusted appropriately.
- (h) Any suspected loss of or damage to a source should be immediately reported to the supervisor and radiation protection officer.

Local rules for electrodeposited sources

7.18. Special care needs to be exercised to minimize the risk of abrading electrodeposited sources and thereby causing a release of the radioactive material and contamination of persons and the workplace. Electrodeposited sources should not be tested for leakage by wiping the layer directly. Instead, the integrity of the electrodeposition can be assessed by checking the storage container for contamination ~~of~~2 by checking the exhaust ports of gas chromatography units or by testing the solutions used to clean the source.

Local rules for radiation generators

7.19. Typical local rules for the safe use of radiation generators in research and education may include the following instructions:

- (a) Shielding or interlocks should never be tampered with.
- (b) Persons should not place any part of the body in the primary beam.
- (c) Appropriate radiation monitors should be used whenever X ray generators are used. Individual dosimeters should be worn by users when indicated by the safety assessment.
- (d) Security systems, warning lights and audible signals should be checked to confirm that they are functioning every time an X ray generator is used.
- (e) Only authorized persons are permitted access to the X ray generator.
- (f) The radiation generator key should be removed when entering or leaving the X ray generator room.
- (g) Faulty equipment should be immediately taken out of service. The repaired equipment should be used only after it has been confirmed that all the safety and warning systems are working correctly.
- (h) Any damage or suspected malfunction of the X ray generator should be immediately reported to the radiation protection officer.

WORKPLACE MONITORING IN RESEARCH AND EDUCATION

7.20. Requirements for workplace monitoring, as part of the operating organization's radiation protection programme, are established in paras 3.96–3.98 of GSR Part 3 [1]. Workplace monitoring comprises measurements made in the working environment and the interpretation of the results. Workplace monitoring can be used to verify the exposures to persons whose who are only exposed to predictable, low levels of radiation. It is particularly useful for students and research workers who are not individually monitored.

7.21. In research and educationeducational facilities, workplace monitoring will need to include dose rates and/or contamination measurements, depending on the radiation sources used. Periodic dose rate monitoring and contamination surveys are required to be performed in controlled areas and supervised areas: (see paras 3.90(h), 3.92(c) and 3.97(a)(iii) of GSR Part 3 [1+]. Continuous area monitoring should be considered in source storage and handling areas, especially where there could be a significant radiological hazard. Further recommendations on workplace monitoring, including selection of instruments for workplace monitoring, are provided in GSG-7 [8].

7.22. For sources used in research and education, the workplace monitoring programme may include measurement of dose rate at the following positions:

- (a) Around source storage facilities, to ensure that an adequate level of shielding is provided;
- (b) Around the barriers during the use of sources or radiation generators, to ensure that dose rates remain below the levels specified by the operating organization or the regulatory body;
- (c) At the users' position during use of the radioactive source or radiation generators, to confirm that radiation levels are acceptable;
- (d) At the end of each source use, to verify that the radioactive source is shielded or, in the case of radiation generators, that the emission of radiation has ceased;

- (e) Around accelerators at the end of the operating cycle, to verify that radiation levels due to activation are below the levels specified by the operating organization or the regulatory body;
- (f) In and around laboratories or rooms where radioactive waste is generated or stored, including effluent storage rooms;
- (g) In rooms adjacent to radiation sources, to verify that radiation levels comply with regulatory requirements for protection of the public;
- (h) Around transport packages and vehicles prior to the transport of radioactive material, to confirm compliance with the dose rate requirements established in SSR-6 (Rev. 1) [26].

7.23. The operating organization should ensure that an adequate number of suitable workplace monitoring instruments, and guidance for users, are made available in the facility. Where continuous monitoring systems are used, the radiation protection officer should set the audio and visual alarm warning levels.

7.24. The instruments used for dose rate monitoring should be calibrated in terms of ambient dose equivalent or directional dose equivalent, as appropriate. The calibration should be current and should be traceable to a standards dosimetry laboratory. For the estimation of whole body external radiation, the quantity is the ambient dose equivalent, $H^*(10)$, and the unit is the sievert (~~Sv~~) and its sub-multiples. More detailed recommendations on dosimetric quantities are provided in paras 2.27–2.72 of GSG-7 [8].

7.25. In laboratories that use unsealed radioactive material, the workplace monitoring programme should include measurement of radioactive contamination ~~in~~ of the following ~~locations~~:

- (a) All working surfaces (including the interior of enclosures), tools, equipment and devices, the floor, and any items to be removed from handling areas for unsealed radioactive material;
- (b) Storage containers for unsealed radioactive material and the internal surfaces of the storage facility;
- (c) Workplace air (as appropriate);
- (d) Radioactive waste and effluent storage rooms;
- (e) Areas adjacent to those in which unsealed radioactive material is handled;
- (f) ~~The external~~ External surfaces of transport packages to confirm compliance with the surface contamination requirements established in SSR-6 (Rev. 1) [26].

7.26. Persons ~~that~~ who have been handling unsealed radioactive material should be checked for personal contamination (including hand, foot, face, body and clothing, as appropriate) when leaving the area.

7.27. If a transport package containing a radioactive source is damaged on arrival, a survey of removable contamination and the external dose rate should be performed. If the dose rate and/or contamination levels are found to be in excess of the limits specified in SSR-6 (Rev. 1) [26], the consignor, carrier and any organization involved during transport who might be affected are required to be notified, and appropriate measures are required to be taken to mitigate the consequences, investigate the incident and report the findings to the regulatory body and the competent authority for transport: ~~(see para. 309 of SSR-6 (Rev.1) [26]).~~

MONITORING AND ASSESSMENT OF INDIVIDUAL EXPOSURE IN RESEARCH AND EDUCATION

7.28. The term ‘monitoring’ refers to the measurement of dose, dose rate or activity for reasons relating to the assessment or control of exposure to radiation or exposure due to radioactive substances, and the interpretation of the results [23]. Monitoring and assessment of individual exposure helps ~~to ensure the~~ optimization of protection and safety and as well as compliance with dose limits.

7.29. Depending on the nature and extent of the activities involving radiation sources, the purposes of a monitoring programme for individual exposure may include the following:

- (a) To assess the exposure of workers and other persons and demonstrate compliance with regulatory requirements.
- (b) To confirm the effectiveness of research and education practices (e.g. the adequacy of supervision and training) and engineered controls.
- (c) To determine whether the radiological conditions are under adequate control and whether operational changes have improved or worsened the situation.
- (d) To periodically evaluate operating procedures by reviewing the monitoring data for individuals and groups. Such data may be used to identify both good and bad features of operating procedures and design characteristics, and thereby contribute to the development of safer procedures.
- (e) To provide information that can be used by workers and other persons to understand how, when and where they are exposed and to motivate them to optimize their exposure.
- (f) To provide information for the evaluation of doses in the event of an accident.

7.30. The monitoring programme should be designed by the operating organization in consultation with the radiation protection officer, and, where appropriate, with qualified experts, on the basis of the safety assessment, with account taken of regulatory requirements.

7.31. Monitoring programmes can be routine, special or confirmatory ~~relating to,~~ depending on the objectives of the monitoring, as follows:

- (a) Routine monitoring is associated with continuing operations and is intended to meet regulatory requirements and to demonstrate that the working conditions, including the level of individual dose, remain satisfactory.
- (b) Special monitoring is investigative in nature and typically covers specific occasions, activities or tasks. It should normally be undertaken at the commissioning stage of new facilities, following major modification to facilities or procedures, or when activities are being performed under abnormal circumstances, such as an accident.
- (c) Confirmatory monitoring is performed to check assumptions made about the exposure conditions.

Each of these types of monitoring programme may involve assessment of external exposure, assessment of skin contamination, and/or assessment of internal exposure due to intakes of radionuclides (using either workplace monitoring or individual monitoring, as appropriate) and interpretation of the results.

Assessment of external exposure using personal dosimeters

7.32. The radiation protection programme should specify the persons that need to wear a

personal dosimeter, the types of dosimeter to be worn, the monitoring period, and arrangements for the assessment of dosimeters and dose record keeping. Personal dosimeters should be worn by all persons (including postgraduate students and researchers, teachers, research workers, ~~and~~ laboratory assistants) who regularly enter controlled areas designated on the basis of external exposure, or where such dosimeters are required by the regulatory body. More detailed recommendations on assessment of external exposure are provided in paras 7.1–7.132 of GSG-7 [8].

7.33. To ensure that personal dosimeters provide an accurate assessment of individual dose, the operating organization should make provision for the following:

- (a) Dosimeters should be worn during all activities with radiation sources identified in the safety assessment.
- (b) A dosimeter should be worn only by the person to whom it is specifically issued. Dosimeters are intended ~~for assessing~~ to assess individual exposures from the use of sources in research and education and should not be worn during medical exposures.
- (c) Dosimeters should be worn in accordance with recommendations from the dosimetry service provider. The dosimeter should be worn on the part of the body for which it is designed and in a location that is representative of the exposure. For example, a ‘whole body’ dosimeter should be placed at waist height when monitoring radiation exposure from benchtop radiation experiments, whereas a ring dosimeter should be placed on a finger of the hand likely to receive the highest exposure, with the measurement element facing towards the radiation source.
- (d) Care should be taken to avoid damaging dosimeters (dosimeters can be damaged by water, high temperature, high pressure and physical impact).
- (e) Dosimeters should be stored in a designated low background location when not in use. A control dosimeter should be placed in this location.
- (f) Dosimeters should be promptly returned to the dosimetry service at the end of the period ~~of wear in which it was worn~~. When an individual might have received an unanticipated high dose, the dosimeter should be promptly returned for urgent processing to assess the individual’s dose.
- (g) The dosimetry service should be informed if it is suspected that the dosimeter has been damaged or has been exposed to radiation while not being worn.

7.34. For the assessment of the occupational exposure of workers, the operating organization is required to obtain dosimeters from an approved dosimetry service: ~~(see para. 3.99 of GSR Part 3 [1+]).~~ Recommendations on approved dosimetry services are provided in ~~Section~~ section 7 of GSG-7 [8]. The operating organization can request that the regulatory body provide a list of approved dosimetry services.

7.35. Individual external doses can be assessed by using personal dosimeters such as thermoluminescent dosimeters, optically stimulating luminescence dosimeters, ~~radio-photo luminescence~~ radiophotoluminescence dosimeters, electronic dosimeters and ~~appropriate~~ neutron monitoring badges, as appropriate. The choice of dosimeter ~~type~~ should be made by the radiation protection officer, possibly in conjunction with a qualified expert in personal dosimetry. The dosimeter should be appropriate for the type of radiation sources being used. In addition to the need to fulfil various technical requirements, the choice of dosimeter may also be influenced by considerations of availability, cost and robustness, as well as regulatory requirements.

7.36. Active personal dosimeters (i.e. electronic dosimeters) give an instantaneous reading of

the dose received. ~~These~~Such dosimeters can be a very useful tool for optimizing exposures in activities involving higher radiation dose rates or for assessing exposures from specific tasks (e.g. source loading and unloading, servicing and maintenance). The dose and/or dose rate alarm function of electronic dosimeters can also help in keeping radiation doses as low as reasonably achievable and ~~for~~in preventing accidents and/or mitigating the consequences of accidents. Where appropriate, electronic dosimeters should be ~~used as~~-complementary to (and not ~~as~~-a substitute for) the use of passive dosimeters.

