DS470
4 January 2021

IAEA SAFETY STANDARDS

for protecting people and the environment

Status: Initial draft (Step 8)
Soliciting comments from Member States (120 days comments period)

Review Committees: RASSC (Lead)
WASSC, TRANSSC, EPReSC, NSGC

Radiation Safety in the Use of Sources in Research and Education

DRAFT SAFETY GUIDE
No. DS470

New Safety Guide

IAEA
International Atomic Energy Agency

CONTENTS

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 protection of people and the environment from harmful effects of ionizing radiation and for the safety of radiation sources. The implementation of these basic 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, should such accidents occur, to mitigate their consequences. This Safety Guide provides guidance 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 types of radiation sources used in research and education. The sources include sealed sources such as small check radioactive sources and large sealed radioactive sources in irradiators, unsealed radioactive sources that are used as tracers in field work and in laboratory work, and material containing naturally occurring radioactive material, X ray generators such as diffraction apparatus and accelerators.

1.3. The users of such 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 carry out their work on more than one campus and may travel to carry out research work in laboratories located in foreign countries.

1.4. The use of radioactive sources can lead to the generation of radioactive waste that needs to be managed and stored by the education institute or the research laboratory. Radioactive material and radioactive waste may need to be transported between laboratories on a campus, and 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 series of Specific Safety Guides for facilities and activities that cover the use of radioactive sources and X ray generators; e.g. industrial irradiators, industrial radiography, nuclear gauges, isotope production facilities, well logging, and the use of radiation sources in medical facilities [2-8]. Detailed recommendations on occupational radiation protection can be found in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [9]. Recommendations on the protection of the public and the environment are provided in in IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment [10]. Requirements and recommendations for radiation protection in emergency exposure situations are in provided in Refs [11-14].

1.6. It is assumed in this Safety Guide that the State has in place an effective governmental, legal and regulatory infrastructure for radiation safety that covers the use of X ray generators and other types of radiation sources in research and educational institutions. Requirements for such infrastructure are established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1),

Governmental, Legal and Regulatory Framework for Safety [15], and recommendations on the implementation of these requirements can be found in Refs [16, 17].

OBJECTIVE

1.7. 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 on the control of occupational exposure and of public exposure, and on safety measures specific to this practice.

1.8. The guidance in this publication is 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 will also be of interest to regulatory bodies and to other relevant agencies involved in design, manufacture, supply and service of equipment in research and education facilities.

SCOPE

1.9. The Safety Guide addresses the radiation protection and safety aspects of the use of X ray generators and other types of radiation sources that are used in research and education.

1.10. The Safety Guide addresses the exposure of students and workers using radiation sources in research and education. It also covers exposure of members of the public who may be inadvertently exposed during the operation of such sources. The use of radiation sources in research and education is a planned exposure situation.

1.11. The exposure of volunteers for the purposes of biomedical research is considered to be a medical exposure. Recommendations on such exposures are provided in SSG-46 [4].

1.12. The requirements relating to the protection of students and research workers carrying out research or studies at research reactor facilities are established in IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors [18], and related recommendations are provided in IAEA Safety Standards Series No. NS-G-4.6, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors [19]. Such facilities and activities are outside the scope of this Safety Guide.

1.13. The 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

1.14. Section 2 provides 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 sources used in research and education are described in Section 3. The duties and responsibilities of the registrant, licensee, radiation safety committee, radiation protection officer and qualified expert, and the content of a radiation protection programme are

described in Section 4. The preparation of a safety assessment is covered in Section 5. Section 6 provides recommendations on the design of facilities, laboratories and equipment. Section 7 covers 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. Section 9 provides recommendations on protection of members of the public. Section 10 provides recommendations on the movement of radioactive material within the licensee's site, and the transport of radioactive material to and from licensee's sites. Section 11 sets out guidance on the arrangements for prevention and mitigation of accidents, and for the preparation of emergency plan and procedures.

1.15. Annex-I provides guidance on the use of sources in secondary schools. Annex-II gives information on the safe use of specific types of radiation sources. Annex-III provides practical guidance on laboratories using naturally occurring radioactive material (NORM) and Annex IV addresses examples of specific on-site actions to consider in emergency plan and procedures for certain emergencies related to the use of sources in research and education.

2. RADIATION PROTECTION PRINCIPLES

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 PRACTICES

2.2. Paragraph 3.16 of GSR Part 3 [1] states:

> ”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 the harm that the exposure to radiation might cause.

2.3. The process of determining if 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 that should cover both the magnitude and the likelihood of expected exposures, and an assessment of the potential exposures. The assumption is made in this Safety Guide that the process of justification has already taken place. The justification process should have specified the type of sources and the type of user allowed for each type of practice, for example the type and activities of sources that are permitted to be used in secondary schools.

2.4. Guidance on the application of the principle of justification is provided in IAEA Safety Standards Series No. GSG-5, Justification of Practices, including Non-Medical Human Imaging [20]. For those research organizations developing new technologies involving the use of radiation sources, GSG-5 [20] 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. Government, regulatory body and operating organization should ensure that the radiation sources in human and animal research are used ethically.

OPTIMIZATION OF PROTECTION AND SAFETY

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. [21]. 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 the life of equipment and facilities, in relation to both exposures from normal operations and potential

exposures. Therefore, all situations — from design, through operation to decommissioning and waste management — should be considered in the optimization process.

2.7. From a practical viewpoint, the principle of optimization of protection and safety calls for an approach that:

(a) Considers all possible actions involving the source(s) and the way workers and students operate with or near the source(s);

(b) Implies a 'management by objective' process with the following sequence: planning, setting objectives, monitoring, measuring performance, evaluating and analysing performance to define corrective actions, and setting new objectives;

(c) Can be adapted to take into account any significant change in the state of techniques, the protection resources available, or the prevailing social context;

(d) Encourages accountability, such that all parties adopt a responsible attitude to the process of eliminating unnecessary exposures.

2.8. The process of optimization should take account of:

(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 exposure;

(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) Social and economic aspects.

2.9. The optimization of protection and safety should be considered at the design stage of equipment and laboratories, when some degree of flexibility is still available. The use of engineered controls should be examined carefully at this stage in defining the protection options. Decisions made at the design stage include the design of shielding, the design of ventilation/fume cupboards, the design of hot laboratories; and the choice of surfaces for clean-up of contamination. At this stage, the content and the scale of the optimization process will depend on the type and nature of the facilities and activities involving sources. For example, when dealing with low activity sealed radioactive sources or with X ray machines, the optimization process can be quite straightforward, involving local rules and appropriate training of the operators. In laboratories using complex equipment, situations may be more complicated, and a structured approach is needed as part of a detailed radiation protection programme, including the use of decision aiding techniques, the establishment of dose constraints, and the establishment of investigation levels.

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

2.11. 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 doses may be reduced can become significant compared with the benefit to be achieved. At some stage, for low doses, the effort might not be worthwhile.

2.12. Even if protection has been optimized at the design stage, there is still a need to implement the optimization principle during the operational phase. 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 is applied in order to keep exposure levels under review and to ensure that they are as low as reasonably achievable. The elaboration of a radiation protection programme, adapted to the specific exposure situations, is an essential element of work management.

2.13. The registrants and licensees should record information on the way in which optimization of protection and safety is being implemented and disseminate the information where appropriate. This information could include the following:

(a) The rationale for proposed operating, maintenance and administrative procedures, together with other options that have been considered and the reason for their rejection;

(b) Periodic review and trend analysis for occupational exposure to individuals in various work groups, and other performance indicators;

(c) The results of internal audits and peer reviews;

(d) Incident reports and lessons learned.

Dose constraints

2.14. Dose constraints are used for optimisation of protection and safety (see para 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.

2.15. 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 in the optimization of protection and safety by the licensee responsible for radiation sources. 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 that has been implemented and for making adjustments as necessary. The setting of the dose constraint 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 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 no.25 of GSR Part 3 [1].

2.16. 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 any dose

constraints should be such that dose limits for occupational exposure are complied with when workers incur exposures from multiple sources or tasks.

2.17. To apply the optimization principle, individual doses should be assessed 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 not be used retrospectively to check compliance with the requirements for protection and safety. Dose constraints should be used prospectively in optimizing radiation protection in various situations encountered in planning and executing tasks, and in designing facilities or equipment. They should therefore be set on a case-by-case basis according to the specific characteristics of the source of exposure . 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 would be working with radiation sources. For research workers, the dose constraint would need to take account of the time that they spend working in the laboratory of their 'home' campus, and of the time spent in laboratories away from the 'home' campus. For members of the public, the dose constraint is a fraction of the public dose limit, used in the design of the shielding for laboratories, waste storage rooms, and in determining discharge limits.

DOSE LIMITS

2.18. The dose limits in planned exposure situations are provided in Schedule III of GSR Part 3 and associated requirements are specified in para 3.26-3.28 of GSR Part 3 [1].

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

(a) An effective dose of 20 mSv per year averaged over five consecutive years (100 mSv in 5 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 consecutive years (100 mSv in 5 years) and of 50 mSv in any single year;
(c) An equivalent dose to the extremities (hands and feet) or the skin[67] of 500 mSv in a year.

Additional restrictions apply to occupational exposure for a female worker who has notified pregnancy or who is breast-feeding (see paras 3.114 of GSR Part 3 [1] and 6.2-6.20 of GSG-7 [9]).

2.20. 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 who use sources in the course of their studies, the dose limits are:

(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[67] of 150 mSv in a year.

2.21. For public exposure, the dose limits are:

(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[67] of 50 mSv in a year.

[67]The equivalent dose limits for the skin apply to the average dose over 1 cm^2 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.

2.22. The dose limits apply to all users of radiation sources including short-time contract workers, research workers, and students. Registrants and licensees should ensure that secondary school students and undergraduate students, that is, students of age less than 16 years, receive the same level of protection and safety as if they were members of the public, for example, the public dose limits should be applied, as these students are most likely only using radiation sources for a few hours per year and considering radio-sensitivity and age factors. Graduate and post-graduate students conducting continuous research or studies using radiation sources for long duration should be afforded the same level of protection and safety as any 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 working at other research organizations, does not exceed these limits. In addition, registrants and licensees should make arrangements for pregnant or breast-feeding research workers or graduate students to meet the requirements of para 3.114 of GSR Part 3 [1].

3. TYPES OF RADIATION SOURCES USED IN RESEARCH AND EDUCATION

3.1. There is a wide variety of radiation sources used in research and education. The sources include sealed radioactive sources, unsealed radioactive materials, and radiation generating machines such as X ray units, accelerators and neutron generators.

3.2. The radioactive sources may be used in teaching students basic science principles in secondary schools or used in the teaching of undergraduate students in universities. The sources can be used to calibrate instruments (e.g. 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

3.3. A large variety of sealed sources are used in research and education. Sealed sources are generally longer half-life radioactive materials firmly contained or bound within a suitable capsule or housing. Sealed sources only present a risk of external radiation exposure unless they have been breached or are leaking. The nuclides and activities vary depending on the application, and sources may be used as sample irradiators, calibration sources, sources used in scientific equipment and neutron sources.

3.4. Sealed sources may be used to calibrate radiation measurement equipment (e.g. area monitors, spectrometers, contamination measuring instruments, analytical radiation measuring equipment). Depending on the instrument to be calibrated, a wide range of radionuclides that can emit alpha, beta, gamma or neutron (for example ^{60}Co, ^{137}Cs, ^{241}Am-Be), may be used. The activity of the source is dependent on the application, and ranges from a few kBq for check sources to TBq for sources used in calibrations. It is possible for some check sources to be exempted from regulatory authorization due to the low activity. However, even with these small sources, best practices guidelines for radiation protection should be employed to minimize the risk of exposure to the worker, public or the environment.

3.5. Sealed sources should be:

(a) Designed, manufactured and tested to meet the requirements of the appropriate ISO standard [22] or an equivalent national standard. These standards set out the normal operating conditions and certain potential accident conditions that a sealed source should withstand;

(b) Leak tested in accordance with the appropriate ISO standard [23] or an equivalent national standard and attested with a valid leak test certificate that is traceable to a standards laboratory, for each source;

(c) Where appropriate, 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) [24].

3.6. A categorization system for sealed sources depending on their potential to cause harm

to human health is provided in IAEA Safety Standards Series, RS-G-1.9, Categorization of Radioactive Sources [25]. This categorization can assist in establishing regulatory requirements that ensure an appropriate level of control for each authorized source in safety and security aspects.

3.7. In addition to sealed sources, plated radioactive sources where a thin layer of radioactivity is coated on a non-radioactive surface are also used in some applications in research and education.

3.8. Sample irradiators are used to irradiate different kinds of samples such as 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, sample irradiators may be specifically designed to expose materials to alpha or beta radiation when using plated sources. Special care needs to be taken to minimize the risk of abrading these plated sources causing a release of the radioactive material. The activity range of sources used in irradiators is very wide from a few kBq to TBq.

3.9. Sealed sources may be used in scientific or measurement equipment such as gas chromatographs or electron capture detectors. In the academic and research environment, these sources may be commercial sealed sources or custom constructed sources that are integrated into commercially available instruments, laboratory designed equipment or a prototype instrument. The radiation sources vary by radionuclide and activity depending on the application, but the radiation exposure risk external to the instrument is generally low for commercial instruments but should be evaluated for laboratory designed instruments. The main exposure risks from these sources are due to improper handling, loss of source integrity or an uncontrolled release of the source or the instrument incorporating the source. Some of these sources might not be controlled by regulation due to the low activity or exempted levels of activity. Nevertheless, some best practice guidelines for radiation protection may be followed such as, the instrument and the source marked with the radiation symbol (trefoil) [26] and the legend 'RADIOACTIVE' and a description of the source including the manufacturer's serial number.

3.10. Neutron sources are generally used for calibration of instruments, to create fission reaction in experimental reactors, in nuclear physics research such as neutron logging and neutron diffraction analysis or as educational tools to demonstrate physics principles. The common nuclides in neutron sources are ^{252}Cf (spontaneous fission), ^{241}Am/^{9}Be using (α,n) reaction or ^{124}Sb/^{9}Be using (γ,n) reaction. Control of neutron sources requires attention to shielding to protect against exposure to both neutron and photon radiations.

UNSEALED SOURCES

3.11. Unsealed sources are radioactive materials that are not within a protective container. These materials are extensively used in research and education. The applications include incorporation as tracers in biomedical or environmental studies, in physics experiments or in radiochemistry laboratories. The radioactive material may be in many physical forms such as liquid for environmental transfer research, or gas for atmospheric research or an activated sample in physics research. Therefore, numerous nuclides (α, β, γ emitters) with a very wide range of activities are used in research facilities. For example, the activity of the stock solution in wet laboratories can vary from a few kBq to multiple GBq with a high specific activity that is often diluted in the laboratory. Research work involving the use of unsealed sources in animal

experiments are also conducted in accordance with the regulations prescribed by the concerned authorities.

3.12. The use of unsealed sources can give rise to internal exposure and to external exposure while handling the sources during experiments or laboratory work, or from events that lead to dispersal of the radioactivity resulting in contamination of the workplace, equipment or environment. Depending on the physical parameters of the unsealed source and the operations involved, the radioactivity may be released as a gas, liquid or solid. As a result, contamination risks depend on the dispersal method, the activity, the nature of the radioactive source, and the chemical and physical forms of the material involved.

3.13. Alpha sources (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, biomedical and medical uses or to study the effects of chronic exposure of some category of workers. They may be incorporated into the experiment as free solid particles or liquids. The activity of the stock solutions is often very small (a few Bq to MBq). Alpha sources may be difficult to detect unless the source also emits a more readily measured radiation such as gamma rays. As a result, caution should be exercised when working with unsealed alpha sources since they have a large biological effectiveness when inhaled or ingested or enter the body through the skin, particularly, if there are openings (e.g. open wounds). The radioactive material may be present as a liquid, gas or dust. The total effective dose from exposure to these radionuclides may be high with internal exposures because of their very long radioactive half-life and biological accumulation in target organs.

3.14. Beta emitters (e.g. ^{32}P, ^{3}H) are often used as molecular label or tracers in biological or environmental studies. The activities used vary from a few kBq to MBq. Beta emitters are generally grouped into two categories: low energy (Emax<150 keV) and high energy (Emax>150 keV). Generally, the radiotoxicity of beta emitters is lower than alpha emitters, but care should be taken with skin, eye lens or hand exposure especially for high energy beta emitters. For low energy beta emitters (^{3}H, ^{14}C), in many cases, higher activities are 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 protective equipment. ^{3}H is widely used in research and is present as a contaminant in accelerator environments; it is known to diffuse into the body when present as skin contamination or from materials such as metals and plastics that are contaminated causing secondary air and surface contamination.

