IAEA
International Atomic Energy Agency

Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources

Standard Syllabus

VIENNA, 2019

TRAINING COURSE SERIES 18 (Rev. 1)

POSTGRADUATE EDUCATIONAL COURSE IN RADIATION PROTECTION AND THE SAFETY OF RADIATION SOURCES

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

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POSTGRADUATE EDUCATIONAL COURSE IN RADIATION PROTECTION AND THE SAFETY OF RADIATION SOURCES

STANDARD SYLLABUS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2019

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FOREWORD

Part of the mandate of the IAEA is to provide for the application of its standards of safety for protection against ionizing radiation and for the safety of radiation sources, at the request of a State. This can be facilitated, inter alia, by encouraging the exchange of information and training of scientists and experts in the peaceful uses of atomic energy.

In this connection, the IAEA developed a standard syllabus for a postgraduate educational course in radiation protection in 1993 and subsequently issued a strategic plan for education and training in radiation and waste safety for the period 2001–2010. The proposed strategy identified the organization of postgraduate educational courses at regional training centres as a key element of a sustainable education and training programme in radiation safety for Member States.

In 2002, the standard syllabus of the postgraduate educational course was revised and updated to account for changes to the IAEA safety standards, and the conclusions and recommendations of relevant international organizations and committees in the field of radiation protection and the effects of ionizing radiation. In 2010, building on the success of the 2001–2010 strategy, the IAEA developed the Strategic Approach to Education and Training in Radiation, Transport and Waste Safety, 2011–2020, again emphasizing the importance of building long term competence in radiation protection and safety in Member States. That same year, noting that several new and revised IAEA safety standards had been introduced since the standard syllabus was last published in 2002, the Steering Committee on Education and Training in Radiation, Transport and Waste Safety recommended that the standard syllabus again be updated accordingly. The present publication provides the revised standard syllabus for the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources, updated to reflect the current IAEA safety standards.

The IAEA is grateful to those experts from various Member States who reviewed the standard syllabus for the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources. The IAEA gratefully acknowledges the contributions of P. Dimitriou (Greece) to the preparation of the initial draft syllabus and of R. Paynter (United Kingdom) to the finalization of the learning objectives. The IAEA officer responsible for this publication was A. Luciani of the Division of Radiation, Transport and Waste Safety.

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1. INTRODUCTION

1.1. BACKGROUND

IAEA has a statutory function to establish standards of safety for the protection of health and minimization of danger to life and property against ionizing radiation, and to provide for the application of these standards through, inter alia, education and training.

IAEA's education and training activities are in-line with the resolutions of the General Conference and reflect IAEA Safety Standards. A comprehensive portfolio of training packages and material in the field of radiation, transport and waste safety has been developed by IAEA. Short-duration courses (between a few days to two weeks) focus on specific radiation safety subjects (e.g. regulatory framework, external and internal occupational exposure, patient protection, radioactive waste management, transport of radioactive material, safety of radioactive sources), and are addressed to specific categories of personnel, including regulators, health professionals, radiation protection officers and operators.

The Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (PGEC) is a 'long-duration' course that provides the initial basic professional training for young professionals who are expected to become, over the course of time, regulators, decision makers, qualified experts in radiation protection or trainers in radiation protection and safety of radiation sources in their home countries. The course was first held under the auspices of IAEA in Argentina in 1981. Since that time more than 1700 students (as of 2017) have attended the PGEC hosted by IAEA regional training centres (RTCs) in Africa (English and French), Europe (English and Russian), Latin America and the Caribbean (Spanish and Portuguese), and Asia (Arabic and English). Modern technology is now used to facilitate a blended learning approach to delivering the PGEC, combining distance-learning methods (typically e-learning) with traditional, in-person teaching. The use of on-line platforms also enables monitoring the progress of students throughout the course as well as facilitating their long-term follow-up.

The 2002 edition of the PGEC standard syllabus [1] has been revised and updated to reflect changes to the IAEA Safety Standards and the conclusions and recommendations of relevant international organizations and committee in the field of radiation protection and effects of ionizing radiations (e.g. International Commission on Radiological Protection, United Nations Scientific Committee on the Effects of Atomic Radiation). It also takes into account, inter alia, the suggestions provided by the IAEA Steering Committee on Education and Training in Radiation, Transport and Waste Safety, the experience gained by the RTCs in organizing the course, as well as the recommendations from the PGEC evaluation conducted by the IAEA Office for Internal Oversight.

1.2. OBJECTIVE

The objective of the IAEA PGEC is to provide foundation training in radiation protection and the safety of radiation sources. It is designed to provide both theoretical and practical training in the multidisciplinary scientific and/or technical bases of international recommendations and standards on radiation protection and their implementation. The standard syllabus provides a harmonized basis for running the PGEC in terms of the theoretical contents of lectures and practical exercises including learning objectives; the minimum facilities and infrastructure of the training facility; and the selection of trainers and students.

1.3. SCOPE

The focus of the standard syllabus is on the radiation safety framework necessary for regulatory and operational controls for protection against ionizing radiation and the safe use of radiation sources in all their applications. It provides a tool to facilitate the integration of courses in radiation protection and the safety of radiation sources into the curricula of educational institutions in Member States.

1.4. STRUCTURE

Section 2 provides an overview on basic physical and human resources necessary for the organization of a course based on the standard syllabus, as well as considerations on the optimal delivery of the course, based on the experience gained by the IAEA in the organization of the course in collaboration with the RTCs. Section 3 provides an overview of the Standard Syllabus and its structure, main learning objectives and suggested duration of each part. Section 4 describes the content of each part of the standard syllabus, the specific learning objectives of each module within a part, and provides a list of practical exercises and a list of reference publications for further reading.

2. IMPLEMENTATION OF THE STANDARD SYLLABUS

2.1. GENERAL CONSIDERATIONS

Advice on the development and implementation of training in protection and safety, as provided in section 5.3 of Safety Reports Series No. 20, Training in Radiation Protection and the Safe Use of Radiation Sources [2], will generally apply to the implementation of the standard syllabus of the PGEC. In this chapter, specific considerations are provided (sections 2.1 to 2.3), taking into account the objectives of the PGEC (section 1.2), and the blend of topics and didactical activities of the standard syllabus, as outlined below.

The Standard Syllabus is structured in theoretical lectures and practical training.

Theoretical lectures cover:

- Basic scientific topics (Part I to Part III of the standard syllabus, including nuclear physics and related matters, quantities and units, biological effect of ionizing radiations);

- Topics specific to radiation protection and safety (Part IV to Part X of the standard syllabus, including the international radiation protection system, IAEA requirements for the regulatory framework, the different types of exposure situations and categories of exposure);

- Special topics aimed at developing students' didactical skills (Part XI: Train-the-trainers), and applying gained knowledge and skills in solving a specific radiation protection problem (Part XII: Work project).

Practical training is used to reinforce and/or to provide a better understanding of theoretical lectures and concepts. It may consist of practical exercises, demonstrations or technical visits, all characterized in terms of their learning objective, number of students involved, working methodology (independent or with the support of a lecturer), expected output and assessment mechanism:

- A practical exercise can be characterized as being a hands-on experience by the students working individually or in small groups under the supervision of a trainer, for example, using laboratory or field equipment, becoming familiar with radiation protection software, applying a laboratory procedure, or solving a case study or carrying out a desk-top exercise. On completion of each practical exercise, it is important to ensure that students submit individual written reports (even if they were working in groups) and that those reports are assessed;

- In some situations, it may be more appropriate for a lecturer (or a student under direct supervision) to provide a demonstration to the whole group, for example, if a training centre has a limited supply of certain types of equipment, or the use of a software has license restrictions, or there are safety concerns about using radioactive material, etc. A questionnaire can be provided to the students to assess the fulfilment of the demonstration objectives. Alternatively, the students might be requested to submit individual reports;

- Technical visits to facilities such as hospitals, industrial radiation facilities and sites with interesting radiation protection issues (such as NORM or Radon) can be very

powerful tools for illustrating how radiation protection and the safety of sources are applied to real-life situations. Good preparation and prior information before the technical visits will maximize the benefits. A questionnaire can be provided to the students to assess the fulfilment of the objectives of the technical visit. Alternatively, the students might be requested to submit individual reports.

The blend of theoretical topics and the variety of practical training methodologies imply for the trainers, students, and training facilities to comply with some basic requirements, as outlined in the following sections.

2.2. TRAINING FACILITIES

While the theoretical lectures would not need facilities and infrastructures different from any other course, availability of instruments, equipment and the access to installations for the practical training should be more carefully considered. In addition to a minimum set of equipment ([2], section 5.3.3) the implementation of the standard syllabus requires the availability of a large variety of instruments and equipment, and the access to a range of facilities and installations, to conduct practical exercises, demonstrations and technical visits in relation to the control of the occupational and public exposure within all the type of exposure situations (planned, existing and emergency exposure situations), and the control of the medical exposure within the planned exposure situation. This might imply, in principle, the availability of, inter alia:

- Physics laboratories with equipment and procedures to conduct basic experiments on nuclear physics, radioactivity and interaction of radiation with matter;

- Laboratories conducting biological testing (e.g. counting of irradiated blood cells) or carrying out epidemiological investigations and studies on assessment of the risks associated with doses;

- Regulatory activities that can be presented for training purposes (e.g. participation in inspection visits; development of regulatory documents; use of software to maintain registries and records of regulatory data, and to manage regulatory information and regulatory activities);

- Technical and scientific supporting organization with equipment, facilities and procedures to provide service, including: radiological monitoring of workers and population (e.g. dosimetric services for the individual monitoring of the external and internal exposure); environmental monitoring and analysis; calibration (e.g. secondary standard dosimetric laboratory); dose assessment (e.g. software and procedure for dose calculation); emergency and preparedness response (e.g. modelling tools to evaluate the dispersion and contamination);

- Industrial facilities with practices including the use or application of industrial radiography, nucleonic gauges and well logging sources, radiotracers, radioisotope production; nuclear installations (e.g. nuclear fuel fabrication plant, nuclear reactor including critical and subcritical assemblies, research reactor, nuclear power plant); mining and processing of raw materials, transport of radioactive material; radioactive waste management;

- Medical facilities for diagnostic radiology and image guided interventional procedures, nuclear medicine (diagnosis and therapy), radiation therapy.

The facilities and installations listed above may not be all necessary to implement a course based on the standard syllabus if consideration is given to the students' specific training needs and the actual radiation safety issues they are expected to face in their professional life: for example, a course offered to students coming from Member States without any nuclear facility, the availability of access to such facilities to conduct practical training within the course would not be needed.

Given that many training centres may not have access to all necessary equipment, expertise or experience to run the PGEC, it will be necessary to establish formal collaborative agreements with other relevant bodies/organizations to ensure that all learning objectives can be met. Universities, the national regulatory body, technical and scientific supporting organization(s), organizations and companies with industrial applications of ionizing radiations and radiation sources; and hospitals are examples of stakeholders that could collaborate in the organization of the PGEC.

2.3. SELECTION OF TRAINERS

In addition to the desired trainers' technical abilities (technical competence in the topic or subject matter being taught, including relevant practical experience), teaching abilities (good didactical and communicational skills), and language skills ([2], section 5.3.5), the implementation of the standard syllabus with the wide range of theoretical topics and practical training offerings requires the involvement of trainers of very different educational backgrounds and levels, and professional experience.

Although tertiary educational levels (MSc or PhD) are generally desirable (e.g. for the theoretical lectures on the basic scientific topics associated to Parts I, II and III), professional experience in specific areas is an important additional asset (e.g. for the theoretical lectures and practical training associated to: regulatory control in Part IV; planned, existing and emergency exposure situations from Part VII to Part X). Teaching abilities would be requested to all the trainers and will be the main asset for the trainers involved in the training-the-trainers activities (Part XI). Beyond the time needed to provide the theoretical lectures and/or to conduct the practical training, all the trainers should ensure their availability for the assessment (e.g. examinations at the end of each part), and, if assigned with supervisory tasks, for providing advice and supervising students' work project (Part XII).

In addition to academic staff, it is highly likely that trainers will also be regulators, qualified experts in radiation protection, medical physicist, and personnel from technical and scientific supporting organizations. A collaboration established with all the relevant stakeholders (e.g. universities, regulatory body, technical and scientific supporting organization(s), hospitals) would facilitate the appointment of suitable trainers.

2.4. SELECTION OF STUDENTS

The students should have had a formal education to a level equivalent to a university degree, preferably in physics. Students with chemistry, life- sciences or engineering qualifications may also be acceptable on a case-by-case basis when viewed in conjunction with relevant work experience. In addition to the academic qualifications, students should have been selected to work in the field of radiation protection and the safe use of radiation sources in their home country. Ideally, students are expected to be already working, or will in the near future be

working, on: development of regulatory provisions and procedures for any facility or activity; provision of advice for the control of occupational, public and medical exposure; establishment of radiation protection programmes. Students aiming to become trainers in radiation protection and safety will also benefit from the course. Evaluation of the impact of the PGEC for the courses conducted in the last 36 years (in preparation) has evidenced that regulators, decision makers, qualified experts and trainers in radiation protection take particular advantage of the knowledge and skills gained in the PGEC.

3. OVERVIEW OF THE STANDARD SYLLABUS

The Standard Syllabus is divided into twelve parts and each part is divided into modules. For each part, the general learning objective is given. Each module is described by the content and a reference to the module's specific learning objectives. For each part, a list of practical training sessions is suggested. These sessions can be practical exercises (e.g. laboratory exercises, case studies), demonstrations, and technical visits. The title of the parts, their general learning objectives and suggested duration for each part (including theoretical and practical sessions) are summarized in Table I.

TABLE I. OVERVIEW OF THE STANDARD SYLLABUS.