Assessment of external exposure using workplace monitoring

7.37. Individual exposures can be estimated from the results of workplace monitoring. ~~It~~This can be particularly useful for staff members who are not individually monitored. The locations selected for workplace monitoring should be representative of the occupancy patterns of individuals. Effective dose can be inferred from the measured ambient dose equivalent $H^*(10)$. ~~Ref.~~Reference [42] provides conversion coefficients from ambient dose equivalent to effective dose for different types of radiation and ~~energies~~energy. The conversion coefficients for photons are close to unity except for very low energy photons. Further recommendations are provided in GSG-7 [8].

Assessment of internal exposure

7.38. For some research activities, certain workers or other persons might receive internal exposures (by ingestion, inhalation or adsorption of radioactive material). The safety assessment should indicate if internal dose assessment is necessary and ~~the~~what arrangements ~~that~~ need to be made for the assessment of such doses.

7.39. The assessment of dose from intakes of radionuclides may be based on the results of individual monitoring involving one or more of the following types of measurement:

- (a) ~~Measurements~~Measurement of radionuclides in the whole body or in specific organs such as the thyroid or the lung;
- (b) Measurement of radionuclides in biological samples such as excreta or breath;
- (c) Measurement of activity concentrations in air samples collected using personal air sampling devices.

7.40. A programme for the assessment of individual internal exposure should be conducted with the assistance, as appropriate, of an appropriate service provider. The internal dose assessment should be made, with the assistance of a qualified expert, as necessary, to determine the effective dose from the measurement data.

7.41. In some situations, internal exposure by inhalation can be reasonably estimated on the basis of workplace monitoring results. Where this is the case, the monitoring programme should take into account detailed information on the worker's occupancy; and on the temporal and spatial variations in air concentrations in the workplace. Where possible, site specific data on characterization of the workplace should be preferred to ~~using~~the use of default values. The measured values should be included in dose records ~~in order~~-to document ~~the fact~~ that the measurement was performed and to provide information to support any possible future reassessment of dose.

RECORDS OF INDIVIDUAL EXPOSURE

7.42. In accordance with para. 3.103 of GSR Part 3 [1], the operating organization is required to keep records of occupational exposure for every worker for whom assessment of occupational exposure is required. The records are required to contain details of the external doses and internal doses received by the workers as well as other information specified in para. 3.105 of GSR Part 3 [1]. This includes clearly identifying any doses received in accidents or during an emergency, as distinct from those doses received during routine work. Further recommendations are provided in GSG-7 [8].

7.43. Paragraph 3.106 of GSR Part 3 [1] states:

“Employers, registrants and licensees:

- (a) Shall provide workers with access to records of their own occupational exposure;
- (b) Shall provide the supervisor of the programme for workers’ health surveillance, the regulatory body and the relevant employer with access to workers’ records of occupational exposure;
- (c) Shall facilitate the provision of copies of workers’ exposure records to new employers when workers change employment;
- (d) Shall make arrangements for the retention of exposure records for former workers by the employer, registrant or licensee, as appropriate;
- (e) Shall, in complying with (a)–(d) above, give due care and attention to maintaining the confidentiality of records.”

When monitored persons no longer work with radiation sources or cease to work in the radiation facility, they should be provided with a summary of their dose records.

7.44. Records are required to be retained until a worker attains or would have attained the age of 75 years, and for not less than 30 years after cessation of the work with radiation:– (see para. 3.104 of GSR Part 3 [1]).

7.45. Paragraph 3.107 of GSR Part 3 [1] states:

“If employers, registrants and licensees cease to conduct activities in which workers are subject to occupational exposure, they shall make arrangements for the retention of workers’ records of occupational exposure by the regulatory body or a State registry, or by a relevant employer, registrant or licensee, as appropriate.”

INVESTIGATION LEVELS

7.46. An investigation level is a value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation would be conducted [23]. Investigation levels should be set so as to provide a warning of the need to review procedures and performance, to investigate what is not working as expected and to take timely corrective action. For example, monthly doses that exceed a certain fraction of the annual dose limit could be investigated. The investigation should be performed with the aim of optimizing protection and safety, and the results should be recorded. More detailed recommendations on investigation levels are provided in paras 3.122–3.128 of GSG-7 [8].

PERSONAL PROTECTIVE EQUIPMENT FOR THE USE OF SOURCES IN RESEARCH AND EDUCATION

7.47. The safety assessment should determine the personal protective equipment that is necessary for work with radiation sources. Personal protective equipment is required to be considered after the provision of engineered controls and administrative controls: (see para. 3.93 of GSR Part 3 [1]).

7.48. Paragraph 3.95 of GSR Part 3 [1] states:

“Employers, registrants and licensees shall ensure that:

- (a) Workers are provided with suitable and adequate ~~PPE~~personal protective equipment that meets relevant standards or specifications, including, as appropriate:
 - (i) Protective clothing;
 - (ii) Respiratory protective equipment the characteristics of which are made known to the users;
 - (iii) Protective aprons, protective gloves and organ shields.
- (b) Where appropriate, workers receive adequate instruction in the proper use respiratory protective equipment, including testing for good fit.
- (c) Tasks requiring the use of certain personal protective equipment are assigned only to workers who on the basis of medical advice are capable of safely sustaining the extra effort necessary.
- (d) All personal protective equipment, including equipment for use in an emergency, is maintained in proper condition and, if appropriate, is tested at regular intervals.
- (e) If the use of personal protective equipment is considered for any given task, account is taken of any additional exposure that could result owing to the additional time taken or the inconvenience, and of any non-radiological risks that might be associated with using personal protective equipment while performing the task.”

For the sources used in research and education, the most common personal protective equipment is that which is intended to minimize the risk of contamination, such as laboratory coats or overalls, gloves, protective glasses and overshoes. In some cases, protective glasses may also be used to protect against external exposure, for example from beta radiation. Other protective equipment, such as lead ~~apron~~aprons, may be needed depending on the circumstances.

7.49. Where laboratory coats are provided, the operating organization should remind individuals to do the following:

- (a) Monitor laboratory coats after working with unsealed radioactive sources;
- (b) Not ~~to~~-wear laboratory coats outside ~~of~~-designated work areas;
- (c) Store laboratory coats on hooks or in lockers within designated work areas;
- (d) Monitor laboratory coats for contamination before laundering.

7.50. The necessary personal protective equipment should be clearly defined in local rules and procedures, and signs should be posted at the entrance to the laboratory to remind individuals of the potential hazards and the need for personal protective equipment. Such signs should be in a language ~~that is~~ understood by all persons in the area and should incorporate signs or symbols that are easy to understand.

7.51. When there is an increased need for contamination control, it is appropriate to consider a physical barrier between controlled areas and other areas. These access control points serve as a clear demarcation between the controlled area and areas with uncontrolled access. The arrangements for access depend on the potential hazards and conditions in the workplace. For example, the personal protective equipment could be as simple as overshoes and laboratory coats or as elaborate as coveralls, boots, gloves, respiratory protective equipment, head protection and eye protection. Personal protective equipment should be put on at the entry point, prior to stepping into the controlled area, and removed immediately prior to leaving the controlled area.

HEALTH SURVEILLANCE PROGRAMME

7.52. The primary purpose of a health surveillance programme is to assess the initial and continuing fitness of workers for their intended tasks. Requirements for such a programme are established in paras 3.108 and 3.109 of GSR Part 3 [1].

7.53. A health surveillance programme may not be necessary for workers using radiation sources in research and ~~education~~educational facilities. Nevertheless, in rare cases of overexposed persons (i.e. ~~at~~exposed to doses much higher than the dose limits), special investigations involving biological dosimetry and further extended diagnoses and medical treatment would be necessary [8]. In cases of internal contamination, additional investigations to determine the intake and retention of radionuclides in the body may be necessary.

7.54. Counselling should be available to students and workers who are concerned about their radiation exposure. Counselling should be given under the advice of an appropriately experienced and qualified occupational physician. Further recommendations are provided in section 10 of GSG-7 [8].

7.55. Any medical examinations of occupationally exposed workers, should follow the general principles of occupational medicine under the direction of a certified medical practitioner. ~~There~~Examinations should be ~~examinations~~completed before work with radiation sources commences and thereafter at periodic intervals. Additional examinations may also be necessary as part of the follow-up to accidents.

7.56. ~~For~~Where itinerant workers ~~who~~ are exposed to a source under the control of the facility at which they work, the operating organization of that ~~laboratory~~facility is required to make special arrangements with the employer of the ~~worker~~workers to ensure that they are provided with the necessary workers' health surveillance:- (see para. 3.109 of GSR Part 3 [1]).

7.57. Health surveillance records are to be kept confidential and preserved in a manner approved by the regulatory body. Records should be maintained for the lifetime of the worker.

INFORMATION, INSTRUCTION AND TRAINING FOR THE USE OF SOURCES IN RESEARCH AND EDUCATION

7.58. ~~Para~~Paragraph 3.110 of GSR Part 3 [1] states:

“Employers, in cooperation with registrants and licensees:

- (a) Shall provide all workers with adequate information on health risks due to their occupational exposure in normal operation, anticipated operational occurrences and accident conditions, adequate instruction and training and periodic retraining in protection and safety, and adequate information on the significance of their actions for protection and safety;
- (b) Shall provide those workers who could be involved in or affected by the response to an emergency with appropriate information, and adequate instruction and training and periodic retraining, for protection and safety;
- (c) Shall maintain records of the training provided to individual workers.”

7.59. The operating organizations of research and ~~education~~educational facilities and activities using radiation sources are responsible for ensuring that the sources are used safely and in compliance with regulatory requirements and local rules. The operating organizations should, therefore, ensure that all persons in research and ~~education~~educational facilities who use radiation sources are appropriately qualified, and are competent and trained in protection and safety at a level appropriate to their responsibilities and activities.

7.60. The radiation protection programme should describe the training programme in protection and safety for all workers and students directly involved in research or education activities requiring the use of radiation sources and associated activities. Training should be specific to the radiation sources used. The radiation protection programme should include a ‘radiation awareness’ programme, where appropriate, for other persons who support the work with radiation sources but are not directly involved, such as managers, general maintenance staff and administrative staff.

7.61. For secondary schools, the radiation protection officer would normally be a member of the science teaching staff. The radiation protection officer should ensure that all those who use radiation sources follow the local rules and associated procedures. The radiation protection officer should provide appropriate written instructions and training to staff and students who use radiation sources in the following areas: safety and security in storage of radiation sources; safe handling of each type of radiation source; correct use of associated equipment; correct use of monitoring equipment; actions to take in the event of an incident or accident involving a radiation source; record keeping; and when to seek the advice from the radiation protection officer.

7.62. For undergraduate or postgraduate university students who undertake experiments using radiation sources, the radiation protection officer should provide a short lecture and written instructions ~~on~~on the basic concepts of radiation protection, on local rules and on the security and safe handling of the radiation sources ~~that~~ the students will be using. The lecture could be ~~pre-recorded for showing~~pre-recorded to be shown at the start of each semester, and could be available on the university ~~website~~web site, with a condition that students watch the video prior to carrying out experiments using the radiation sources.