3.15. Unsealed gamma emitters (^{125}I, ^{131}I, ^{133}Xe, ^{60}Co, ^{137}Cs) may be used in environmental applications and are widely used in research especially in wet chemical laboratories involving biological and medical research including PET (Positron Emission Tomography) radionuclides research (^{18}F, ^{11}C etc). In these experiments, the radioactive material is attached to a molecule as a tracer to follow the molecule's biological or environmental route or behaviour. The types of materials used vary depending on the specific chemical or physical parameters or systems being studied. In medical applications, it is desirable to use radioactive sources with short half-lives as radiopharmaceuticals. However, certain research work may need to be done with a long half-life radioactive material to effectively study the material's biological properties. These materials may also present an exposure risk at a distance due to the longer range of the photons as compared to beta radiations. It may be necessary to consider whole body and hand exposure when flasks or syringes are used.

3.16. Environmental research often involves the use of radioactive sources in the form of 'radiotracers' to study processes and interactions in the natural environment, such as sediment

transport, water currents, or effluent distribution. It may also include unintended by-products handled in accelerator based research and environmental samples collected in the affected areas after a nuclear disaster. These studies require the release of unsealed sources into the environment. Once deployed, the source is deemed to be dispersed and irretrievably disposed of. There are generally other hazards associated with radiotracer studies in waterways or at sea. These include the loss of a package containing the source or a spill/contamination on board a vessel. Detailed preparation is required for each study to reduce the risk of an unplanned event, whilst planning for mitigation of such an event, should it occur. Each radiotracer study requires a detailed safety assessment; all aspects of safety and the potential impact on the environment should be considered.

3.17. Naturally occurring radioactive materials (NORM)[1] are used in educational and research establishments. NORM includes material in the natural state as well as material in which the activity concentrations of radionuclides of natural origin may have been changed by man-made processes, including the residues from these processes. The use of NORM varies from minerals containing NORM in showcases in secondary schools, to research projects involving NORM in universities or research centres. Laboratory activities using NORM are diverse. Examples of laboratory activities include sample analysis of raw materials, products and residues, process related research, research for recycling or reuse of residues, waste conditioning and management, 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 [27] and may be carried out in a specific laboratory at an industrial site, or in a separate laboratory offsite. Research may also be carried out at university laboratories, or at technical support organizations.

3.18. Laboratories that provide calibration and equipment testing services for the measurement of radon contain radon chambers of various sizes, from less than 1 m^3 to tens of m^3. These chambers contain a source of radon. Such radon sources generally do not release high activity during the calibration studies.

RADIATION GENERATORS

3.19. The radiation environment in research and education is not limited to radioactive materials. There is increasing application of machine generated radiations such as X rays and accelerated particles such as electrons and protons. The potential exposure from some of these sources may be very high and require particular attention. In addition to the intentional generation of X rays for a specific application, they may be generated as a secondary radiation when particles, such as electrons or protons, are accelerated or are produced in high energy laser applications.

3.20. 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. Some examples such as Crookes tubes and other cold cathod discharge tubes are given in Annex I of

[1] NORM is radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides [27].

this Safety Guide.

3.21. Another application of low-energy X rays is electron microscopy and analytical measurements. In electron microscopy, the X rays are generally well shielded by the microscope and associated housings. Hand-held devices that generate a specific energy beam that may be used to identify materials based on their characteristic X rays are also used. These hand-held devices may produce very intense but narrow X ray beams. If the user modifies the shield housing or places a body part into the beam significant exposures may result.

3.22. X ray machines are used also to either generate an image of materials or irradiate a material for sterilization purposes using high radiation doses. These devices range from hand-held instruments to fixed devices in shielded rooms. The hand-held instruments used to image materials have integrated shielding. Other applications including an X ray machine installed in a specially designed room or shielded cabinet where a sample is imaged or irradiated can generate such high dose rates to present a risk to health for a person who would access the X ray field. These facilities warrant provision of shielding and interlocks to protect people from the radiation fields. Computed tomography (CT) uses a narrow high intensity X ray beam to produce cross-sectional and 3D images; it is used in areas 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. In these applications, protection and safety of the operators should be considered to avoid acute exposures.

3.23. Accelerators may be used for medical purposes as well as physics and materials science research. The radiological hazards associated with these devices include the primary and secondary radiations (such as X rays, electrons, neutrons) produced during the operation. Many of these facilities produce radiation fields of sufficient energy to make the structural components of the accelerator radioactive and so, care should be taken to control the area around the device during and possibly after operation due to high residual radiation fields. An assessment should be made of the potential for release of radioactive material into the air or activation of air constituents as well as the device’s components. In addition, exposure to magnetic and electric fields and high voltage associated with the accelerator operation should also be considered for protection of workers.

4. DUTIES AND RESPONSIBILITIES

GENERAL

4.1. GSR Part 3 [1] establishes recommendations on duties and responsibilities related to the use of radiation sources. This section provides recommendations on these 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 exemption or authorization of practices, the review and assessment of applications for authorization, inspection of facilities and activities, and enforcement of the regulations and law relating to radiation safety.

GRADED APPROACH

4.3. The graded approach is a concept that underpins the application of the system of protection and safety. Paragraph 2.12 GSR Part 3 [1] states "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 process for justification and for authorization.

4.5. Registrants and licensees, and employers are required to use the graded approach in the measures they take for protection and safety. For example, university departments with accelerators, or with laboratories using unsealed sources producing waste would have a more detailed safety assessment and a more elaborate set of local rules compared to a department with a few check sources or a secondary school that may have very limited (in numbers and activity) radioactive sources.

OPERATING ORGANIZATION, REGISTRANT AND LICENSEE

4.6. The operating organization is the organization applying for authorization or authorized to operate a facility and responsible for its safety [17].

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

> **"The person or organization responsible for facilities and activities that gives rise to radiation risks shall have the prime responsibility for protection and safety. Other parties shall have specified responsibilities for protection and safety".**

The prime responsibility for protection and safety that is assigned to the person or organization responsible for any facility or activity that gives rise to radiation risks cannot be delegated: see

para. 2.39 of GSR Part 3 [1]. Other parties have specified responsibilities for protection and safety in support of the licensee or registrant responsibilities: see para. 2.41 of GSR Part 3 [1].

4.8. The principal parties responsible for protection and safety in a research or education facility are:

(a) Registrants or licensees, or the person or organization responsible for the facilities and activities. In the context of this Safety Guide, this is the educational, or research entity that is responsible for the facility where the radiation sources are stored or used;

(b) Employers and/or academic or research advisors who are generally the persons with the direct operational oversight of the radiation source. In the context of this Safety Guide, for most academic staff, researchers and students, the employer is (or is from) the same organization as the registrant or licensee. However, there will be some academic staff, researchers and students that carry out research at more than one organization. These academic staff, researchers and students will have one employer but use the radiation sources owned by more than one registrant or licensee.

4.9. Other parties with specified responsibilities in relation to protection and safety include:

(a) Radiation protection officers;

(b) Qualified experts or any other party to whom a principal party has assigned specific responsibilities;

(c) Workers or other users of radiation sources, such as students, other than those listed in (a)–(b);

(d) External service provider for supplying sealed and unsealed radiation sources and radiation generating equipment and providing monitoring, transport and/or disposal services.

MANAGEMENT SYSTEM, STRUCTURE AND POLICIES

4.10. The registrant, licensee, and employer are required to ensure that protection and safety is effectively integrated into the overall management system: see Requirement 5 of GSR Part 3 [1].

4.11. The registrant, licensee, and employer are required to demonstrate commitment to protection and safety at the highest levels within the organization. In accordance with para. 2.48 of GSR Part 3 [1], the management system is required to be designed and implemented to enhance protection and safety by:

(a) Applying the requirements for protection and safety coherently with other requirements, including requirements for operational performance, general safety and security of radioactive material;

(b) Describing the planned and systematic actions necessary to provide adequate confidence that the requirements for protection and safety are fulfilled including the application of lessons learned from experience;

(c) Ensuring that protection and safety are not compromised by other requirements;

(d) Promoting a positive safety culture.

4.12. The registrant and licensee, and employer are required to be able to demonstrate the effective achievement of the protection and safety requirements: see para. 2.50 of GSR Part 3 [1].

4.13. The management system should include a description of the management structure as it relates to radiation safety. This structure, which may be presented in the form of an organizational chart, should show the names of the relevant radiation protection officer (see paras 4.25 and 4.26) and the members of the radiation safety committee (see paras 4.21–4.24). The chart should clearly show the line of reporting, with their responsibilities. An example of an organizational chart for a large research or education facility, with multiple research departments and laboratories using radiation sources, that may be spread across more than one site is shown in Fig.1. For smaller research or educational facilities, the chart can be simpler with relevant responsible entities, for example a radiation protection officer and some qualified experts if necessary.

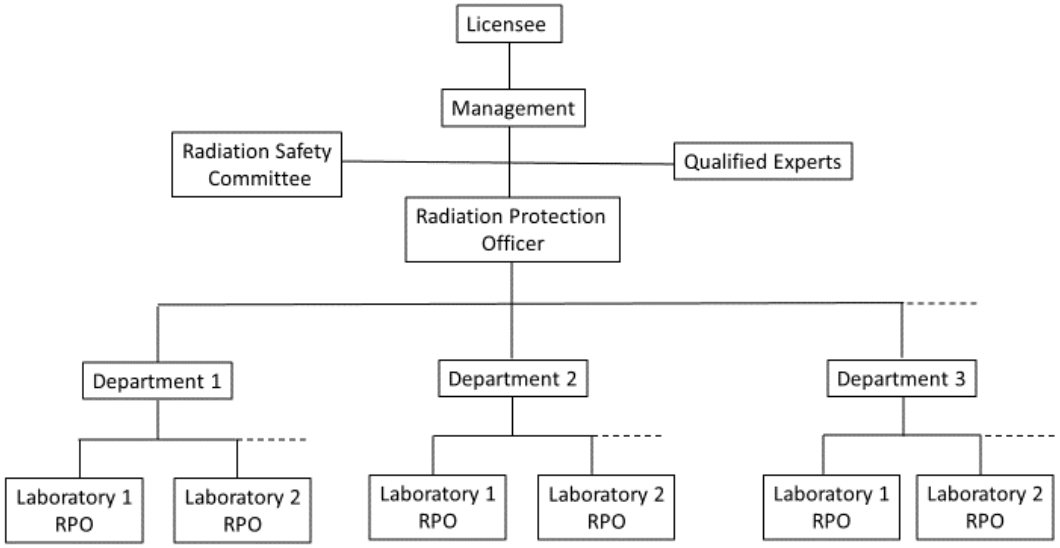

Fig.1 Example of an organizational chart for radiation safety in a large research or education facility.

4.14. The roles of the radiation protection officer and the radiation safety committee should be clearly defined in the radiation protection programme (see Requirement 24 of GSR Part 3 [1]). The radiation protection officer and the radiation safety committee should oversee the effectiveness of the radiation protection program.

4.15. In research organizations that are authorized to work with radiation sources, workers

from multiple organizations may operate together; or workers from one organization, may work for different organizations. Under these conditions, the management structure should clearly specify the responsible persons at each location for the worker. If responsibilities are shared, this should be defined in the management structure. Examples of these extended organizations include cases where:

(a) The operating organization has more than one location of operation;

(b) The worker is employed by several entities;

(c) The worker is not employed or affiliated with the operating organization;

(d) The worker is engaged in experiments that involves sources that are not under the control of his employer;

4.16. The registrant and licensee, and employer are required to establish and implement an appropriate radiation protection programme (see paras 4.18–4.20), and should ensure that in the implementation of this programme:

(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;

(c) Any failures or shortcomings in protection and safety are identified, corrected, and steps are taken to prevent their recurrence;

(d) Arrangements are made to consult with relevant interested parties;

(e) Appropriate records are maintained.

4.17. The registrant and licensee, the employer and the radiation protection officer are required to ensure that all personnel engaged in activities relevant to protection and safety have appropriate education, training and qualification (see Requirement 26 of GSR Part 3 [1]) so that they understand their responsibilities and can perform their duties competently, with appropriate judgment and in accordance with appropriate safe procedures of operation.

RADIATION PROTECTION PROGRAMME

4.18. 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 activities planned to be conducted in laboratories. The programme should be based on the operating organization’s safety assessment, and it should address both planned exposure situations and emergency exposure situations including potential exposures.

4.19. The radiation protection programme should cover the main elements contributing to protection and safety. The structure and contents of the radiation protection programme should be documented to an appropriate level of detail. The radiation protection programme should include as essential elements:

(a) Management structure and policies;

(b) Assignment of individual responsibilities for radiation safety;

(c) Safety assessment;

(d) Arrangements for control of radiation sources;

(e) Arrangements for protection of workers: These include, local rules, designation of controlled or supervised areas; arrangements for individual monitoring of workers, monitoring workplaces and environment, and a health surveillance programme as appropriate;

(f) Education and training programme on the nature of the radiation hazards, and protection and safety: This training should be adapted to the experiments and practices conducted and renewed as often as necessary or in case of a new experiment;

(g) Arrangements for protection of public: These include control of discharges into the environment, management of radioactive waste and compliance with dose limits;

(h) Arrangements for mitigation of the consequences of accidents, and for emergency preparedness and response;

(i) Methods for periodically reviewing and auditing the performance of the radiation protection programme;

(j) Quality assurance and process improvement.

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

4.20. These elements of a 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. More detailed guidance on radiation protection programme is available in Ref. [9].

RADIATION SAFETY COMMITTEE

4.21. In academic and research organizations where research of diverse nature involving radiation or radioactive material is conducted, it may be appropriate to establish a radiation safety committee by the operating organization to oversee the radiation protection programme. The registrant and licensee should appoint staff members who have expertise in the various types of radiation sources used in the organization to the radiation safety committee. In addition, the radiation safety committee or other equivalent relevant body should include senior management (representing operating organization), the radiation protection officer, health, safety and environment officers, laboratory managers and medical staff or any other relevant staff.

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

4.23. In its oversight role of the radiation protection program, the radiation safety committee should be responsible for:

(a) Establishing policies and approving procedures to improve the effectiveness of the programme in compliance with regulatory requirements;

(b) Review and approval of all proposals for the use of radiation sources and conditions of use as recommended by the radiation protection officer;

(c) Regular reviews of all aspects of the radiation protection programme. This includes programme documentation, guidance, training and related information;

(d) Making recommendations for improvements in the radiation protection programme;

(e) Providing guidance and direction on the performance of the radiation protection officer's duties;

(f) Communication of regular reports to all staff about relevant radiation safety issues;

(g) Establishing training procedures and criteria;

(h) Conducting audits of the radiation protection programme to comply with regulations and organizational policy;

(i) Enforcing compliance with the protection and safety program, including imposing sanctions for non-compliance;

(j) Acting in accordance with any role that has been assigned in the emergency plan, in the event of any incident or accident;

(k) Reviewing information or analysis reports of abnormal events, incidents or accidents and making recommendations for improvements in radiation protection programme as well as to avoid their reoccurrence.

4.24. Prior to the introduction of a new radiation source approval should be obtained from the radiation safety committee and prior to its use, the committee should:

(a) Review the design criteria and design features relating to the exposure and potential exposure of workers in all operational situations and accident conditions including the related monitoring aspects;

(b) Make recommendations and setting conditions on the proposed work with the new radiation source(s).

RADIATION PROTECTION OFFICER

4.25. The radiation protection officer is a person who is technically competent in radiation protection matters associated with the organization's activities who is designated by the licensee to oversee the application of protection and safety requirements. In the academic and research environment, this person should also have a working knowledge of the laboratory practices, general health, safety and environment principles and institutional culture as it relates to the organization's activities. The radiation protection officer should have a strong working relation with other health, safety and security officials in the organization to implement an effective radiation protection programme in research where safety includes biological, chemical and physical safety considerations. The radiation protection officer should be granted sufficient authority, resources and organisational freedom to effectively oversee the protection and safety programme and, if required, to stop unsafe activities.

4.26. The licensee should designate a radiation protection officer in accordance with the requirements established by the regulatory body. The designation should be in writing and integrated into a job description that assigns the radiation protection officer the organizational responsibilities and authority to effectively implement the safety program. The designation should include responsibilities to:

(a) Oversee the application of the relevant regulatory requirements and compliance;

(b) Ensure that all workers using radiation sources are instructed in and comply with safe operating practices;

(c) Identify and control access to controlled areas and supervised areas;

(d) Evaluate and make recommendations to the radiation safety committee on proposals for the use of radiation sources;

(e) Optimize exposure controls and maintain engineering features and other equipment that contribute to controlling exposure of workers and members of the public;

(f) Conduct and periodically assess the radiation protection programme including monitoring and recording of individual doses, routine radiation surveys and environmental monitoring;

(g) Maintain the radioactive source inventory and relevant training and safety records;

(h) Arrange statutory tests for leakage of radioactive material, in accordance with Ref. [23];

(i) Undertake a programme of periodic safety checks of safety systems and warning signals and alarms, and of general conditions at the facility;

(j) Ensure the control of radioactive waste including collection, packaging, storage and disposal;

(k) Liaise with laboratory directors, faculty, laboratory managers, medical service, contractors, designers and suppliers with regard to radiation protection matters and significant changes to physical or operational aspects of the facility;

(l) Ensure the adequacy of safety assessments and contingency plans for full range of postulated emergencies with consequences for radiation protection;

(m) Investigate and take part in analyses of any accident or incident at the facility such as:

  (i) Any of the operational parameters subject to periodic quality control being out of the normal ranges established for operational conditions;

  (ii) Any equipment failures, operating errors, unusual events or circumstances that cause, or have the potential to cause, doses in excess of regulatory dose limits (e.g. failure of a radioactive source to return to the shielded position).

