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

Standard Syllabus

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FOREWORD

Part of the mandate of the IAEA, as stated in Article III (A.6) of the Statute, is to provide for the application of the IAEA's 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 field of peaceful uses of atomic energy (Article III (A.4)).

General Conference resolution GC(XXXV)/RES/552(1991) requested the IAEA's Director General to prepare "a comprehensive proposal for education and training in both radiation protection and nuclear safety". General Conference resolution GC(XXXVI)/RES/584 (1992) took positive note of the proposal for education and training in radiological protection and nuclear safety contained in document GC(XXXVI)/1016, endorsed its content and requested the Director General to prepare a report on a possible programme of activities on education and training in radiological protection and nuclear safety. Report GC(XXXVII)/1067 (1993) subsequently clearly distinguished between educational and training courses, workshops and seminars, and emphasized that educational courses (of a longer duration) that were based on the standard syllabus were aimed at young professionals, who in the course of time might become trainers in radiation protection and nuclear safety in their home countries. General Conference Resolution GC(43)/RES/13 (1999) requested the IAEA Secretariat to strengthen the education and training programme. In response, GOV/2000/34-GC(44)/7, Attachment 6 described the status of education and training activities already implemented and planned and specified an action to intensify postgraduate educational course activities in accordance with General Conference resolutions and to develop, in a systematic way, syllabuses and training material for specific target groups and specific uses of radiation sources and radioactive materials. General Conference Resolution GC(44)/RES/13(2000) urged the Secretariat to implement all the actions mentioned in Attachment 6. Further, General Conference Resolutions GC(45/RES/10C in 2001 and GC(46)/RES/9C in 2002 urged the Secretariat to continue to strengthen its current efforts in this area.

The present publication is a revision of the original version of the Standard Syllabus of the Postgraduate Educational Courses in Radiation Protection that was published in April 1995 (IAEA-SYL-01). This revision of the Standard Syllabus takes into account the requirements and recommendations of the IAEA Safety Series No. 115 (1996) and related Safety Guides, as well as experience gained from the Postgraduate Educational Course in Radiation Protection conducted in several regions in recent years in Argentina, South Africa, Syria, Malaysia and Belarus. The general aim of the course has not changed, which is to provide initial basic professional training in radiation protection and safety for young professionals who would become trainers in later years.

The IAEA is grateful for the contribution made by experts from various Member States who took part in the review of the Standard Syllabus for Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources.

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EDITORIAL NOTE

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

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1. INTRODUCTION

1.1. BACKGROUND

The aim of the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources is to meet the needs of professionals at graduate level, or the equivalent, for initial training to acquire a sound basis in radiation protection and the safety of radiation sources. The course also aims to provide the necessary basic tools for those who will become trainers in radiation protection and in the safe use of radiation sources in their countries. 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 participants should have had a formal education to a level equivalent to a university degree in the physical, chemical or life sciences or engineering and should have been selected to work in the field of radiation protection and the safe use of radiation sources in their countries. The present revision of the Standard Syllabus takes into account the requirements of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), IAEA Safety Series No. 115 (1996) and recommendations of related Safety Guides, as well as experience gained from the Postgraduate Educational Course on Radiation Protection and Safety of Radiation Sources held in several regions in recent years. The general aim of the course, as mentioned, is the same. Some of the improvements in the present version are as follows:

- The learning objective of each part is specified.
- The prerequisites for each part are specified.
- The structure of the syllabus has been changed: the parts on Principles of Radiation Protection and on Regulatory Control were moved ahead of Dose Assessment and after Biological Effects of Radiation. The part on the interface with nuclear safety was dropped and a module on radiation protection in nuclear power plants has been included.
- A part on Training the Trainers was included to fulfill the aim of the course in relation to the concept of 'train the trainers'.
- The suggested duration of each part has been revised. More emphasis is given to Regulatory Control and Occupational Radiation Protection. The total suggested duration has not changed (18 weeks)[1], but the syllabus is flexible enough to tailor the duration and course content to specific needs.
- The content and technical terms have been revised in light of the IAEA Safety Glossary.
- Unnecessary repetition of topics has been eliminated.
- Practical training sessions (demonstrations, laboratory exercises, case studies, technical visits and simulations) have been included for each part.

A comprehensive list of publications for reference and for distribution to participants and lecturers has been included.