7.63. For postgraduate university students and for research workers who work with radiation sources, the radiation protection officer should ensure that training appropriate to the sources used is provided. The training should include the basic concepts of radiation protection, safe handling of radiation sources, local rules, and — when appropriate, — management of radioactive waste and as well as transport and movement of radioactive material. After successfully completing the basic radiation safety training, postgraduate students and research workers should receive specific training on the radiation sources they will use, the radionuclides and their activity (or output, for radiation generators), the physical form of the radioactive

source, and other hazards linked with their work (e.g. biological, chemical, physical). This training should be provided by a person skilled in the experiments and procedures to be used. The training should also cover emergency preparedness and response topics including the emergency plan and procedures and the rehearsal of procedures for implementing mitigatory actions and protective actions. Training on security aspects should be an integral part of the training.

7.64. Knowledge and skills should be kept up to date through a programme of refresher training. Such training should include a review of the basic concepts of radiation protection, information on changes to equipment, policies and procedures, experience gained from past events ~~occurred~~ at the facility, and changes, if any, in regulatory requirements. The frequency of refresher training should be consistent with regulatory requirements. Refresher training is typically given at intervals of two years or less. Such training could be combined with other refresher training on experimental techniques. Changes in regulations or notifications of safety issues should be disseminated as written instructions as soon as practicable, and then followed up by inclusion in refresher training.

7.65. An assessment should be made of the trainees' ability to safely conduct the activities for which training has been provided. Trainees should not be permitted to independently conduct activities with radiation sources until they have successfully demonstrated the necessary skills. The training programme should establish the criteria for completing the training, such as the minimum score needed to pass written examinations and practical exercises, as well as the procedures to be followed if a trainee fails. Examinations should include evaluation of the theoretical knowledge and practical skills associated with the handling of radiation sources, as appropriate. Successful completion of the training should be documented with a certification of competence. Those who do not successfully demonstrate adequate skill should be retrained or not allowed to work with sources.

7.66. Where appropriate, information on the additional requirements applicable to trainees under the age of 18 and persons who are pregnant or breastfeeding (see paras 7.68–7.73) should be included in the training programme.

7.67. Training records should be consistent with regulatory requirements and any recommendations from the regulatory body. Further information on training can be found in Ref. [43].

CONDITIONS OF SERVICE AND SPECIAL ARRANGEMENTS

7.68. Requirement 27 of GSR Part 3 [1] states that **“Employers, registrants and licensees shall not offer benefits as substitutes for measures for protection and safety.”**

7.69. Requirement 28 of GSR Part 3 [1] states:

“Employers, registrants and licensees shall make special arrangements for female workers, as necessary, for protection of the embryo or fetus and breastfed infants. Employers, registrants and licensees shall make special arrangements for protection and safety for persons under 18 years of age who are undergoing training.”

Pregnant or breastfeeding workers

7.70. GSR Part 3 [1] does not explicitly require a worker to notify an employer of a suspected

pregnancy or of breastfeeding. However, it is necessary that workers understand the importance of making such notifications so that their working conditions may be modified in accordance with Requirement 28 of GSR Part 3 [1]. Paragraph 3.113(b) of GSR Part 3 [1] establishes requirements for the employers, in cooperation with registrants and licensees, to provide workers with appropriate information in this regard.

7.71. The employer who has been notified of a suspected pregnancy is required to adapt the working conditions in respect of occupational exposure so as to ensure that the embryo or fetus is afforded the same broad level of protection as is required for members of the public: (see para. 3.114 of GSR Part 3 [1]). The limitation of the dose to the embryo or fetus does not mean that pregnant ~~worker~~workers should avoid work with radiation, but it does mean that the employer should carefully review ~~the~~their exposure conditions.

7.72. Information, advice and, if indicated, counselling for pregnant workers should be made available (see also para. 7.54). Further recommendations are provided in GSG-7 [8].

Persons under 18 years of age who are undergoing training

7.73. Paragraph 3.116 of GSR ~~part~~Part 3 [1] states:

“Employers, registrants and licensees shall ensure that persons under the age of 18 years are allowed access to a controlled area only under supervision and only for the purpose of training for employment in which they are or could be subject to occupational exposure or for the purpose of studies in which sources are used.”

8. RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING IN RESEARCH AND EDUCATION

MANAGEMENT OF RADIOACTIVE DISCHARGES IN RESEARCH AND EDUCATION

8.1. Paragraphs 3.132–3.134 of GSR Part 3 [1] establish requirements regarding discharges of radioactive substances. Research and ~~education~~educational facilities that plan to discharge liquid or airborne radioactive substances to the environment are required to apply for an authorization from the regulatory body.

8.2. Paragraph 3.131(a) of GSR Part 3 [1] requires that any radioactive waste generated is kept to the minimum practicable in terms of both activity and volume. Discharges to the environment should also be kept to the minimum practicable, and interim storage for decay of radionuclides should be performed whenever practicable. The regulatory body is required to establish or approve authorized limits for discharges: (see para. 3.123 of GSR Part 3 [1]).

8.3. IAEA Safety Standards Series No. GSG-9, Regulatory Control of Radioactive Discharges to the Environment [44], provides recommendations on the authorization and control of discharges. It includes recommendations for the facility on making an application for an authorization for discharges and for a regulatory body on dealing with the application for discharges.

8.4. When applying for an authorization for ~~discharged~~discharges, the operating organization of the research or ~~education~~educational facility should specify the characteristics and activity of the radioactive substances to be discharged, and the possible locations and methods of

discharge from the facility.

8.5. The application for an authorization should include an appropriate environmental radiological impact assessment in which all significant exposure pathways by which discharged radionuclides could give rise to exposure of members of the public are considered, and in which the level of public exposure (i.e. the dose to the representative person) is estimated. Recommendations on performing such an assessment are provided in IAEA Safety Standards Series No. GSG-10, Prospective Radiological Environmental Impact Assessment for Facilities and Activities [45].

8.6. The application should also specify the control measures used to ensure that discharges are in compliance with regulatory requirements. These measures should be reviewed periodically, and whenever a practice changes, to ensure that effective control of discharges is maintained. The operating organization should aim to impose control measures at the source to mitigate radioactive discharges. For example, engineered controls (e.g. a fume hood equipped with a charcoal filter to remove radioiodine) should be used to reduce the activity discharged to the atmosphere; the effectiveness of such controls should be confirmed. Any such engineered controls (e.g. ventilation systems, ducting, filters, drainage systems, manipulators, shielding, spillage control systems) should be maintained and tested at appropriate intervals.

8.7. Some research or ~~education~~educational facilities that plan to discharge only small quantities of radioactive material (e.g. laboratories using radiotracers) may satisfy the criteria for exemption from the requirements for an authorization for discharges. Such exemptions may be granted on a case-by-case basis by the regulatory body or may be established in regulations. An exemption from authorization should take into account the discharges from all facilities on the site (e.g. all laboratories on the campus).

8.8. The operating organization is required to promptly report to the regulatory body any discharges that exceed the authorized limit, in accordance with reporting criteria established by the regulatory body:- (see para. 3.137(d) of GSR Part 3 [1]). The regulatory body may specify a monitoring programme for discharges as part of the authorization. Further recommendations on the regulatory control of discharges are provided in in GSG-9 [44].

8.9. In the case of discharges to the environment, the radiation monitoring programme should, where necessary, include measurement (periodically or continuously, as appropriate) of such releases using instrumentation capable of detecting the relevant radionuclides at activity levels well below the authorized limit. Monitoring equipment is available to measure the integrated radiation released to the atmosphere for a prescribed time period or to provide an instantaneous measurement.

RADIOACTIVE WASTE MANAGEMENT IN RESEARCH AND EDUCATION

8.10. Paragraph 3.131 of GSR Part 3 [1] and IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [46], establish requirements for the management of radioactive waste. IAEA Safety Standards Series No. SSG-45, Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education [47], provides recommendations on how to meet these requirements.

8.11. In addition to disused sealed sources², research and ~~education~~educational facilities mainly generate radioactive waste consisting ~~in~~of unsealed radioactive material that is no longer needed, ~~and as well as~~ contaminated materials and items.

8.12. Sealed radioactive sources that are unused or no longer used should be considered for recycling and reuse as an alternative to disposal, with appropriate authorization from the regulatory body. Recycling and reuse of such sources can include the following ~~such sources~~ [47]:

- (a) The reuse of sealed radioactive sources by the owner or by a new owner with appropriate authorization;
- (b) The recycling of sealed radioactive sources by the manufacturer or by another authorized organization undertaking recycling;
- (c) The decontamination and/or reuse of material, such as equipment and protective clothing;
- (d) The recycling and reuse of materials that have met the conditions for the removal of regulatory control, as defined by the regulatory body.

When sealed sources are no longer needed, they become disused and should be returned to the original supplier or manufacturer. If this is not possible, disused sealed sources should be either transferred to a centralized waste management facility or disposed of by a route authorized by the regulatory body. Disused sealed sources awaiting return to their supplier or ~~for~~ transfer to an authorized waste management facility should be stored safely and securely in the research or ~~education~~educational facility's radioactive waste storage room. Disused sealed sources in certain devices (e.g. gamma irradiators) that cannot be moved to a waste storage room should continue to be monitored, and arrangements should be made for their return to the supplier or manufacturer as soon as possible. Disused sealed sources should be recorded in the sealed ~~source~~source inventory or included in the inventory of radioactive waste.

8.13. A waste storage room or building should be provided to accommodate the radioactive waste (liquid and/or solid, as appropriate) generated by the research or ~~education~~educational facility. Radiation warning signs and the trefoil symbol [28] should be displayed at entrances to such rooms. The room or building should be specifically designed to meet the storage needs of the radioactive waste generated. The design should take into account other hazards associated with the waste, such as chemical or biological hazards, and should comply with the regulatory requirements for the storage of these types of waste. The waste store can be in the same building where the waste is generated or in a different building within the site of the facility. Access to the waste store should be limited to persons with appropriate training who have been approved by the radiation protection officer.

8.14. The radioactive waste store should be provided with a ventilation system and a ~~fire-fighting~~firefighting system. The store should have easily cleaned, non-porous floors and walls and, where appropriate, shielding to optimize occupational exposure and public exposure. Appropriate radiation monitors should also be made available. Where necessary, storage tanks for radioactive effluent should be equipped with a level measurement and alarm system, spill

² A disused sealed source is a radioactive source, comprising radioactive material that is permanently sealed in a capsule or closely bonded and in a solid form (excluding reactor fuel elements), and that is no longer used, and is not intended to be used, for the practice for which an authorization was granted [23].

containment, apron and shielding.