(n) Identify radiation protection problems associated with the operations, and recommend and initiate, or provide corrective actions;

(o) Interrupt an unsafe or non-compliant operation to maintain radiation safety and inform other relevant departments such as health, safety or security as appropriate.

LABORATORY RADIATION PROTECTION OFFICER

4.27. The laboratory radiation protection officer (or equivalent) is responsible for ensuring

that the requirements of the radiation protection programme are implemented on a day-to-day basis restricted to the specific laboratory assigned.

QUALIFIED EXPERTS

4.28. The licensee 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 its regulatory requirements and developing or improving protection and safety.

WORKERS

4.29. In GSR Part 3 [1], 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". In the context of this Safety Guide, the term worker includes administrative, academic and research workers (e.g. post-doctoral research fellows) employed by the research or education facility and would also include contract cleaners, visiting academic and research workers employed by other universities undertaking collaborative research. All workers have recognized rights and duties in occupational radiation protection, including additional rights for those who declare pregnancy or breast-feeding or are under the age of eighteen. Undergraduate and graduate students who just use radiation sources intermittently as part of their academic learning or studying process such as demonstration of experiments by teacher with sealed or unsealed sources should be afforded the same level of protection and safety as any members of the public.

4.30. The requirements on workers in respect of protection and safety are listed in paras 3.83 and 3.84 of GSR Part 3 [1] and relate to among others: 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 to the management and to act in a responsible manner with regard to protection and safety. The requirements for protection and safety of workers in emergency exposure situations are established in Section 4 of GSR Part 3 [1] and in GSR Part 7 [11]. Recommendations on protection of workers in a nuclear or radiological emergency are provided in Section 4 of GSG-7 [9].

Workers who are not employed by the registrant or licensee

4.31. Organizations where workers (e.g. academic appointees, research workers) use radiation sources and are not employed by the registrant or licensee should ensure that the workers have the same level of protection and safety as full-time workers employed by the registrant or licensee.

4.32. Organizations where workers use radiation sources but are not employed by the registrant or licensee require special consideration to ensure regulatory compliance due to possible lack of clear reporting lines. The relevant responsibilities of the operating organization and the employer of the worker should be clearly specified in contractual arrangements.

4.33. When a worker is not employed by the registrant or licensee, an agreement should be in place that specifies there be cooperation between the employer and the organization on:

(a) The development and use of means of ensuring protection and safety for workers who are engaged in work that involves or could involve a source that is not under the control of their employer are at least equivalent to those for employees of the registrant or licensee;

(b) Assessment of the doses received by workers and documentation of the worker's current annual cumulative effective dose prior to commencing work with radiation sources at the registrant or licensee's facility;

(c) Details of the radiation protection programme of the registrant or licensee and contact information of the radiation protection officer;

(d) A clear allocation and documentation of the responsibilities of the employer and those of the registrant or licensee for protection and safety.

4.34. 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 [1]], and any other necessary information;

(b) Shall provide appropriate information to the employer, including any available information relevant for compliance with the requirements of these Standards that the employer requests;

(c) Shall provide both the worker and the employer with the relevant exposure records."

4.35. The responsibilities of the licensee and the employer of the worker will depend on the specific regulatory requirements. The licensee should clarify with the employer of the worker the allocation of responsibilities for matters such as:

(a) Local rules;

(b) Workplace monitoring arrangements;

(c) Individual dosimetry and dose record keeping;

(d) Training on radiation safety, particularly when the equipment and radiation sources are new to the researcher;

(e) Health surveillance arrangements.

4.36. The licensee should verify that the worker has the appropriate qualifications and has received adequate training in both radiation safety and source operation techniques. If such is not the case, the licensee should provide the worker specific training for using the radiation sources and good practices in radiation protection. The licensee should verify that all procedures and other relevant documents are provided in a language known to the worker. Additional recommendations on itinerant workers are provided in paras 6.21–6.39 of GSG-7 [9].

4.37. Operating organizations should 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 safely dealt with at the end of their lifetime or stored or appropriately disposed of as waste. A risk based ranking of radioactive sources and practices in five categories is provided in IAEA Safety Standards Series No.RS-G-1.9 Categorization of Radioactive Sources [25]. Recommendations on the safety and security of Category 1, 2 and 3 sources are given in the Code of Conduct on the Safety and Security of Radioactive Sources [28].

4.38. Operating organizations should ensure that they obtain radioactive sources from only authorized suppliers and that disused sources are returned to the original supplier or transferred to another authorized body (see Section 8). 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 [28] and its supplementary guidance on import and export controls [29]. The research and education facilities where animal experiments are carried out involving unsealed sources, should take care to ensure that these animals are not released without making a safety assessment of such release.

4.39. Licensees are required to conduct periodic inventories of sources, to confirm that they are in their assigned locations and are secured: see para. 3.53 of GSR Part 3 [1]. Sources should be only removed from a source storage container/location or moved to another authorized location by authorized and trained workers. For sealed source(s) or mobile radiation generator(s), the users should log their name, the date and time, and the location the source or the generator was moved to. For unsealed source(s), the users should log their name, the date and time, and the quantity of the source withdrawn. When an unsealed source is no longer needed, it should be disposed of appropriately as radioactive waste and recorded as such. These records should be audited by the radiation protection officer at least once per month, to ensure that all radioactive sources are where they are supposed to be.

4.40. 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) [24]. The loaning licensee should also ensure that the other research facility is authorized for the specific source and document the transfer, time period and any other conditions to establish responsibility.

4.41. Any suspected loss of control of a radioactive source should be promptly investigated by the registrant or licensee. If source loss, damage or theft is confirmed, the operating organization is required to notify the regulatory body (se para. 3.55 of GSR Part 3 [1]) in accordance with the emergency plan and established emergency procedures.

Security of radioactive material

4.42. The security of radioactive material aims to prevent, detect, delay and respond to unauthorized access to radioactive material for malicious act like unauthorized removal and/or sabotage of radioactive material. Since some of the radioactive material used for research and education purposes can cause serious injuries, it may therefore be assumed that there could be a significant impact if these material 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, Nuclear Security Series No. 20 [30] sets out the objective and the essential elements of a State's nuclear security regime. Nuclear Security Series No. 14 [31] provides

recommendations to States and competent authorities on how to develop or enhance, to implement, and to maintain a nuclear security regime for radioactive material, associated facilities, and associated activities. Nuclear Security Series No. 11 [32] contains more specific guidance to assist States in the development of regulatory requirements for the security of radioactive sources. Nuclear Security Series No. 9-G (Rev.1) [33] provides guidance on the security of radioactive material during transport.

Safety-Security Interfaces

4.43. 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. The interested parties should strive for the promotion of safety culture and of security culture with respect to radioactive sources, advocating and supporting the exchange of ideas between, and the combination of, safety culture and security culture.

4.44. 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 the regulatory body has responsibility for both the safety and security of radioactive sources under the regulatory infrastructure. Additionally, para 4.14 of GSR Part 7 [11] stipulates requirements for emergency exposure situations in this context.

4.45. For inspection purposes, there may be 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 in place may need to be readily accessible. However, this information may also be of potential value to an adversary and therefore security considerations may require that the confidentiality of some sensitive information be protected. Guidance on the protection and confidentiality of sensitive information in nuclear security is provided in the IAEA Nuclear Security Series publication on Security of Nuclear Information [34]. An appropriate balance needs to be maintained between the availability of information for safety reasons and the need to protect sensitive information for security reasons.

Security Measures

4.46. The accidental loss of sources used for research and education purposes, which may have security as well as safety implications, is addressed through the control measures described in paras 4.37-4.41. The primary security concerns are therefore the possibility of unauthorized removal or sabotage of radioactive sources. It should be noted that effective security measures will also provide some inherent benefit toward safety by preventing accidental loss of control.

4.47. Safety and security measures designed against the loss of radioactive sources or for protection against radiation incidents can also provide some benefit against the unauthorized removal or sabotage of those sources. However, the element of intent involved in unauthorized removal or sabotage means that additional considerations apply for higher activity sources, and additional and/or different security measures may be needed to protect against unauthorized removal or sabotage.

4.48. The Nuclear Security Series provides guidance on how to define the requirements and how to implement 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. Nuclear Security Series No. 11-G (Rev.1) [32] suggests using the system for categorization of radioactive sources described in RS-G-1.9 [25] 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 Category 3 or higher, (i.e. Category 2 or 1) then the security measures described in Nuclear Security Series 11-G (Rev.1) [32] should be applied for those radioactive sources.

SAFETY CULTURE

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

> "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;
>
> (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."

4.50. The senior management of the organization is required to promote and maintain a positive safety culture within the operating organization. This should include promoting relevant safety expectations within the organization, compliance with regulatory requirements, periodic evaluation of the rules and procedures for their effectiveness, engaging relevant management and staff on overall efficacy of protection and safety, implementing adequate training programmes to follow the rules and procedures correctly, disseminating and promoting the knowledge of accidents or any incidents to learn from their occurrence and improve safety culture, maintaining an environment where staff feel free to raise concerns without fear of retaliation and eliciting safety related proposals from staff through incentive systems.

HUMAN FACTORS

4.51. In accordance with para. 2.52 of GSR Part 3 [1], the principal parties and other parties having specified responsibilities in relation to protection and safety are required to take into account human factors and to support practices that minimize the risk of human and organizational failures. The operating organization should also address human factors by supporting good performance and good practices to prevent human and organizational failures, with attention being given to the design of equipment, the development of safe operating procedures, limits and conditions, as appropriate, training and the use of safety systems to mitigate consequences of human error.

QUALITY ASSURANCE AND PROCESS IMPROVEMENT

4.52. 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. This periodic review should identify performance problems to be addressed and modifications that could improve the effectiveness of the radiation protection programme and prevent or limit the likelihood and magnitude of exposures in anticipated operational occurrences and accident conditions.

4.53. A key part of this periodic review process is a routine series of workplace audits, including the designation and qualifications of the persons who will conduct them, their frequency, the expectations of the audit team, the reporting of results and their follow-up.

4.54. Research, experimental work, education and its associated activities are required to be carried out in accordance with the established management system. Due to the nature of these activities, there may be changes from the original proposal. To ensure the radiation protection programme meets the needs of changing programmatic needs, a quality assurance and process improvement programme that is a cooperative effort between research and safety staff should be in place. This management system should be designed to ensure the basic programmatic needs, that all equipment and safety systems are assessed for appropriateness and regularly checked and tested, and that any faults or deficiencies are brought to the attention of the management and are promptly remedied.

4.55. The management should also ensure that the correct operational procedures are being followed, and that the quality assurance programme specifies the relevant checks and audits to be made and the records to be kept.

4.56. The operating organization should have a mechanism for the collection and analysis of data and information including lessons from incidents and accidents (including those reported by other similar operating organizations) and have arrangements in place to take them into account to enhance safety.

5. SAFETY ASSESSMENT

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

> **"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."**

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. GSR Part 3 [1] specifies two types of safety assessments: generic and specific to the facility or source. A generic safety assessment is usually sufficient for types of sources with a high degree of uniformity in design. A specific safety assessment is usually required in other cases; however, the specific safety assessment should not include those aspects covered by a generic safety assessment, if a generic safety assessment has been conducted for the source. The safety assessments needed in the context of 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 placement in the research and education facility will nearly always require some form of specific safety assessment.

GRADED APPROACH TO SAFETY ASSESSMENT

5.4. A safety assessment should consider the graded approach, i.e. in which the stringency of the control measures and conditions applied are commensurate, to the extent practicable, with the characteristics of the practice or the source within a practice, likelihood and magnitude of exposures and possible consequences of, and the level of risk associated with, a loss of control of the source. A graded approach is also required to be taken to the application of regulatory requirements: see para. 2.18 of GSR Part 3 [1].

GENERAL ASPECTS OF SAFETY ASSESSMENT

5.5. The operating organization should conduct and document a safety assessment for each type of radiation source. The radiation risks arising from routine use of the radiation source together with the probability and magnitude of potential exposures should be taken into account. Radioactive materials and radiation generating devices that are low hazard or exempt from regulatory control should have a straightforward safety assessment.

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

5.7. In the event of work already being carried out where no safety assessment has previously been made, the operating organization should carry out and document a retrospective safety assessment. The retrospective safety assessment should either confirm that all the relevant control measures are in place or identify any additional control measures that should be put in place.

5.8. The radiation safety assessment should be complemented with other related risk assessments such as biological, chemical, pharmacological or physical that may impact overall safety.

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

METHODOLOGY FOR THE SAFETY ASSESSMENT

The safety assessment is an assessment of all aspects of a practice that are relevant to protection and safety; for an authorized facility, this includes siting, design and operation of the facility.

5.10. A safety assessment should:

(a) Describe how the radiation sources will be used, the conditions and locations of the use of radiation sources, and the design of the laboratory or facility where the radiation source will be used;

(b) Describe the provisions for defense in depth, as appropriate, by using several layers of protection (i.e. physical barriers, systems to protect the barriers, and administrative procedures) that would have to fail or be bypassed before there could be any consequences for people or the environment;

(c) Determine the expected likelihood and magnitudes of exposures in normal operation and in the event of accidents.

(d) Describe 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.

(e) Outline the training and experience of the individuals responsible for supervision and use of the radiation sources;

(f) Evaluate the implications of any proposed modifications in the experimental or equipment design that may impact protection and safety.

(g) Evaluate the implications for protection and safety of security measures or of any modifications to security measures.

(h) Describe 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 a radiation source into the environment e.g. radiotracer study.

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 to the facility or activity. These should include recommendations on the requirements for training of workers, external and internal exposure monitoring, for designation of controlled areas and supervised areas, and for protection of the public and environment. In addition, the assessment should provide specifications of engineering control measures for safety such as shielding, ventilation, fume hood, glove boxes, information on any generation of radioactive waste and its management, and information on reasonably foreseeable events including arrangements for emergency preparedness and response.

REVIEW OF THE SAFETY ASSESSMENT

5.12. The safety assessment should be reviewed whenever there is a significant change in the conditions of use of a radiation source. In general, a safety assessment should be reviewed whenever any of the following conditions apply:

(a) Modifications to facilities or procedures, or the acquisition of a new radiation source(s) or a source with different radiation characteristics (e.g. different source type or total number of sources);

(b) Operating experience or findings of the analysis of failures or errors, indicates that current safety measures are invalid or are not fully effective;

(c) Significant changes to relevant guidelines, standards or regulations have been made or are envisaged.

5.13. It is advisable to carry out a periodic review of the safety assessment even if the above conditions do not initiate a review. Periodic reassessment ensures that current working practices are reflected, and changes have not been overlooked. Operating organizations should consider a review frequency based on the hazards involved and the dynamic nature of the work.

5.14. The safety assessment should be independently reviewed within the operating organization’s management system. Revisions and modifications of the safety assessment should be approved by the appropriate body such as the qualified expert or the organization’s radiation safety committee and submitted or made available to the regulatory body.

RECORD OF THE SAFETY ASSESSMENT

5.15. The report of the safety assessment should form an integral part of the documentation of the radiation protection programme. In some States, the safety assessment report may be required to be submitted to the Regulatory Body when applying for licence or authorization as well as decommissioning.

5.16. The safety assessment should be kept for the lifetime of the operating organization. If the operator ceases to exist the report should be handed over to the new operating organization.

6. DESIGN OF FACILITIES, LABORATORIES EQUIPMENT AND SOURCES

GENERAL

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 facility. Provisions for the incorporation of radiation safety features are best made at the facility design stage (for laboratories and other related rooms). The siting and layout should take into account the types of radiation sources, the frequency and the purpose of its use.

6.2. 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.

6.3. The location for work with radiation sources in research and education is diverse. The radiation sources may be used in a controlled facility or in a laboratory that is simultaneously used by other workers or in an open environment. In all cases, it is the responsibility of the registrant and licensee to ensure that the facilities and laboratories, equipment containing radiation sources and radiation sources are designed, manufactured, and handled to minimize exposure of workers and the public so far as is reasonably achievable.