Part No.	Part title	Objective	Suggested duration (hours)
I	Review of fundamentals	To provide the students with an understanding of the fundamental principles of physics and mathematics used in radiation protection, including radioactive processes, nuclear reactions and statistical methods. Students will be aware of sources of radiation and understand the interactions of radiation with matter	70
II	Quantities and measurements	To provide the students with an understanding of the radiometric, dosimetric and operational quantities of radiation protection and their measurement units, enabling them to carry out related calculations. To provide the students with practical experience to set up and operate different types of radiation detectors, recognize their operating principles, characteristics and limitations and analyze and interpret the measurement data.	60
III	Biological effects of ionizing radiation	To provide the students with an awareness of the effects of radiation at the molecular and cellular levels and an understanding of the tissue reactions that can result in stochastic and deterministic health effects. They will be introduced to the models used for estimating risk coefficients for stochastic effects.	30
IV	The international system of radiation protection and the regulatory framework	To provide the students with an understanding of the role played by international organizations in radiation protection, including the ICRP's recommendations on the international system of radiological protection. To provide an overview of the relevant IAEA Safety Standards, including the main components of the legal and regulatory framework for safety, the relevant regulatory control measures, as well as the main principles of safety culture and building competence in radiation safety.	40

V	Assessment of external and internal exposures (other than medical)	To enable the students to measure, monitor, calculate and interpret the doses to individuals arising from external exposure, including designing a monitoring programme for individual dose assessment and for the workplace. To enable the students to use appropriate techniques to assess the doses to individuals arising from intakes of radionuclides in simple cases of internal contamination.	60
VI	Planned exposure situations - generic requirements	To provide the students with an understanding of the generic requirements for radiation protection with respect to planned exposure situations for all categories of exposure (occupational, public and medical exposures).	15
VII	Planned exposure situations: non-medical applications	To provide the students with a good understanding of the practical application of radiation protection principles and concepts in a wide range of planned exposure situations (excluding medical). Students will also be able to develop suitable radiation protection programmes for a wide range of applications.	100
VIII	Planned exposure situations, medical applications	To provide the students with a general understanding of the application of radiation protection principles in medical applications.	60
IX	Emergency exposure situations and emergency preparedness and response	To provide the students with an understanding of the basic requirements for protection against emergency exposure situations. To provide the students with an understanding of the system of emergency preparedness and response, including the basic requirements, principles, goals, planning basis, protective and other response actions, and public communication. Students will also be aware of the arrangements that have to be in place for an effective and efficient response during a nuclear or radiological emergency.	40
X	Existing exposure situations	To provide the students with an understanding of the basic requirements for protection against existing exposure situations. Students will also be aware of the causes of existing exposure situations, the approaches to mitigate their consequences, and the circumstances where occupational exposure requirements must be applied.	15

XI	Training the trainers	To be able to organize and implement training courses. To develop didactic skills. To apply the didactic skills to the oral presentation of Part XII.	30
XII	Project assignment	To apply the knowledge and skills acquired within the course in addressing a specific problem of radiation protection and safety and to present the findings and conclusions.	80

4. THE STANDARD SYLLABUS

4.1. PART I: REVIEW OF FUNDAMENTALS

Objective: To provide the students with an understanding of the fundamental principles of physics and mathematics used in radiation protection, including radioactive processes, nuclear reactions and statistical methods. Students will be aware of sources of radiation and understand the interactions of radiation with matter.

4.1.1. Content

Module	Content	Learning Objective (No.)
I.1. Introduction	**Introduction** Overview of the training course: aim, learning objectives, content and schedule. Introduction to radiation protection and the safety of radiation sources	N.A
I.2. Basic physics and mathematics used in radiation protection	**Basic atomic and nuclear physics** Atom, nucleus, protons, neutrons, electrons; atomic mass unit; elements, periodic table of elements; isotopes of an element; stable and unstable nuclides; electron shells; electron binding energy; excitation; ionization; accelerated particles; bremsstrahlung; energetic spectrum: characteristic X ray radiation and bremsstrahlung; internal conversion; auger electron **Radioactivity** Nuclear stability; the line of stability; unstable nuclei; radionuclides; modes of radioactive decay and types of spectra: alpha, beta, gamma; positron, orbital electron capture, internal conversion; activity; units; decay constant; half-life; law of radioactive decay; mean life; decay chains and equilibrium **Nuclear reactions** Types of reactions; induced radioactivity; fission and fusion (energy considerations); cross section; energies of reactions **Basic mathematics** Differentiation/integration; decay equations (exponential functions); first order ordinary linear differential equations with a constant **Statistics** Accuracy; precision; mean, median, mode; standard deviation; confidence levels; probability theory; random variables; different types of distributions (binomial,	LO.I.2.01 LO.I.2.02 LO.I.2.03 LO.I.2.04 LO.I.2.05 LO.I.2.06 LO.I.2.07 LO.I.2.08 LO.I.2.09 LO.I.2.10 LO.I.2.11 LO.I.2.12

Module	Content	Learning Objective (No.)
	Poisson, Gaussian, log-normal); scatter diagram; student T test; Chi square	
	Chauvenet's criteria, regression; correlation; practical application to counting; curve fitting by least square methods	
I.3. Interaction of radiation with matter	**Charged particle radiation**	LO.I.3.01
	Heavy particles (alpha, proton nuclei)	LO.I.3.02
	Energy transfer mechanisms, ionization and excitation, scattering nuclear interaction; range–energy relationship; Bragg curve; stopping power; shielding	LO.I.3.03 LO.I.3.04
	Beta particles	LO.I.3.05
	Mechanisms of energy transfer; bremsstrahlung; empirical relationships; Bragg curve; stopping power; shielding; Cerenkov radiation	LO.I.3.06
	Uncharged radiation	
	X and gamma rays	
	Photoelectric effect; Compton scattering; pair production; secondary photon production; linear and mass attenuation coefficient; exponential attenuation; effect of Z on absorbing medium; build-up correction; shielding.	
	Neutrons	
	Interaction mechanism: scattering; absorption; radioactive capture (n,p), (n,γ) and other. Energy dependence; shielding	
I.4. Sources of Radiation	**Natural radiation**	LO.I.4.01
	Terrestrial radionuclides: Uranium (^{235}U and ^{238}U), ^{232}Th, ^{40}K; important radionuclides in ^{238}U and ^{232}Th decay chains (Ra, Rn emanation); NORM	LO.I.4.02 LO.I.4.03
	Cosmic radiation: types of cosmic radiation; variation with latitude and altitude	LO.I.4.04 LO.I.4.05
	Human made radioactive sources	
	Radioactive sources: beta, alpha, gamma and X ray sources; isotopic neutron sources; sealed sources; unsealed sources and isotope generators; source enclosures; production of radioisotopes; fallout	
	Nuclear reactors: review of fission and fusion reactions; moderation of neutrons; multiplication factor, criticality. Types of reactors; basic elements of a nuclear reactor; research reactors; nuclear fuel cycle installations	

Module	Content	Learning Objective (No.)
	Radiation generators Charged particle production: linear accelerators; cyclotrons; betatrons X ray production: low energy X ray machines; linear accelerators; other machines; principles and spectra; filtration and beam quality Neutron production: fission; fusion; spallation; (p, n), (d, n), (α, n) and (γ, n) reactions; neutron production for neutron therapy Applications of ionizing radiation in medicine, industry, food and agriculture; consumer products	

4.1.2. Learning Objectives

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
I.1. Introduction	-	-
I.2. Basic physics and mathematics used in radiation protection	LO.I.2.01	describe the structure of the atom and identify the basic constituents of the nucleus.
	LO.I.2.02	describe how atoms are grouped into elements in accordance with their atomic number, and how these elements are arranged in the periodic table.
	LO.I.2.03	explain the concept of isotopes of a specific element.
	LO.I.2.04	describe the process of ionization and the mechanisms by which an atom is ionized.
	LO.I.2.05	explain the mechanisms for the production of bremsstrahlung and characteristic X ray radiation.
	LO.I.2.06	describe the modes of decay and the types of radiation emitted (alpha, beta, positron emission, gamma).
	LO.I.2.07	explain the differences between gamma radiation and X radiation.
	LO.I.2.08	define the unit of radioactivity, the concept of half-life and the law of radioactive decay.
	LO.I.2.09	explain the concepts of secular equilibrium and transient equilibrium.
	LO.I.2.10	summarize the properties of neutrons.
	LO.I.2.11	explain the concept of nuclear fission.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.I.2.12	relate the appropriate statistical methods and tests to relevant radiation protection situations.
I.3. Interaction of radiation with matter	LO.I.3.01	explain the different types of interactions of heavy particles (alpha, proton, nuclei) with matter and the associated concepts of stopping power and shielding.
	LO.I.3.02	describe the different types of interaction of beta particles with matter and the associated processes of bremsstrahlung and Cherenkov radiation.
	LO.I.3.03	describe photon interactions with matter, including the Photoelectric Effect, Compton Scattering and Pair Production.
	LO.I.3.04	describe the process of the attenuation of radiation in shielding material and the concept of half-value thickness and linear and mass-attenuation coefficients.
	LO.I.3.05	explain neutron interaction mechanisms, neutron energy dependence and types of neutron shielding.
	LO.I.3.06	describe the process of neutron activation.
I.4. Sources of Radiation	LO.I.4.01	list natural sources of radiation (naturally occurring terrestrial radionuclides, cosmic radiation), the three naturally occurring decay series, the topic of natural radionuclides in building material, and describe the mechanisms of exposure to ^{222}Rn.
	LO.I.4.02	describe the wide range of applications of radioactive sources in industry, medicine and research.
	LO.I.4.03	describe the uses of unsealed radioactive substances in medicine and their method of production.
	LO.I.4.04	explain the basic criteria for the construction of alpha, beta and gamma sources.
	LO.I.4.05	summarize the different types of nuclear reactor.

4.1.3. Practical exercise

No.	Practical exercise	Type
I-1	Presentation of different types of radiation sources and explanation of their application; natural and human made radionuclides; consumer products; radon sources	Demonstration

I-2	Demonstration of radioactive decay: charts of nuclides, use of books and software for sources of nuclear data	Demonstration
I-3	Application of the radioactive decay equation; use of some simple mathematical codes	Exercise
I-4	Measurement of half-life	Laboratory exercise
I-5	Counting of statistics using a Geiger–Müller or similar counter and radioactive source and verifying the statistical distributions	Laboratory exercise
I-6	Bremsstrahlung radiation production and its attenuation	Demonstration
I-7	Ranges of alpha and beta particles	Demonstration
I-8	Moderation and absorption of neutrons	Demonstration
I-9	Measurement of half value thickness (HVT) with the different absorbent materials	Laboratory exercise
I-10	Demonstration of backscattering of beta radiation	Demonstration
I-11	Demonstration of absorption of beta or gamma radiation within sources of different thickness ('self-absorption')	Demonstration
I-12	Determination of maximum energy levels of beta radiation by absorption	Laboratory exercise

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4.2. PART II: QUANTITIES AND MEASUREMENTS

Objective: To provide the students with an understanding of the radiometric, dosimetric and operational quantities of radiation protection and their measurement units, enabling them to carry out related calculations. To provide the students with practical experience to set up and operate different types of radiation detectors, recognize their operating principles, characteristics and limitations and analyze and interpret the measurement data.

4.2.1. Content

Module	Content	Learning Objective (No.)
II.1. Quantities and units	**Radiometric quantities and interaction coefficients**	LO.II.1.01
	Radiation field; fluence (rate); energy fluence (rate); cross section; mass attenuation coefficient; mass stopping power	LO.II.1.02 LO.II.1.03
	Dosimetric quantities	LO.II.1.04
	Exposure (rate); kerma (rate); concepts of dosimetry: energy imparted; lineal energy; absorbed dose (rate); linear energy transfer (LET); organ dose	
	Radiation protection and operational quantities	
	Radiation weighting factor w_R; equivalent dose; tissue weighting factor w_T; effective dose; aligned and expanded field; personal dose equivalent H_p (0.07) and $H_p(10)$; ambient dose equivalent H*(d) and directional dose equivalent (H'(d)). Intake and committed doses	
II.2. Radiometric and dosimetric calculations and measurements	**Radiometric and dosimetric calculations**	LO.II.2.01
	Relationship between fluence, kerma and absorbed dose; electronic equilibrium; air kerma rate constant; calculation of kerma and absorbed dose	LO.II.2.02 LO.II.2.03
	Bragg-Gray cavity principle; measurement of absorbed dose with ionization in gas filled cavity; electronic equilibrium; composition of homogeneous cavity; large cavity; small cavity; recombination effects; correction factors for determination of absorbed dose to water in photon and electron beams	LO.II.2.04 LO.II.2.05
	Point sources, plane sources, and volume sources; absorption and scattering in air and in the body; attenuation of primary radiation and build-up of secondary radiation; influence of geometry	
	Calculation of dose from neutron sources	

Module	Content	Learning Objective (No.)
II.3. Principles of radiation detection and measurement	**Detectors** General properties of radiation detectors; simplified detector model, modes of operation; energy and efficiency (geometric and intrinsic) calibration; background, geometry, statistics; pulse counting scalers and rate meters; discriminators; tissue equivalence; resolution; pulse height analysis - coincidence and anticoincidence; pulse shape analysis; dead-time correction; computer analysis of spectra Detectors used for radiation protection purpose: principle of functioning, properties, operational features, main associated electronic components, measurement applications Gas filled detectors. Ionization chambers with current measurements; pressure ionization chamber; extrapolation chambers; proportional chambers; GM tubes Scintillation detectors (solid and liquid scintillators), semiconductor detectors, photographic emulsions, thermoluminescent detectors, nuclear track detectors, neutron detectors, detectors using (n,γ) or (n,p) reactions, imaging detectors **Comparison of the various types of detectors for appropriate measurement purposes**	LO.II.3.01 LO.II.3.02 LO.II.3.03 LO.II.3.04

4.2.2. Learning Objectives

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
II.1. Quantities and units	LO.II.1.01	explain the concepts of radiation field and fluence.
	LO.II.1.02	explain the dosimetric quantities exposure, kerma and absorbed dose and the associated units.
	LO.II.1.03	explain the quantities equivalent dose, effective dose, committed dose, committed effective dose.
	LO.II.1.04	apply the operational quantities ambient, directional and personal dose equivalent.
II.2. Radiometric and dosimetric calculations and measurements	LO.II.2.01	explain how radiation dose rate varies with the distance from sources of different geometries.
	LO.II.2.02	apply the inverse square law for radiation emissions

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		from a point source.
	LO.II.2.03	apply the concepts of attenuation and build up in practical scenarios.
	LO.II.2.04	describe the potential exposure issues associated with scatter and “skyshine”.
	LO.II.2.05	calculate doses from neutrons in a range of scenarios.
II.3. Principles of radiation detection and measurement	LO.II.3.01	describe the general principles of radiation detection and understand the concepts of energy efficiency, resolution and limit of detection.
	LO.II.3.02	explain the principles and operation of ionization chambers, Geiger–Müller tubes and scintillation detectors.
	LO.II.3.03	choose the appropriate detector for a given radiation field.
	LO.II.3.04	describe the different types of personal dosimeters (film, thermoluminescent, optically stimulated luminescence, electronic).