8.15. As part of the management of radioactive waste, the operating organization is required to characterize and classify the waste in accordance with requirements established or approved by the regulatory body:- (see Requirement 9 of GSR Part 5 [46]). This classification is required to take into account the physical, mechanical, chemical, radiological and biological properties of the waste:- (see para. 4.10 of GSR Part 5 [46]). Examples of different forms of radioactive waste from research and ~~education~~educational facilities and activities include vials that contain residual radioactivity, decomposable biological waste, infectious waste requiring sterilization, broken glassware, contaminated clothing and liquid organic chemicals (e.g. liquid scintillation solutions). If animal carcasses containing radioisotopes are to be incinerated, adequate care should be exercised to ensure that radioactive waste arising from incineration is disposed of safely. Containers to allow segregation of different types of radioactive waste should be provided in areas where the waste is generated. The containers need to be suitable for their purpose (e.g. in terms of volume, shielding and leaktightness). The internal surface of these containers should be smooth to enable easy decontamination or be lined with removable strong polythene sheets/ or bags that can be disposed of as radioactive waste and replaced ~~by~~with fresh ones.

8.16. The volume and activity of waste produced by a research ~~and education~~or educational facility is required to be minimized:- (see para. 3.131(a) of GSR Part 3 [1]). To meet this requirement, the following measures should be taken:

- (a) The volume of water or solvent used to wash laboratory items should be minimized.
- (b) Non-radioactive ~~wastes~~waste should not be mixed with radioactive waste.
- (c) Waste should be sorted by physical form (e.g. plastic and metal solid waste, organic and aqueous liquid waste)
- (d) Solid waste should be segregated from liquid, powder and gaseous wastes and should be divided into disused sealed sources and contaminated solid objects.
- (e) Short half-life ~~wastes~~waste should be separated from long half-life ~~wastes~~waste.
- (f) Suitable containment should be provided for waste to ensure that contamination does not occur in storage. ~~This~~Containment may include drip or spill trays or dykes, taking into account the physical and chemical properties of the waste.

8.17. Each waste container should be managed to control the total activity in the container and to ensure that ~~the~~ packaging is suitable for meeting ~~the~~ waste acceptance criteria specified by waste disposal services and, if applicable, the relevant transport package requirements. The operating organization should also implement procedures to ensure that the dose rate and contamination levels on the exterior of the container are kept as low as practicable. The inventory (~~radionuclide(s)~~radionuclides and total activity) in each waste container should be recorded on the outside of each container, together with the date, details of any radiation monitoring equipment used, and the names of the persons responsible for generating the waste and for managing the waste.

8.18. Waste containing short half-life radionuclides should be stored in a designated part of the waste storage facility (and shielded, as necessary) until the radioactivity has decayed to below the clearance levels specified in ~~Schedule~~schedule I of GSR Part 3 [1] or the equivalent national standards. When clearance levels have been met, the waste can be treated as non-radioactive waste.

8.19. Solid waste containing long half-life nuclides should be transferred to a facility ~~that is~~

authorized for management of this type of waste. The waste should be promptly disposed of to such a facility to limit the accumulation of radioactive waste and thereby reduce the radiological hazard at the research or ~~education~~educational facility. If waste containers are suitable for ~~re-use~~reuse, they may be returned by the waste management facilities to the research or ~~education~~educational facility in compliance with the requirements of SSR-6 (Rev. 1) [26] for the safe transport of empty packagings.

8.20. Some research laboratories that use materials containing NORM (e.g. a pilot plant for processing NORM) may generate significant quantities of residues and waste containing NORM. Recommendations on the management of NORM residues and waste are provided in IAEA Safety Standards Series No. SSG-60, Management of Residues Containing Naturally Occurring Radioactive Residues Material from Uranium Production and ~~other NORM~~Other Activities [48].

8.21. Liquid effluent containing radionuclides with long half-lives that cannot be discharged under the terms and conditions of the authorization should be stored in specific tanks or containers (shielded, as appropriate) and transferred to a waste management facility ~~that is~~ authorized to receive this type of waste. In some cases, liquid waste can be treated at the research or ~~education~~educational facility and the resulting solid waste ~~is then~~ disposed of in accordance with regulatory requirements.

8.22. The operating organization is required to maintain an inventory of all radioactive waste that is generated, stored, transferred or disposed of: ~~(see para. 3.131(e) of GSR Part 3 [17]).~~ Records should identify the origin of all radioactive waste in storage and all radioactive waste that has been disposed of. These records are required to be retained for a period specified by the regulatory body: ~~(see para. 3.11 of GSR Part 5 [46]).~~ The records for each waste container should include the following:

- (a) Container identification number.
- (b) ~~Name(s)~~Names of the persons and the laboratory that generated the waste.
- (c) The date on which the container was placed in the storage room.
- (d) The contents and the results of radiation monitoring when the container was closed and transferred to storage:
 - Total activity (and for liquid waste, activity concentration);
 - Dose rate;
 - External surface contamination.
- (e) Estimated decay period (for the clearance of waste containing radionuclides with a short half-life ~~—~~; see para. 8.18).
- (f) Any additional hazards associated with the waste, such as biological or chemical.
- (g) The contents and the results of radiation monitoring when the container is either cleared for disposal as non-radioactive waste, ~~or is~~ transferred to an authorized external waste management facility:
 - Total activity (and for clearance purposes and for liquid waste, activity concentration);
 - Dose rate;
 - External surface contamination.
- (h) Date of clearance for disposal as non-radioactive waste, or date of transfer to an authorized external radioactive waste management facility.
- (i) Particulars of the waste management facility where the waste was transferred.
- (j) Records of confirmation of final authorized disposal.

8.23. If different research laboratories store radioactive waste in the same facility, the operating organization should establish rules describing the responsibilities of the persons in each laboratory and the waste acceptance criteria for each laboratory. Each laboratory should maintain a record of the inventory of radioactive waste generated by that laboratory. When radioactive ~~wastes~~waste from several laboratories ~~are~~is consolidated, the responsibility for the radioactive waste may be transferred to the radiation protection officer for the facility.

8.24. Radiation generators that are no longer used should be made inoperable prior to disposal (~~for example e.g.~~ by cutting power supply or destroying the X ray tube). For accelerators, measurement should be made to verify that there is no residual radioactivity due to activation. If radioactivity remains, the contaminated or activated material should be treated as radioactive waste. If radiation generators were used for experiments with unsealed sources, measurements should be made to confirm that surface contamination is within the regulatory limits. Once made inoperable and any residual radioactivity ~~has been~~ removed, the radiation generator can be sent for reuse, for recycling of materials, or to an appropriate disposal facility. X ray tubes often contain hazardous material and may need to be disposed of as hazardous waste in compliance with other applicable regulations, such as for obsolete electrical equipment.

DECOMMISSIONING OF RESEARCH AND ~~EDUCATION~~EDUCATIONAL FACILITIES

8.25. Requirements for the decommissioning of facilities are established in IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [49]. Associated recommendations are provided in IAEA Safety Standards Series No. SSG-49, Decommissioning of Medical, Industrial and Research Facilities [50].

8.26. When the use of radiation sources in a research or ~~education~~educational facility or activity ceases with no plans to resume in the foreseeable future, the facility should be decommissioned. Examples include situations where equipment is no longer used, a programme of research is completed, or a laboratory is closed. The decommissioning process should include the following:

- (a) Sealed sources should be transferred to an authorized organization: ~~(see para. 8.12).~~
- (b) Unsealed sources should either be discharged to the environment in accordance with an authorization (see paras: 8.1–8.9), or ~~else~~ transferred to an authorized radioactive waste disposal facility (-see para. 8.21).
- (c) Radiation generators should be made inoperable and any radioactive components removed: ~~(see para. 8.24).~~
- (d) Records should be kept by the operating organization of all receipt, storage, transfer or disposal of radioactive sources and radioactive waste (including acknowledgements of receipt and disposal provided by authorized disposal facilities for radioactive waste).
- (e) A comprehensive workplace monitoring survey should be made, to confirm that no radioactive sources, radioactive waste or contamination remain in the facility. This survey should involve a combination of direct monitoring, analysis of wipes of surfaces and floors, and sampling and analysis of other materials, as appropriate.
- (f) All radiation trefoils and warning notices should be removed from the facility.
- (g) A final decommissioning report is required to be prepared: ~~(see para. 9.1 of GSR Part 6 [49]).~~ This report should include the final radiation survey and details of the storage, transfer or disposal of radiation sources. The final decommissioning report is also required to be submitted to the regulatory body for review and approval.

9. RADIATION PROTECTION OF THE PUBLIC IN THE USE OF SOURCES IN RESEARCH AND EDUCATION

9.1. Public exposure might be incurred by persons in and around facilities where radiation sources are used in research and education. This includes secondary school students and undergraduate and postgraduate students in universities who use radiation sources as part of their academic studies. Persons who work in such facilities but not in a role that is directly involved in the use of radiation, such as administrative support staff, are required to be provided with the same level of protection as members of the public: ~~(see para. 3.78 of GSR Part 3 [1]).~~

9.2. An assessment of the risk of public exposure is required to be undertaken as part of the safety assessment: ~~(see para. 4.19 of GSR Part 4 (Rev. 1) [37]).~~ This assessment is required to indicate whether adequate measures are in place to control public exposure: ~~(see para. 4.25 of GSR Part 4 (Rev. 1) [37]).~~

9.3. Recommendations in relation to the protection of the public from discharges of radioactive material from research and ~~education~~educational facilities are provided in paras 8.1–8.9 of this Safety Guide.

9.4. The primary means for protecting the public from direct external exposure from research and ~~education~~educational facilities is to ensure that equipment containing radiation sources is adequately shielded. Shielding, including shielding around radiation sources, structural shielding (where necessary) and shielding provided for radioactive waste storage locations, is required to be sufficient to ensure that protection is optimized: ~~(see para. 3.49(d) of GSR Part 3 [1]).~~

9.5. The restriction of access to controlled areas (see para. 3.90(c) of GSR Part 3 [1]) and, where appropriate, to supervised areas, is an important means of controlling the exposure of members of the public and also personnel ~~that~~who do not directly work with radiation sources. There should be a limited number of entry points to each controlled area, and ~~there~~signs should be ~~signs~~ placed at each entry point stating clearly who is permitted to enter the area.

9.6. Requirement 32 and para. 3.137 of GSR Part 3 [1] establish the requirements to be met by facilities and activities with respect to monitoring and reporting of public exposures.

10. TRANSPORT AND MOVEMENT OF RADIOACTIVE SOURCES USED IN RESEARCH AND EDUCATION

10.1. SSR-6 (Rev. 1) [26] ~~assign~~assigns responsibilities to: the consignor (a person, organization or government that prepares a consignment of radioactive material for transport); the carrier (the person, organization or government that undertakes the carriage of radioactive material); and the consignee (the person, organization or government that receives a consignment of radioactive material).

10.2. Transport of radioactive material is a complex activity, and a comprehensive overview of the relevant requirements established in SSR-6 (Rev.1) [26] is outside the scope of this Safety Guide. Recommendations on how to meet the requirements established in SSR-6 (Rev. 1) [26] are provided in IAEA Safety Standards Series No. SSG-26 (Rev. 1), Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition) [51].

10.3. Emergency preparedness and response arrangements for the transport of radioactive material are required, in accordance with GSR Part 7 [10] and SSR-6 (Rev. 1) [26]. Specific recommendations on these arrangements are provided in IAEA Safety Standard Series No. SSG-65, Preparedness and Response for a Nuclear or Radiological –Emergency Involving the Transport of Radioactive Material [52]. Guidance on security in the transport of radioactive material should also be followed [35], taking into account that radioactive sources might be more vulnerable to theft during transport.