1.2. OBJECTIVE

The objective of the Standard Syllabus is to facilitate the integration of courses in radiation protection and the safety of radiation sources into the curricula of educational institutions in Member States and to achieve both consistency and a common level in the technical content of such courses.

[1] Could be extended.

1.3. SCOPE

The focus of the course is on the technical and administrative framework necessary for regulatory and operational controls for protection against ionizing radiation and the safe use of radiation sources in all their applications.

1.4. STRUCTURE

Section 2 provides an overview of the Standard Syllabus and its structure, prerequisites and learning objectives, and suggested duration for each part. Section 3 describes the content of each part of the syllabus and provides a list of practical exercises and a list of reference publications. A compiled list of references is given in the Bibliography at the end of the report.

2. OVERVIEW OF THE STANDARD SYLLABUS

The Standard Syllabus of the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources is divided into eleven parts and each part is divided into modules. For each part, the prerequisite is indicated as well as the general learning objective. Each module is described by the content and the link to the training material and the reference publication. The content of each module is described by short sentences and key words. The list of reference publications for each module is also presented. For each part, a list of practical training sessions is suggested. These sessions can be demonstrations, laboratory exercises, case studies, technical visits, simulation exercises or workshops.

The prerequisites, general learning objectives and recommended duration for each part are summarized in Table I. The prerequisite for the course is that the participants should have had a formal education to a level equivalent to a university degree in physics, chemistry, life sciences or engineering and should have been selected to work in the field of radiation protection and the safety of radiation sources in their countries.

TABLE I. OVERVIEW OF THE STANDARD SYLLABUS

Part No.	Part	Pre-requisite	Objective	Suggested duration (weeks)
I	Review of fundamentals	Formal education	To become familiar with the basic knowledge in nuclear physics and related matters	2
II	Quantities and measurements	Part I	To understand dosimetric quantities and their measurement units and to perform related calculations. To be familiar with different types of radiation detectors and their operating principles, characteristics and limitations. To be able to choose the appropriate detector for a given radiation field and dosimetric quantities	1.5
III	Biological effects of ionizing radiation	Part I + Part II	To become familiar with the mechanisms of different types of biological effects following exposure to ionizing radiation. To be aware of the models used to derive risk coefficients for estimating the detriment	1
IV	Principles of radiation protection and the international framework	Parts I–III	To become aware of the ICRP's conceptual framework and international recommendations in radiation protection and safe use of radiation sources. To become acquainted with the role played by international organizations in radiation protection	0.5
V	Regulatory control	Part IV	To become acquainted with the elements of a regulatory infrastructure for radiation protection and safety	1.5
VI	Assessment of external and internal exposures	Parts I–IV	To be able to estimate the doses to individuals arising from both external and internal exposures	2.5
VII	Protection against occupational exposure	Parts I–V	To be able to use the concepts of occupational radiation protection in developing a radiation protection programme for any practice.	3
VIII	Medical exposures in diagnostic radiology, radiotherapy and nuclear medicine	Parts I–VI	To be able to apply the radiation protection principles to medical exposures (diagnostic and interventional radiology, radiotherapy and nuclear medicine). To understand the concepts used for calculating doses to patients and to carry out quality assurance.	2

TABLE I. (cont.)

Part No.	Part	Pre-requisite	Objective	Suggested duration (weeks)
IX	Exposure of the public due to practices	Parts I–VII	To become aware of the various pathways by which the public might be exposed to radiation as a result of practices and the methods for determining the doses	1.5
X	Intervention in situations of chronic and emergency exposure	Parts I–VII + Part IX	To become aware of the causes and consequences of situations of chronic exposure and of radiological and nuclear accidents, and of approaches to mitigating the consequences	1.5
XI	Training the trainers	Parts I–X for preparation of training events	To be able to organize and conduct national training courses. To develop didactic skills	1
			Total	**18 weeks**

3. THE STANDARD SYLLABUS

PART I: REVIEW OF FUNDAMENTALS

Prerequisite: Formal education at degree or equivalent level in physics, chemistry, life science or engineering.

Objective: To gain a basic knowledge of nuclear physics and related matters.