4.2.3. Practical exercise

No.	Practical exercise	Type
II-1.	Demonstration of each type of portable monitor for alpha, beta, gamma and neutron radiations and explanation of the respective applications; use and consultation of equipment manuals	Demonstration
II-2.	Calculational exercises on quantities	Exercises
II-3.	Determination of characteristics of Geiger–Müller detectors: counting rate versus voltage curve; response to different radiation energies	Laboratory exercise
II-4.	Use of a low background Geiger–Müller/scintillator system for measurement of low activity beta emitting sources	Laboratory exercise
II-5.	Calibration of a gamma scintillation spectrometer or semiconductor spectrometer in terms of energy and activity	Laboratory exercise
II-6.	Analysis of a complex gamma spectrum using semiconductor detectors	Laboratory exercise

II-7.	Calibration of an alpha spectrometry system in terms of energy and activity	Laboratory exercise
II-7a.	Calibration of beta spectrometer by maximum energy of the spectra	Laboratory exercise
II-8	Reading of photographic films for individual dosimetry that have been exposed to different types of radiation at different energies	Demonstration
II-9	Reading of thermoluminescent dosimeters	Demonstration
II-10.	Making measurements with track etching systems	Demonstration
II-11.	Making measurements of low activity of tritium and carbon-14 by liquid scintillation counting systems	Laboratory exercise
II-12.	Neutron detection and spectrometry using thermal neutron detectors and polyethylene moderator spheres	Laboratory exercise
II-13.	Identification of unknown radionuclides	Laboratory exercise

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4.3. PART III: BIOLOGICAL EFFECTS OF IONIZING RADIATION

Objective: To provide the students with an awareness of the effects of radiation at the molecular and cellular levels and an understanding of the tissue reactions that can result in stochastic and deterministic health effects. They will be introduced to the models used for estimating risk coefficients for stochastic effects.

4.3.1. Content

Module	Content	Learning Objective (No.)
III.1. Effects of radiation at the molecular and the cellular level	**Review of cell biology** Basic concept of cell; cell structure; functions of different organelles; cell cycle; types of cell division; types of activities during cell division The structure of chromosomes, DNA and RNA; DNA replication; DNA transcription; point mutations **Effects of radiation on cells. Phases of damage and modifying factors** Breakage of chemical bonds by excitation and ionization; biologically important elements; direct and indirect effects of radiation: generation of free radicals, interaction with DNA; interaction with other cell constituents. DNA damage response and repair; chromosome breaks; mitosis; mitotic dysfunction; consequences of cell damage; cell death; consequences of cell death; epigenetic responses to radiation; cell necrosis; apoptosis, cellular signalling; cell sensitivity; Relative Biological Effectiveness (RBE); adaptive responses; modifying factors. Biological indicator of dose: chromosome aberrations, biological dosimetry, micronuclei (MN) assay, Electron Spin Resonance (ESR).	LO.III.1.01 LO.III.1.02 LO.III.1.03 LO.III.1.04 LO.III.1.05 LO.III.1.06 LO.III.1.07
III.2. Deterministic Effects	**Effects of high doses** Tissue and organ reactions; cell survival curves; early and late reactions in tissues and organs; general dose-response curve; threshold; severity; acute radiation syndrome; effect of radiations on hematopoietic system, gastrointestinal tract, and cardio-neurovascular dysfunction; lethal dose; effect of local irradiation: to skin and its structures, thyroid, lung, eye lens, gonads; threshold doses; effect of fractionation and dose rate Case histories (accidental exposures)	LO.III.2.01 LO.III.2.02 LO.III.2.03 LO.III.2.04 LO.III.2.05 LO.III.2.06 LO.III.2.07 LO.III.2.08 LO.III.2.09

Module	Content	Learning Objective (No.)
III.3. Stochastic somatic effects	**Tumorigenesis (also oncogenesis or carcinogenesis)** Mechanisms of radiation tumorigenesis; sources of data: animal models of radiation tumorigenesis, atomic bomb survivors, dial painters, medical exposures, miners, and others **Dose-response relationship** Absolute and relative risk models; dose and dose rate effectiveness factors (DDREF); radiation-associated human tumors; genetic susceptibility to cancer; hereditary; estimation of cancer risk from epidemiological data; risk coefficients; radiation detriment, and tissue weighting factors; fatal and non- fatal cancers; ICRP risk factors	LO.III.3.01 LO.III.3.02 LO.III.3.03
III.4. Stochastic hereditary effects	**Hereditary effects** Elementary genetics; natural mutations; chromosomal and gene mutations; sources of data: men and animals; concept of doubling dose; risk coefficients for genetic effects	LO.III.4.01 LO.III.4.02 LO.III.4.03
III.5. Effects on the embryo and foetus	**Radiation effects** Basic embryogenesis; tissue reactions: sensitivity at different stages of development; malformations; brain development and retardation; stochastic effects: induction of leukemia and solid cancers	LO.III.5.01 LO.III.5.02
III.6. Epidemiological studies and issues	**Epidemiological studies** Statistical requirements, current types of studies; methods of sampling to establish cohorts; association and confounding factors; power and precision; prospects and pitfalls	LO.III.6.01 LO.III.6.02 LO.III.6.03
III.7. The concept of radiation detriment	**Radiation detriment** Need for an aggregated measure of harm; radiation weighting factor w_R; tissue weighting factor w_T, effective dose; concept of radiation detriment, collective dose; approach adopted by ICRP; risk comparison	LO.III.7.01 LO.III.7.02 LO.III.7.03

4.3.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
III.1. Effects of radiation at the molecular and the cellular level	LO.III.1.01	explain the concept and structure of cells.
	LO.III.1.02	describe the cell cycle and the process of division.
	LO.III.1.03	describe the DNA and chromosomal structures.
	LO.III.1.04	explain the mechanisms by which ionizing radiation damages DNA and know the major types of damage.
	LO.III.1.05	describe the DNA repair processes.
	LO.III.1.06	describe the evolutionary phases of radiation induced damage in an organism.
	LO.III.1.07	explain the factors that influence cellular and organ/tissue radiosensitivity.
III.2. Deterministic Effects	LO.III.2.01	define tissues reactions and distinguish early and late reactions in tissues and organs.
	LO.III.2.02	describe the factors that influence radiation sensitivity.
	LO.III.2.03	describe the causes of Acute Radiation Syndrome and how it is characterized.
	LO.III.2.04	list the main Acute Radiation Syndromes.
	LO.III.2.05	give an overview of hematopoiesis and the influence of ionizing radiation on the hematopoietic system.
	LO.III.2.06	describe, in general terms, the two categories of effects of ionizing radiation on gastrointestinal physiology.
	LO.III.2.07	summarize cardio-neurovascular dysfunction in lethal irradiation.
	LO.III.2.08	explain what is meant by “localized” radiation exposure and the possible consequences of such exposure.
	LO.III.2.09	explain what characterizes Cutaneous Radiation Syndrome (CRS).
III.3. Stochastic Somatic effects	LO.III.3.01	explain what is meant by a “stochastic effect” of ionizing radiation and summarize the relative risk of ionizing radiation for carcinogenesis.
	LO.III.3.02	summarize the early stages, and mechanisms, of oncogenesis and the main sources of data for the effects of radiation exposure on humans.
	LO.III.3.03	explain the concept of a risk factor.
III.4. Stochastic hereditary	LO.III.4.01	explain the difference between somatic and hereditary effects of exposure to ionizing radiation and describe the

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
effects		sources of data for hereditary effects in humans.
	LO.III.4.02	summarize the causes of hereditary effects.
	LO.III.4.03	provide an overview risk coefficient for hereditary effects and appropriate data resources.
III.5. Effects on the embryo and foetus	LO.III.5.01	summarize basic embryology and the varying sensitivity of the embryo and foetus at different stages of development.
	LO.III.5.02	explain the possible effects of prenatal exposure.
III.6. Epidemiological studies and issues	LO.III.6.01	explain how epidemiology is used in radiation protection.
	LO.III.6.02	describe epidemiological parameters.
	LO.III.6.03	give an overview of several examples of epidemiological studies.
III.7. The concept of radiation detriment	LO.III.7.01	explain the concepts of tissue weighting factor, effective dose, and collective dose.
	LO.III.7.02	summarize the components of health detriment associated with stochastic effects.
	LO.III.7.03	specify the current dose limits for both occupational and public exposure and the rationale behind the values set.

4.3.3. Practical exercise

No.	Practical exercise	Type
III-1	Biological dosimetry	Demonstration or case study
III-2	Interpretation of epidemiological data	Case study
III-3	Assessment of the risks associated with doses	Case study

4.3.4. Bibliography to Part III

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- Heritable Effects of Radiation. 2001 Report to the General Assembly with Scientific Annex, United Nations, New York (2001).

- Summary of low-dose radiation effects on health, 2010 Report to the General Assembly with Scientific Annex, United Nations, New York (2010).

4.4. PART IV: THE INTERNATIONAL SYSTEM OF RADIATION PROTECTION AND THE REGULATORY FRAMEWORK

Objective: To provide the students with an understanding of the role played by international organizations in radiation protection, including the ICRP's recommendations on the international system of radiological protection. To provide an overview of the relevant IAEA Safety Standards, including the main components of the legal and regulatory framework for safety, the relevant regulatory control measures, as well as the main principles of safety culture and building competence in radiation safety.

4.4.1. Content

Module	Content	Learning Objective (No.)
IV.1. International organizations	**The role of International organizations in Radiation Protection** International Atomic Energy Agency (IAEA) International Commission on Radiological Protection (ICRP) International Commission on Radiation Units and Measurements (ICRU) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) International Labour Organisation (ILO) World Health Organization (WHO) Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) Food and Agriculture Organization of the United Nations (FAO) OECD Nuclear Energy Agency (OECD/NEA) Pan American Health Organization (PAHO) United Nations Environmental Program (UNEP) Other organizations: European Atomic Energy Community (EURATOM), International Organization for Standardization (ISO), International Source Suppliers and Producers Association (ISSPA), World Nuclear Association (WNA)	LO.IV.1.01
IV.2. Framework of radiation protection	**Relevant organizations and their role** The contribution of UNSCEAR scientific data; ICRP recommendations; International Atomic Energy Agency: establishment and implementation of safety standards, legally binding instruments, conventions	LO.IV.2.01 LO.IV.2.02 LO.IV.2.03
IV.3. ICRP's recommendations	**Introduction to ICRP's recommendations** Structure and aims of the recommendations; structure of the system of protection; scope of the recommendations;	LO.IV.3.01 LO.IV.3.02

Module	Content	Learning Objective (No.)
	exclusion and exemption	LO.IV.3.03
	The system of radiological protection of humans	
	Types of exposure situations; categories of exposure, the identification of the exposed individuals; levels of radiological protection	
	The principles of radiological protection	
	Justification; optimisation of protection; dose constraints and reference levels; dose limits	
	Medical exposure of patients	
	Justification for medical exposure of patients; optimisation of protection for patient doses in medical exposures	
	Protection of the environment	
	The objective of radiological protection of the environment; reference animals and plants	
IV.4. IAEA's Safety Fundamentals	**Safety objective and principles**	LO.IV.4.01
	Safety Fundamentals: the fundamental safety objective, the associated safety principles (intent and purpose)	
IV.5. Governmental, legal and regulatory framework for safety	**Legislative framework**	LO.IV.5.01
	Scope of basic legal framework: statutory base; enabling legislation	LO.IV.5.02
		LO.IV.5.03
	Responsibilities and functions of the government	LO.IV.5.04
	National policy and strategy	LO.IV.5.05
	Establishment of a framework for safety	LO.IV.5.06
	Establishment of a regulatory body, independence of the regulatory body	LO.IV.5.07
	Prime responsibility for safety, compliance with regulations and responsibility for safety	
	Coordination of different authorities with responsibilities for safety within the regulatory framework for safety	
	The global safety regime	
	International obligations and arrangements for international cooperation	
	Sharing of operating experience and regulatory experience	
	Responsibilities and functions of the regulatory body	
	Organizational structure of the regulatory body and allocation of resources; effective independence in the performance of regulatory functions	

Module	Content	Learning Objective (No.)
	Staffing and competence of the regulatory body	
	The management system of the regulatory body	
	Liaison with advisory bodies, support organizations and authorized parties	
	Stability and consistency of regulatory control	
	Authorization of facilities and activities by the regulatory body; demonstration of safety for the authorization of facilities and activities	
	Review and assessment of information relevant to safety; graded approach to review and assessment of a facility or an activity	
	Inspection of facilities and activities; types of inspection of facilities and activities; graded approach to inspections of facilities and activities	
	Establishment of an enforcement policy	
	Requiring of corrective action by authorized parties	
	Regulations and guides; review of regulations and guides; promotion of regulations and guides to interested parties	
	Safety related records	
	Communication and consultation with interested parties	
IV.6. IAEA Basic Safety Standards	**Introduction to Basic Safety Standards**	LO.IV.6.01
	Background; objective; scope; structure	LO.IV.6.02
	General requirements for protection and safety	LO.IV.6.03
	Application of the principles of radiation protection	LO.IV.6.04
	Establishment of a legal and regulatory framework	
	Responsibilities of the regulatory body	
	Responsibilities of other parties	
	Management requirements	
IV.7 Assessment of effectiveness of the regulatory programmes	**Management and assessment of the effectiveness of the Regulatory Program**	LO.IV.7.01 LO.IV.7.02
	Management system; collection and analysis of program data; program performance criteria	
	Levels of program assessment	
	Methodology to assess the effectiveness: performance indicators, performance criteria; peer review	
IV.8 Safety	**Implementation of requirements for the safety**	LO.IV.8.01