10.4. The operating organization of the research or educationeducational facility will have the responsibility of a consignor when the facility sends a consignment of radioactive material, and of a consignee when the facility receives a consignment of radioactive material. In some cases, the operating organization may also have the responsibilities of the carrier, for example when using mobile radiation sources for field-workfieldwork. The receipt of radioactive materials may be a regular occurrence for some research and educationeducational facilities. Shipments will also take place when the research or educationeducational facility returns disused radioactive sources to the supplier, when radioactive waste is transferred to a licensed waste management facility or when radioactive samples are transferred to another licensed facility. The radiation protection officer or other suitably trained person should prepare procedures for the consignment, carriage and receipt, as appropriate, of radioactive material in accordance with SSR-6 (Rev. 1) [26].

10.5. ~~Transport~~The transport of radioactive material and devices that contain radioactive sources for research work or studies should be made in compliance with national (and international when relevant) regulations for the transport of radioactive material. If a package containing radioactive material is found to be damaged when it is received, the extent of any contamination and the external dose rate are required to be assessed and appropriate action taken for its safe management:- (see paras 510 and 511 of SSR-6 (Rev. 1) [26].)

10.6. Persons using radioactive material at a research or educationeducational facility may sometimes need to move a radioactive source within the facility or site. Radioactive sources should only be moved within the research or educationeducational facility in containers that provide for the safety of the source and the protection of workers and the public. Dispersible sources (e.g. radioactive liquids) should be housed in a sealed container that includes sufficient absorbent material to keep any spill within the containment system. Containers should also provide adequate shielding, and should be moved on a cart or trolley under the direct supervision of an authorized person; in. In addition, the radiation protection officer should be informed of the movement of the source. The security of radioactive sources being moved should be maintained. The radiation protection officer should prepare procedures for the movement of radioactive material between buildings on the same site.

11. EMERGENCY PREPAREDNESS AND RESPONSE FOR RADIATION SOURCES IN RESEARCH AND EDUCATION

11.1. ~~As defined in~~ GSR Part 7 [10], defines an emergency is as follows:

“A non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human life, health, property or the environment.

“This includes nuclear and radiological emergencies and conventional emergencies such as fires, releases of hazardous chemicals, storms or earthquakes.

“This includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.”

11.2. ~~As defined in~~ GSR Part 7 [10], defines a nuclear or radiological emergency ~~is as follows~~:

“An emergency in which there is, or is perceived to be, a hazard due to:

- (a) The energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction;
- (b) Radiation exposure.”

11.3. A radiological emergency can occur as a result of human error, equipment failure or an external event. It can be caused by or be combined with other types of ~~emergencie~~emergency (e.g. earthquake, flood) or a nuclear security event. Examples of radiological emergencies for sources used in research and education include the following:

- (a) A spill or leak of an unsealed radioactive source;
- (b) A sealed source becoming jammed in a gamma irradiator;
- (c) A sealed source getting disconnected or damaged during operation;
- (d) Failure of engineered control measures (e.g. interlocks, warning signals);
- (e) A fire or explosion involving a radioactive source or radioactive waste;
- (f) The loss of containment or shielding of a container housing a radioactive source during storage, use or transport;
- (g) Incorrect disposal of a container housing a sealed source as scrap;
- (h) Unauthorized radioactive discharge to the environment;
- (i) A loss of control of a radioactive source or of the facility caused by a nuclear security event, such as theft of a radioactive source or sabotage of the facility.

11.4. The likelihood of a radiological emergency associated with the use of radiation sources in research and ~~education~~educational facilities is required to be considered as part of the safety assessment performed by the operating organization~~:-~~ (see para. 3.43 of GSR Part 3 [1]). The likelihood of any emergency that could affect workers, students, the public or the environment and warrant emergency response actions should be identified in the safety assessment. This then provides a basis for establishing emergency arrangements.

11.5. Based on the safety assessment and the potential consequences of a radiological emergency, arrangements for emergency preparedness and response are required to be made in accordance with GSR Part 7 [10]. Recommendations on these arrangements are provided in GSG-2 [11], GS-G-2.1 [12], GSG-11 [13] and IAEA Safety Standards Series No. GSG-14, Arrangements for Public Communication in Preparedness and Response for a Nuclear or Radiological Emergency [53].

11.6. Many radiation sources used in research and education are of low hazard and are unlikely to give rise to a significant radiological emergency. Some higher activity sources (i.e. classified as a dangerous source³) fall into emergency preparedness category IV, as set out in table 1 of

³ A dangerous source is a source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. This categorization is used for determining the need for emergency arrangements and is not to be confused with categorizations of sources for other purposes. This is based on dangerous quantities of radioactive material (D values³), as described in Ref. [54].

GSR Part 7 [10]; very high activity sources might even be in emergency preparedness category III. The applicability of the requirements established in GSR Part 7 [10] to facilities and activities in emergency preparedness categories III and IV is set out in the annex to GSR Part 7 [10], and this should be used when establishing emergency arrangements and during the preparation of emergency plans and procedures.

11.7. Emergency arrangements that correspond to the identified emergency preparedness category are required to be established by the operating organization: (see paras 4.16 and 4.17 of GSR ~~part~~Part 7 [10]). If a research or ~~education~~educational facility plans to use mobile dangerous sources (emergency preparedness category IV), it is required to have arrangements for dealing with emergencies at an unforeseen location (e.g. see paras 5.13 and 5.29 of GSR Part 7 [10]). A graded approach should be applied when establishing emergency arrangements. Arrangements for addressing any perceived hazards and non-radiation-related hazards should also be established.

EMERGENCY PLANS AND PROCEDURES FOR SOURCES IN RESEARCH AND EDUCATION

11.8. Prevention of accidents is the best means for avoiding potential exposures. Requirement 15 of GSR Part 3 [1] establishes requirements based on good engineering practice, defence in depth, and facility based arrangements to achieve this.

11.9. Although prevention of accidents is the first priority, events that would necessitate protective actions or other response actions could still occur. The operating organization is required to have an emergency plan and procedures prepared in advance, for the goals of emergency response to be achieved and for the emergency response to be effective: (see para. 3.42 of GSR Part 3 [1] and Requirement 23 of GSR Part 7 [10]). Recommendations on considerations to be taken into account in an emergency plan are provided in GS-G-2.1 [12].

11.10. Notices outlining the procedures for notification of an emergency and activation of the emergency response should be clearly and visibly posted in locations where they might be needed, and persons should be trained in these procedures.

11.11. Emergency procedures should, as appropriate, include instructions for the following:

- (a) ~~Notification~~Initiating notification of an emergency and ~~activation~~of activating the emergency response;
- (b) Taking protective actions including evacuation;
- (c) ~~Communication~~Communicating and ~~coordination~~coordinating with response organizations;
- (d) Identifying the nature and extent of external support, requesting and obtaining off-site support (e.g. from emergency services, health officials and radiation protection specialists – see para. 11.12);
- (e) Obtaining details on the radiological characteristics of the emergency, associated non-radiological aspects when relevant, and prognostics regarding the development of the emergency including ~~onsite~~on-site and ~~offsite~~off-site consequences;
- (f) Establishing a cordoned off area and access control;
- (g) Implementing actions to protect site personnel and emergency workers in accordance with the emergency plan;

- (h) Determining details for communication with the public;
- (i) Providing appropriate medical attention or treatment to affected individuals.

The operating organization of the research and ~~education~~educational facility or activity should consult relevant experts (e.g. a qualified expert on radiation protection) and organizations when developing the emergency plan and procedures.

11.12. Implementation of the emergency plan and procedures may involve off-site support (e.g. off-site response organizations, emergency services and radiological assessor⁴). The emergency plan for a research or ~~education~~educational facility should set out detailed arrangements for obtaining such off-site support. When off-site response organizations (i.e., emergency services such as ~~firefighters and~~ rescue brigades, ~~and~~ ambulance services) provide support on ~~the~~ site, they should be informed of the presence of radioactive material and, where appropriate, radioactive waste. Access to evacuated areas should be assessed by the radiation protection officer or, where appropriate, by the radiological assessor⁵. Irrespective of the radiological situation, lifesaving actions should be prioritized and promptly implemented.

11.13. In accordance with para. 6.19 of GSR Part 7 [10], the operating organization is required to submit its emergency plan to the regulatory body for approval. This should be done when applying for an authorization and whenever the emergency plan is revised.

11.14. Paragraph 6.36 of GSR Part 7 [10] states:

“Arrangements shall be made to maintain, review and update emergency plans, procedures ~~and other arrangements~~ and to incorporate lessons from research, operating experience (such as in the response to emergencies) and emergency exercises.”

11.15. Recommendations on the protection of emergency workers, including guidance values for restricting exposure, are provided in section 4 of GSG-7 [8].

11.16. If it is suspected that a sealed radioactive source might have been damaged, it should be ensured that any release of radioactivity is detected promptly, and the extent of the contamination should be assessed and measures taken to prevent any further spread. Examples of immediate on-site actions to be taken in ~~ease of~~ an emergency involving sealed sources at research and ~~education~~educational facilities are provided in Annex V of this Safety Guide.

EMERGENCY EQUIPMENT FOR SOURCES IN RESEARCH AND EDUCATION

11.17. In accordance with paras 6.22 and 6.23 of GSR Part 7 [10], the operating organization is required to ensure that all necessary tools, instruments, supplies, equipment, communication systems, facilities and documentation for responding to emergencies are maintained in a manner that ensures that they are readily available and functional for use under emergency conditions. The operating organization is required to establish a programme to

⁴ A radiological assessor is a person who or team that, in the event of a nuclear or radiological emergency, assists the operator or off-site response organizations by performing radiological surveys, performing dose assessments, controlling contamination, ensuring the radiation protection of emergency workers and formulating recommendations on protective actions and other response actions [10].

ensure the availability and reliability of such supplies, equipment, systems, facilities and documentation, including arrangements for inventory control, resupply, testing and calibrations:— (see para. 6.34 of GSR Part 7 [10]).

11.18. The equipment to be deployed in a radiological emergency at a research or ~~education~~educational facility will depend on the type of source and the nature of the emergency. For emergencies involving radioactive sources, some or all of the following equipment may be needed:

- (a) Suitable functional and calibrated monitoring instruments to measure both dose rates (high and low) and/or contamination;
- (b) An adequate number of personal dosimeters (passive dosimeters ~~such as~~(e.g. optically stimulated luminescence dosimeters, thermoluminescent dosimeters,) or film badges; or active dosimeters ~~such as~~(e.g. electronic dosimeters));
- (c) Suitable personal protective equipment;
- (d) Barrier materials and notices;
- (e) Lead bricks, lead sheets, lead shots or other shielding material, as appropriate, for the ~~source(s)~~sources;
- (f) Suitable tools for source handling and other operations (e.g. long handled tongs, pliers, screwdrivers, bolt cutters, adjustable spanner, torch);
- (g) Materials and agents for decontamination;
- (h) A spare empty shielded container;
- (i) Plastic sheets and bags for radioactive waste, airtight bags for gaseous sources, a wipe test kit and a measuring tape;
- (j) Communication equipment (e.g. mobile phones) including essential contact details;
- (k) Spare batteries for radiation monitoring instruments, electronic personal dosimeters, mobile phones and torches;
- (l) Stationery (e.g. pens, paper, calculator).