6.4. Specific guidance on the selection of radiation sources for use in secondary schools is provided in Annex I.

DESIGN OF FACILTIY AND LABORATORIES

6.5. The design of the laboratories will depend on the type of radiation source to be used in the laboratories. There are some general design requirements that are common to all facilities where sources are used for research and education purposes. There are specific design requirements for facilities handling sealed sources and unsealed radioactive sources and radiation generating devices.

General design requirements for facilities

6.6 The general design requirements of facilities where radioactive sources and/or radiation generators are used and that are designated include the following:

(a) The room(s) where sources are handled should be located preferably at one end of the building where the studies are to be carried out. This area which has to be used exclusively for the purpose of the intended studies should not be frequented by persons who are not concerned with the activities. Where possible, this area should be located away from the main entrance to the premises.

(b) Provisions should be made for adequate illumination and ventilation.

(c) An exclusive enclosure with low background radiation should be available for storing individual dosimeters when not in use.

(d) Space should be provided for working with the sources and for storing records relating to inventory of radioactive sources, disposal of sources, individual dose, calibration of radiation monitors, servicing and maintenance of equipment, incidents and emergencies and other reports.

(e) Shielding requirements should be individually tailored to meet any regulatory requirements and be based on the intended workload and the type of work to be undertaken. Further assessments should be undertaken if any of the factors in the shielding design changes, e.g. when the nature of occupancy in an adjacent room is altered.

6.7 The shielding of walls (including doors and windows), floor and ceiling needs to be designed to optimize protection and safety of workers and the public. Evaluation of shielding requirements would depend on the classification of areas within the facility, the nature of work to be done, maximum energy and current of the radiation generator and, in the case of radionuclides, type and energy of radiation emitted by radionuclides, the maximum activity intended to be used and the relevant dose limits. It is better to shield sources, where possible, rather than the room or the workers. Shielding (e.g. lead bricks or lead pots) is needed for storage and for source handling operations. Appropriate shielded packagings should be used for transport of radioactive sources.

6.8 Care should be taken to avoid excessive overestimates of required shielding by multiplication of conservative assumptions. For example, workload, use and occupancy factors are often overestimated, and the persons to be protected are considered as remaining permanently in the most exposed place of the adjacent room. Therefore, a balanced decision needs to be achieved and accumulation of overly conservative measures should be avoided. Specification of shielding, including calculations, should be performed by a qualified expert in radiation protection in collaboration with the radiation protection officer and meet any relevant requirements of the regulatory body.

6.9 Shielding requirements in respect of facilities where self-shielded irradiators are used would depend upon factors such as the radiation levels on the exterior of such equipment, the nature of occupancy around and the period of operation of the equipment. In places where very low activity radioactive sources and low rating radiation generating equipment are handled, structural shielding might not be required.

Specific design requirements

6.10 The design of facilities where radioactive sources are handled should include for the following provisions:

(a) A storage area should be available for the radioactive sources and for radioactive waste arising in the facility;

(b) A source handling area or areas should be identified.

(c) A room free from radioactive contamination should be available for housing sensitive counting equipment. The level of background radiation in the counting room should be low.

6.11 Laboratories where unsealed sources are used should have nonporous surfaces. Floors in areas of potential contamination need to be finished with an impermeable material, that is

washable, easily replaceable, should the need arise, and resistant to chemical damage and curved at all joints where the walls meet the floor, sealed and glued to the floor. The walls should have a smooth and washable surface, with adequate painting. For this purpose, strippable paints may be considered so that if a surface gets contaminated, it would be possible to remove the contaminated portion of the paint over the affected surface and replace it with fresh paint. The removed layer of paint should be treated as radioactive waste and managed accordingly. All surfaces where unsealed radioactive materials are used or stored, such as benches, tables, seats, doors and drawer handles, need to be smooth and non-absorbent for ease of cleaning and decontamination.

6.12 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 that should be handled in laboratory hoods vented through an appropriate filter (activated charcoal for iodine) prior to atmospheric discharge.

6.13 Appropriate access controls should be provided in laboratories and rooms where radiation sources are used. Radiation warning signs and the trefoil symbol [26] should be displayed at entrances to laboratories.

6.14 Radioactive sources should be stored in a secure box or room that provides suitable shielding and security for the sources. The storage location should have fire protection and should be located away from corrosive material and protected against chemical hazards. The storage facility should be constructed of materials that provide sufficient shielding to reduce dose rates on the external surface/wall to below the relevant levels specified by the regulatory body. Where appropriate, the storage facility should be designated as a controlled area or supervised area. The door to the storage facility should be kept locked and the keys should be held only by authorized personnel. Keys should be of specific design that cannot be easily reproduced. A warning notice incorporating the radiation symbol (trefoil) [26] and information on area designation should be displayed on the door.

6.15 A room or suitable controlled storage location for the interim storage of radioactive waste needs to be made available in each department that uses unsealed radioactive sources. The room should be locked, properly marked and ventilated. A warning notice incorporating the radiation symbol (trefoil) [26] 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

6.16 Dedicated irradiation facilities or self-shielded irradiators involve detailed design and operating considerations [2]. Self-shielded irradiators are normally designed to contain the radioactive material during the entire operational life cycle 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 [35], IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [36], or equivalent national standard, to ensure that the design safety features are incorporated consistently. Whenever possible source containers should be designed to be robust and difficult to gain unauthorized access to assist in achieving high levels of source security. The operating organization should also ensure that information on the safe use of the equipment is provided by the supplier. The operating

organization should also ensure that this information is made available to workers in a language they understand.

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

6.18 Specific guidance on the design of X ray analysis equipment and for neutron generators is provided in Annex II.

DESIGN OF SEALED RADIOACTIVE SOURCES

6.19 Sealed sources should be designed, manufactured and tested to ensure that they meet the requirements of the appropriate ISO Standard 2919 [22] or an equivalent national standard.

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

(a) The international ionizing radiation symbol (trefoil) [26];
(b) The word 'RADIOACTIVE' in visible letters;
(c) The chemical symbol(s) and mass number of the radionuclide(s) (e.g. '^{137}Cs' or '^{241}Am');
(d) The source activity for each radionuclide and reference date;
(e) The identification of the sealed source (model and serial number) and manufacturer.

6.21 Source storage containers should allow 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 [37] or IEC 62598 [38] or equivalent national standards for dose rates outside of the equipment and for labelling. 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.

6.22 In accordance with RSG-1.9 [25], sealed sources of Category 1, 2 or 3, may require enhanced safety and security precautions as specified by the concerned authority.

6.23 Some manufacturers give 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 environment impact during the source life. It is an indication of the period of time over which the source should retain its design integrity.

6.24 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 carried out 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 assessment by a qualified expert with access to appropriate facilities.

6.25 Certificates for special form radioactive material should be retained and used as a reference for the radiation protection officer.

TEMPORARY FIELD SITES

6.26 Work areas in temporary locations, including field locations, should be established according to the safety assessment and controlled by the worker following the local rules under the supervision of the radiation protection officer. Signs and boundary markings should be put in place to warn individuals and to control access to the work area. Local rules should be followed throughout the handling of the radiation source(s) and until all radiation sources have been properly secured after the work has been completed.

7. OCCUPATIONAL RADIATION PROTECTION

7.1. Paragraphs 3.68-3.116 of GSR Part 3 [1] establish requirements on occupational exposure, and it covers responsibilities for protection of workers, compliance by workers, requirements for monitoring and recording of occupational exposure, co-operation between employers and licensees, arrangements under radiation protection programme, assessment of occupational exposure, workers health surveillance, information, instruction and training, conditions of service and special arrangements for female workers who are pregnant or breast-feeding and for apprentices. Recommendations on occupational radiation protection are provided in GSG-7 [9]. This section focuses on the protection and safety of workers in the use of sources in research and education facilities and activities. Some elements of the radiation protection programme for protection of workers also provide protection of the public e.g. designation of controlled and supervised areas, and the access to such areas.

DESIGNATION OF CONTROLLED AREAS AND SUPERVISED AREAS

7.2. Various laboratories, rooms and areas within rooms in education and research facilities should be classified 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 the requirements in paras 3.89-3.90 of GSR Part 3 [1], for controlled areas, and paras 3.91-3.92 for supervised areas, including requirements for delineation of areas, warning signs, protection and safety measures, control of access and provision of personal protective equipment, individual and area 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 low enough to ensure compliance with the dose limits for exposure of the public. Classification of areas within the education and research facility should be based on the analysis of the activities involving radiation sources, and not only on the location of equipment and the radiation sources. The following paragraphs give general guidance, and it would be expected that the final decisions by the registrant or licensee for particular laboratories, rooms and work areas in education or research facility would be based on the expert advice of a qualified expert in radiation protection or the radiation protection officer.

7.4. In defining the boundaries of any controlled area, the licensee is required to take account of the magnitudes 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. The designation of such areas should be based on the safety assessment. Examples of laboratories that should be designated as controlled areas are accelerator laboratories, laboratories where Category 1, 2 or 3 sealed sources are used, and some laboratories that use significant activities of unsealed radioactive material and where care is required to prevent contamination. The radiation protection programme should describe how controlled areas are designated, provided with signs and monitored for the conduct of experimental or educational works. To limit the extent of the controlled area, shielding should be used where practicable on both radiation generators and radioactive sources. Additional local shielding (e.g. lead sheets) should also be provided, as appropriate. There should be access control to prevent unauthorized entry to controlled areas.

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

7.6. Operating organizations are required to designate supervised area as any area not already designated as 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 done in a supervised area.

7.7. It is important to consider all hazards when establishing control boundaries. It may be possible that other hazards due to research work being carried out in the facility present a greater risk than the radioactivity and require more prescriptive controls.

7.8. For the use of small levels of radioactivity that do not present an exposure hazard to bystanders, the teaching or research activities may be carried out in rooms or areas that are not designated as controlled areas or as supervised areas; or may be carried out in areas that are temporarily designated as such for the duration of the teaching or research activity.

7.9. 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.

LOCAL RULES

7.10. 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".

7.11. The operating organization should ensure that work involving occupational exposure is adequately supervised and that the rules, procedures and measures for protection and safety are made known to those workers to whom they apply. The operating organization should also take all reasonable steps to ensure that the rules, procedures and measures for protection and safety are observed. Further recommendations are provided in paras 3.87-3.92 of GSG-7 [9].

7.12. Local rules should describe the specific requirements for a designated area. Local rules and procedures should include sufficient information and guidance for workers to carry out their duties safely and in compliance with regulatory requirements and cover all situations where there is the potential for radiation exposure, including routine operation, waste management, emergency response, and transport and movement. Typical local rules for sealed

and unsealed sources and radiation generators are provided in paras 7.18, 7.24 and 7.31 respectively.

Unsealed sources

7.13. Unsealed sources are radioactive powders, liquids, and gases that are not sealed in a container designed to prevent leakage. Unsealed sources in the form of radioactive chemicals are sometimes used at levels that could pose both internal and external radiation hazards. However, during handling of these chemicals the exposure risk is primarily from ingestion, inhalation, or skin contamination. Dispersal of the radioactive material could result in contamination of the workplace, equipment or environment. Contamination risks are dependent on the dispersion method (from air or liquid), the activity, nature of radioactive emitter, and the chemical and physical forms of the material involved.

7.14. While handling unsealed alpha emitters particular care should be taken due to the high radiotoxicity when inhaled or ingested. Caution should also be exercised to avoid skin contamination. Internal contamination assessment due to alpha emitters is not straightforward unless the source also emits a more readily measurable radiation such as gamma.

7.15. Generally, the radiotoxicity of beta emitters is lower than alpha emitters, but care should be taken with skin, eye lens or hand exposure especially for high energy beta emitters. Exposure to low-energy beta emitters is controlled by minimizing contamination and the use of personnel protective equipment. Special care should be taken with ^{3}H which is widely used in research and could be present as a contaminant in accelerator environments. It is known to diffuse into the body very easily when present as skin contamination or from materials such as metals and plastics that are contaminated causing secondary air and surface contamination.

7.16. Unsealed gamma or X ray sources give rise to an external exposure. In addition, these materials may also present a risk of internal exposure . Along with the external radiation dose assessment, it may be necessary to consider internal doses and hand exposure when flasks or syringes are used.

7.17. 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 prudent laboratory practices [39].

7.18. Typical local rules for the safe handling of unsealed sources may include the following:

(a) Work with unsealed sources should be conducted away from areas frequented by persons and in an area that is appropriate for the materials used. Such an area should be determined on the basis of the safety assessment;

(b) Workers should make use of any required shielding materials and devices;

(c) The area should be posted with appropriate radiation warning signs and the radiation sources clearly labelled;

(d) Workers should wear personal protective equipment such as laboratory coats, gloves that are appropriate for the radiological, biological and chemical hazards associated with the materials being used, safety glasses and close-toed shoes;

(e) Workers should use appropriate individual dosimeters and workplace monitors whenever they work with the source;

(f) Materials with the potential for release of vapours or gas should be handled in a fume hood or, if dry and dusty operations are involved, in a glove box approved for protection against airborne releases and spread of contamination;

(g) Workers should use remote handling tools where possible;

(h) Workers should check the work areas and themselves for the presence of radioactive contamination before leaving the work area with an appropriate instrument;

(i) Workers should remove personal protective equipment and wash hands before leaving the work area;

(j) Workers should refrain from smoking, drinking, storing food, eating, chewing (e.g. gum), applying cosmetics (including medical or barrier creams), licking labels, or any other action that can increase the risk of transferring radioactive materials to the body during work in the laboratory;

(k) Mouth pipetting should not be carried out by any workers;

(l) Workers should maintain good housekeeping practices;

(m) All radioactive source or sample containers should be kept closed when not in use;

(n) Radioactive waste generation should be minimized to the extent possible and should be stored in suitable, clearly labelled containers;

(o) Radioactive effluents should be disposed of only in designated approved sinks. When sink disposal is authorized by the regulatory body, such disposals should be recorded and be within applicable limits. Authorization for disposal should consider the chemical as well as radiological characteristics of the material.

(p) Workers should report about any observed abnormal conditions to their supervisor and the radiation protection officer immediately (see Section 12).

7.19. Specific guidance for the handling of NORM in research and education facilities is provided in Annex III.

Sealed sources

7.20. Sealed sources are radioactive sources in which the radioactive material is either permanently sealed in a capsule or closely bonded and in a solid form. The main hazard from sealed sources is external exposure to radiation. Sealed sources in research or academic facilities range from lower level check sources to high activity sources housed in a shielded container. The sources should be stored in appropriate shielded containers when not in use. Low activity sources may be stored in shielded containers. High activity sources should be stored in specially designed shielded housings that protect the user from exposure, allow sample irradiation by authorized workers and provide appropriate security to control access to the source.

7.21. For sources included in commercial instruments, the risk of external radiation exposure is generally low because such devices are designed to provide adequate shielding. However, external exposure levels should be evaluated for laboratory designed instruments and devices. The main exposure risks from these sources are those that may result from improper handling, failure of the safety system such as failed source retraction, failure in closing the shield, loss of source integrity or loss of control of the device.

7.22. When using plated sources (alpha or beta sources), special care needs to be exercised to minimize the risk of abrading these plated sources causing a release of the radioactive material and contamination of workers and workplace.

7.23. When working with sealed sources, operators should use only the ones that meet international or equivalent national standards (see Section 6).

7.24. Typical local rules for the safe handling of sealed sources may include the following:

(a) Appropriate shielding should be used. For neutron sources, shielding is needed to protect against exposure to both neutron and photon radiations;

(b) Workers should use appropriate individual dosimeters and workplace monitors whenever they work with the source;

(c) Workers should remain at a sufficient distance from the source, since the radiation level decreases inversely as the square of the distance;

(d) Remote handling tools should be used;

(e) The amount of time workers are exposed to the source should be minimized;

(f) Sources should not be left unattended;

(g) All work should be planned in advance and executed as planned;

(h) Workers should report any suspected loss of or damage to a source to the supervisor and radiation protection officer immediately.

Radiation Generators

7.25. X ray generators give rise to an external exposure hazard. Access to the X ray beam should be prevented. Even low energy beams can pose a significant hazard in and around the primary beam near the X ray source. Handling a sample while the X ray beam is ON could result in a significant extremity dose.

7.26. In addition to the intentional generation of X rays for a specific application, they may be generated as secondary radiation when charged particles such as electrons or protons are accelerated or are produced in high energy laser applications.

7.27. X ray generators are generally well shielded. However, if the user modifies the shield housing or places a body part in the primary beam, significant exposures may result. Hence the shield housing should be checked to confirm that dose rates comply with regulatory requirements.

7.28. The hazards from accelerators include exposure to the primary and secondary radiations (such as X rays, gamma rays, electrons, and neutrons) produced during operation. Many of these facilities produce radiation fields of sufficient energy to make the structural components of the accelerator radioactive. Access to the area around the accelerator device should be controlled during and after operation due to high residual radiation fields (activation products), in addition to the magnetic fields, electric fields and high voltage associated with the accelerator operation.