Module	Content	Learning Objective (No.)
assessment for facilities and activities	**assessment** Safety assessment process Graded approach to safety assessment Management use and maintenance of the safety assessment Methodology to assess the effectiveness; possible radiation risk, safety functions, site characteristics, provision for radiation protection, engineering aspect, human factors. Defence in depth and safety margins. Safety analysis: deterministic/ probabilistic analysis, criteria for judging safety, uncertainty and sensitivity analysis, use of operating experience data. Investigations of accidents, incidents and abnormal exposures and follow-up with corrective action. Lessons learned from experience, performance indicators, performance criteria; peer review	
IV.9. Safety and security of radioactive sources	**Code of Conduct on the safety and security of radioactive sources** Scope and objectives Basic principles: legislation and regulations; regulatory body; import and export of radioactive sources; role of the IAEA Guidance on import, export, transport of radioactive sources, national inventory of radiation sources; recovery of orphan sources **IAEA's tool in support of regulatory activities** Introduction to Regulatory Authority Information System (RAIS)	LO.IV.9.01 LO.IV.9.02
IV.10 Safety culture and building competence in radiation safety	**Safety culture of staff at all levels** Priority to safety: policies, procedures; responsibilities; the lines of authority for making decisions; organizational arrangements; communication lines; safety culture indicators; examples of safety culture **National strategy for education and training in radiation, transport and waste safety** Legal framework: national policy and strategy for safety Relevant stakeholders National committees for establishing a national strategy for education and training and for monitoring its implementation Analysis of education and training needs	LO.IV.10.01 LO.IV.10.02

Module	Content	Learning Objective (No.)
	Design of the national education and training programme Development and implementation of the national education and training programme Evaluation of the national education and training programme	

4.4.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
IV.1. International organizations	LO.IV.1.01	summarize the mandates of the international organizations and their roles in radiation protection.
IV.2. Framework of radiation protection	LO.IV.2.01	describe the role of UNSCEAR, ICRP and IAEA within the framework of radiation protection.
	LO.IV.2.02	explain the different types of IAEA Safety Standards and their hierarchy.
	LO.IV.2.03	explain the difference between IAEA binding and non-binding legal instruments.
IV.3. ICRP's recommendations	LO.IV.3.01	summarize the recommendations of ICRP Publication 103.
	LO.IV.3.02	describe the system of radiological protection and the types and categories of exposure.
	LO.IV.3.03	explain the basic principles of radiation protection.
IV.4. IAEA's Safety Fundamentals	LO.IV.4.01	describe the fundamental safety objective and the associated safety principles of the IAEA Fundamental Safety Principles.
IV.5. Governmental, legal and regulatory framework for safety	LO.IV.5.01	explain the main responsibilities and functions of the government.
	LO.IV.5.02	explain the main responsibilities and functions of the regulatory authority.
	LO.IV.5.03	summarize the elements of a radiation safety regulatory infrastructure.
	LO.IV.5.04	explain the different types of authorizations of a facility or activity.
	LO.IV.5.05	explain the purpose of the review and assessment of a facility or activity.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.IV.5.06	explain the purpose of the review of a facility or activity.
	LO.IV.5.07	describe the application of the concept of the graded approach.
IV.6. Introduction to IAEA's Basic Safety Standards	LO.IV.6.01	state the objective and scope of the IAEA BSS.
	LO.IV.6.02	explain the types of exposure situation and the categories of exposure.
	LO.IV.6.03	explain the division of responsibilities for radiation protection between the government, the regulatory body and other relevant parties.
	LO.IV.6.04	describe the management requirements for protection and safety.
IV.7 Assessment of effectiveness of the regulatory programmes	LO.IV.7.01	explain the main element of a management system.
	LO.IV.7.02	list the main performance indicators for regulatory activities.
IV.8 Safety assessment for facilities and activities	LO.IV.8.01	describe the main elements of the process for safety assessment.
IV.9. Safety and security of radioactive sources	LO.IV.9.01	state the requirements of the Code of Conduct.
	LO.IV.9.02.	explain the purpose of the use of to Regulatory Authority Information System (RAIS).
IV.10 Safety culture and building competence in radiation safety	LO.IV.10.01	list the main attributes to a strong safety culture.
	LO.IV.10.02	explain the concept of a national strategy education and training in radiation, transport and waste safety.

4.4.3. Practical exercise

No.	Practical exercise	Type
IV-1	Preparation of a conceptual regulatory framework for a country with a defined type and number of radiation sources	Case study

IV-2	Use of computer aided materials for an information system for a regulatory authority (including the IAEA Regulatory Authority Information System, RAIS)	Case study
IV-3	Study of the licensing process for an industrial or a medical practice	Case study
IV-4	Conduct of a safety review for a license application for an industrial radiography facility or other type of practice	Case study
IV-5	Evaluation of an application for the use of radioactive sources in smoke detectors or other consumer product (the principle of justification being taken into account)	Case study
IV-6.	Preparation of a press release by a regulatory authority on a topical issue	Case study
IV-7	Checklist for an inspection exercise to an industrial irradiator facility	Case study

4.4.4. Bibliography to Part IV

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4.5. PART V: ASSESSMENT OF EXTERNAL AND INTERNAL EXPOSURES (OTHER THAN MEDICAL)

Objective: To enable the students to measure, monitor, calculate and interpret the doses to individuals arising from external exposure, including designing a monitoring programme for individual dose assessment and for the workplace. To enable the participants to use appropriate techniques to assess the doses to individuals arising from intakes of radionuclides in simple cases of internal contamination.

4.5.1. Content

Module	Content	Learning Objective (No.)
V.1. Assessment of occupational exposure due to external sources of radiation	**The monitoring programmes for individual dose assessment** Design of monitoring programmes Personal dosimetry Assessments of effective dose in various external exposure conditions: practical approximations Integrating personal dosimeters (TLD, film, condenser chambers, etc.) calibrated for personal dose equivalent; use of electronic personal dosimeters; performance requirements for personal dosimeter Whole body, extremities and skin dosimetry Routine, special, accidental exposure assessment Analysis of uncertainties: (Type A) inhomogeneity of detector sensitivity readings due to limited sensitivity and background, variability of detector readings at zero dose; (Type B) energy dependence, directional dependence, non-linearity of the response, fading due to temperature and humidity, effects due to exposure to light, or to other types of ionizing radiation, mechanical shock, calibration errors, variation in local natural background **Dose reconstruction techniques** Accident dosimetry; cytogenetic; EPR; TLD dose construction with Alderson phantoms; criticality dosimetry **Monitoring programme for the work place** Routine, task related and special monitoring; fixed and portable monitors; monitoring for work planning purposes; monitoring to detect changes in the working environment; monitoring systems for radiation fields, for surfaces; use of ambient dose equivalent and directional dose equivalent **Interpretation of measurements**	LO.V.1.01 LO.V.1.02 LO.V.1.03 LO.V.1.04 LO.V.1.05 LO.V.1.06 LO.V.1.07 LO.V.1.08

Module	Content	Learning Objective (No.)
	Recording levels; evaluation of doses to whole body, extremities and skin; calculation of the effective dose caused by external exposure; routine, task related and special monitoring by external exposure; routine, task related and special monitoring	
	Calibration	
	Calibration of radiation beam; Bragg-Gray cavity principle; measurement of absorbed dose with ionization in gas filled cavity; electronic equilibrium; composition of homogeneous cavity; large cavity; small cavity; recombination effects; correction factors for determination of absorbed dose to water in photon and electron beams	
	Primary and secondary standards; sources used for calibration; routine testing of equipment, performance testing, type testing	
	Quality management system	
	Quality control procedures; intercomparison; proficiency test	
	Primary and secondary standards; sources used for calibration; routine testing of equipment, performance testing, type testing	
V.2. Assessment of occupational exposure due to intakes of radionuclides	**Modes of intake**	LO.V.2.01
	Inhalation (particle sizes, AMAD, determination of size distribution of aerosols), ingestion and absorption through skin or wounds	LO.V.2.02 LO.V.2.03
	Special case of tritiated water and vapour: intake through skin of splashed water and of vapour and respiratory intake	LO.V.2.04 LO.V.2.05
	Intakes of radionuclides by workers; intakes of radionuclides by members of the public	
	Introduction to biokinetic models used by ICRP	
	Quantitative aspects of intake; uptake into blood and transport to various organs; deposition in organs	
	Modelling by compartment models; relationships between compartments as one basis for specifying monitoring procedures; retention and elimination; exponential compartments, biological half-life and effective half-life	
	Biokinetic models for internal exposure assessment: ICRP models (reference individual) and relevant parameters; human respiratory model (HRTM); human alimentary tract model (HATM); entry through wounds and intact skin;	

Module	Content	Learning Objective (No.)
	overview on systemic models	
	Monitoring programme	
	Monitoring programme: need, design of a routine monitoring programme, methods of measurement, frequency of monitoring, reference levels, special monitoring	
	Workplace monitoring: surface and air monitoring; the concept of Derived Air Concentration (DAC)	
	Individual monitoring - direct methods: principles; measurement geometry: whole body, thyroid, lung; methods of detection; measurement procedures	
	Individual monitoring - indirect methods: biological samples (urine, faeces, breath, blood, nose blows, tissue sample); normalization of samples; physical samples (air samples, surface samples); handling methods; methods of analysis (radiochemical separation, detection)	
	Performance requirements for detection systems in internal dosimetry	
	Calculation of committed effective dose	
	Committed effective dose; committed effective dose per unit of intake; committed effective dose per unit intake in the standard adult and as a function of age; consistency of the measurements with biokinetic models	
	Calculation of the organ contribution to the effective dose	
	Primary and secondary limits; special case of radon and radon progeny	
	Introduction to guidelines (EURADOS) and software for internal dose calculation (characteristics and availability)	
	Calibration	
	Calibration for direct and indirect measurement techniques	
	Quality management system	
	Quality control procedures; intercomparison; proficiency test	
V.3. Assessment of the public exposure	**Basic concepts**	LO.V.3.01
	Exposure pathways; critical groups and representative person; generic methods for assessing doses; uncertainties in dose assessments	
	Assessment of the public exposure due to radioactive discharges to the environment	

Module	Content	Learning Objective (No.)
	Monitoring strategy: monitoring at source and environmental monitoring; sampling technics and monitoring quantities; interpretation of monitoring results Examples of application to different sources: medical facilities, radioisotope production plants, waste management facilities, nuclear installations **Assessment of the public exposure due to other scenarios** Scenarios for public exposure and identification of parameters important for the assessment. Graded approach to public exposure assessment	

4.5.2. Learning Objectives

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
V.1. Assessment of occupational exposure due to external sources of radiation	LO.V.1.01	design an individual monitoring programme.
	LO.V.1.02	describe the different types of personal dosimeter and under what circumstances each is suitable.
	LO.V.1.03	interpret dosimeter results.
	LO.V.1.04	identify the circumstances where dosimeter results may not provide an adequate estimate of dose.
	LO.V.1.05	explain the concepts behind acceptable accuracy and uncertainty, and be able to apply these concepts to determining the uncertainties and detection limits for practical dosimetry systems.
	LO.V.1.06	specify the measurement techniques that can be used for accident dosimetry.
	LO.V.1.07	describe basic workplace monitoring principles, and be able to determine monitoring methods that can be used as part of the program for assessment of exposure due to external radiation and intake of radionuclides.
	LO.V.1.08	describe radiation protection instrument calibration and test techniques and requirements.
V.2. Assessment of occupational exposure due to intakes of radionuclides	LO.V.2.01	summarize the principles involved in development and use of biokinetic models, as well as the need for individual specific models when intakes approach relevant limits.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.V.2.02	describe the principles and criteria used to determine the need for monitoring for internal exposure assessment.
	LO.V.2.03	explain the principles and techniques that are used for the direct measurement of radioactive material deposited in the human body.
	LO.V.2.04	describe indirect monitoring principles and limitations and know how to select the appropriate measurement techniques and assessment methods.
	LO.V.2.05	evaluate information provided by a dosimeter or a measurement of intake, with special emphasis on the indication that a high or unusual exposure occurred, and to identify those steps that may need to be taken.
V.3. Assessment of the public exposure	LO.V.3.01	specify methods to assess dose to the public.

4.5.3. Practical exercise

No	Practical exercise	Type
V-1.	Development of a routine monitoring programme (internal and external exposures)	Case study
V-2.	Interpretation of measurements made with a personal dosimeter	Case study
V-3.	Demonstration of practical monitoring systems for areas, surfaces and air	Demonstration
V-4.	Calibration of different dosimeters in secondary standard dosimetry laboratory (SSDL)	Technical visit to a SSDL
V-5.	Measurement of the radionuclide content of the body by whole body counting	Technical visit to a whole body counting facility
V-6.	Measurement of radionuclides using bioassay techniques – associated quality assurance and quality control procedures	Laboratory exercise
V-7	Calculation of internal doses using ICRP models for acute contamination with specific radionuclide	Exercises

V-8	Thyroid monitoring	Laboratory exercise
V-9	Radon/Thoron monitoring using passive and active methods	Laboratory exercise

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4.6. PART VI: PLANNED EXPOSURE SITUATIONS - GENERIC REQUIREMENTS

Objective: To provide the students with an understanding of the generic requirements for radiation protection with respect to planned exposure situations for all categories of exposure (occupational, public and medical exposures).