Procedures and instructions on use of emergency equipment should be available.

TRAINING AND EXERCISES FOR EMERGENCIES INVOLVING RADIATION SOURCES

11.19. Persons who have been assigned responsibilities in implementing the emergency plan for radiation sources used in research and education are required to be adequately qualified and trained for the effective fulfilment of their duties:— (see paras 6.9 and 6.28 of GSR Part 7 [10]). This should include familiarization with the emergency plan as well as specific training on implementing emergency procedures and on the use of the emergency equipment, as appropriate. The provisions for training for emergencies should be reviewed periodically to ensure the continued proficiency of the personnel in implementing the emergency response actions.

11.20. Persons should implement only those parts of the emergency plan and procedures for which they have been trained.

11.21. Exercise programmes are required to be developed and implemented to ensure that all specified functions to be performed for emergency response, as well as organizational interfaces, are tested at suitable intervals:— (see paras 6.30–6.33 of GSR Part 7 [10]). Recommendations on the preparation, conduct and evaluation of exercises (including guidance

on various types of ~~exercises, exercise and~~ their purpose~~),~~ as well as examples of scenarios for category III facilities, are provided in Ref. [55].

11.22. Training for an emergency involving radiation sources used in research and education should cover the following, as appropriate:

- (a) ~~Recognizing~~Recognition of the conditions indicative of an emergency;
- (b) Notification of an emergency and activation of the emergency response, including, where necessary, requesting and obtaining assistance from off-site emergency services;
- (c) Implementation of necessary on-site mitigatory actions and protective actions, and other response actions, including provision of immediate first aid~~, and procedures for~~ evacuation of non-essential persons from the facility;
- (d) Assessment of the emergency situation;
- (e) Use of emergency equipment (e.g. firefighting equipment);
- (f) Use of personal protective equipment;
- (g) Use of workplace monitoring equipment;
- (h) Implementation of recovery actions, decontamination, ~~assessing~~assessment of shielding and, where necessary, ~~providing~~provision of additional shielding;
- (i) ~~Collecting~~Collection of radioactive waste for disposal;
- (j) Communication with off-site response organizations and the public.

ANALYSINGANALYSIS OF EMERGENCIES INVOLVING RADIATION SOURCES

11.23. Arrangements are required to be made to undertake a timely and comprehensive analysis of a radiological emergency and of the emergency response~~;~~ (see Requirement 19 of GSR Part 7 [10~~+~~]). If the emergency was caused by an equipment malfunction, the supplier should be promptly informed so that they can inform other users and so that the equipment can be evaluated, and appropriate action taken, and similar emergencies can be avoided.

11.24. A comprehensive report on the findings of the analysis of the emergency and the response should be prepared by the radiation protection officer in consultation with relevant interested parties and, if necessary, with a qualified expert~~(s)~~ or experts. The report should be submitted to the senior management of the research or ~~education~~educational facility, as well as to the regulatory body and, as appropriate, to other relevant authorities at ~~the~~ local, regional or national level. The report should include the following:

- (a) A detailed description of the emergency, including specifications of the equipment and radiation sources involved;
- (b) Environmental and working conditions at the time of the emergency, with particular reference to whether ~~or not~~ these conditions played any significant part in causing the emergency or affecting the outcome;
- (c) The root ~~cause(s)~~causes of the emergency~~,~~ and identification of the event as due to equipment failure, human error, a malicious act or ~~another~~other cause;
- (d) A detailed description of the emergency response actions implemented and details of any deviations from the emergency plan or procedures, and the reasons for and consequences of ~~these~~those deviations;
- (e) The persons involved in the emergency response, their qualifications and training~~,~~ and the actions they performed;
- (f) An assessment and summary of the doses received by all affected individuals;

- (g) ~~Corrective~~The corrective actions identified, with the ~~aims~~aim of preventing similar emergencies in the future and improving overall radiation safety, nuclear security and the emergency arrangements;
- (h) The proposed means and time frame for implementation of the corrective actions identified, and the persons responsible for implementing the actions;
- (i) Details of the radioactive waste ~~arisings~~arising from the emergency and its management.

The report on the findings of the analysis of the emergency and the response should be kept for a period specified by the regulatory body.

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ANNEX I

USE OF NATURALLY OCCURRING RADIOACTIVE MATERIAL ~~(NORM)~~ IN RESEARCH AND EDUCATION

I-1. ~~NORM~~ Naturally occurring radioactive material (NORM) is defined as radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides [I-1]. It includes material in the natural state as well as material in which the activity concentrations of the naturally occurring radionuclides may have been changed by ~~man-~~madeartificial processes, including the residues from these processes.

I-2. NORM may be used in educational institutions and may range from minerals on display in science laboratories in schools; to research projects involving NORM for students at universities. Research activities using NORM are diverse; and include: sample analysis of raw materials, products and residues; process related research; research into recycling or reuse of residues, waste management and the decontamination of process equipment and plant installation parts; and the construction and operation of pilot plants. In many cases, research laboratories using NORM are part of the industrial activity (see, for example, Ref. [I-2]1), and such activities may be performed in a specific laboratory at an industrial site; or in a separate laboratory off the site. Research may also be undertaken in university laboratories; or at technical support organizations.

SAFETY ASSESSMENT FOR USES OF NORM IN RESEARCH AND EDUCATION

I-3. The scope and extent of the safety assessment is expected to be commensurate with the proposed use of NORM. In schools, analytical laboratories and small research projects, the quantity of NORM is normally small and the activity and/or activity concentration are below the exemption values specified in Scheduleschedule I of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [I-3]. By applying a graded approach, the safety assessment ~~that is~~ necessary for this type of application will therefore be straightforward.

I-4. The results of an initial safety assessment are intended to be considered in the selection of the site and the design of laboratories or other locations where NORM is used. The assessment needs to ~~considers~~consider all pathways by which students, research workers, members of the public and the environment might be exposed. The amount of NORM that will be used may vary significantly between projects and may range from small amounts for sample analysis; to hundreds of ~~ton~~tonnes in pilot processing plants. However, as the volume of the NORM handled in a laboratory or pilot processing plant will always be much smaller than at a full-scale operating industrial site, the safety assessment will usually be less detailed. When research is performed in a laboratory at a NORM industrial site, the safety assessment may be part of the overall safety assessment for the industrial facility.

EXPOSURE PATHWAYS AND ENGINEERED CONTROLS IN THE USE OF NORM IN RESEARCH AND EDUCATION

I-5. In most cases, NORM used in research and education is unlikely to cause significant external exposures. In most cases, the external dose rates from NORM used in research and education are so low that routine dose rate monitoring and protective measures (e.g. shielding) are not needed.

I-6. In some research facilities, there might be significant localized dose rates, for example from deposits containing elevated activity concentrations of ~~radium-226~~²²⁶Ra (e.g. in vessels, tubing or other equipment). In such cases, one or more of the following measures may be needed:

- (a) Minimizing the time spent in areas with significant dose rates;
- (b) ~~Ensure~~Ensuring that optimum distances are maintained between any accumulation of NORM and exposed people;
- (c) Providing shielding between the NORM and potentially exposed people.

The first two measures normally involve the designation of supervised or controlled areas to which access is restricted (see Requirement 24 of GSR Part 3 [I-3]). The use of shielding is an effective means of reducing dose rates around radiation sources, but it might not be feasible for the bulk accumulation of NORM in pilot plants. However, the principle may be partially applied by ensuring that the NORM deposits ~~remains~~remain enclosed within the structure of the plant (e.g. in vessels) prior to ~~its~~their disposal. If NORM waste with a high activity concentration is stored, the shielding provided by lower activity concentration ~~wastes~~waste may be used to reduce gamma dose rates on the exterior of the waste storage facility.

I-7. In pilot plants processing NORM, stockpiles of raw materials, products, residues and waste containing natural radionuclides can accumulate. In some cases, this can lead to occupational exposures that necessitate radiation monitoring. Significant external exposures can occur where high-grade uranium or thorium ores are processed or where there is a significant enhancement of the activity concentration of radionuclides in parts of the plant (e.g. as can occur ~~in~~with scales in tubing, ~~in~~with sediments in drums and vessels, and in waste tanks). Gamma dose rates in the workplace can be routinely measured with portable instruments, and individual exposures can be assessed using a variety of dosimeters (active or passive).

I-8. The handling of NORM can easily lead to dust formation, and dust control measures may be needed in pilot plants or laboratories handling large quantities of NORM. To ensure that these measures are adequate, monitoring programmes for the sampling and analysis of dust may be necessary. The primary method of control over airborne contaminants is through engineered controls (i.e. containment), adequate ventilation and dust control systems, or use of ~~glove boxes~~gloveboxes. Recommendations on dust control measures and the control of occupational exposures from NORM are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [I-4].

I-9. Dust containing NORM can lead to surface contamination of floors, walls, and external parts of ~~the~~ plant and equipment. Good housekeeping and material control are often necessary to control the buildup and spread of NORM on surfaces, and to reduce resuspension and airborne contamination. Routine monitoring of surface contamination may be needed, for example to assess the efficiency of control measures and to monitor equipment and materials for compliance with clearance criteria established by the regulatory body.

I-10. Processing operations can result in contaminated scrap and other materials that might be released into the public domain. Administrative controls over the movement, use and release of such materials may need to be implemented.

I-11. Ventilation may also be needed to control exposures due to radon. The performance of such systems needs to be monitored closely using suitable instrumentation.

CONTROLLING EXPOSURES FROM NORM IN RESEARCH AND EDUCATION THROUGH ADMINISTRATIVE CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT

I-12. In addition to engineered controls, administrative controls (including training and instruction of personnel) and personal protective equipment may also be needed (see para. 3.93 of GSR Part 3 [I-3]).

I-13. The operating organization may need to establish local rules and written procedures (see para. 3.94 of GSR Part 3 [I-3]) including, where appropriate, procedures for the cleanup of spills of NORM. These procedures might include the following instructions:

- (a) To use protective clothing in the correct manner to reduce the risk of transferring contamination;
- (b) To refrain from smoking, drinking, eating, chewing (e.g. gum), applying cosmetics (including medical or barrier creams), touching the face (mouth, nose or eyes) with contaminated hands, licking labels, or any other actions that increase the risk of transferring NORM to the face during work;
- (c) To use suitable respiratory protective equipment, where provided;
- (d) To apply, where practicable, methods that keep dispersible forms of NORM contained or wet to prevent airborne contamination;
- (e) To implement good housekeeping practices to prevent the spread of NORM contamination;
- (f) To observe industrial hygiene rules such as careful washing of hands.

I-14. Personal protective equipment is required to be suitable and adequate (i.e. selected with due consideration of the hazards involved) (see para. 3.95 of GSR Part 3 [I-3]). The equipment also needs to be convenient and comfortable to use. For research activities involving large quantities of NORM, coveralls, head coverings, gloves, boiler suits, and impermeable footwear and aprons may be appropriate.