7.29. Accelerator facilities warrant special consideration for shielding and interlocks to protect people from the radiation fields because they can generate such high dose rates.

7.30. An assessment should be made of the potential for release of radioactive material into the workplace, activation of air constituents as well as activation of the device's components.

7.31. Typical local rules for the safe handling of radiation generators include the following:

(a) Workers should not place any part of the body in the primary beam;

(b) Workers should use appropriate individual dosimeters and workplace monitors whenever they work with the source;

(c) Security systems, warning lights and audible signals should be checked to confirm that they are functioning every time before switching on the X ray generator;

(d) Personal access to the X ray generator should be controlled; only authorized persons should be permitted access to the X ray generator;

(e) It should be ensured that the radiation generator key is removed when entering or leaving the X ray generator room;

(f) Faulty equipment should be immediately taken out of service;

(g) Workers should report any damage or suspected malfunction of the generator to the radiation protection officer;

(h) Shielding or interlocks should never be tampered with.

WORKPLACE MONITORING

7.32. The requirements for workplace monitoring are set out in para 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 occupational exposures to workers whose work involves exposure to predictable low levels of radiation. It is particularly important for students and research workers who are not individually monitored. In research and education facilities, workplace monitoring will need to address both external exposure and contamination, depending on the radiation sources used in the laboratories, rooms and other areas. Workplace monitoring should be performed and documented as part of the organization's radiation protection programme. Further recommendations on workplace monitoring, including selection of instruments for workplace monitoring, are provided in GSG-7 [9].

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

(a) Around the source storage facility, to ensure that an adequate level of shielding is provided;
(b) Around the barriers during the use of sources or radiation generators, to ensure dose rates remain below the levels specified by the operating organization or the regulatory body;
(c) At the operator position during use of the radioactive source or radiation generators to confirm that radiation levels are acceptable and optimized;
(d) At the end of each source use, to verify that the radioactive source has returned to its shielded position or the emission of radiation has ceased, in the case of radiation generators;
(e) Around radiation generators and accelerators, at the end of the operating cycle to measure activation and verify that radiation levels are within the regulatory limits;
(f) In laboratories or rooms where radiation sources are stored or used, including waste and effluent storage rooms;
(g) In rooms adjacent to radiation sources or generators to verify that radiation levels comply with regulatory requirements for protection of the public;
(h) Around transport packages and vehicles prior to transport of radioactive sources.

7.34. The licensee should ensure that adequate workplace monitoring instruments (number and appropriate types) and guidance for users are made available in the facility. Where continuous measurement monitors are used, the radiation protection officer should set the audio and visual alarm levels for warning the workers and other persons.

7.35. The instruments used for workplace monitoring should be calibrated in terms of ambient dose equivalent. 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. For more detailed guidance, see GSG-7 [9].

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

(a) All working surfaces (including the interior of enclosures), tools, equipment and devices (including dosimetry systems, computers, weighing balance, glassware), the floor and any items to be removed from unsealed source handling areas;
(b) Source storage containers and facility;
(c) Workplace air (as appropriate);
(d) Waste and effluent storage rooms;
(e) Rooms and spaces adjoining the unsealed sources handling area;
(f) Transport packages.

7.37. Workers should be checked for personal contamination including hand, foot, face, body and clothing while leaving after work with unsealed sources.

7.38. Periodic dose rate monitoring and contamination surveys should be carried out in controlled areas and supervised areas. Continuous area monitoring should be considered in source storage and handling areas. If a transport package containing a radioactive source is

damaged on arrival, a survey of removable contamination and the external dose rate should be carried out. If the radiation and/or contamination levels are found to be in excess of the limits specified in SSR-6 (Rev. 1) [24], the consignor, carrier and any organization involved during transport who may be affected should be notified, and appropriate measures should be taken to mitigate the consequences, investigate the incident and report the findings to the regulatory body and the competent authority for transport (see also para. 309 in SSR-6 (Rev.1) [24].

MONITORING AND ASSESSMENT OF OCCUPATIONAL EXPOSURE

7.39. The general term 'monitoring' refers to a process that includes the making of measurements related to the assessment or control of exposure to radiation and radioactive materials. A monitoring programme includes measurement, interpretation and assessment. Monitoring and assessment of occupational exposure helps to ensure the optimization of protection and safety and compliance with dose limits.

7.40. Depending on the nature and extent of a practice, the purposes of the monitoring programme include:

(a) Assessing the exposure of workers and students (see para 2.22) and demonstrating compliance with regulatory requirements;
(b) Confirming the effectiveness of work practices (e.g. the adequacy of supervision and training) and engineering standards;
(c) Determining the radiological conditions in the workplace, whether these are under adequate control and whether operational changes have improved or worsened the situation;
(d) Periodic evaluation of operating procedures from a review of the collected 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 radiation work practices;
(e) Providing information that can be used by workers to understand how, when and where they are exposed and to motivate them to reduce their exposure;
(f) Providing information for the evaluation of doses in the event of accidental exposures.

7.41. 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 national regulatory requirements.

7.42. Monitoring programmes can be routine, special or confirmatory relating to the objectives of the monitoring:

(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 operations are being carried out under abnormal circumstances such as an accident.
(c) Confirmatory monitoring is performed to check assumptions made about the exposure conditions.

7.43. Each of these types of individual monitoring may involve assessment of external

exposure (made using monitors worn by individual workers), assessment of skin contamination and assessment of internal exposure due to intake of radionuclides and interpretation of such measurements.

Assessment of external exposure using individual dosimeters

7.44. The radiation protection programme should specify the workers that should wear an individual dosimeter, the types of dosimeters to be worn, the monitoring period, and arrangements for the assessment of dosimeters and dose record keeping. The dosimeters should be worn by all post-graduate students and researchers, teachers, research workers, laboratory assistants, and any other workers who regularly enter controlled areas designated on the basis of external exposure, or where required by the regulatory body. Recommendations on assessment of external exposure can be found in Ref. [9].

7.45. To ensure the dosimeter provides an accurate assessment of the dose to the worker, the following guidelines should be followed:

(a) Dosimeters should be worn by the worker at all times when carrying out any work with radiation and a dosimeter should be worn only by the person to whom it is specifically issued. These dosimeters are intended for assessing occupational exposures and should not be worn by the worker if they are undergoing personal medical procedures.

(b) Dosimeters should be worn in accordance with recommendations from the dosimetry service provider. The dosimeter should be worn on the body area for which the dosimeter is designated and on an area that is representative of the exposure. For example, the dosimeter should be placed at waist height when monitoring radiation exposure from benchtop radiation experiments or a finger ring placed on a finger of the dominant hand with the measurement element facing away from the hand.

(c) Care should be taken to avoid damaging the measuring element of the dosimeter (e.g., dosimeters can be damaged by water, high temperature, high pressure and physical impact);

(d) Dosimeters should not be exposed to radiation when not being worn by the worker (the dosimeter should be stored in a designated low background location when not in use). A control dosimeter should be placed in the low background location as stated above beside the personal dosimeters when not worn for the purpose of dose evaluation.

(e) Dosimeters should be promptly returned to the dosimetry service at the end of the period of wear. When a worker is suspected to have been or actually involved in an emergency or may have received an unanticipated high exposure, the dosimeter should be promptly returned for urgent processing to assess the individual's dose and reporting to the licensee the result of the dose evaluation;

(f) The dosimetry service should be informed if the registrant or licensee suspects that the dosimeter was damaged or was exposed to radiation while not being worn.

7.46. The licensee should obtain dosimeters from an approved or accredited service provider. The dosimetry service provider should hold accreditation as a dosimetry service facility for the dosimeter types issued by the provider. The licensee can request that the regulatory body provide them with a list of approved or accredited dosimetry service providers. Individual

external doses are assessed by using individual monitoring devices such as thermoluminescent dosimeters, optically stimulating luminescence dosimeters, radio photo luminescence dosimeters, film badges, electronic dosimeters and appropriate neutron monitoring badges, as appropriate.

7.47. The choice of dosimeter type should be made by the radiation protection officer, possibly in conjunction with a qualified expert in radiation 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 the requirements of the regulatory body.

7.48. Direct reading or electronic dosimeters give an instantaneous reading of the dose received. These can be a very useful tool for measuring exposures in higher radiation dose rate operations or specific tasks (e.g. source loading and unloading). The alarm function of the electronic dosimeter can be useful in keeping radiation doses as low as reasonably achievable. Such a dosimeter may help to alert workers to situations where high dose rates might be encountered, hence prevent and/or mitigate the consequences of accidents. In these situations, the dosimeter would alarm at a pre-determined accumulated dose or dose rate set by the operating organization to warn the wearer. Where appropriate, electronic dosimeters should be used as complementary to and not as substitute for the passive dosimeters.

Assessment of external exposure using workplace monitoring

7.49. Occupational exposures can be estimated from the results of workplace monitoring. It can be particularly useful for staff members who are not individually monitored. The locations selected for workplace monitoring should be representative of the workers' occupancy. The effective dose for personnel can be inferred from the measured ambient dose equivalent H*(10). Ref. [40] provides conversion coefficients from ambient dose equivalent to effective dose for different types of radiation and energies. The conversion coefficients for photons are close to unity except for very low energy photons. Further recommendations are provided in GSG-7 [9].

Assessment of internal exposure

7.50. Certain workers might receive internal exposures (by ingestion, inhalation or adsorption of radioactive material). Employers are responsible for identifying those workers and for arranging appropriate individual monitoring. The safety assessment should indicate if internal dose assessment is necessary and if the radiation protection officer needs to make arrangements for the assessment of internal doses [9]. The effective dose reported is the sum of internal and external doses.

7.51. The assessment of doses received by workers 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 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 excretions or breath;

(c) Measurement of activity concentrations in air samples collected using personal air sampling devices worn by the worker and representative of the air breathed by that worker.

7.52. A bioassay programme should be conducted with the assistance of an appropriate facility or service provider. The internal dose assessment should be made, with the assistance of an expert as necessary, to determine the effective dose from the bioassay data.

7.53. 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 provide 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 default values. The measured values should be included in dose records in order to document the fact that the measurement was carried out and to provide information to support any possible future reassessment of dose.

RECORD KEEPING

7.54. In accordance with para. 3.103 of GSR Part 3 [1], the registrant or licensee and employer are required to keep records of occupational exposure for every worker for whom assessment of occupational exposure is required.

7.55. The records should contain details of the external and internal doses received by the workers. When multiple dosimeters are worn, the calculated dose and determination method should be included in the record. The calculated internal dose and determination method should be included in the record. When applicable, dose records should clearly identify 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. [9].

7.56. Those subject to individual monitoring should be informed of their individual doses. The licensee should make arrangements for the records to be made available to the radiation protection officer, regulatory body, and centralized national database when required. When monitored personnel 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. The licensee should make arrangements for the retention of the individual's dose records, either by the licensee or by another body as specified in national regulations. 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].

7.57. In satisfying the record keeping requirements, the licensee should ensure that appropriate confidentiality of the records is maintained.

7.58. If the research or education facility ceases to conduct activities involving occupational exposure to ionizing radiation, the licensee or registrant and employer are required to 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: see para 3.107 of GSR Part 3 [1].

INVESTIGATION LEVELS

7.59. Investigation levels are different from dose constraints and dose limits; they are used 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. Exceeding an investigation level

should prompt such actions. The following are examples for research and education facilities of levels and their related tasks that should not normally be exceeded and, therefore, could be suitable as investigation levels. For example, monthly doses to workers as fraction of dose limit say around 2 mSv, should be investigated. The investigation should be carried out with a view to improving the optimization of occupational protection and the results should be recorded. Investigation levels should also be set for workplace monitoring, with account taken of exposure scenarios and the predetermined values adopted for investigation levels for workers. Recommendations on investigation levels are provided in GSG-7 [9].

PERSONAL PROTECTIVE EQUIPMENT

7.60. The safety assessment should determine the personal protective equipment (PPE) that is necessary. PPE selection should be considered the last line of defence after providing for engineered controls and administrative controls.

7.61. In accordance with, para. 3.95 of GSR Part 3 [1], the operating organization is required to ensure that:

(a) Workers are provided with suitable and adequate PPE that meets relevant standards or specifications, including, as appropriate:

  (i) Protective clothing to minimize the risk of contamination such as laboratory coat or overalls, gloves, safety glasses and overshoes;

  (ii) Respiratory protective equipment with appropriate characteristics to remove the respiratory hazards from the air and that meets the users' physical requirements;

  (iii) Protective equipment to reduce external exposure such as aprons, protective gloves, protective glasses, and organ shields.

(b) Workers receive adequate instruction in the proper use, fitting, and testing of respiratory protective equipment when required;

(c) All PPE, including equipment for use in an emergency, is maintained in proper condition and, if appropriate, is tested at regular intervals;

(d) Account is taken of any additional exposure that could result from the additional time taken or the inconvenience, and of any non-radiological risks that might be associated with using PPE while performing the task.

7.62. Workers should be reminded to:

(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.

7.63. The necessary PPE should be clearly defined in local rules and procedures and signs posted at the laboratory or controlled access entry to remind individuals of the anticipated hazards and the need for PPE. Such postings should be in a language that is understood by all

workers in the area and use signs or symbols that are easily understandable.

7.64. When there is a need for tighter contamination control in the work area, 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 work area and the public access areas. The arrangements for access depend on the potential hazards and conditions in the workplace. For example, the PPE could be as simple as overshoes and laboratory coat or as elaborate as protective body suit, boots, gloves respiratory protection, head protection and eye protection. The PPE 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

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

7.66. No specific health surveillance related to exposure to ionizing radiation is necessary for workers or students in research and education facilities, who are not subject to occupational exposure. Under normal working conditions, the exposures are very low and no specific radiation related examinations are necessary.

7.67. Only in rare cases of overexposed workers, at doses much higher than the dose limits, would special investigations involving biological dosimetry and further extended diagnoses and medical treatment be necessary [9]. In cases of internal contamination, additional investigations to determine the intake and retention of radionuclides in the body may be required.

7.68. Counselling should be available to students and workers who are concerned about their radiation exposure, such as researchers who are or may be pregnant. Counselling should be given under the advice of an appropriately experienced and qualified expert. Further recommendations are provided in GSG-7 [9].

7.69. When considered necessary, medical examinations of occupationally exposed research workers, should follow the general principles of occupational medicine under the direction of a certified medical practitioner. There should be examinations before radiation work commences, and as required by any incidents and periodic reviews thereafter. For itinerant workers who are exposed to a source under the control of the laboratory at which they work, the management of that laboratory should make special arrangements with the employer of the worker to ensure that they are provided with the necessary workers' health surveillance.

7.70. 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

7.71. Para 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."

7.72. Persons performing research, experimental work and education using radioactive sources are responsible for ensuring that their work is carried out safely and in compliance with all relevant regulations and local rules. Employers should, therefore, ensure that all workers in research and education facilities who use radiation sources are appropriately qualified, and who are competent and trained in protection and safety at a level appropriate to their responsibilities and activities.

7.73. The radiation protection programme should describe the full scope of the training programme in protection and safety for all workers directly involved in research or education activities. The training programme of workers should be specific to the radiation sources that they use. It should include a radiation 'awareness' programme, where appropriate, for other staff who support the work with radiation sources but not directly involved such as managers, custodians, general maintenance and administrative staff who may be inadvertently exposed.

7.74. For secondary schools, the radiation protection officer or equivalent individual would have management functions and would normally be a member of the science teaching staff, who might not have any training or formal qualifications in addition to those needed to teach science. The radiation protection officer should ensure that all those who work with radiation sources follow the local rules or procedures. The radiation protection officer should provide appropriate written instructions and training to each member of staff or student who works with radiation sources in the following areas: safety and security in storage of radiation sources; safe handling of each type of radiation source; correct handling of associated equipment; correct use of equipment used for monitoring purposes; action to take if a radioactive source is dropped or a spill occurs; record keeping; and when to seek the advice from the radiation protection officer.

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

7.76. For post-graduate university students and for research workers who are required to work with radiation sources, the radiation protection officer should ensure that training appropriate to the types of sources used is provided to the post-graduate students and research workers. The training should include fundamentals of radiation protection, safe handling of radiation sources, and when appropriate, management of radioactive waste and transport and movement of radioactive material. After successfully completing the basic radiation safety training, the new

worker (post-graduate student, research worker) should receive specific training on the radiation sources, radionuclides and their activity, the physical form of the radioactive source, and other hazards linked with their work (biological, chemical, physical). This training should be provided by a worker skilled in the experiments and procedures to be used. An assessment should be made of the new workers' ability to safely conduct those activities. New workers should not be permitted to independently conduct activities with radiation sources until they have successfully demonstrated the required skills. The training should provide practical exercises including emergency response plans and the rehearsal of mitigation procedures. Training on security aspects should be an integral part of the overall training.