4.6.1. Content

Module	Content	Learning Objective (No.)
VI.1 Generic requirements for planned exposure situations	**Planned exposure situation**	LO.VI.1.01
	Introduction to the planned exposure situation	LO.VI.1.02
	Scope of the requirements	LO.VI.1.03
	Field of application of the requirements for planned exposure situations	LO.VI.1.04
		LO.VI.1.05
	Graded approach	LO.VI.1.06
	Exemption and clearance (criteria for exemption and clearance); notification and authorization (registration or licensing)	LO.VI.1.07
		LO.VI.1.08
	Justification of practices	LO.VI.1.09
	Responsibilities; practices deemed not to be justified; justification of human imaging for purposes other than medical diagnosis or treatment	
	Optimization of protection and safety	
	Responsibilities; establishment of dose and risk constraints; optimization of occupational and public exposure; time, distance and shielding; ALARA, minimum number of sources; protection against contamination; housekeeping; hierarchy in protective measures infrastructure (design) and procedures	LO.VI.1.10 LO.VI.1.11
	Dose limits	
	Responsibilities; establishment of dose limits for public exposure and occupational exposure. Specified dose limits for public and occupational exposures resulting from planned exposure situations	
	Responsibilities of the relevant parties	
	Protection and safety in planned exposure situations; safety assessment for facilities or activities; monitoring for verification of compliance; prevention and mitigation of accidents; potential exposures; investigations of abnormal circumstances and feedback of information on operating experience; safety of radiation generators and radioactive	

Module	Content	Learning Objective (No.)
	sources; human imaging for purposes other than medical to be subject to the system of protection and safety	
VI.2 Requirements for occupational exposure in planned exposure situations	**Scope of the requirements**	LO.VI.2.01
	Field of application of occupational exposure requirements in planned exposure situations	LO.VI.2.02
		LO.VI.2.03
	Requirements and responsibilities of the relevant parties, specific to occupational exposure	LO.VI.2.04
		LO.VI.2.05
	Responsibilities of the regulatory body in respect of the occupational exposure: optimization, dose limits; monitoring and recording of occupational exposure	LO.VI.2.06
		LO.VI.2.07
	Responsibilities of employers, registrants and licensees, workers' obligations and duties	LO.VI.2.08
	Radiation protection programme	
	Prior radiological evaluation and safety assessment; scope and structure of the radiation protection programme; responsibility and commitment of registrants, licensees and employers; responsibility of workers and others at the workplace; classification of areas (controlled areas, supervised areas); local rules and personal protective equipment; individual monitoring; monitoring of the workplace; radiation protection organization; special administrative arrangements; infrastructure; role of the radiation protection officer; role of the qualified expert; training; lines of communication (internal, between employers, with regulatory authority); safety culture; quality assurance; emergency preparedness	LO.VI.2.09 LO.VI.2.10 LO.VI.2.11 LO.VI.2.12 LO.VI.2.13 LO.VI.2.14 LO.VI.2.15
	Assessment of the occupational exposure and health surveillance of workers	
	Exposure assessment; exposure records	
	Health surveillance: objectives; responsibilities; medical examination of workers; counselling; management of overexposed workers; medical records	LO.VI.2.16 LO.VI.2.17
	Safety and security of sources	LO.VI.2.18
	Physical protection of sources and waste; leak testing; signs and tagging; conditioning; shielding; storage; decommissioning; emergency procedures	LO.VI.2.19 LO.VI.2.20
	Features of facility design	LO.VI.2.21 LO.VI.2.22
	Design feature (considering also scattering effects); ventilation system; shielding calculation; safety interlocks; remote handling equipment; fume hoods; hot cells; glove boxes; changing room; physical barriers; storage facilities;	LO.VI.2.23 LO.VI.2.24

Module	Content	Learning Objective (No.)
	liquid effluent pipeline and decay control; fixed radiation monitors; warning signs; quality assurance; commissioning survey and regulatory review	LO.VI.2.25 LO.VI.2.26
	Personal protection	LO.VI.2.27
	Protective clothing; respiratory protection; contamination control; decontamination of surfaces and use of personal protective equipment; administrative and procedural control	LO.VI.2.28 LO.VI.2.29
	Classification of areas	
	Controlled and supervised areas; policies and procedures	
	Local rules and supervision; compliance with dose limits; record keeping and reporting	
	Quality assurance	
	Establishment of quality management system: routine assessment of management and technical performance; audits and review; self-assessment; feedback for improvements	
	Information, instruction and training	
	Provision of adequate information, instruction and training for protection and safety of workers; categories of persons to be trained; development of competence through training (basic, initial and refresh training); training methods; systematic approach to training	
	Condition of service	
	Requirements in respect of the service conditions for occupational exposure of workers and safety related issues	
	Special arrangements for workers	
	Female workers; protection of the embryo and foetus; breast-feeding infants, persons under 18 years of age	
VI.3 Requirements for public exposure in planned exposure situations	**Scope of the requirements**	LO.VI.3.01
	Field of application of public exposure requirements in planned exposure situations	LO.VI.3.02 LO.VI.3.03
	Responsibilities of the government and the regulatory body specific to public exposure	LO.VI.3.04 LO.VI.3.05
	Dose and risk constrains; dose limitation; operational limits; provisions when a source within practice could cause public exposure outside the territory	LO.VI.3.06 LO.VI.3.07
	System of protection and safety against public exposure in planned exposure situations	LO.VI.3.08 LO.VI.3.09

Module	Content	Learning Objective (No.)
	Responsibilities of relevant parties in respect of control and optimization of the public exposure; visitors to a controlled area or a supervised area; external exposure and contamination in areas accessible by the public	
	Management of radioactive waste and discharges	
	Responsibilities of relevant parties to manage radioactive waste and discharges of radioactive material to the environment in accordance with the authorization	
	Monitoring and reporting	
	Responsibilities of the relevant parties related to environmental monitoring programmes: records, assessment of doses to the public, verification of compliance with discharge limits, derived environmental reference levels, dose constraints for source related monitoring, dose limits for individual related monitoring; recording of the result; retention of records and reporting, capability to carry out emergency monitoring	
	Consumer products	
	Responsibilities of the relevant parties related to the exemption or authorized use of consumer products by the public; requirements related to: design and construction of the products, legible label information and instruction	
VI.4. Requirements for medical exposure	**Scope of the requirements**	LO.VI.4.01
	Field of application of respect of medical exposure in planned exposure situations	LO.VI.4.02
		LO.VI.4.03
	Responsibilities of government specific to medical exposure	LO.VI.4.04
		LO.VI.4.05
	Responsibilities of the government in respect of the authorization of the relevant parties; diagnostic reference levels, dose constraints (carers and comforters, volunteers in biomedical research); criteria and guidelines for the release of patients undergone therapeutic procedures	LO.VI.4.06
		LO.VI.4.07
		LO.VI.4.08
	Responsibilities of the regulatory body specific to medical exposures	LO.VI.4.09
		LO.VI.4.10
	Responsibility of the regulatory body in respect of health professionals with responsibilities for medical exposure (including radiological medical practitioners, medical physicists, medical radiation technologists and any other health professionals with specific duties in relation to the radiation protection of patients)	
	Responsibilities of registrants and licensees specific to	

Module	Content	Learning Objective (No.)
	medical exposure Appropriate referral; responsibility for ensuring protection and safety; appropriate information of the subject to exposure on the expected benefits and risks **Justification of medical exposure** Generic justification; justification for an individual patient; specific justification for radiological procedures as part of a health screening or as part of a programme of biomedical research **Optimization of protection and safety for medical exposure** Design considerations; operational considerations; calibration; dosimetry of patients; diagnostic reference levels; quality assurance; dose constraints **Pregnant or breast-feeding women** Arrangements for appropriate radiation protection in cases where a woman is or might be pregnant or is breast-feeding **Release of patients after radionuclide therapy** Arrangements for appropriate radiation protection for members of the public and for family members before the release of patients after radionuclide therapy **Unintended and accidental medical exposure** Responsibilities of the registrants and licensees in respect of minimization of the likelihood of unintended or accidental medical exposures; requirements related to the investigation of unintended and accidental exposure **Reviews and records** Periodic radiological reviews at a medical radiation facility; keeping of records	

4.6.2. Learning Objectives

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
VI.1 Generic requirements for planned exposure	LO.VI.1.01	describe all the core requirements in the Basic Safety Standards relating to planned exposure situations and where responsibility for addressing those requirements

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
situations		lies.
	LO.VI.1.02	explain the concept of the “graded approach”.
	LO.VI.1.03	explain the difference between “notification” and “authorization”.
	LO.VI.1.04	describe the concepts of “exemption” and “clearance” and the circumstances under which they apply.
	LO.VI.1.05	explain the hierarchy of justification of practices, optimization of practices and dose limitation.
	LO.VI.1.06	describe the fundamental principles relating to the prevention and mitigation of accidents and the concepts of good engineering practice and defence in depth.
	LO.VI.1.07	explain the requirement for, and importance of, investigation and feedback of information on operating experience.
	LO.VI.1.08	list the specific requirements relating to generators and radioactive sources.
	LO.VI.1.09	summarize the specific requirements relating to human imaging other than for the purposes of medical diagnosis or treatment, or for biomedical research.
	LO.VI.1.10	explain the hierarchy in protective measures.
	LO.VI.1.11	explain the concept of ALARA.
VI.2 Requirements for occupational exposure in planned exposure situations	LO.VI.2.01	identify the planned exposure situations for which the Basic Safety Standards requirements apply in respect of occupational exposure.
	LO.VI.2.02	state the specific responsibilities of the regulatory body with respect to occupational exposures.
	LO.VI.2.03	summarize the requirements for monitoring and recording of occupational exposures.
	LO.VI.2.04	explain the importance of co-operation between employers, registrants and licensees.
	LO.VI.2.05	describe the concept of the radiation protection programme and list the components that make up such a programme.
	LO.VI.2.06	explain what is meant by “classification of areas” and be able to apply the criteria for classification to operational situations.
	LO.VI.2.07	describe the requirements for, and means of, assessing occupational exposures and for health surveillance and

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		the objective of the associated record keeping.
	LO.VI.2.08	state the specific requirements for female workers.
	LO.VI.2.09	develop a radiation protection programme.
	LO.VI.2.10	carry out a safety assessment.
	LO.VI.2.11	describe the role of the qualified expert (in radiation protection).
	LO.VI.2.12	describe the role of the radiation protection officer.
	LO.VI.2.13	develop and implement a workplace monitoring programme.
	LO.VI.2.14	specify suitable health surveillance arrangements for workers who are subject to occupational exposure.
	LO.VI.2.15	describe the health surveillance requirements associated with emergency response scenarios.
	LO.VI.2.16	explain the concept of the physical protection of radioactive sources.
	LO.VI.2.17	carry out a leak test of a sealed radioactive source.
	LO.VI.2.18	specify appropriate radiation warning signs for a facility.
	LO.VI.2.19	assess the suitability of the shielding arrangements for a range of different radiation sources and applications.
	LO.VI.2.20	provide guidance on safety interlock arrangements for a facility.
	LO.VI.2.21	recommend appropriate contamination control arrangements to a range of scenarios.
	LO.VI.2.22	develop an appropriate respiratory protection programme.
	LO.VI.2.23	classify areas as controlled or supervised.
	LO.VI.2.24	develop suitable local rules for a facility.
	LO.VI.2.25	specify the delineation, dosimetry and record keeping requirements for controlled and supervised areas.
	LO.VI.2.26	specify the responsibilities of the government or regulatory body with regard to optimization.
	LO.VI.2.27	explain the concept of dose constraints.
	LO.VI.2.28	list the key elements of a quality assurance programme.
	LO.VI.2.29	apply the systematic approach to the development of training courses.

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
VI.3 Requirements for public exposure in planned exposure situations	LO.VI.3.01	identify the circumstances in which the Basic Safety Standards requirements for public exposure apply in planned exposure situations.
	LO.VI.3.02	summarize the specific responsibilities of the government and regulatory bodies with respect to public exposures in planned situations.
	LO.VI.3.03	describe the general considerations specific to public exposures that must be taken by relevant parties.
	LO.VI.3.04	describe the specific considerations in relation to radioactive waste and discharges.
	LO.VI.3.05	state the specific requirements for monitoring and reporting relating to public exposures in planned exposure situations.
	LO.VI.3.06	specify the objectives and components of an environmental monitoring programme.
	LO.VI.3.07	specify the reporting requirements for environmental monitoring.
	LO.VI.3.08	describe the different environmental monitoring sampling techniques.
	LO.VI.3.09	describe the different objectives of pre-operational, operational and post-operational monitoring programmes.
VI.4. Requirements for medical exposure	LO.VI.4.01	explain what is meant by “medical exposure” and give the general responsibilities of the government and regulatory bodies in respect of such exposures.
	LO.VI.4.02	describe the specific responsibilities of registrants and licensees with respect to medical exposures.
	LO.VI.4.03	explain the criteria for the justification of medical exposures.
	LO.VI.4.04	describe the range of factors that should be considered with respect to optimization of protection in medical exposures.
	LO.VI.4.05	describe the concepts of a) diagnostic reference levels and b) dose constraints and how these should be applied.
	LO.VI.4.06	explain the importance of quality assurance in medical exposures.
	LO.VI.4.07	state the specific requirements for pregnant and breast-feeding women.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.VI.4.08	describe the specific requirements relating to the release of patients after radionuclide therapy.
	LO.VI.4.09	specify the requirements in the event of unintended or accidental exposures.
	LO.VI.4.10	explain the importance of regular reviews and maintenance of records.

4.6.3. Practical exercise

(no suggested practical exercise)

4.6.4. Bibliography to Part VI

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4.7. PART VII: PLANNED EXPOSURE SITUATIONS IN NON-MEDICAL APPLICATIONS

Objective: To provide the students with a good understanding of the practical application of radiation protection principles and concepts in a wide range of planned exposure situations (excluding medical). Students will also be able to develop suitable radiation protection programmes for a wide range of applications.