I-15. Respiratory protective equipment may need to be worn by persons handling NORM or undertaking repair and maintenance activities on the associated plant or equipment ~~or plant~~. To ensure the comfort of the workers, powered air respirators are often preferable to other types of respiratory protective equipment. Persons provided with such equipment are required to be properly trained in its use (see para. 3.95(b) of GSR Part 3 [I-3]).

I-16. Monitoring of airborne dust may be appropriate, for example in research facilities or activities in which there is a possibility of receiving significant doses from the inhalation of dust.

NORM RESIDUES AND WASTE IN RESEARCH AND EDUCATION

I-17. Materials and equipment involving NORM may need to be decontaminated in accordance with regulatory requirements before being released from a research facility. Decontamination operations can give rise to a radiological hazard that may need to be controlled. Recommendations on the management of NORM residues and waste are provided in IAEA Safety Standards Series No. SSG-60, Management of Residues Containing Naturally Occurring

Radioactive ~~Residues~~Material from Uranium Production and ~~other NORM~~Other Activities [I-5]. If the research facility or pilot plant is located at the same site as an operational NORM industrial facility, the management of NORM residues and waste from the research facility or pilot plant is likely to be controlled under the same waste management arrangements as used for other NORM facilities on the site.

REFERENCES TO ANNEX I

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- [I-3] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).
- [I-4] INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ~~ORGANIZATION~~OFFICE, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, IAEA, Vienna (2018).
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ANNEX II USE OF RADIATION SOURCES IN SECONDARY SCHOOLS

II-1. The following criteria are normally applied to the use of radiation sources in secondary schools:

- (a) Radiation sources are only used when there is a clear educational benefit associated with their use (justification principle).
- (b) Sealed radioactive sources are used in preference to unsealed sources, unless only unsealed sources can fulfil the intended educational purpose. The sources used are of a design and type suitable for school science.
- (c) Radioactive sources with the lowest activity that can achieve the intended teaching purpose are used. Exempt sources are preferred.

Examples of sealed sources used in schools (taken from Ref. [II-1]) are presented in Table II-1, together with the relevant exemption values from [Table I.1](#) of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [II-2].

Table II-1. EXAMPLES OF SEALED SOURCES USED IN SECONDARY SCHOOLS [II-1]

Radionuclide	Maximum activity used in schools (kBq)	Exemption value from GSR Part 3 [II-2] (kBq)
Cobalt-60	200	100
Strontium-90	80	10
Caesium-137	200	10
Americium-241	40	10

II-2. Sealed sources are generally designed, manufactured and tested to ensure that they meet the requirements of ISO [standard 2919](#) [II-3] or an equivalent national standard.

II-3. Examples of unsealed sources used in secondary schools include the following:

- (a) Radon-220 (thoron) generators for half-life experiments; thoriated gas mantles and thoriated tungsten inert gas (TIG) welding rods;
- (b) Mini-generators using [caesium-137](#) (^{137}Cs) for half-life experiments;
- (c) Rocks and other geological samples that contain naturally occurring radionuclides.

II-4. Certain [apparatus/equipment](#) used in science departments can be a source of incidental radiation. For example, [an](#) apparatus in which high-speed electrons strike a target in a (partial)

vacuum may produce X rays. These conditions typically exist in evacuated tubes where the accelerating voltages are in the range of 10 kV or more. Crookes tubes and other cold cathode discharge tubes are common examples [II-4]. To avoid exposure to unwanted X rays, it is preferable to limit the electron acceleration voltage to 5 kV in such discharge tubes. Other types of apparatus that produce incidental X rays are cathode ray tubes — such as television receivers and visual display units (which are often exempt from regulatory control); — and electron microscopes.

II-5. Schools are expected to have appropriate risk assessments, handling procedures and contingency plans for the use and storage of radiation sources. A staff member of the school's science department may be designated to be responsible for the day-to-day supervision of the safety, security and proper use of radiation sources. Access to the sources needs to be restricted to qualified and trained staff.

II-6. Radiation sources in secondary schools are handled in ways that minimize exposure to staff and students. For example, radioactive sources are mostly handled by appropriately qualified and trained staff, with only certain activities being undertaken by students (normally under the direct supervision of staff). The handling of some geological specimens containing natural radionuclides can produce dust, and care is needed to avoid contamination. Persons who have access to radioactive sources need to be made aware of any control measures, handling procedures and contingency plans.

II-7. Special attention should be given for knowledge transfer among staff members, especially when they retire or leave the organization, to ensure that levels of protection and safety are maintained.

II-8. The use of radioactive sources for teaching students under the age of 16 years is usually restricted to teacher demonstrations, with students staying at least 2 metres away from the sources. Closer inspection of devices containing low activity radioactive sources may be allowed, provided the sources are fully enclosed. Contamination of any part of the body is to be avoided, for example by keeping radioactive rocks in suitable transparent containers.

II-9. Students 16 years of age and above may be allowed to handle sealed radioactive sources in order to perform standard experiments on the properties of ionizing radiation. In such cases, the teacher in charge will ensure that the students are sufficiently responsible, have received appropriate instruction and have understood the appropriate handling procedures. The teacher will also closely supervise all such experiments.

II-10. Only radiation sources that give rise to a low radiation hazard are used in secondary schools. Consequently, it is expected that the exposure of ~~both~~ teachers and students in secondary schools will be well below the dose limits for public exposure specified in ~~Schedule~~ schedule III of GSR Part 3 [II-2], namely:

- (a) An effective dose of 1 mSv in a year;
- (b) An equivalent dose to the lens of the eye of 15 mSv in a year;
- (c) An equivalent dose to the skin of 50 mSv in a year.

II-11. Records of all the radiation sources in a school are usually kept. These records include the details of each source, as well as when each source was acquired, when and by whom they have been used, and how each source might be disposed of in accordance with

regulatory requirements. Sources are checked periodically to make sure they remain in good condition, including leak testing at least every two years.

II-12. When not in use, radiation sources are kept in a suitable (*i.e.* safe and secure) storage facility at the school, located away from areas frequented by students.

REFERENCES TO ANNEX II

- [II-1] AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY, Use of Radiation in Schools, Safety Guide, Radiation Protection Series No. 18, [ARPANSA, Melbourne](#) (2012).
- [II-2] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).
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ANNEX III

RADIATION PROTECTION OF STUDENTS IN MEDICAL AND PARAMEDICAL EDUCATION

III-1. This ~~Annex~~ provides examples of radiation protection measures for undergraduate students in medical and paramedical education programmes. The education programmes for undergraduate students in the course of their medical and paramedical education generally include clinical training exercises and demonstrations.

III-2. During ~~the~~ practical training in ~~healthcare~~ health care settings, students in medical and paramedical education programmes could receive radiation exposures similar to those received by medical workers, albeit for a much shorter time period. A study of the exposure of undergraduate medical students during clinical training [III-1] showed that the doses received were below 1 mSv.

III-23. Examples of medical and paramedical education programmes involving radiation sources are shown in Table III-1.

TABLE III-1. EXAMPLES OF EDUCATIONAL PROGRAMMES FOR STUDENTS IN MEDICAL AND PARAMEDICAL EDUCATION

Type of educational institution	Educational programmes involving radiation exposure
University	Programmes for practices involving learning scientific research (e.g. experiments on biological effects of radiation) and technical methods of medical research (e.g. experiment experiments using radioisotope tracer techniques)-)
University or other training institutions for nurses	Clinical training programmes for care of patients who receive diagnostic or therapeutic medical exposures (e.g. nuclear medicine or radiation therapy -radiotherapy)
University (faculty of medicine) or other educational institutions for radiological practitioners and technologists	Clinical training programmes for various types of medical exposures (e.g. diagnostic and interventional radiology, nuclear medicine, and radiation therapy -radiotherapy)
Educational institutions for paramedical students	Specific training programme for medical exposures associated with emergency medicine-
University or other educational institutions for dental practitioners	Training programmes for dental radiology-
University or other educational institutions for veterinarians	Training programmes for veterinary uses of ionizing radiation-

III-3-4. Clinical training is especially important in the education of medical and paramedical professionals. During this training, students should observe the various medical procedures typical of the practice and demonstrate the ability to operate ~~such~~ medical exposure equipment

in accordance with these procedures while optimizing protection and safety. When clinical training includes patients, it is important that the local rules and procedures specific to the workplace are followed and isthat the medical exposures are performed under appropriate supervision.

GOOD RADIATION PROTECTION PRACTICE FOR STUDENTS IN MEDICAL AND PARAMEDICAL EDUCATION

Education and training in radiation protection before clinical training

III-45. Important topics for the education and training programme for medical and paramedical students are provided in Refs [III-2- to III-5]. The primary trainer and lecturer is expected to have relevant expertise in radiation protection and knowledge about the radiation sources used in practice.

III-56. In some cases, medical and paramedical students could receive the necessary training in radiation protection from a separate research institute or a university, i.e. that specializes in providing such training (see, for example, Ref. [III-6]).

III-67. A typical radiation protection training programme for nurses involved in medical exposures includes the following subjects:

- (a) Principles of radiation, including radioactive decay, radiation emissions and units;
- (b) Effects of radiation exposure;
- (c) Demonstrations (e.g. use of radiation monitoring instruments);
- (d) Radiation protection requirements and recommendations (e.g. principles of radiological protection, ICRPInternational Commission on Radiological Protection recommendations, IAEA safety standards, and regulatory requirements);
- (e) Radiation protection of patients and medical personnel.

Radiation protection in clinical training of medical students

III-78. The radiation protection measures taken for each medical procedure are important subjects in the education and training of medical students. In addition to study within real clinical settings, other educational tools are available, for example to enable students to investigate the spatial distribution of radiation in a medical facility during a medical exposure. For example, a visualization method can be used to make it easy to understand scattered radiation and the doses to medical staff [III-7]. These tools can also investigate the effect of personal protective equipment, such as lead aprons, and help promote the optimization of radiation protection of students in the education programme.

III-89. Students of diagnostic radiology will need to receive instruction in the proper positioning of a patient to obtain accurate diagnostic information while minimizing exposure of the patient and medical staff. During training, students can use a phantom, also called a positioning doll, to practice positioning skills [III-8].

REFERENCES TO ANNEX III

- [III-1] ~~M. M. ABUZAID, W. M. M., ELSHAMI, CHRISTOPHER W., STEELMAN, C.,~~ Measurements of ~~Radiation Exposure~~ radiation exposure of ~~Radiography Students~~ radiography students during ~~Their Clinical Training Using Thermoluminescent Dosimetry~~, ~~Radiation Protection Dosimetry, Volume~~ their clinical training using thermoluminescent dosimetry, *Radiat. Prot. Dosim.* **179**, Issue 3, May (2018, Pages) 244–247.
- [III-2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Education and Training in Radiological Protection for Diagnostic and Interventional Procedures. ~~ICRP, Publication 113. Ann. ICRP 39 (5), Elsevier~~ (2009).
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ANNEX IV

USE OF SPECIFIC TYPES OF RADIATION SOURCE IN RESEARCH AND EDUCATION

X RAY ANALYSIS EQUIPMENT

IV-1. A wide range of X ray equipment is used in universities, scientific establishments and research laboratories for the analysis of materials. This equipment makes use of the phenomena of X ray diffraction, absorption or fluorescence.