7.77. The knowledge and skills should be kept up to date through a programme of refresher training. Such training should include a review of the fundamentals of protection and safety, and information on changes to equipment, policies and procedures, 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 less than two years. Such training could be combined with other refresher training on experimental techniques. However, 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.

7.78. The trainee should successfully complete a test of the ability to safely work with radiation sources on completion of the training. The training programme should establish the criteria for completing the training such as the minimum passing score on written and practical examinations, as well as the procedures to be followed if an applicant fails an examination. Examinations should include evaluation of 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.

7.79. Information on the additional requirements applicable to trainees under the age of 18 and trainees who are pregnant or breast-feeding should be included in the training programme.

7.80. Training records should be consistent with regulatory requirements and any recommendations from the regulatory body. The details of the training programme and the requirements should be incorporated into the radiation protection programme. Further information on training can be found in Ref. [41].

CONDITIONS OF SERVICE AND SPECIAL ARRANGEMENTS

7.81. As required by para. 3.111 of GSR Part 3 [1], no special benefits are to be offered to staff because they are occupationally exposed. It is simply not acceptable to offer benefits as a substitute for measures for protection and safety.

Pregnant or breast-feeding female workers

7.82. GSR Part 3 [1] does not explicitly require a female worker to notify an employer of a suspected pregnancy or of breast-feeding. However, it is necessary that female 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 female workers with appropriate information in this regard.

7.83. The employer of a female worker, who has been notified of her 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 women should avoid work with radiation, but it does imply that the employer should carefully review the exposure conditions with regard to exposure under planned exposure situations and potential exposure.

7.84. Information, advice and, if indicated, counselling for pregnant workers should be made available (see also para. 7.71). Further recommendations are provided in GSG-7 [9].

8 DISCHARGES, RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING

DISCHARGES

8.1. Paragraph 3.132 of GSR Part 3 [1] establish requirements regarding application for authorization for discharges. Research and education facilities that plan to discharge liquid effluent or airborne effluents or solid wastes to the environment are required to make an application for authorization for such discharges. The regulatory body is required to establish or approve authorized limits for discharges.

8.2. IAEA Safety Standards Series No. GSG-9, Regulatory Control of Radioactive Discharges to the Environment [42] provides recommendations on the process for the authorization of discharges. It includes guidance for the facility making an application for authorization for discharges and for a regulatory body on dealing with the application for discharges.

8.3. When applying for an authorization for discharge, the radiation protection officer of the research or education facility should specify the characteristics and activity of the material to be discharged, and the possible points and methods of discharge from the laboratories/facility; to determine by an appropriate pre-operational study all significant exposure pathways by which discharged radionuclides could give rise to exposure of members of the public; and to assess the doses to the representative person due to the planned discharges. The radiation protection officer should also specify control measures to limit discharges in compliance with regulatory requirements. The safety assessment should be reviewed periodically and whenever a practice changes to ensure that effective control of discharges is maintained.

8.4. Some laboratories in research and education facilities that plan to discharge small quantities of radioactive material e.g. laboratories using radiotracers, may satisfy the criteria for an exemption from the requirements for an authorization for discharges. Such exemptions are granted on a case-by-case basis by the regulatory body or established in guidance provided by the regulatory body.

8.5. The potential discharges and public exposures will depend on the proposed practice (such as a benchtop experiment with unsealed radioactive materials or activation of materials in an accelerator) and the chemical, physical and radioactive properties of the materials used in the process (such as volatile radio-iodine released to the air or soluble materials washed and/or released in water effluent). The radiation protection officer should impose control measures at the source to mitigate discharges. Specific equipment, for example a fume hood equipped with a charcoal filter to remove radioiodine, should be used or tested to reduce radioactive discharge and their effectiveness should be confirmed. Any engineered control measures put in place should be maintained at appropriate intervals.

8.6. The radiation protection officer should promptly report to the regulatory body any discharges that exceed the authorized limit, in accordance with reporting criteria established by the regulatory body. 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 [42].

8.7. If atmospheric releases are likely, the radiation monitoring programme should include an appropriate or continuous measurement of atmospheric releases using instrumentation capable

of detecting the relevant radionuclides at a level lower than established investigation levels. Atmospheric monitors are available to measure the integrated radiation released for a prescribed time period or instantaneous readout to assess environmental releases.

RADIOACTIVE WASTE MANAGEMENT

8.8. Paragraph 3.131 of GSR Part 3 [1] and IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [43] establish requirements for the management of radioactive waste.

8.9. 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 [44] provides recommendations on how to meet the requirements in GSR Part 3 [1] and GSR Part 5 [43].

8.10. Research and education facilities may generate two types of radioactive waste:

(a) Sealed sources that have completed their operating life;
(b) Materials and items contaminated with radionuclides from unsealed sources such as contaminated clothing, vials containing residual radioactivity, contaminated absorbent pads, contaminated glassware and liquids.

8.11. When sealed sources are no longer required, they should be returned to the original supplier. 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 waiting for return to their supplier or for transfer to an authorized waste management facility should be stored in the research or education facility's radioactive waste storage room. Disused sources should be included in the inventory of radioactive waste.

8.12. A waste storage room or building should be designed to accommodate the liquid and solid radioactive waste generated by the laboratories of the research and education facility. 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 types of hazards in the waste such as chemical or biological waste and comply with the regulation and rules for these types of waste. The waste storage room or building can be in the same building as the laboratories or in a different building within the premises of the facility. Access to the waste storage room or building should be limited to those with appropriate training and approved by the radiation protection officer.

8.13. The radioactive waste storage room or building should be equipped with ventilation and fire-fighting systems, easily cleaned non-porous floors and walls, shielding to minimize worker and public doses and have available radiation monitors appropriate for the type, physical form and activity of the radioactive waste that is stored in the facility. Where necessary, storage tanks for radioactive effluent should be equipped with a level measurement and alarm system, spill control, apron and shielding wall.

8.14. The management of the radioactive waste requires the grouping (segregation) of the waste on the basis of the expected time for the decay of the radionuclides, initial activity and physical half-life and the physical form of the waste. Examples of different physical forms include vials that may contain residual radioactivity, biological waste which may undergo decomposition,

infectious waste requiring sterilization, broken glassware, contaminated clothing and 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 (for example, in terms of volume, shielding and leak tightness). The internal surface of these containers should be smooth to enable easy decontamination or be lined with removable strong polythene sheets/bags which can be disposed of as radioactive waste and replaced by fresh ones.

8.15. The volume and radioactivity of waste produced by the research and education facility should be minimized. For this purpose, the volume of water or solvent to wash laboratory items should be minimized. Non-radioactive wastes should not be mixed with radioactive waste. Waste should be sorted by physical form (e.g. for solid waste: plastic, metal; for liquid waste: organic, aqueous) and type of radionuclide depending on half-life. Solid waste should be segregated from liquid, powder and gaseous wastes. Then solid wastes should be divided into disused sealed sources and contaminated solid objects. Short half-life wastes should be separated from long half-life wastes. Suitable containment should be provided for waste sources to ensure that contamination does not occur in storage. This may include drip/spill trays or dykes and may require consideration of physical and chemical properties of the waste. Mixing of liquid wastes should not take place in stores.

8.16. Each waste container should be managed to control the total activity in the container and ensure packaging as required by waste disposal services and to ensure that the radiation and contamination levels on the exterior of the container are kept as low as possible. The inventory (radionuclide and total activity) for each waste container should be recorded on the waste container with the date, the radiation monitor used, the names of producer and controller.

8.17. Solid waste containing short half-life radionuclides should be stored in a shielded part of the waste storage facility until the radioactivity has decayed to below the clearance levels specified in Schedule I of GSR Part 3 [1]. When clearance levels have been met, the waste can be treated as non-radioactive waste.

8.18. Solid waste containing long half-life nuclides should be transferred as authorized by national regulations to a facility that is authorized for management of this type of waste. The containers should be promptly disposed of to such a facility to minimize radiation exposure, limit accumulation of radioactive materials and reduce the risks associated with incidents. If waste containers are suitable for re-use, they may be returned by the waste management facilities to the research laboratories in compliance with the requirements of SSR-6 (Rev. 1) [24] for the safe transport of emptypackagings.

8.19. 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. Guidance on the management of NORM residues and waste can be found in IAEA Safety Standards Series No. SSG-60, Management of Radioactive Residues from Uranium Production and other NORM Activities [27].

8.20. 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 shielded tanks or containers and transferred to a licensed/approved waste management facility for this type of waste or treated and the resulting solid waste should be disposed of with regulatory approval.

8.21. Records should identify the origin of all radioactive waste in storage and for all radioactive waste that has been disposed of. These records should be retained for a period specified by the regulatory body (usually indefinitely) and for each waste container that includes:

- Container identification number;
- Name of research staff and laboratory producing waste in the container;
- Date of placing the waste container in the storage room;
- Results of the radiation measurements when the container or tank was closed:
    - Total activity and in the case of liquid waste, activity concentration;
    - Radiation dose rate;
    - External contamination measurement;
- Estimated decay period (for radionuclides with short half-life);
- Results of radiation measurements when it is cleared for disposal, for transfer to an external waste management facility:
    - Total activity or activity concentration (for liquid);
    - Container radiation measurements;
    - External contamination measurement;
- Date of clearance for disposal, or of transfer to an external radioactive waste management facility;
- Particulars of the waste management facility where the waste was transferred;
- Records of confirmation of disposal as per authorization.

8.22. If several research laboratories store radioactive waste in the same waste storage room or building, the radiation protection officer should establish rules describing the responsibilities of the research workers in each laboratory. Each laboratory should be responsible for the management of the waste produced in the laboratory, including maintaining a record of the inventory of radioactive waste produced by that laboratory. When radioactive wastes from several laboratories are consolidated, the responsibility for the radioactive waste should be transferred to the radiation protection officer for the facility.

8.23. Radiation generators that are no longer used should be made inoperable prior to disposal (for example by cutting power supply or destroying the tube of the X ray generator). Radiation measurement should be made to verify that no residual radioactivity remains, in the case of accelerators. If radioactivity remains because of activation, the contaminated or active material should be treated as radioactive waste. If radiation generators were used for experiments with unsealed sources, surface contamination measurement should also be done to confirm that radioactive contamination on the surface is within the regulatory limits. Once made inoperable and any residual radioactivity is removed, the radiation generator can be sent for reuse of materials or to a scrap merchant or to a hazardous disposal site as appropriate. X ray tubes may contain hazardous material and may require disposal as a hazardous waste.

DECOMMISSIONING

8.24. When the use of radiation sources in equipment or laboratory is terminated with no plans to resume in the foreseeable future, the equipment or laboratory should be formally decommissioned [SSG-49]. Examples include situations where an experimental equipment is no longer being used, a programme of research is completed, or a laboratory is closed. All radiation sources should be secured and removed in a manner that is consistent with the national regulatory framework. The process should include the following:

(a) Sealed sources should be transferred to an authorized organization. As a best practice the operating organization should return the sealed sources to the original supplier or disposed of through a channel authorized by the regulatory body.

(b) Unsealed sources should be transferred to an authorized organization. They can be transferred as waste and appropriately managed or disposed of through a channel authorized by the regulatory body.

(c) The radioactive waste (solid or liquid) should be disposed of following the channels authorized by the regulatory body.

(d) Radiation generators should be made inoperable: see para. 8.23.

(e) Comprehensive records should be kept by the operating organization of all receipt, storage, transfer or disposal of radioactive sources (including acknowledgements provided by recipients or by disposal facilities for radioactive waste).

(f) A comprehensive radiation survey should be made, to confirm that no radioactive sources or contamination have been left on the site. This should involve a combination of direct monitoring and analysis of wipes of surfaces and floors.

(g) All radiation trefoils and notices should be removed from the site.

(h) A decommissioning report should be prepared that includes the final radiation survey and details of the storage, transfer or disposal of sources of radiation. The final decommissioning report should be submitted to the regulatory body.

(i) Operating organizations should inform the relevant authorities when all sources of radiation have been removed from the site and forward a copy of the comprehensive report indicated in (e).

9 RADIATION PROTECTION OF THE PUBLIC

9.1. Public exposure may be incurred by persons in and around laboratories or facilities where radiation sources are used in research and education. These persons fall into two categories – those who work at the laboratory but not in a role that is directly involved in the use of radiation such as administrative support staff; and those members of the public who are present in or near the wider facility. All these persons are to be afforded the same level of radiation protection as any member of the public, as required by para. 3.78 of GSR Part 3 [1]. In addition, secondary school students and undergraduate and post-graduate students in universities who just uses radiation sources intermittently as part of their academic learning and studying process should be afforded the same level of protection and safety as any member of the public.

9.2. An assessment of the risk of public exposure will have been undertaken as part of the safety assessment (see section 5). This will indicate the need for additional controls to minimize the risk of public exposure.

External exposure

9.3. The primary means for protecting the public is to ensure the shielding integrity of all equipment containing sources or radiation generators in the research and education facilities. All shielding including equipment shielding, structural shielding of the building, where necessary, and shielding provided for radioactive waste storage locations, should be sufficient in order to ensure that the public dose limits and any dose constraint for the public that the regulatory body may have approved are not exceeded.

Control of access

9.4. Following adequate shielding, control of access to controlled areas, where relevant, is the next most important step in controlling doses to members of the public and personnel other than those who are occupationally exposed. There should be a limited number of entry points to the controlled areas and these should be controlled by the laboratory staff, and there should be signage placed at the entry points stating clearly who is permitted to enter the controlled area.

Monitoring and reporting

9.5. Requirement 32 and para. 3.137 of GSR Part 3 [1] establish the requirements to be met by the facility with respect to monitoring and reporting of public exposures. In the facility, procedures should be in place to ensure that:

a) The requirements regarding public exposure are satisfied;
b) Appropriate records of the results of the monitoring programmes are kept.

10 TRANSPORT AND MOVEMENT OF RADIOACTIVE SOURCES

10.1. SSR-6 (Rev. 1) [24] assign responsibilities for individuals and organizations involved in the transport of radioactive material: the consignor (a person, organization or government that prepares a consignment 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).

10.2. Transport of radioactive material is a complex activity, and a comprehensive overview of the relevant requirements that are provided in SSR-6 (Rev.1)[24] is outside the scope of this Safety Guide. Guidance on how to meet transport related requirements is provided in IAEA Safety Standards Series No. SSG-26, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material [45]. Emergency preparedness and response arrangements for transport of radioactive material are required to be in place, in accordance with GSR Part 7 [11]. Specific guidance is provided in IAEA Safety Standard Series No.SSG-65(in publication) [46]. Guidelines on security in the transport of radioactive material should also be followed [33], especially given that radioactive sources are more vulnerable to theft during transport.

10.3. The licensee of the research or education facility will have the responsibility of a consignor when the facility forwards a consignment, and of a consignee when the facility receives a consignment of radioactive material. Receipt of radioactive materials may be a regular occurrence for some research and education facilities. Shipments may take place when the research or education facility returns disused radioactive sources to the supplier, the sources are transferred to a licensed waste management facility or samples are transferred to another licensed facility. The radiation protection officer or other relevant staff /expert should prepare guidelines in accordance with SSR-6 (Rev. 1) [24] that should be followed by research workers for the receipt and shipment of radioactive material.

10.4. Transport of radioactive material and devices that contain radioactive sources for research work or studies, out of the research and education facility's site should be made in compliance with national (and international when relevant) regulations for transport of radioactive material. If a package containing a radioactive source is damaged on arrival, a survey of removable contamination and the external dose rate should be carried out and appropriate action should be taken for its safe management.

10.5. Research workers using radioactive materials at the research or education facility may sometimes need to move a radioactive source within the facility or site. Radioactive sources should only be moved within the research or education facility in containers that provide safety of the source and adequate protection of workers and public. The sources should be housed in a sealed container that will contain the radioactivity having necessary absorbent material to contain any spill within its containment system and adequate shielding. It should be moved on a cart or trolley that is under the direct supervision of the authorized research worker and with the knowledge of the radiation protection officer. The security of radioactive sources being moved should be maintained at all times. The radiation protection officer should prepare guidelines that are to be followed by research workers for the movement of radioactive material between buildings.

11 EMERGENCY PREPAREDNESS AND RESPONSE

GENERAL

11.1. As defined in GSR Part 7 [11] an emergency is:

> "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 [11], a nuclear or radiological emergency is:

> "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 at a research or education facility can occur as a result of operator error, equipment failure or an external event. Examples of radiological emergencies include:

(a) Spill or leak of an unsealed radioactive source;

(b) Sealed source becoming jammed in an irradiator;

(c) A sealed source getting disconnected or damaged during operation;

(d) Failure of engineered control measures (for example, interlocks, warning signals);

(e) A fire or explosion involving a radioactive source;

(f) An event that results in the loss of containment/ or shielding of a container housing a radioactive source during storage, use or transport;

(g) A natural disaster (e.g. a hurricane) affecting the facility;

(h) Disposal of a container housing a sealed source as scrap;

(i) Unauthorized discharge to the environment;

(j) A nuclear security event resulting in a loss of control of a radioactive source or of the facility, such as theft of radioactive source or sabotage.