4.7.1. Content

Module	Content	Learning Objective (No.)
VII.1. Safety in industrial radiography	**Industrial radiography** Overview of industrial radiography; types of exposure devices (gamma radiography sources and containers; X ray radiography equipment; pipe crawler equipment; real time radiography); organizational responsibilities of shielded enclosures; site radiography procedures; storage and transport of sources; safety associated with the equipment maintenance; radiation protection programme: protection of workers; protection of the public; emergency preparedness and response; lessons learned from accidental exposure in industrial radiography, management of disused sources	LO.VII.1.01 LO.VII.1.02 LO.VII.1.03 LO.VII.1.04
VII.2. Safety in industrial irradiators and accelerators	**Industrial irradiators and accelerators** Overview of industrial irradiators and accelerators; organizational responsibilities; basic requirements for safety, specific regulatory requirements; features of facility design; safety associated to the equipment; maintenance; radiation protection programme: protection of the workers; emergency preparedness and response; lessons learned from accidental exposure in industrial irradiators and accelerators; management of disused sources	LO.VII.2.01 LO.VII.2.02 LO.VII.2.03 LO.VII.2.04
VII.3. Safety in the use of nuclear gauges and well logging sources	**Nucleonic gauges and well logging sources** Overview of gauging and well logging devices; organizational responsibilities; basic requirements for safety; safety associated to the equipment; accidents involving nuclear gauge and well logging; lesson learned; radiation protection programme; protection of workers and the public; management of disused sources	LO.VII.3.01 LO.VII.3.02
VII.4. Safety in the use of tracers	**Radiotracers** Overview of tracer uses; organizational responsibilities; basic requirements for safety; radiation protection programme. Control of effluents; protection of workers	LO.VII.4.01

Module	Content	Learning Objective (No.)
	and the public	
VII.5. Safety in radioisotope production plants	**Radioisotope production plants** Overview of radioisotope production plants; organizational responsibilities; basic requirements for safety. Safety associated to the plant; specific regulatory requirements; radiation protection programme. Cyclotron facilities; control of effluents; protection of workers and the public; features of facility design; emergency planning and preparedness; safe transport of radioisotopes	LO.VII.5.01 LO.VII.5.02 LO.VII.5.03 LO.VII.5.04 LO.VII.5.05
VII.6. Safety in nuclear installations	**Nuclear installations** Types of installations: nuclear fuel fabrication plant, nuclear reactor (including critical and subcritical assemblies, research reactor, NPP), spent fuel storage facility, enrichment plant, reprocessing facility; basic requirements for safety; safety features and design principles (redundancy, diversity, physical separation, multiple barrier concept); radiation protection programme; protection of workers and the public, emergency planning and preparedness	LO.VII.6.01 LO.VII.6.02 LO.VII.6.03
VII.7. Safety in mining and processing of raw materials	**Mining and processing of raw materials** Overview of mining and processing of raw materials; basic requirements for safety; regulatory considerations; exclusion, exemption and clearance; remediation; radiation protection programme; engineering controls, e.g. ventilation; protection of workers and the public	LO.VII.7.01 LO.VII.7.02 LO.VII.7.03 LO.VII.7.04 LO.VII.7.05
VII.8. Safe transport of radioactive material	**Safe transport** Regulatory terminology; basic safety concepts: materials and packages; activity limits and material restrictions; package limits and typical contents; material requirements, package requirements and design; material and package test procedures; controls and communications; labels, transport index; fissile material; consignor's and carrier's responsibilities; emergency planning and preparedness; national competent authorities; international model organizations and agreements; international liability and insurance; information services provided by the IAEA; training	LO.VII.8.01 LO.VII.8.02 LO.VII.8.03
VII.9. Safety in radioactive waste management	**Radioactive waste management** Sources of radioactive waste including medical applications, waste types, waste classification, waste characterization. Basic technical management options: dilute and disperse, concentrate and contain, storage for	LO.VII.9.01 LO.VII.9.02 LO.VII.9.03 LO.VII.9.04

Module	Content	Learning Objective (No.)
	decay and clearance from control; waste minimization. Pre-disposal waste management: collection, segregation, treatment, conditioning, secure storage	LO.VII.9.05
	Control of effluents: approach to regulatory control, establishing authorized discharge levels. Radiation protection programmes in place at the various types of waste management facilities. Management of disused sealed sources: technical options and safety aspects. Management of waste from decommissioning. Solid waste disposal: disposal options for different waste types, safety principles and technologies for assuring long term safety, safety assessment methods. Management of waste from uranium and thorium, mining and milling	
	Management of NORM and TENORM waste; clean-up of contaminated areas	
VII.10. Consumer products	**Consumer products**	LO.VII.10.01
	Definition and consideration of particular practices. System for protection and safety of consumer products. Notification and authorization.	LO.VII.10.02 LO.VII.10.03
	Optimization, criteria for exemption from regulatory control. Import, transport and disposal of consumer products. International harmonization of the sale of consumer products to the public	

4.7.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
VII.1. Safety in industrial radiography	LO.VII.1.01	develop a radiation protection programme for industrial radiography in both site radiography and shielded enclosure scenarios.
	LO.VII.1.02	specify the required safety and warning systems for site radiography and radiography in a shielded enclosure.
	LO.VII.1.03	instruct persons on the actions to be followed in the event of an emergency involving a gamma radiography source or an X ray set.
	LO.VII.1.04	specify the vehicle labelling, placarding and documentation requirements for vehicles transporting

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		gamma radiography containers.
VII.2. Safety in industrial irradiators and accelerators	LO.VII.2.01	describe the categorization system for industrial irradiators.
	LO.VII.2.02	summarize the design requirements for industrial irradiators and accelerators.
	LO.VII.2.03	assess the adequacy of the interlock and warning systems installed on industrial irradiators and accelerators.
	LO.VII.2.04	identify reasonably foreseeable accidents or incidents covering industrial irradiators and accelerators, and specify emergency plans to address them.
VII.3. Safety in the use of nuclear gauges and well logging sources	LO.VII.3.01	describe the different types of nuclear gauge used in industry and their methods of operation.
	LO.VII.3.02	summarize the safety and warning systems required for the different categories of gauge.
VII.4. Safety in the use of tracers	LO.VII.4.01	develop a radiation protection programme for the safe use of tracers in a range of scenarios.
VII.5. Safety in radioisotope production plants	LO.VII.5.01	summarize the different processes that are used to produce radioisotopes.
	LO.VII.5.02	describe the radiological hazards associated with the production of radioisotopes.
	LO.VII.5.03	describe control methods for radiological hazards in radioisotope production plants.
	LO.VII.5.04	describe the requirements of a radiation protection programme for radioisotope production facilities.
	LO.VII.5.05	describe the content of emergency plans for radioisotope production plants.
VII.6. Safety in nuclear installations	LO.VII.6.01	describe the different types of nuclear plant and facility.
	LO.VII.6.02	summarize the key radiation protection organizational arrangements.
	LO.VII.6.03	explain the principal safety procedures followed when planning radiation protection work activities in a nuclear installation.
VII.7. Safety in mining and processing of raw	LO.VII.7.01	state which raw materials are subject to regulatory control and which are outside the scope of regulatory control.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
materials	LO.VII.7.02	explain the importance of the graded approach to control operations for the processing of raw materials.
	LO.VII.7.03	design an initial workplace monitoring programme to assess the magnitude of the radiation hazard from raw material processing.
	LO.VII.7.04	specify individual monitoring arrangements, where required, for persons working with raw materials.
	LO.VII.7.05	explain the engineering and administrative protection arrangements that can be used to restrict radiation exposure from raw materials.
VII.8. Safe transport of radioactive material	LO.VII.8.01	specify the packaging requirements and transport labels for a range of radioactive materials.
	LO.VII.8.02	describe the performance tests that different types of packages are required to pass.
	LO.VII.8.03	list the consignor's and consignee's responsibilities.
VII.9. Safety in radioactive waste management	LO.VII.9.01	specify the responsibilities of the licensee/registrant with regard to waste management and disposal.
	LO.VII.9.02	list the waste classifications.
	LO.VII.9.03	describe how to minimise waste.
	LO.VII.9.04	describe the disposal methods for radioactive waste.
	LO.VII.9.05	develop a waste management programme.
VII.10. Consumer products	LO.VII.10.01	define what is a consumer product.
	LO.VII.10.02	list commonly available consumer products and state the radionuclide in each.
	LO.VII.10.03	explain the process of justification and optimization of a type of consumer product.

4.7.3. Practical exercise

No.	Practical exercise	Type
VII-1	Visit to industrial radiography facility	Technical visit
VII-2	Visit to an irradiator or accelerator for industrial or research use	Technical visit

VII-3	Visit to radioisotope production facility	Technical visit
VII-4	Preparation of an organizational chart and highlights of a radiation protection programme in an industrial facility (industrial radiography or irradiator)	Case study
VII-5	Application of the 'as low as reasonably achievable' (ALARA) principle for occupational exposure	Case study
VII-6	Leak testing of sealed sources	Laboratory Exercise
VII-7	Use of personal protective equipment in nuclear installations	Demonstration
VII-8	Choice of a personal dosimeter and monitoring instruments	Demonstration
VII-9	Preparation of a laboratory to work temporarily with unsealed sources	Demonstration
VII-10	Monitoring a workplace for external radiation; selection of instrumentation; interpretation of results	Demonstration
VII-11	Monitoring a workplace for surface and air contamination; use of gross alpha and beta measurements and gamma spectrometry, and of air sampling techniques	Demonstration
VII-12	Decontamination of surfaces	Laboratory Exercise
VII-13	Determination of individual dose due to air contamination	Case study
VII-14	Management of personal dose records, dose reduction measures special monitoring, follow-up measures	Case study
VII-15	Comparison of predicted doses to personnel on the basis of workplace monitoring with the results of individual monitoring in mixed radiation fields	Case study

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4.8. PART VIII: PLANNED EXPOSURE SITUATIONS IN MEDICAL APPLICATIONS

Objective: To provide the students with a general understanding of the application of radiation protection principles in medical applications.

4.8.1. Content

Module	Content	Learning Objective (No.)
VIII.1. General considerations	**General principles**	LO.VIII.1.01
	Medical exposure for diagnostic and treatment purposes; registration of professionals; licensees; role and responsibilities of the radiological medical practitioner, medical physicist and medical radiation technologist	LO.VIII.1.02 LO.VIII.1.03 LO.VIII.1.04
	Training	LO.VIII.1.05
	Workers to be trained; content of the training programmes; updating of programmes; refresher training	LO.VIII.1.06 LO.VIII.1.07
	Unintended and accidental medical exposures	
	Identification and investigation of unintended and accidental medical exposures; reporting to the regulatory body, when appropriate; lessons learned and feedback into operation	
	Records	
	Identification of the information to be recorded related to the type of medical exposure	
VIII.2. Diagnostic radiology and image guided interventional procedures	**Introduction**	LO.VIII.2.01
	Radiation protection principles applicable to diagnostic radiology and image guided interventional procedures	LO.VIII.2.02 LO.VIII.2.03
	Justification	LO.VIII.2.04
	Levels of justification; special cases – pregnancy, paediatric patients; alternative techniques; assessment of the detriment; referral guidelines	LO.VIII.2.05 LO.VIII.2.06
	Optimization	LO.VIII.2.07
	Design considerations for equipment	LO.VIII.2.08
	International requirements or standards (IEC, ISO) for radiation generators; basic technical characteristics; regular review and maintenance	LO.VIII.2.09 LO.VIII.2.10
	Operational considerations	LO.VIII.2.11
	Choice of appropriate equipment; factors affecting patient dose and choice of technique and parameters to deliver the minimum exposure of the patient to fulfil the clinical	LO.VIII.2.12 LO.VIII.2.13 LO.VIII.2.14

Module	Content	Learning Objective (No.)
	purpose; exposure of pregnant women; use of organ shielding	LO.VIII.2.15
	Calibration	LO.VIII.2.16
	Calibration of radiation generators, including quantities, protocols and traceability; calibration of dosimeters	LO.VIII.2.17 LO.VIII.2.18
	Dosimetry of patients	LO.VIII.2.19
	Assessment of typical doses for common radiological procedures and image guided interventional procedures	LO.VIII.2.20 LO.VIII.2.21
	Diagnostic reference levels and dose constraints	LO.VIII.2.22
	Diagnostic reference levels for the patient on the basis of relevant surveys; dose constraints for carers and comforters	LO.VIII.2.23
	QA programme for medical exposures	LO.VIII.2.24
	Organizational elements; acceptance testing and routine testing of equipment; periodic audit and review	LO.VIII.2.25 LO.VIII.2.26
	Unintended and accidental medical exposures	LO.VIII.2.27
	Examples	LO.VIII.2.28
	Control of the occupational and public exposure. Safety assessment, particularities	
	Control of the occupational exposure: particularities related to the design, source of occupational exposure, definition of areas, local rules examples, personnel to be considered occupationally exposed and related dose assessment methods, personal protective equipment, definition of investigation levels, dose restriction. Control of the public exposure: sources of the public exposure, measures to ensure the control of the public exposure (design, control of visitors, signals). Safety assessment: identification of the aspects that have to be considered when doing safety assessment, risks and the possible accidents	
VIII.3. Nuclear medicine: diagnosis and therapy	**Introduction**	LO.VIII.3.01
	Radiation protection principles applicable to nuclear medicine procedures	LO.VIII.3.02 LO.VIII.3.03
	Justification	LO.VIII.3.04
	Levels of justification; special cases – pregnancy, paediatric patients, breastfeeding women; alternative techniques; assessment of the detriment	LO.VIII.3.05 LO.VIII.3.06
	Referral guidelines	LO.VIII.3.07
	Optimization	LO.VIII.3.08
	Design considerations for equipment	LO.VIII.3.09

Module	Content	Learning Objective (No.)
	International requirements or standards (IEC, ISO) for imaging devices; basic technical characteristics of radiation detectors and monitors; regular review and maintenance ***Operational considerations*** Choice of appropriate equipment and radiopharmaceuticals; factors affecting patient dose; minimizing the exposure of the patient (noting the difference in approach between diagnostic and therapeutic procedures); exposure of pregnant women; exposure of breast-feeding women ***Calibration*** Calibration of sources, including quantities, protocols and traceability; calibration of dosimeters ***Dosimetry of patients*** Determination of the dose in nuclear medicine (diagnosis and therapy): Introduction to MIRD scheme for dose calculation ***Diagnostic reference levels and dose constraints*** Diagnostic reference levels for the patient on the basis of relevant surveys; dose constraints for carers and comforters ***QA programme for medical exposures*** Organizational elements; acceptance testing and routine testing of equipment; periodic audit and review ***Release of patients after therapy*** Activity in patients to be discharged after treatment in nuclear medicine **Unintended and accidental medical exposures** Examples **Control of the occupational and public exposure. Safety assessment, particularities** Control of the occupational exposure: particularities related to the design, source of occupational exposure, definition of areas, local rules examples, personnel to be considered occupationally exposed and related dose assessment methods, personal protective equipment, definition of investigation levels, dose restriction. Control of the public exposure: sources of the public exposure, measures to ensure the control of the public exposure (design, control of visitors, signals). Safety assessment: identification of the aspects that have to be considered when doing safety	LO.VIII.3.10 LO.VIII.3.11 LO.VIII.3.12 LO.VIII.3.13

Module	Content	Learning Objective (No.)
	assessment, risks and the possible accidents	
VIII.4. Radiation therapy	**Introduction**	LO.VIII.4.01
	Radiation protection principles applicable to Radiation therapy (teletherapy and brachytherapy) procedures	LO.VIII.4.02
	Justification	LO.VIII.4.03
	Levels of justification; Special cases – pregnancy; paediatric patients; Alternative techniques; Assessment of the detriment	LO.VIII.4.04 LO.VIII.4.05 LO.VIII.4.06
	Optimization	LO.VIII.4.07
	Design considerations for equipment	LO.VIII.4.08
	International requirements or standards (IEC, ISO) for radiation generators and radioactive sources; regular review and maintenance	LO.VIII.4.09 LO.VIII.4.10
	Operational considerations	LO.VIII.4.11
	Delivering the prescribed dose to the planning target volume while ensuring the exposure to other volumes is as low as reasonably achievable.	LO.VIII.4.12 LO.VIII.4.13
	Introduction to the concept of dose distribution and its use for treatment planning; use of organ shielding; exposure of women of reproductive capacity	
	Calibration	
	Calibration of sources, including quantities, protocols and traceability; calibration of dosimeters	
	Dosimetry of patients	
	Introduction to patient dosimetry in teletherapy and brachytherapy.	
	QA programme for medical exposures	
	Organizational elements; acceptance testing and routine testing of equipment; periodic audit and review	
	Unintended and accidental exposures	
	Examples	
	Control of the occupational and public exposure. Safety assessment, particularities	
	Control of the occupational exposure: particularities related to the design, source of occupational exposure, definition of areas, local rules examples, personal to be considered occupationally exposed and related dose assessment methods, personal protective equipment, definition of investigations levels, dose constraint. Control of the public	