Module	Content	References
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	Prospectus, programme
I.2. Basic physics and mathematics used in radiation protection	**Basic nuclear physics** Introduction to atomic structure Neutrons, protons and electrons; periodic table; atomic mass, isotopes of element; excitation, ionization; binding energy; accelerated particles; characteristic X rays, bremsstrahlung; auger electrons, internal conversion; energies **Radioactivity** Nuclear stability; unstable nuclei; radionuclides; modes of disintegration alpha, beta, gamma; types of spectra; positron; electron capture; table of radionuclides; activity; law of radioactive decay; half-life; decay constant; mean life; activity, units; decay chains and equilibrium **Nuclear reactions** Types of reactions; induced radioactivity; fission and fusion (energy considerations); cross section; energetics of reactions **Basic mathematics** Differentiation/integration; decay equations (exponential functions); first order ordinary linear differential equations with a constant **Statistics** Accuracy; precision; reliability; student T test; Chi square; probability theory; random variables; distributions: different types (log-normal, binomial, Poisson, Gaussian); scatter diagram; mean, mode, median; standard deviation; standard error; confidence levels; regression; correlation; practical application to counting; curve fitting by least square methods	Lecture notes [1, 2, 3]

Module	Content	References
I.3. Interaction of radiation with matter	**Charged particle radiation**	Lecture notes
	Heavy particles (alpha, proton nuclei)	[2, 3]
	Energy transfer mechanisms, ionization, scattering nuclear interaction; range–energy relationship; Bragg curve; stopping power; shielding	
	Beta particles	
	Mechanisms of energy transfer; relationships; bremsstrahlung; Cerenkov radiation; shielding	
	Uncharged radiation	
	X and gamma rays	
	Photoelectric effect; Compton scattering; pair production; secondary photon production; linear mass attenuation coefficient; exponential attenuation; effect of Z on absorbing medium; buildup correction; shielding	
	Neutrons	
	Interaction; scattering; absorption; energy categories; neutron activation; radioactive capture (n,p), (n,γ); moderation; shielding	
	Induced radioactivity: by charged and uncharged particles	
I.4. Sources of radiation	**Natural radiation**	Lecture notes
	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, etc.); NORM	[3]
	Cosmic radiation: types of cosmic radiation; variation with latitude and altitude	
	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; fallout; general safety of radiation sources; production of radioisotopes	
	Nuclear reactors: review of fission and fusion reactions; moderation of neutrons; neutrons, multiplication factor, criticality; basic elements of a nuclear reactor; types of reactors; research reactors; nuclear fuel cycle installations	

Module	Content	References
	Radiation generators Charged particle production: linear accelerators; betatrons; cyclotrons X ray production: low energy X ray machines; linear accelerators; other machines; principles and spectra; filtration and beam quality Neutron production: (d,n) reactions and (p,n) reactions; neutron production for neutron therapy Applications of ionizing radiation in medicine, industry, and agriculture Consumer products	

REFERENCES TO PART I

[1] CEMBER, H., Introduction to Health Physics, 3rd Edition, McGraw-Hill, New York (2000).

[2] FIRESTONE, R.B., BAGLIN, C.M., FRANK-CHU, S.Y. (Eds), Table of Isotopes (8th Edition, 1999 update), Wiley, New York (1999).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safe Use of Radiation Sources, Training Course Series No. 6, IAEA, Vienna (1995).

PRACTICAL EXERCISES TO PART I

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	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.	Radon emanations	Demonstration
I-7.	Ranges of alpha and beta particles	Demonstration
I-8.	Moderation and absorption of neutrons	Demonstration
I-9.	Demonstration of shielding properties of different materials and examples of shielding calculations	Demonstration
I-10.	Demonstration of backscattering of beta radiation	Demonstration
I-11.	Demonstration of absorption of beta radiation within sources of different thickness (‘self-absorption’)	Demonstration
I-12.	Determination of maximum energy levels of beta radiation by absorption	Laboratory exercise
I-13.	Study of attenuation of gamma radiation as a function of thickness and atomic number Z	Laboratory exercise

PART II: QUANTITIES AND MEASUREMENTS

Prerequisite: Successful completion of Part I.

Objective: To understand dosimetric quantities and their measurement units and to perform related calculations. To be familiar with different types of radiation detectors and their operating principles, their characteristics and limitations. To be able to choose the appropriate detector for a given radiation field and dosimetric quantities.