11.4. The hazards associated with the use of radiation sources or radiation generators in research and education facilities and the consequences of a radiological emergency are required to be assessed by the registrant or licensee in consultation with the radiation protection officer and, if necessary a qualified expert, to provide a basis for establishing emergency arrangements [11]. Emergencies that could affect workers, students (for instance, graduate and post-graduate students doing research using radiation sources), the public (e.g. school students and undergraduate students of age less than 16 years, administrative staff of the facility) or the environment and could warrant emergency response actions should be identified in the hazard assessment for the research and education facility.

11.5. Based on the assessed hazards and the potential consequences, arrangements for emergency preparedness and response for the facility should be established in accordance with GS-G-2.1 [13]. Research and education facilities using dangerous sources for scientific purposes typically fall into emergency preparedness category III or IV, as set out in GSR Part 7 [11]. Emergency arrangements that correspond to the identified emergency preparedness category are required to be established for any such facility. If a research or education facility plans to use in their work mobile dangerous sources (emergency preparedness category IV), it is required to have arrangements in place for dealing with such type of emergencies. Many facilities will not fall into any of the established categories and thus require only limited arrangements. Addressing the perceived hazards or other non-radiological hazards in these circumstances may warrant implementing parts of emergency arrangements, as applicable.

11.6. The applicability of the various provisions of requirements in GSR Part 7 [11] to facilities in emergency preparedness category III and IV is set out in the annex of GSR Part 7 [11] and these should be used when establishing emergency arrangements and during the preparation of emergency plans and procedures for the research and education facility.

EMERGENCY PLANS AND PROCEDURES

11.7. Prevention of accidents is the best means for avoiding potential exposure and GSR Part 3 [1] establishes requirements based on good engineering practice, defence in depth, and facility-based arrangements to achieve this. Design considerations are covered in Section 6 of this Safety Guide.

11.8. Although prevention of incidents and accidents is the first line of defence in depth, events that would necessitate protective actions or other response actions could still occur. The operating organization is required to have in place an emergency plans and procedures prepared in advance, for the goals of emergency response to be achieved and for the emergency response to be effective [1, 11].

11.9. The important elements to be included in a facility (on-site) emergency plan are outlined in GS-G-2.1 [13]; this may be used as a basis for developing the emergency plan for the research and education facility. Notices outlining the procedures for notification of an emergency and activation of an emergency response should be clearly and visibly posted inside the facility at locations where they might be needed, and staff should be trained in these procedures.

11.10. The emergency plan for the research and education facility should be based on the postulated scenarios identified as a result of hazard assessment and should address, but not be limited to, scenarios such as theft of sources, on-site contamination, personal contamination or

leaking due to damage of the source, accidental radioactive releases to the environment and overexposures of workers. Emergency procedures should include:

(a) Protocols for notification of an emergency and activation of an emergency response;

(b) Communication and coordination among emergency workers and response organizations;

(c) Identifying the nature and extent of external support and obtaining support from off-site emergency services such support including health officials and radiation protection specialists, as necessary;

(d) Instructing the site personnel and accounting for the site personnel in an emergency;

(e) Establishing cordoned off area and access control;

(f) Implementing measures to protect site personnel and emergency workers in accordance with the response plan;

(g) Identifying persons and determining details for communication with the public.

A qualified expert or radiation protection adviser should be consulted, where possible, when drawing up emergency plans and procedures.

11.11. Implementation of the emergency plan and procedures may involve off-site support (e.g. off-site response organizations, emergency services and radiation protection specialists), in accordance with GSR Part 7 [11] and GS-G-2.1 [13]. The emergency plan should set out detailed arrangements for obtaining such off-site support.

11.12. In accordance with para. 6.19 of GSR Part 7 [11], 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.

11.13. Arrangements are required to be made to maintain, review and update emergency plans, procedures and to incorporate lessons learned from research, operating experience (such as in the response to emergencies) and emergency exercises: see para 6.36 of GSR Part 7 [11].

11.14. Recommendations on the protection of emergency workers including guidance values for restricting exposure are provided in GSG-7 [9].

11.15. Guidance on emergency plans and procedures are addressed in GS-G-2.1 [13]. Examples of immediate on-site actions to be taken in case of an emergency at research and education facilities with sources, radiation generators and irradiators are provided in Annex IV of this Safety Guide.

11.16. The emergency plan and procedures should consider events such as fire and natural disasters (for example; flooding, earthquakes) affecting the research and education facility.

11.17. When off-site emergency services (for example, the fire brigade and medical support) are required to provide support on-site, they should be informed of the presence of radioactive material or source. Access to evacuated areas (e.g. building) should be assessed by the radiation protection officer or by the radiological assessor. Irrespective of the radiological situation, life saving actions should be prioritized and promptly implemented.

EMERGENCY EQUIPMENT

11.18. In accordance with para. 6.22 of GSR Part 7, 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 they are readily available and functional for use under emergency conditions. All necessary tools, instruments, supplies, equipment, communication systems, facilities and documentation should be subject to a quality management programme that includes arrangements for inventory control, resupplies, testing and calibrations: see para. 6.34 of GSR Part 7 [11].

11.19. The equipment to be deployed in an emergency would depend on the hazard, as identified in the assessment. For emergencies involving sources, the following equipment may be needed:

(a) Appropriate and functional monitoring instruments to measure both high and low dose rates;

(b) Adequate number of personal dosimeters (optically stimulated luminescence dosimeters, thermoluminescent dosimeters, or film badges);

(c) Additional electronic dosimeters;

(d) Personal protective equipment;

(e) Barrier materials and notices;

(f) Lead bricks, lead sheets, lead shots or other shielding material as appropriate for the sources used;

(g) Suitable tool kits for source handling and other operations (e.g. long handled tongs, pliers, screwdrivers, bolt cutters, adjustable spanner, torch);

(h) Materials and agents for decontamination;

(i) A spare empty shielded container;

(j) Plastic sheets and bags for waste, airtight bags for rupture of gaseous sources, a swipe test kit and a measuring tape;

(k) Communication equipment (e.g. mobile phones) including essential contact details;

(l) Spare batteries for survey meters, electronic personal dosimeters, mobile phones and torches;

(m) Pens, paper, calculator and an incident logbook with first responder sheets;

(n) Equipment manuals, procedures and instructions.

11.20. If it is suspected that a sealed radioactive source might have been damaged, it should be ensured that the release of radioactivity is detected promptly, and the extent of the contamination is assessed and contained.

TRAINING AND EXERCISES

11.21. In accordance with Requirement 25 of GSR Part 7 [11], personnel who have been assigned responsibilities in implementing the emergency plan are required to be adequately qualified and trained for the effective fulfilment of their duties. This should include familiarization with and understanding of the plans, procedures, analytical tools and other

arrangements, together with specific training on implementing emergency procedures and on the use of the emergency equipment, as appropriate. Provisions for training should be reviewed periodically to ensure the continued proficiency of the personnel in implementing the emergency response workers.

11.22. The personnel should implement only those parts of the emergency plans and procedures for which they have been authorized and trained.

11.23. Exercise programmes are required to be developed and implemented to ensure that all specified functions required 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 [11]. Recommendations on the preparation, conduct and evaluation of exercises including guidance on various types of exercises, their purpose, as well as examples of scenarios for category III facilities, are provided in GSG-2 [12]. Exercises including mock drills should be conducted periodically to ensure safe evacuation of staff, students and any visitors who may be present when an emergency like fire and natural disasters occurs.

11.24. Training should cover the following:

(i) Recognizing the circumstances indicative of an emergency;

(ii) Procedures for notification of an emergency and activation of emergency response, including provisions for obtaining assistance from off-site emergency services;

(iii) Implementation of necessary on-site mitigatory actions and protective actions, including provision of immediate first aid, and procedures for evacuation of non-essential personnel from facility;

(iv) Assessment of the situation;

(v) Use of emergency response tools and equipment including firefighting equipment;

(vi) Use of personal protective equipment;

(vii) Use of workplace monitoring equipment;

(viii) Implementation of recovery actions, decontamination, assessing shielding requirement and providing the required shielding;

(ix) Procedure for collection of radioactive waste for disposal;

(x) Measures to be followed for their protection during the emergency response;

(xi) Communication with off-site services and the public;

(xii) Investigation of the cause of the emergency;

(xiii) Preparation of report on the occurrence and the management of the emergency.

REPORTING

11.25. Arrangements are required to be made to undertake a timely and comprehensive analysis of the emergency and the emergency response: see Requirement 19 of GSR Part 7 [11]. A comprehensive report on the findings of the analysis should be prepared by the radiation protection officer in consultation, as appropriate, with relevant interested parties and, if necessary, with qualified expert(s) or radiation protection adviser(s).

11.26. The report should be submitted to senior management as well as to the regulatory body and, as appropriate, to other relevant authorities at local, regional or national level. 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.

11.27. The report should include the following:

(a) A detailed description of the emergency, including specifications of the equipment and 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) of the emergency and identification of the event as due to machine error, human error, breach of security or any other cause;

(d) A detailed description of the emergency response actions implemented and particulars of deviations, if any, from the plans, the reasons for the same and consequences thereof;

(e) The personnel involved in the emergency response, the work they carried out, and their skills and qualifications;

(f) An assessment and summary of the doses received by all affected individuals;

(g) Corrective actions identified with the aim of preventing similar emergencies in the future and necessary for improving overall radiation safety, security and emergency arrangements;

(h) Proposed means and timeframes for implementation of the corrective actions identified and personnel who have been assigned the responsibility to implement the actions;

(i) Details of waste arisings from the emergency and its management.

11.28. The report should be kept for a period specified by the regulatory body.

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ANNEX I

USE OF RADIATION SOURCES IN SECONDARY SCHOOLS

I–1. Radioactive sources are used only when there is an educational benefit. Sealed sources should be used, whenever possible, in preference to unsealed sources, unless only unsealed sources are needed for the intended purpose. Sources with activity as close to the exempt activity as possible for the particular radionuclide or the lowest activity source possible to achieve the required teaching purpose are recommended. Exempt sources are not subject to regulatory requirements and may generally be dealt with as though they were not radioactive. Examples of suitable sealed sources for use in schools is presented in Table I–1. Sealed sources have to be of a design and type suitable for school science. Sealed sources are generally designed, manufactured and tested to ensure that they meet the requirements of the appropriate ISO standard 2919 [I-1] or an equivalent national standard.

Table I-1. SEALED SOURCES SUITABLE FOR USE IN SCHOOLS

	Max activity of sealed sources recommended for use in schools (kBq)	Exempt activity from GSR-Part 3 Schedule 1 (kBq)
Cobalt-60	200	100
Strontium-90	80	10
Caesium-137	200	10
Americium-241	40	10

I–2. Some unsealed sources may also be used in schools. Examples are:

- Small quantities of uranium glass and intact smoke detectors;
- Radon-220 (thoron) generators for half-life experiments; thoriated gas mantles, tungsten inert gas (TIG) welding rods;
- Mini-generators using caesium-137 for half-life experiments;
- Rocks and other geological samples that contain radioactive isotopes.

I–3. The activity concentration and quantity of material of unsealed sources used in secondary schools may not be greater than the corresponding exempt activity concentration and exempt quantity. Certain apparatus found in science departments can be a source of incidental radiation. 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 [I-2]. To avoid exposure of students 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, and electron microscopes. These types of apparatus are usually exempt from regulatory control. However, precautions should be taken to avoid exposure of students to these radiation sources.

I–4. A staff member of the school's science department may be designated to be responsible for the, safety, security and proper use of radiation sources. That staff member should ensure that appropriate risk assessments and contingency plans are produced for all uses and storage of the radiation sources.

I–5. Radiation sources are generally handled in ways that minimize exposure to staff and students. Only appropriately qualified and trained staff should handle radioactive sources; handling of sources by students may generally be restricted. Where formal training is not provided, a staff member can be made responsible for ensuring that those who have access to and /or use sources are aware of control measures including local rules and procedures.

I–6. Class work with radioactive sources for students under 16 years of age should be restricted to teacher demonstrations only. Students may be kept at least 2 metres away from the sources during demonstrations. However, closer inspection of devices containing low-level radioactive sources is acceptable provided the sources are fully enclosed. Contamination of any part of the body should be avoided, particularly with radioactive rocks, which may be kept in suitable transparent containers.

I–7. Students 16 years of age and above may handle sealed radioactive sources in order to carry out standard investigations of the properties of ionizing radiations. The teacher in charge may ensure that the students are sufficiently responsible, have received appropriate instruction and have seen and understood the appropriate sections of the local rules. The teacher should directly and closely supervise all work.

I–8. Teachers and students in secondary schools should be subject to the public dose limits, 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.

I–9. Records of all radiation sources should be properly maintained, showing what they are, when they were acquired, when and by whom they have been used, and how they might be disposed of, subject to current regulations. Sources should be checked periodically to make sure they remain in good condition including leak testing preferably once every two years. The school should have a suitable radiation detector.

I–10. When not in use, radiation sources should be kept in a suitable store. The store should be located away from areas frequented by students with necessary security arrangements. Adequate shielding and warning of the presence of radioactive material should be provided.

REFERENCE TO ANNEX I

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ANNEX II

SAFE USE OF SPECIFIC TYPES OF RADIATION SOURCES

X ray analysis equipment

II–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 and fluorescence.

II–2. X ray analysis units produce highly intense X ray beams that are low in energy relative to those utilized in medical diagnosis and therapy. However improper use can result in radiation exposure, particularly to the eyes, fingers and hands.

II–3. Modern units are designed with interlocked barriers that enclose all system components in a manner that minimizes radiation levels. Such 'enclosed' systems reduce potential risks to personnel that are inherent in the operation of 'open beam' systems. For enclosed systems, standard operating procedures should include references to the various interlocks present in the system and the means for recognizing any failures.

II–4. There are a number of handheld X ray fluorescence analysers (XRF) available on the market but all of them operate in a similar manner. Suppliers should provide adequate radiation safety information. However, this might not always be available particularly if equipment is purchased second-hand or via the Internet. In such an event, the user should obtain the relevant information on radiation safety from a radiation protection expert before using the device.

II–5. Some hand-held equipment may contain a battery-powered X ray tube, which emits a radiation beam (the 'primary beam') in the forward direction. The radiation levels are most intense at the beam aperture at the front end 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 X ray tubes operate typically in the range 30-50 kV and up to ~55 mA, with a beam angle of up to 45˚ above the horizontal. 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 may be provided by the manufacturer and the user should take advantage of the test stand.

II–6. Exposure to a primary beam from an X ray analysis unit is avoidable by using a combination of equipment safety features, working rules and radiation monitoring. Operating organizations should develop and maintain detailed working procedures based on the appropriate legislation and issue working rules to all operators.

II–7. Enclosures should be designed to provide adequate shielding and should be interlocked to prevent accidental exposures. Other key safety features include:

– Clear warning on the equipment to indicate that it is capable of emitting X rays;

– Key-operation or password-protection to prevent unauthorized operation;

– Housing designed to shield against leakage of X rays;

– Exposure control switch that has to be pressed continuously to generate X rays. Handheld units should be designed for two-handed operation;

– A fail-to-safety warning light to indicate when X rays are being generated;

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

II–8. All safety features should be tested and maintained at appropriate intervals.

II–9. The greatest risk of radiation exposure from X ray analysis equipment occurs during maintenance when personnel may potentially be exposed to the primary beam or intense scatter radiation. Therefore, it is imperative that manufacturer's guidelines be followed. The equipment should only be repaired and maintained by properly trained and authorized persons.

II–10. Typical working rules for the operation of X ray analysis equipment are as follows:

a) Users of X ray analysis equipment should avoid exposing any part of the body to the primary beam;

b) All warning lights should be confirmed to be operational before the equipment is used;

c) No sample, collimator or analysing crystal should be changed or adjusted or handled in any other manner while the X ray tube is energised unless it is done by remote means from outside the shielded enclosure with the concurrence of the radiation protection officer;

d) Equipment should be immediately taken out of service if it is suspected of being damaged or any of the safety and warning systems are not working and resumption of use of the X ray equipment should not be permitted until the defunct, damaged safety system is duly repaired/reconditioned, with confirmation of this determined through comprehensive radiation monitoring if shielding has been impaired;

e) Exposure times should be as short as possible;

f) Visual alignment or adjustment should not be carried out while the X ray tube is energised unless a viewing system is used which is shielded or designed to prevent exposure of the eye or other parts of the body to the primary beam;

g) The X ray analysis unit should not be operated, by inactivation of an interlock or with its enclosure or a part thereof removed without prior approval of the regulatory body or unless the X ray tube is wholly enclosed by the tube housing with all apertures completely covered by interlocked shutters and/or fixed covers.