Module	Content	Learning Objective (No.)
	exposure: sources of the public exposure, measures to ensure the control of the public exposure (design, control of visitors, signals), patients receiving permanent implants, disuse sources). Safety assessment: identification of the aspects that have to be considered when doing safety assessment, risks and the possible accidents	

4.8.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
VIII.1. General considerations	LO.VIII.1.01	describe the range of practices that result in medical exposures to ionizing radiation.
	LO.VIII.1.02	describe the goal(s) in optimization of medical exposures.
	LO.VIII.1.03	explain how diagnostic reference levels are derived and applied.
	LO.VIII.1.04	list the categories of radiological medical personnel, describe their roles and functions and explain the qualifications and competences required for each role.
	LO.VIII.1.05	describe what is meant by the terms “unintended” and “accidental” medical exposures.
	LO.VIII.1.06	plan an investigation into an unintended or accidental medical exposure.
	LO.VIII.1.07	explain the uses of SAFRAD and SAFRON.
VIII.2. Diagnostic radiology and image guided interventional procedures	LO.VIII.2.01	describe the principles of, and technologies associated with, diagnostic radiology.
	LO.VIII.2.02	apply the three levels of justification to a diagnostic radiology investigation.
	LO.VIII.2.03	describe what defines the “appropriateness” of medical diagnostic radiography equipment.
	LO.VIII.2.04	describe the aspects that should be considered as part of general design features.
	LO.VIII.2.05	list specific design features associated with diagnostic radiography technologies.
	LO.VIII.2.06	explain the requirements for, and relevance of, maintenance with respect to diagnostic radiography equipment.

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
	LO.VIII.2.07	describe how optimization of patient dose in diagnostic radiology is influenced by operational considerations.
	LO.VIII.2.08	discuss the specific operational considerations pertinent to optimization of patient dose for a range of diagnostic radiology techniques.
	LO.VIII.2.09	describe the importance of patient dosimetry in the process of optimization of patient protection.
	LO.VIII.2.10	apply the concept of "typical dose" to the optimization process.
	LO.VIII.2.11	explain the direct and indirect methodologies for estimating patient dose in diagnostic radiology and image guided interventional procedures.
	LO.VIII.2.12	outline the operational quantities that may be used to determine patient dose in diagnostic radiology procedures.
	LO.VIII.2.13	apply the concept of diagnostic reference levels to the optimization of patient doses in diagnostic radiology.
	LO.VIII.2.14	explain the quantities used for diagnostic reference levels for diagnostic radiology.
	LO.VIII.2.15	explain how DRLs are derived and how they are used in practice.
	LO.VIII.2.16	explain the difference between DRLs and dose constraints.
	LO.VIII.2.17	describe the objectives of quality assurance programme in diagnostic radiology and the essential components of such a programme.
	LO.VIII.2.18	explain the difference between quality assurance and quality control in the in the context of diagnostic radiology.
	LO.VIII.2.19	list the systems to be tested as part of a quality assurance programme and explain why these are relevant.
	LO.VIII.2.20	list the appropriate published standards with respect to accepted tolerances in QA testing.
	LO.VIII.2.21	discuss the potential for serious harm resulting from diagnostic radiology and the consequences of not adopting good practice.
	LO.VIII.2.22	explain why pregnant patients warrant particular consideration with respect to radiation protection.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.VIII.2.23	describe the varying radiation risk to the embryo/foetus during pregnancy.
	LO.VIII.2.24	apply appropriate protocols to ascertain the possibility of pregnancy.
	LO.VIII.2.25	explain the significance of pregnancy in the justification process.
	LO.VIII.2.26	describe what constitutes an appropriate radiation safety structure within a diagnostic radiology environment.
	LO.VIII.2.27	apply the basic requirements for the control of occupational and public exposure to the diagnostic radiology environment.
	LO.VIII.2.28	describe the key aspects to be considered when undertaking a safety assessment of medical radiological facility.
VIII.3. Nuclear medicine: diagnosis and therapy	LO.VIII.3.01	explain what is meant by the term "nuclear medicine" and how it may be applied to diagnosis and treatment.
	LO.VIII.3.02	describe the general considerations relevant to the justification of nuclear imaging and nuclear therapy procedures.
	LO.VIII.3.03	summarize the specific issues relevant to the justification of nuclear medicine procedures in pregnant or breast-feeding patients.
	LO.VIII.3.04	describe the specific issues relevant to the justification of nuclear medicine procedures to pediatric patients.
	LO.VIII.3.05	explain the specific issues relevant to the justification of nuclear medicine procedures to bio-medical research volunteers.
	LO.VIII.3.06	describe the equipment used in nuclear medicine and what investigations or treatments it may be used for.
	LO.VIII.3.07	explain the importance of the routine performance testing and calibrations in the nuclear medicine environment.
	LO.VIII.3.08	describe the general operational considerations pertinent to the optimization of patient dose in nuclear medicine (imaging and therapy).
	LO.VIII.3.09	explain the importance of calibration of sources used in nuclear medicine and where detailed guidance on accepted protocols can be found.
	LO.VIII.3.10	explain the importance of calibration of dosed

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		calibrators.
	LO.VIII.3.11	describe the MIRD scheme for dose calculations.
	LO.VIII.3.12	explain the factors that must be addressed when releasing (discharging) patients who have undergone nuclear medicine investigations or treatment.
	LO.VIII.3.13	apply the basic requirements for the control of occupational and public exposure to the nuclear medicine environment
VIII.4. Radiation therapy	LO.VIII.4.01	describe the basic principles and aims of radiation therapy.
	LO.VIII.4.02	describe the main methods of radiation therapy and the equipment used.
	LO.VIII.4.03	describe the general considerations relevant to the justification of radiation therapy.
	LO.VIII.4.04	describe the general operational considerations pertinent to the optimization of patient dose in radiation therapy.
	LO.VIII.4.05	explain the concept of treatment planning.
	LO.VIII.4.06	describe the calibration protocols and explain the relative quantities.
	LO.VIII.4.07	explain the need for quality assurance and quality control in radiation therapy.
	LO.VIII.4.08	describe the basic quality control procedures for external beam radiation therapy equipment, simulator, treatment planning system, dose delivery.
	LO.VIII.4.09	describe the basic quality control procedures for LDR and HDR remote afterloading units.
	LO.VIII.4.10	describe the main concepts and quantities associated to the dosimetry of patients in radiation therapy.
	LO.VIII.4.11	describe the pathways that can potentially lead to unintended or accidental exposures in radiotherapy.
	LO.VIII.4.12	apply the basic requirements for the control of occupational and public exposure to the radiation therapy environment
	LO.VIII.4.13	describe the main design aspects, with particular consideration to shielding, for radiation therapy facilities

4.8.3. Practical exercise

No.	Practical exercise	Type
VIII-1	Determination of doses to patients	Demonstration
VIII-2	Optimization of patient protection in diagnostic radiology and image guided interventions	Demonstration
VIII-3	Optimization of patient protection in nuclear medicine and radiation therapy	Demonstration
VIII-4	Quality control procedures in medical application	Case Study
VIII-5	Visit to a hospital: departments of radiology, radiotherapy, nuclear medicine; demonstration of procedures and specification of the information to be recorded	Technical visit
VIII-6	Analysis of accidents in medical exposure	Case study
VIII-7	Preparation of an organizational chart and highlights of a radiation protection programme in a hospital (radiotherapy, diagnostic radiology or nuclear medicine)	Case study
VIII-8	Shielding calculations for an X ray facility	Exercise

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4.9. PART IX: EMERGENCY EXPOSURE SITUATIONS AND EMERGENCY PREPAREDNESS AND RESPONSE

Objective: To provide the students with an understanding of the basic requirements for protection against emergency exposure situations. To provide the students with an understanding of the system of emergency preparedness and response, including the basic requirements, principles, goals, planning basis, protective and other response actions, and public communication. Students will also be aware of the arrangements that have to be in place for an effective and efficient response during a nuclear or radiological emergency.

4.9.1. Content

Module	Content	Learning Objective (No.)
IX.1 Basic requirements and principals	**Basic Safety Standards requirements** Scope Generic requirements: emergency management system Public exposure: preparedness and response for an emergency Exposure of emergency workers: arrangements for controlling the exposure of emergency workers Arrangements for the transition from an emergency exposure situation to an existing exposure situation	LO.IX.1.01
	General principles Goals of emergency preparedness and response; principles and dose concepts used in emergency exposure situations; exposure pathways and basic radiation protection techniques in case of a nuclear or radiological emergency; main protective actions in case of accidental releases into the environment; types of emergencies and lessons learned from past accidental events	LO.IX.1.02
IX.2 Planning basis for emergency exposure situations	**Planning basis** Assessment of hazards; emergency preparedness categories; using D-values for hazard assessment; concept of operations for a nuclear or radiological emergency	LO.IX.2.01 LO.IX.2.02
IX.3 Protection strategies for emergency exposure situations	**Protection strategy** Development of protection strategies for emergency exposure situations At the planning stage; optimization of protection strategies during the response phase; generic criteria and	LO.IX.3.01 LO.IX.3.02 LO.IX.3.03 LO.IX.3.04

Module	Content	Learning Objective (No.)
	operational intervention levels to be used for decision making purposes	
IX.4 Protection of the public and protection of the workers	**Protective actions and other response actions** Actions to mitigate the consequences of a nuclear or radiological emergency; protective actions during nuclear emergencies; protective actions during radiological emergencies, protection of emergency workers and helpers	LO.IX.4.01 LO.IX.4.02
IX.5 Emergency management system and operations	**Emergency management system** Roles and responsibilities in emergency preparedness and response; generic emergency response organizations; incident command system; response integration and coordination	LO.IX.5.01
IX.6 Radiological assessment	**Radiological assessment** Environmental monitoring in emergencies; field radiation and contamination monitoring methods; field sampling and sample measurements; challenges in environmental monitoring; public monitoring; dose projections; dose assessment of external exposure and dose assessment of internal exposure; decontamination actions	LO.IX.6.01
IX.7 Medical response in emergency exposure situations	**Medical response** Responsibilities and management of medical response (pre-hospital and in hospital); the triage of victims; diagnosis and treatment; physical and biological dosimetry (its application for diagnosis, treatment and prognosis), training of those involved in medical management of the victims (medical, paramedical staff); psychological effects	LO.IX.7.01 LO.IX.7.02 LO.IX.7.03 LO.IX.7.04 LO.IX.7.05
IX.8 Providing instructions to and communicating with the public in a nuclear or radiological emergency	**Providing instructions and communicating with the public** Providing warning and instructions to the population in the affected areas; risk perception; objectives of emergency communication; essential components of public communication planning; communicating concepts related to radiation emergency; communicating the health hazard	LO.IX.8.01 LO.IX.8.02
IX.9 Plans and procedures, training and exercises	**Elements of infrastructure** Step by step approach to develop emergency response plans and procedures; content of emergency response plans and procedures; integrated planning concept; development and implementation of training programs	LO.IX.9.01 LO.IX.9.02

Module	Content	Learning Objective (No.)
	for the key positions competencies within the emergency response organization; preparation, conduct and evaluation of emergency response exercises	
IX.10 International arrangements	**Role of IAEA**	LO.IX.10.01
	Role of IAEA in emergency preparedness and response; IAEA Safety Standards in emergency preparedness and response; IAEA Response and Assistance Network (RANET)	LO.IX.10.02

4.9.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
IX.1 Basic requirements and principals	LO.IX.1.01	summarize the basic requirements for emergency exposure situations.
	LO.IX.1.02	explain the generic principles for protection against emergency exposure situations.
IX.2 Planning basis for emergency exposure situations	LO.IX.2.01	describe the different types of radiological accident.
	LO.IX.2.02	describe some major accidents and explain the lessons to be learnt.
IX.3 Protection strategies for emergency exposure situations	LO.IX.3.01	apply the methodology for determining the threat categories of practices.
	LO.IX.3.02	explain the concepts of emergency planning areas and zones.
	LO.IX.3.03	describe the International Nuclear Events Scale (INES).
	LO.IX.3.04	describe the recommended general structure of a nuclear and radiological emergency response organization.
IX.4 Protection of the public and protection of the workers	LO.IX.4.01	specify the objective of writing an emergency plan.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
	LO.IX.4.02	list the principal components of emergency plans and procedures.
IX.5 Emergency management system and operations	LO.IX.5.01	list the main tasks of response initiator, radiological assessor, first responder and on-scene controller.
IX.6 Radiological assessment	LO.IX.6.01	describe the main element to be considered when conducting a radiological assessment.
IX.7 Medical response in emergency exposure situations	LO.IX.7.01	describe the tasks of emergency medical responders on and off- site.
	LO.IX.7.02	explain the process of population monitoring.
	LO.IX.7.03	explain the functions of a reception centre.
	LO.IX.7.04	list the relevant physical and biological dosimetry methods used for diagnosis and treatment.
	LO.IX.7.05	summarize the importance of psychological effects of nuclear or radiological accidents, and describe the actions to reduce and manage psychological consequences.
IX.8 Providing instructions to and communicating with the public in a nuclear or radiological emergency	LO.IX.8.01	summarize the methods of communication with the media and the public in an emergency.
	LO.IX.8.02	list the topics that need to be communicated.
IX.9 Plans and procedures, training and exercises	LO.IX.9.01	describe the approach to develop emergency response plans and procedures.
	LO.IX.9.02	summarize the content of emergency response plans and procedures.
IX.10 International arrangements	LO.IX.10.01	describe the role of IAEA in emergency preparedness and response.
	LO.IX.10.02	list the main IAEA Safety Standards and publications in emergency preparedness and response.