IV-2. X ray analysis equipment produces intense X ray beams; improper use can result in very high localized radiation exposures, particularly to the eyes, fingers and hands. Exposure to a primary beam from an X ray analysis unit is prevented by a combination of engineered safety features, safe working procedures (local rules), radiation monitoring and other safety checks.

IV-3. Modern X ray analysis equipment is designed with interlocked barriers that enclose all system components in a manner that minimizes the radiation hazard. For such equipment, the various safety interlocks present in the system and the means for recognizing any failures can be described in the local rules.

IV-4. Suppliers of X ray equipment are required to provide information on radiation safety; (see para. 3.49 of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [IV-17]). Advice on radiation safety may also be sought from a qualified expert before using prior to use of the equipment.

IV-5. Some ~~hand-held~~handheld X ray fluorescence analysers contain a battery-powered X ray tube that emits a radiation beam in the forward direction. The radiation levels are most intense at the beam aperture at the front of the equipment and reduce in intensity with increasing distance. If unshielded, the radiation in the main beam can be measured several metres from the equipment. The exposure time varies depending on the material being analysed but is typically less than one minute. For analysis of small components, an enclosed, interlocked test stand is expected to be used.

IV-6. Enclosures for X ray analysis equipment are expected to provide adequate shielding and safety systems to prevent accidental exposures. Typical safety features include the following:

- (a) A clear warning on the equipment to indicate that it is capable of emitting X rays.
- (b) Key operation or password protection to prevent unauthorized operation.
- (c) A tube housing designed to shield against leakage of X rays.
- (d) A warning light to indicate when X rays are being generated.
- (e) For handheld X-ray equipment:
 - (i) An exposure control switch that has to be pressed continuously to generate X rays. Handheld units are usually designed for two-handed operation (i.e. to prevent a hand being in the beam).

- (ii) A proximity sensor that prevents X rays being generated unless a sample is positioned against the aperture. Where this is not practical, a low-count (backscatter) interlock can be fitted. Ideally, both safety systems are fitted.

All safety features need to be tested and maintained at appropriate intervals.

IV-7. A greater risk of radiation exposure from X ray analysis equipment often occurs during maintenance, (i.e. in situations where maintenance personnel might potentially be exposed to the primary beam or to high levels of scattered radiation). Therefore, it is imperative that the maintenance procedures recommended by the manufacturer are followed by properly trained and authorized persons.

IV-8. Typical local rules for the operation of X ray analysis equipment are as follows:

- (a) Users of X ray analysis equipment are to avoid exposing any part of the body to the primary beam.
- (b) The correct operation of all warning lights is to be confirmed before the equipment is used.
- (c) No sample, collimator or analysing crystal is to be changed, adjusted or handled in any manner while the X ray tube is ~~energised~~energized, unless it is done by remote means from outside the shielded enclosure with the approval of the radiation protection officer.
- (d) The X ray equipment is to be immediately taken out of service if it is suspected of being damaged or if any of the safety and warning systems are not working. Resumption of use of the X ray equipment is not to be permitted until ~~the equipment~~ has been repaired and radiation monitoring has been undertaken to confirm that the equipment is adequately shielded.
- (e) Visual alignment or adjustment of the X ray beam is not to be undertaken while the X ray tube is ~~energised~~energized, unless a viewing system that is shielded and designed to prevent exposure of the eye or other parts of the body to the primary beam is used.
- (f) The X ray analysis equipment is not to be operated with any interlocks inactivated or with the enclosure (or a part thereof) removed, unless this has been approved by the radiation protection officer.

NEUTRON GENERATORS

IV-9. A neutron generator is a small-sized accelerator of deuterium nuclei that produces 14 MeV neutrons. Its components include the accelerator tube (neutron tube), a target containing deuterium or tritium, a high voltage power supply and a measurement module. The following radiation safety aspects need to be considered:

- (a) The dose rate (neutron and gamma radiation) at 1 ~~metrem~~ from the neutron generator during operation at nominal power;
- (b) The dose rate (gamma radiation) at a specified distance from the neutron generator after being operated for 1 hour at nominal power;
- (c) The tritium activity in the target.

IV-10. Gamma radiation is emitted both during neutron generation (from inelastic interaction of high energy neutrons) and for some time after the generator is turned off (from capture of

thermal neutrons and radioactive decay of neutron activation products). The regulatory body may specify a value for the maximum dose rate immediately after switching off the generator, below which either unrestricted handling of the equipment (or else handling only by authorized personnel) is allowed. Otherwise, a hold time may be established to allow for the decay of activation products.

IV–11. Neutron generators can give rise to some radioactive contamination on external surfaces. In such cases, appropriate personal protective equipment is worn, and suitable beta contamination checks are made.

IV–12. When not in use, neutron generator tubes with tritium targets are treated in the same way as sealed sources.

REFERENCE TO ANNEX IV

- [IV–1] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

ANNEX V
EXAMPLES OF SPECIFIC ~~EXAMPLE~~ ACTIONS TO CONSIDER IN EMERGENCY PLANS AND PROCEDURES FOR RADIATION SOURCES USED IN RESEARCH AND EDUCATION

V-1. Examples of immediate on-site actions to be taken in ~~ease of response to~~ an accident or an emergency at research and ~~education educational~~ facilities involving X ray generators and radioactive sources are briefly described in this ~~Annex annex~~. Recommendations on emergency plans and procedures are provided in IAEA Safety Standards Series No. ~~GSGGS-G-2.1~~, Arrangements for Preparedness for a Nuclear or Radiological Emergency [V-1].

X RAY GENERATORS

V-2. For X ray generators, turning off the electrical power supply (e.g. using appropriately located and distinctively marked emergency power cut-off push buttons) immediately stops any radiation being produced. All relevant persons are generally trained to recognize when the equipment containing X ray generators is not functioning correctly.

SELF-SHIELDED GAMMA IRRADIATORS

V-3. Self-shielded gamma irradiators typically contain a Category 1 or Category 2 sealed radioactive source [V-2]. A radiological emergency can occur ~~due owing to the~~ leaking of a source, the failure of a safety system, the failure of the equipment to function as designed, or ~~due to the occurrence of~~ a nuclear security event. The emergency plan may include the following on-site actions:

- (a) In the event of a suspected fault, persons are to leave the irradiator room immediately.
- (b) Access to the irradiator room is to be prevented (e.g. locking the door).
- (c) The supervisor and the radiation protection officer are to be informed immediately of the situation. The operating organization ~~willis to~~ contact the manufacturer of the irradiator, and take the advice of the radiation protection officer and, if necessary, a qualified expert to determine further actions. The operating organization ~~willis~~ also ~~to~~ inform the regulatory body.
- (d) The radiation protection officer ~~willis to~~ monitor the area outside the irradiator room to determine if actions are needed to protect workers and the public.

SEALED RADIOACTIVE SOURCES INCORPORATED IN OTHER EQUIPMENT

V-4. The emergency plan for sealed radioactive sources needs to address scenarios such as damage to the equipment resulting in increased dose rates, damage to a source leading to contamination, and failure of a safety system leading to the exposure of persons. The following actions could be taken in the event of such an emergency:

- (a) Persons are to move away from the radioactive source, and ensure that any other persons in the vicinity are evacuated and informed that there might be an emergency.

- (b) The radiation protection officer is to be informed. The radiation protection officer ~~willis~~ to measure the radiation dose rates and record any doses measured by direct reading individual dosimeters.
- (c) The radiation protection officer ~~willis~~ to establish a cordoned off area (or confirm the appropriateness of such an area) based on the monitoring results and any pre-established criteria (e.g. observables in the emergency plan~~).~~ The operating organization ~~willis~~ to prevent unauthorized access to the cordoned off area and keep the area under surveillance.
- (d) The operating organization ~~willis~~ to inform the regulatory body and seek assistance as described in the emergency plan.
- (e) The radiation protection officer ~~willis~~ to undertake the following actions:
 - (i) Implement the pre-established emergency plan and procedures.
 - (ii) Move to a location away from the cordoned ~~off~~ off area and rehearse the planned course of action before entering the area to implement the emergency plan, using the personnel, emergency equipment and ~~personnel~~personal protective equipment described in the plan.
 - (iii) Call for technical assistance, as necessary, from a qualified expert or from the manufacturer of the source and/or equipment, as appropriate, in accordance with the emergency plan.
 - (iv) Implement the planned course of action to regain control over the source. Under no circumstances is the source to come into contact with the hands or other parts of the body. If the course of action taken is unsuccessful, persons are to leave the cordoned ~~off~~ off area and maintain surveillance of the area.
 - (v) When the situation has been brought under control and the source is safe, return personal dosimeters to the dosimetry service for rapid assessment.~~Perform;~~ perform an investigation and estimate any doses received.~~Prepare;~~ prepare an accident report; and notify the regulatory body, in accordance with regulatory requirements.

SPILLAGE OF UNSEALED RADIOACTIVE MATERIAL

V-5. Following spillage of unsealed radioactive material, the following actions are to be taken:

- (a) If the spill is liquid, absorbent pads are to be placed over the spill to prevent further spread of contamination.
- (b) Persons are to be evacuated from the immediate area of the spill, taking precautions to avoid spreading contamination. All persons evacuated from ~~the~~ the affected area are to be monitored for contamination when leaving the ~~room;~~area (particularly their shoes, if the spill was on the floor).
- (c) The radiation protection officer is to be informed immediately; and arrangements made for decontamination of the affected area under the direct supervision of the radiation protection officer.

- (d) If internal exposure is possible, the radiation protection officer ~~should~~is to consider the need for whole body counting (or thyroid monitoring in the event of exposure to radioiodine) or bioassay sampling and analysis.
- (e) If clothing is contaminated, it is to be removed and placed ~~it~~ in a plastic bag labelled 'RADIOACTIVE'.
- (f) If contamination of skin occurs, ~~it~~the skin is to be washed immediately. If contamination gets in the eyes, they are to be irrigated with copious amount of sterile water.
- (g) When the contamination is contained, procedures for cleaning small spills are to be followed, taking particular care that contaminated waste is placed in plastic bags that are appropriately labelled and stored. Protective clothing, including disposable gloves, is to be worn.
- (h) The area is to be decontaminated and monitored for residual activity, for example, ~~using~~ using a contamination monitor or performing a wipe test.
- (i) Cleaning and monitoring are to be repeated until the measurements indicate that the spill has been removed, trying to keep the volume of contaminated waste as small as possible. (In some cases, such as with short-lived radionuclides, it may be better to prevent access to the area for sufficient time to allow radioactive decay~~:-.)~~.)
- (j) Access to the contaminated area is to be restricted until decontamination has been completed and the area has been declared by the radiation protection officer to be fit for re-occupation.
- (k) Any radioactive waste generated, for example liquid waste from the decontamination activities, is to be properly managed.

REFERENCES TO ANNEX V

- [V-1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS~~—AND,~~ WORLD HEALTH ORGANIZATION, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. ~~GSGGS-G-2.1~~, IAEA, Vienna (2007). (A revision of this publication is in preparation.)
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