Neutron generators

II–11. A neutron generator is a small-size accelerator of deuterium nuclei. Its components include the accelerator tube (neutron tube), target containing deuterium or tritium, high voltage power supply and a measurement module.

II–12. Usually Tritium containing targets are used for neutron tubes; these targets composed of the layer of porous titanium saturated by Tritium are placed on a Zirconium or Tungsten disk. 14 MeV fast neutrons are produced due to reaction resulting from the target bombardment by deuterons accelerated to 80–140 keV.

II–13. The following radiation safety aspects should be considered during neutron generator operation:

— equivalent dose rate at 1.0 m from the neutron tube of the neutron generator operated at nominal power;
— equivalent dose rate at a specified distance from target of neutron tube of neutron generator operated within 1 hour at nominal power;
— tritium activity in the target.

II–14. 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 interaction and radioactive decay of neutron activation products). If the dose rate at a specified distance from the tube target (measured immediately after switching off the generator) is below the value specified by the regulatory body, the generator is deemed not to have any radiation hazard. If the equivalent dose rate at specified distance from the tube target (measured immediately after the generator switching off) is below the dose rate constraint value established for occupational exposure, authorized personnel can handle the generator. Otherwise, a hold time should be established to allow for the decay of radioactivity activated in tube parts.

II–15. The neutron generators can have some radioactive contamination of outer surfaces. Appropriate personal protective equipment is recommended. Beta contamination checks are needed periodically (at least once a year, upon receiving and shipping out of neutron generators, and following recovery from an incident with neutron generator).

ANNEX III

LABORATORIES USING NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM)

III–1. NORM is defined as: “Radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides” [III–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-made processes, including the residues from these processes. All naturally occurring radioactive materials, whether in their natural state or processed, that are subject to regulatory control in terms of the IAEA’s safety standards fall within the definition of NORM.

III–2. NORM may be used in educational institutions and may vary from minerals in showcases in science laboratories in schools, to research projects involving NORM for students at universities. Laboratory activities using NORM are diverse. Examples of laboratory activities include sample analysis of raw materials, products and residues, process-related research, research for recycling or reuse of residues, waste conditioning and management, 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 and may be carried out in a specific laboratory at an industrial site, or in a separate laboratory offsite. Research may also be carried out at university laboratories, or at technical support organizations. There are various types of industries involving NORM where regulatory controls for radiation protection and residue/waste management may be necessary that are described in Ref. [III-2].

Safety assessment for uses of NORM in research and education

III–3. The scope and extent of the safety assessment should be commensurate with the proposed use of NORM. In schools, analytical laboratories and small research projects, the mass and activity of NORM material will in general be small or below the exemption values specified in Schedule I of GSR Part 3. The safety assessment that is necessary for this type of applications may therefore be restricted, applying the graded approach as appropriate.

III–4. In other research and education, the results of the initial safety assessment should be factored into the selection of the site and design of the NORM laboratory. The assessment should consider all pathways by which students, research workers, the public and the environment may be subject to radiological hazards. The scope and depth should be sufficient to identify and evaluate relevant risk components over the lifetime of the use of NORM in the laboratory. The diversity of research subjects implies that the amount of NORM that will be used in a laboratory will vary significantly between projects and may range from small amounts for sample analysis, to hundreds of tons 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 be less detailed.

III–5. When research is performed in a laboratory at the NORM industrial site, the safety assessment will be part of the overall safety assessment for the industrial facility. The specific safety issues for the research laboratory, if appropriate, should be reflected in the safety assessment for the facility.

Exposure pathways in laboratories containing NORM

III–6. The presence of NORM in laboratories is unlikely to cause external exposures approaching or exceeding annual dose limits for workers. External dose rates from NORM usually encountered in NORM laboratories are so low that routine radiation monitoring and protective measures are not needed.

III–7. In laboratories containing pilot plants processing NORM, stockpiles of raw materials, products, residues and waste containing natural radionuclides can build up. The radionuclides in such NORM stockpiles include a wide variety of gamma emitters and emission energies, and will lead to occupational exposures that necessitate radiation monitoring. Strong gamma emitters include ^{226}Ra and its short-lived decay products (uranium decay chain) and ^{208}Tl (thorium decay chain). Gamma exposures are of particular importance where high-grade uranium or thorium ores are processed or where there is a significant enhancement of radionuclide activity in parts of the plant installation (e.g. scales in tubing, sediments in drums and vessels, and waste tanks). Workplace gamma dose rates can be routinely measured with portable instruments and individual exposures can be assessed using a variety of active and passive dosimeters.

III–8. The processing, handling and transport of NORM can easily lead to dust formation. Dust control measures may be needed in pilot plants or laboratories handling large quantities of NORM. The control measures generally restrict the airborne concentrations of radioactive dust to meet the requirements for dose limitation. To ensure that the methods for the control of dust are in place and adequate, programmes for the sampling and control of dust need to be formalized. The primary method of control over airborne contaminants is through engineered design and optimal operation of adequate ventilation and dust control systems. Such control systems should be engineered into the workplace design prior to commencement of operations. Further guidance to control occupational exposure to dust in NORM industries can be found in Ref. [III-3]. Dust containing natural radionuclides can lead to surface contamination of floors, walls, and external parts of installations and equipment. Good housekeeping and material control is therefore necessary to control surface contamination, to reduce resuspension and airborne contamination, and to reduce the spread of contaminated raw materials, products, residues and waste materials from the laboratory processing installation into uncontaminated areas. Routine monitoring of surface contamination may be needed, e.g. to assess the efficiency of material and dust control systems, to assess the ingestion of material, and to monitor equipment and materials for compliance with clearance criteria established by the regulatory authorities.

III–9. Processing operations can result in contaminated scrap and other materials which may be released into the public domain. Administrative controls over the movement and use of such materials should be implemented.

III–10. When considerable amounts of NORM are processed in a pilot plant, the safety assessment should address the ventilation aspects of the plant to reduce inhalation exposures. The performance of the ventilation system is a critical part of the system of occupational protection in the case of radon exposures and needs to be monitored closely using suitable instrumentation. In the case of facilities handling thorium chain nuclides, adequate ventilation should be provided to reduce inhalation exposures due to long-lived thorium isotopes and thoron progeny nuclides.

Controlling occupational exposure

III–11. In cases where there are significant but localized dose rates, such as deposits containing radium in vessels, tubing or other equipment, the safety assessment should address the following basic rules to minimize any external exposure and its contribution to total dose:

a. Minimize the duration of any necessary external exposure;

b. Ensure that optimum distances are maintained between any accumulation of NORM (installation part) and exposed people;

c. Maintain shielding material or equipment between the NORM and potentially exposed people.

III–12. The first two measures in practice involve the designation of supervised or controlled areas to which access is limited or excluded. The use of shielding material is an effective means of reducing dose rates around radiation sources, but it might not be feasible to apply shielding at a bulk accumulation of NORM in pilot plants. However, the principle may be applied by ensuring that NORM remains enclosed within (and behind) steel wall(s) of the plant or equipment such as a vessel for as long as feasible while preparations are made for the disposal of the material. If NORM waste of high specific activity is stored, some form of localized shielding with lower activity wastes or materials may be necessary to reduce gamma dose rates to acceptably low levels on the exterior of the waste storage facility.

III–13. The safety assessment should include, where appropriate, control measures such as quality in design, installation, maintenance, operation, workplace monitoring, administrative arrangements and instruction of personnel. These control measures should be used to the maximum extent possible before personal protective equipment (PPE) for the safety and protection of workers is used. Where reasonable control measures are not sufficient on their own for providing safe working conditions, personal protective equipment should be provided to restrict the exposures of the workers.

III–14. The operator should establish written procedures, including procedures for the clean-up of spills, to be followed in the event of any significant radiation hazard arising from the loss, escape or release of raw material from the NORM laboratory.

III–15. In the absence of suitable control measures, internal exposure may result from the ingestion or inhalation of NORM while working with uncontained material or as a consequence of the uncontrolled dispersal of radioactive contamination. The risk of ingesting or inhaling any radioactive contamination present should be addressed in the safety assessment and will be minimized by complying with the following basic rules, whereby workers:

— use protective clothing in the correct manner to reduce the risk of transferring contamination;
— refrain from smoking, drinking, eating, chewing (e.g. gum), applying cosmetics (including medical or barrier creams, etc.), licking labels, etc. or any other actions that increase the risk of transferring radioactive materials to the face during work;
— use suitable respiratory protective equipment as appropriate to prevent inhalation of any likely airborne radioactive contamination;
— apply, where practicable, only those work methods that keep NORM contamination wet or that confine it to prevent airborne contamination;

— implement good housekeeping practices to prevent the spread of NORM contamination;
— observe industrial hygiene rules such as careful washing of protective clothing and hands after finishing the work.

III–16. When the safety assessment indicates the use of PPE, the equipment should be selected with due consideration of the hazards involved. The equipment should not only provide adequate protection but also be convenient and comfortable to use. Coveralls, head coverings, gloves, boiler suits and impermeable footwear and aprons should be provided in accordance with the risks of contamination and as necessary and appropriate for the working conditions, such as in decontamination.

III–17. The use of respiratory protective equipment should comply with the radiation dose limits for individuals is acceptable only in specific circumstances. Internal contamination should generally be controlled using engineered designs such that respiratory protective equipment is not necessary for routine tasks. However, respiratory equipment may need to be worn by persons undertaking corrective measures, repair and maintenance, and in other special circumstances if levels of airborne contaminants, radioactive or nonradioactive, exceed the relevant dose constraints or derived concentrations. During such work, the area should be monitored to estimate possible exposures. Workers who may have to use such equipment should be properly trained in its use, operation, maintenance and limitations.

III–18. Powered air respirators or helmets with face shields are often preferable to other types of respirators for the comfort of the workers using them, provided that they offer effective respiratory protection. This is especially important in operations such as pilot plants handling highly active materials e.g. uranium product.

Workplace and individual monitoring

III–19. When indicated by the safety assessment, workplace and/or individual monitoring should be part of the radiation protection programme. The safety assessment should specify the quantities to be measured; where and when the measurements are to be made and at what frequency; the most appropriate measurement methods and procedures; and reference levels and the actions to be taken if they are exceeded. Airborne dust monitoring may need to be performed regularly whenever there is a possibility of receiving significant doses from the inhalation of dust, i.e. in larger NORM research facilities such as pilot plants.

NORM residues and waste

III–20. Materials and equipment should be decontaminated as far as practicable and in accordance with any applicable regulatory requirements for clearance or authorized release before being released from the laboratory or pilot plant. Decontamination operations can give rise to occupational exposure that may need to be controlled.

III–21. Details on the management of NORM residues and waste is given in [III-4]. 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 should be controlled under the same regulatory approach for the control of other NORM facilities on the site.

REFERENCES TO ANNEX III

[III-1] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection (2018 Edition), IAEA, Vienna (2019).

[III-2] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials, IAEA Safety Report Series No. 49, IAEA, Vienna (2006).

[III-3] INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, IAEA, Vienna (2018).

[III-4] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of Radioactive Residues from Uranium Production and other NORM Activities, IAEA Safety Standards Series No. XXX (DS459), IAEA, Vienna (20XX).

ANNEX IV

EXAMPLES OF SPECIFIC ACTIONS TO CONSIDER IN EMERGENCY PLANS AND PROCEDURES

IV–1. Examples of immediate on-site actions to be taken in case of an emergency at research and education facilities with sources, radiation generators and irradiators are briefly described below. More general guidance on arrangements for preparedness including emergency plans and procedures are provided in Ref. [IV–1].

X ray generators

IV–2. For laboratories that contain X ray generators, turning off the primary electrical source immediately stops any radiation being produced. All relevant staff should be adequately trained to recognize when the equipment containing X ray generators is not functioning correctly or, for example, when a programming error in the software is suspected.

Self-shielded irradiators

IV–3. Self-shielded irradiators can contain a Category 1 or Category 2 sealed radioactive source. Radiological emergency that may occur includes failure of a safety interlock, the equipment failure to function as designed or leaking of a source. The emergency plan should include the following on-site actions, for example;

a) The worker should leave the irradiator room, to reduce his or her exposure;

b) Measures should be implemented to prevent access to the irradiator room (e.g. lock door);

c) The worker should inform the supervisor and radiation protection officer of the situation. The licensee or the designated official for managing the emergency, should take charge of the situation and contact the manufacturer of the irradiator, take the help of the radiation protection officer and, if necessary, a radiation protection expert for further action and inform the regulatory body;

d) The radiation protection officer should monitor the area outside the locked room to determine areas where levels of radiation warrant taking actions to protect workers and the public;

e) Upon bringing the situation under control with the help of the manufacturer and the expert, the licensee should terminate the emergency after the radiation protection officer is satisfied that radiation levels in the facility are within the regulatory limits.

Sources incorporated in devices

IV–4. The response plan for emergencies involving sources should 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 licensee/registrant or the person designated as person in charge for managing emergencies:

– Remain calm and move away from the radioactive source, and ensure that any other workers in the vicinity are evacuated and informed that there might be an emergency;

– Inform the radiation protection officer of the operating organization;

– Measure the radiation dose rates and record any doses measured by direct reading individual dosimeters;

– Establish the cordoned off area based on the pre-established criteria (e.g. observables), consistent with regulatory requirements and the emergency response plan and procedures;

– Prevent unauthorized access to the cordoned off area;

– Use necessary personnel protective equipment;

– Maintain surveillance of the controlled cordoned area;

– Inform the relevant authorities and seek assistance as prescribed in the emergency response plan and procedures

The radiation protection officer should:

– Implement the pre-established emergency plans and procedures;

– Move to a location away from the cordoned area and rehearse the planned course of action before entering the cordoned area to implement the emergency plan;

– Implement the planned course of action to regain control over the source, as may be appropriate to the equipment, the actual situation and authorizations; under no circumstances should the source come into contact with the hands or other parts of the body;

– If the course of action taken is unsuccessful, leave the cordoned area and maintain surveillance of the cordoned area;

  Call for technical assistance, if necessary, from a qualified expert or from the manufacturer of the source and/or equipment, as appropriate. Such action should form part of the emergency plan and procedures, in which case it should be planned and agreed upon between the various parties in advance;

– When the situation has been brought under control and the source is safe, investigate the emergency and estimate the doses received;

– Return personal dosimeters to the dosimetry service for rapid assessment;

– Prepare an accident report and notify the regulatory body, in accordance with regulatory requirements.

Spillage of unsealed radioactive source

IV–5. Following spillage of unsealed radioactive sources, the person responsible for

emergency management should:

a) Throw absorbent pads over the spill to prevent further spread of contamination;
b) Evacuate people present at the place where the spill occurred from the area immediately with necessary and adequate attention on the risk of spread of contamination;
c) Inform the radiation protection officer immediately, and arrange for decontamination of the affected area under the direct supervision of the radiation protection officer;
d) Monitor all people evacuated from affected area for contamination when leaving the room, (particularly monitor their shoes, if the spill was on the floor);
e) When internal exposure is possible, consider the need for a whole body counting or bioassay that is appropriate for the specific radionuclide. For example, perform a thyroid monitoring in the event of exposure to radioiodine;
f) If clothing is contaminated, remove and place it in a plastic bag labelled 'RADIOACTIVE';
g) Instruct the personnel that –
   (i) If contamination of skin occurs, wash immediately;
   (ii) If contamination of eyes occurs, flush irrigate the eyes with copious amount of water;
   (iii) When the contamination is contained, the procedures outlined for cleaning small spills may be followed, taking particular care that the contaminated waste bags are appropriately labelled and stored;
   (iv) While carrying out the response operations use protective clothing and disposable gloves;
   (v) Decontaminate the area, monitor for residual activity, for example, using a contamination monitor or performing a wipe test;
   (vi) Continue the cycle of cleaning and monitoring 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 simpler to "quarantine" the area for sufficient time to allow decay – e.g. cover the spill site, such as with a laboratory coat, and prevent access to the area);
   (vii) Use plastic bags to hold contaminated items. Suitable bags, as well as damp paper towels should always be available;
   (viii) Restrict the entry to the contaminated area until decontamination has been completed and the area is declared by the radiation protection officer as fit for re-occupation.
h) Arrange for proper management of radioactive waste generated, for example liquid waste after the decontamination activities as explained in Section 8 of this Safety Guide.

REFERENCES TO ANNEX IV

[IV–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. GSG-2.1, IAEA, Vienna (2007).

CONTRIBUTORS TO DRAFTING AND REVIEW

Boal, T.	International Atomic Energy Agency
García-Tenorio, R.	CSN, University of Seville, Spain
Haridasan, P.P.	International Atomic Energy Agency
Harrison, D.	ARPANSA, Australia
Nandakumar, A.	Consultant, India
Provens, H.	CEA, France
Ring, J.P.	BIDMC, Harvard University, United States of America
Shaw, P.	International Atomic Energy Agency