4.9.3. Practical exercise

No.	Practical exercise	Type
IX-1	Application of certain models for dose assessment in the case of nuclear or radiological emergency or prolonged exposure situation	Laboratory Exercise
IX-2	Response to a hypothetical emergency: loss of a gamma radiography source	Case study
IX-3	Response to a hypothetical accident: environmental release of a substantial amount of radioactive material	Case study
IX-4	Estimation of the individual doses during an accidental following overexposure	Case study
IX-5	Search for a lost source	Simulation
IX-6	Response to a hypothetical transport accident with radioactive material	Simulation
IX-7	Communication with the public during a hypothetical emergency situation	Simulation

4.9.4. Bibliography to Part IX

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4.10. PART X: EXISTING EXPOSURE SITUATIONS

Objective: To provide the students with an understanding of the basic requirements for protection against existing exposure situations. Students will also be aware of the causes of existing exposure situations, the approaches to mitigate their consequences, and the circumstances where occupational exposure requirements must be applied.

4.10.1. Content

Module	Content	Learning Objective (No.)
X.1. Basic requirements and principles	**Introduction and background**	LO.X.1.01
	Review of the types of exposure situation	LO.X.1.02
	Determining the applicable type of exposure situation, especially where there are elements of more than one type of exposure situation	LO.X.1.03 LO.X.1.04
	Basic Safety Standards requirements	
	Exclusion of exposures that are unamenable to control	
	Exposures that are subject to the requirements for existing exposure situations — exposures due to contamination of areas by past activities and accidents, exposure to natural sources: commodities, other materials, radon, cosmic radiation	
	General requirements for existing exposure situations	
	National strategy, assignment of responsibilities, legal and regulatory framework, identifying and evaluating exposures of concern	
	Protection strategy for reducing doses; establishing reference levels	
	Justification and optimization of remedial/protective actions; creating perspective: worldwide exposures to natural sources	
X.2. Remediation of areas contaminated by residual radioactive material	**Legal and regulatory framework**	LO.X.2.01
	Examples of contaminated areas	LO.X.2.02
	Remediation strategy, identifying areas for remediation; funding mechanisms	LO.X.2.03
	Planning and implementation of remediation; regulatory considerations	
	Management of radioactive waste	
	The remediation programme	
	Prior assessment	

Module	Content	Learning Objective (No.)
	Remediation plan: justification and optimization	
	Implementation of remedial actions: protection and safety (including protection of remediation workers), radioactive waste management. Post-remedial activities: possible controls and restrictions	
	Case study	
	Remediation of coastal and marine phosphate residue deposits: the Taparura Project at Sfax, Tunisia	
X.3. Exposure to short-lived progeny of ^{222}Rn	**Basic concepts**	LO.X.3.01
	Radon and how it leads to exposure of the lung	LO.X.3.02
	Special quantities for concentration and exposure: potential alpha energy, equilibrium factor, equilibrium equivalent quantities. ^{222}Rn concentration as a surrogate for ^{222}Rn progeny concentration	LO.X.3.03 LO.X.3.04 LO.X.3.05
	^{222}Rn concentrations and associated health effects	LO.X.3.06
	Concentrations in buildings and underground workplaces. Epidemiological studies of lung cancer due to ^{222}Rn progeny: underground mineworkers, ^{222}Rn in homes	LO.X.3.07
	Effective dose due to ^{222}Rn progeny exposure	
	Control of exposure	
	Identifying exposures of concern — national surveys	
	National action plan to address high ^{222}Rn concentrations, public information campaigns	
	Reference levels for ^{222}Rn concentrations	
	Justification and optimization of remedial actions in workplaces, dwellings and other buildings	
	Methods for reducing ^{222}Rn concentrations in buildings	
X.4. Exposure to radionuclides in commodities and to cosmic radiation	**Exposure to radionuclides in commodities**	LO.X.4.01
	Commodities to which the requirements apply; reference levels for radionuclides in commodities	LO.X.4.02 LO.X.4.03
	Food — guideline post-emergency contamination levels; drinking water — remedial measures, guideline contamination levels	
	Fertilizer/soil amendments — activity concentrations, exposures, implications for control	
	Construction materials — exposure pathways, remedial action for existing buildings, preventive measures for new buildings	

Module	Content	Learning Objective (No.)
	Exposure to cosmic radiation Sources and characteristics of cosmic radiation; average worldwide doses Dose rates in commercial aircraft Exposure of aircrew and implications for control Exposure of space crew and implications for control	

4.10.2. Learning Objectives

Module	Learning Objectives	
	No.	**Description** On completion of the module, student will be able to:
X.1. Basic requirements and principles	LO.X.1.01	define the concept of existing exposure situations.
	LO.X.1.02	explain why some exposures are not amenable to control and give examples.
	LO.X.1.03	specify the responsibilities of the government with regard to existing exposure situations.
	LO.X.1.04	describe the process of the optimization of remedial and protective actions.
X.2. Remediation of areas contaminated by residual radioactive material	LO.X.2.01	recognize an existing exposure situation that requires remediation.
	LO.X.2.02	specify the subjects that need to be incorporated into a national strategy for remediation.
	LO.X.2.03	develop and implement a remediation programme for an area contaminated by residual radioactive material.
X.3. Exposure to short-lived progeny of ^{222}Rn	LO.X.3.01	explain the primary exposure pathways arising from inhalation of ^{222}Rn.
	LO.X.3.02	identify scenarios where there may be enhanced ^{222}Rn air concentrations and the risk of significant exposure.
	LO.X.3.03	design a national survey to identify areas of radon concern and identify areas and buildings that have priority in the survey.
	LO.X.3.04	explain the key components of a national action plan for the reduction of radon exposure.
	LO.X.3.05	apply national reference levels for ^{222}Rn in workplaces and in dwellings.
	LO.X.3.06	specify remedial actions to reduce radon levels in

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		domestic dwellings.
	LO.X.3.07	specify protective actions for the restriction of radon exposure in the workplace.
X.4. Exposure to radionuclides in commodities and to cosmic radiation	LO.X.4.01	specify commodities that may contain radionuclides.
	LO.X.4.02	identify international guidance for radionuclides in food and water.
	LO.X.4.03	explain the sources of cosmic radiation and the pathways of exposure.

4.10.3. Practical exercise

No.	Practical exercise	Type
X-1	Measurement of radon in dwellings and comparison with reference level	Laboratory Exercise
X-2	Estimation of the individual doses remediation of contaminated area by residual radioactive material	Case study
X-3	Estimation of the individual doses due to commodities	Case study
X-4	Communication with the public and the information media after remediation of contaminated area by residual radioactive material	Simulation

4.10.4. Bibliography to Part X

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

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4.11. PART XI: TRAINING THE TRAINERS

Objective: To be able to organize and implement training courses. To develop didactic skills. To apply the didactic skills to the oral presentation of Part XII.

4.11.1. Content

Module	Content	Learning Objective (No.)
XI.1. Being a trainer (introduction)	**General considerations on how people learn** Factors that can affect the success of a training sequence: classroom environment, learner's frame of mind; teacher/trainer. Different ways of learning. Different person's styles. Need to adapt the trainer style to meet the needs of different learners.	LO.XI.1.01 LO.XI.1.02 LO.XI.1.03
XI.2. How adults learn	**Comparison between andragogy and pedagogy.** Andragogy – Knowles' model. Honey and Mumford – learning styles. Kolbe's learning cycle: the importance of experience and reflection. Motivation – why it is important and how to improve it. Application to training sequences in radiation protection.	LO.XI.2.01 LO.XI.2.02 LO.XI.2.03 LO.XI.2.04
XI.3. Course design and lesson planning	**Analysis of training needs** Systematic approach to learning. Knowledge, competence and qualification processes. Characteristics of the persons to be trained: qualified experts; radiation protection officers; qualified operators; health professionals; medical practitioners; workers including the operators of the radiation application and those marginally involved in the work; staff from regulatory authorities; and emergency response personnel. **Course design** Aims and objectives, syllabus, course programme, lecture plans, lecture notes, story boards, training materials. Optimization of learning time to meet objectives. Training methods: classroom based training; distance learning; on the job training. Preparation of demonstrations, practical exercises, case studies and field visits. Preparation of examinations (course assessments). **Course assessments** Benefits of assessments. Objective, moment and different ways to assess the learning. Use of the results of the assessments. **Course evaluation**	LO.XI.3.01 LO.XI.3.02 LO.XI.3.03 LO.XI.3.04 LO.XI.3.05 LO.XI.3.06 LO.XI.3.07 LO.XI.3.08 LO.XI.3.09

Module	Content	Learning Objective (No.)
	Pre- and post-tests. Learners and trainers' feedback. Performance indicators.	
XI.4. Communication with a group	**Being a lecturer** Factors that help and hinder our message getting through when talking to a group. Creation of the right atmosphere. Motivation of learners. Adaptation of the language. Body language. Enhancing group discussions. Asking and answering questions. Active listening.	LO.XI.4.01 LO.XI.4.02 LO.XI.4.03 LO.XI.4.04 LO.XI.4.05
XI.5. Teaching aids	**Using teaching aids** Variety of teaching aids available: presentation, flipchart, videos, simulators, voting systems, teaching games etc. Pros and cons of them. Effective use of teaching aids in a training sequence. Use of e-learning tools and methodologies. Simple rules for stronger PowerPoint presentations. Presentation of data.	LO.XI.5.01 LO.XI.5.02 LO.XI.5.03 LO.XI.5.04
XI.6. Oral presentation for the work project	**Presenting the project** Preparation of oral presentations for the work project (part XII) by the students. Application of the didactic skills presented in part XI. Support from the lecturer of part XI. Delivery of presentation by the students. Assessment by the lecturer and the rest of the students.	LO.XI.6.01

4.11.2. Learning Objectives

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
XI.1. Being a trainer (introduction)	LO.XI.1.01	recognize that there is no single, definitive solution to a training issue.
	LO.XI.1.02	describe some different styles of trainers.
	LO.XI.1.03	identify that a trainer should be able to adapt his style to meet the needs of different learners.
XI.2. How adults learn	LO.XI.2.01	describe the difference between andragogy and pedagogy.
	LO.XI.2.02	explain the main elements of Kolbe's learning cycle.
	LO.XI.2.03	discuss on the importance of motivating and engaging learners.
	LO.XI.2.04	recognize the need to create a comfortable atmosphere

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
		for the learners.
XI.3. Course design and lesson planning	LO.XI.3.01	explain the requirements for educational level, training and work experience of the different professional or job categories of persons to be trained in radiation protection in Member States.
	LO.XI.3.02	identify the training aims and objectives considering the category of the learners.
	LO.XI.3.03	select the most appropriate training method for the specific audience.
	LO.XI.3.04	describe the story board technique for planning a training sequence.
	LO.XI.3.05	apply the story board technique for making an interactive and effective training sequence with different training activities.
	LO.X.3.06	value the benefits of assessments.
	LO.X.3.07	decide on what, when and how to assess and what to do with the results of the assessments.
	LO.X.3.08	describe the benefits of a pre- and post-test evaluation.
	LO.X.3.09	explain how statistics and data extracted from the feedback questionnaires and pre- and post-test evaluations can be used as indicators of performance for the training.
XI.4. Communication with a group	LO.XI.4.01	explain the factors that help and hinder a message getting through when talking to a group.
	LO.XI.4.02	describe the aspects that make face-to-face training effective and interactive.
	LO.XI.4.03	describe the aspects that help to achieve a good performance.
	LO.XI.4.04	identify the elements that contribute to be a good listener.
	LO.XI.4.05	discuss on different type of questions and how to answer questions in a group setting.
XI.5. Teaching aids	LO.XI.5.01	list the main teaching aids available.
	LO.XI.5.02	describe the pros and cons of the different teaching aids.
	LO.XI.5.03	explain some simple rules for stronger PowerPoint presentations.
	LO.XI.5.04	discuss on different ways to present data.

Module	Learning Objectives	
	No.	Description On completion of the module, student will be able to:
XI.6. Oral presentation for the work project	LO.XI.6.01	apply the didactic skills acquired during this part (XI) to the preparation and delivery of the oral presentations of the work project.

4.11.3. Practical exercises

No.	Practical exercise	Type
XI-1	Pre-test on soft skills	Written Questionnaires
XI-2	Giving a three-minute talk on a general topic	Talk
XI.3	Group exercise: Planning a training sequence: preparation of a training sequence on radiation protection and the safety of radiation sources with a variety of training activities using the storyboard technique	Case study
XI-4	Preparation and delivery of the oral presentation for the work project (Part XII)	Presentations

4.11.4. Bibliography to Part XI

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4.12. PART XII: WORK PROJECT

Objective: To apply the knowledge and skills acquired within the course in addressing a specific problem of radiation protection and safety and to present the findings and conclusions.

Procedure for implementing part XII

Selection and assignment of topics for the work project

The course director contacts students in due time before the beginning of the course, providing information on the purpose of the work project and requesting them to propose a topic of the work project to be agreed with their local supervisors (i.e. in students' organization). The work project should address a problem in radiation protection and safety, of interest in the organization where the participant might be already working, and/or of relevance at national level. The work project should provide the opportunity to apply the knowledge and skills gained throughout parts IV to X, with particular emphasis on the use of the IAEA Safety Standards.

Students should inform the course director on the identified topic of the work project, providing the contact details of their local supervisor. The course director will arrange a meeting of the students with the lecturers that could oversee students' work project (work project supervisor). Once the topic has been agreed upon, and a lecturer has been designated to oversee the work project, students' local supervisors are informed.

Conduct of the work project

The implementation of the project may involve time for discussion with the work project supervisor, library work, experimental/practical work, preparation of project report and final presentation. This should be considered in the preparation of the schedule by the course director. The course director and work project supervisor should ensure that the students have access to necessary resources.

- Literature survey: to update on the recent developments and to establish the state of the art, particularly in relation to the latest IAEA Safety Standards and their application;
- Experimental/practical work: the necessary resources should be made available.

At least two weeks should be dedicated to the work project within the course timetable; this period could be distributed along the whole course.

Assessment of the work project

The students should be informed in advance on the assessment criteria for the work project. The assessment is carried out through:

- Report**:** students should prepare a report on the work project, including a brief summary, state of the art, relevance/justification for the project, material and methods (including relevant IAEA Safety Standards), results, conclusions and recommendations, references.
- Oral presentation: students should publicly present the work project. The students should be encouraged to use a large variety of teaching tools during their presentation. The oral presentation of the work project is included in part XI Training the Trainers.

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