Module	Content	References
II.1. Quantities and units	**Radiometric quantities and interaction coefficients:** Radiation field; fluence (rate); energy fluence (rate); cross section; mass attenuation coefficient; mass stopping power **Dosimetric quantities**Exposure (rate); kerma (rate); energy imparted; absorbed dose (rate); linear energy transfer (LET), lineal energy; organ dose **Radiation protection quantities** Equivalent dose (rate); radiation weighting factor (w_R); Effective dose, tissue weighting factor (w_T); operational quantities: ambient dose equivalent; directional dose equivalent; personal dose equivalent; intake; committed dose	Lecture notes [3, 4, 5, 6]
II.2. Dosimetric calculations and measurements	**Dosimetric calculations** Relationship between fluence, kerma and absorbed dose; air kerma rate constant; calculation of kerma and absorbed dose 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 Point sources, plane sources, and volume sources; absorption and scattering in air and in the body; attenuation of primary radiation and buildup of secondary radiation; concepts of extended and aligned fields; influence of geometry Calculation of dose from neutron sources Microdosimetry; tissue equivalent detectors	Lecture notes [2, 3, 4, 5, 6]

Module	Content	References
II.3. Principles of radiation detection and measurement	**Detectors** Gas filled detectors Ionization chambers with current measurements; condenser chambers; pressure ionization chamber; extrapolation chambers; proportional chambers; GM tubes Scintillation detectors Solid and liquid scintillators; quenching Semiconductor detectors Photographic emulsions Thermoluminescent detectors Nuclear track detectors Neutron detectors Detectors using (n,γ) or (n,p) reactions or activation or others Imaging detectors Other detectors: electrets; self-powered detectors; thermally stimulated exoelectron emission (TSEE); radiophotoluminescent detectors (RPLD) **Measurement techniques** Efficiency (geometric and intrinsic), background, geometry, statistics; pulse counting scalers and rate meters; discriminators; resolution; pulse height analysis - coincidence and anticoincidence; pulse shape analysis; computer analysis of spectra	[1, 6]

REFERENCES TO PART II

[1] KNOLL, G.T., Radiation Detection and Measurement, 3rd Edition, Wiley, New York (2000).

[2] ATTIX, F.H., Introduction to Radiological Physics and Radiation Dosimetry, Wiley, New York (1986).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in Photon and Electron Beams: An International Code of Practice, Second Edition, Technical Reports Series No. 277, IAEA, Vienna (1997).

[4] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Quantities and Units in Radiation Protection Dosimetry, Report No. 51, ICRU, Bethesda, MD (1993).

[5] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Fundamental Quantities and Units for Ionizing Radiation, Report No. 60, ICRU, Bethesda, MD (1998).
[6] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safe Use of Radiation Sources, Training Course Series No. 6, IAEA, Vienna (1995).

PRACTICAL EXERCISES TO PART II

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.	Determination of background level of radiation	Demonstration
II-5.	Measurement of beta radiation levels for beta emitter samples and determination of total efficiency	Laboratory exercise
II-6.	Use of a low background Geiger–Müller system for measurement of low activity beta emitting sources	Laboratory exercise
II-7.	Calibration of a gamma scintillation spectrometer in terms of energy and activity	Laboratory exercise
II-8.	Analysis of a complex gamma spectrum using semiconductor detectors	Laboratory exercise
II-9.	Calibration of an alpha spectrometry system in terms of energy and activity	Laboratory exercise
II-10.	Calibration of ZnS(Ag) scintillation counter for alpha activity measurements	Laboratory exercise
II-11.	Reading of photographic films for individual dosimetry that have been exposed to different types of radiation at different energies	Demonstration
II-12.	Reading of thermoluminescent dosimeters	Demonstration
II-13.	Making measurements with track etching systems	Demonstration
II-14.	Making measurements of low activity of tritium and carbon-14 by liquid scintillation counting systems	Laboratory exercise

No.	Practical exercise	Type
II-15.	Neutron detection and spectrometry using BF3 detectors and polyethylene moderator spheres	Laboratory exercise
II-16.	Identification of unknown radionuclides	Laboratory exercise
II-17.	Preparation of standard uranium sources	Laboratory exercise

PART III: BIOLOGICAL EFFECTS OF IONIZING RADIATION

Prerequisite: Successful completion of Part I and Part II.

Objective: To become familiar with the mechanisms of different types of biological effects following exposure to ionizing radiation. To be aware of the models used to derive risk coefficients for estimating the detriment.

Module	Content	References
III.1. Effects of radiation at the molecular and the cellular level	**Basic radiation chemistry** Breakage of chemical bonds by excitation ionization; biologically important elements; direct and indirect effects of radiation: generation of free radicals, interaction with DNA; interaction with proteins and lipids **Effects of radiation on cells** Chromosomes; DNA; point mutations, chromosome breaks, mitosis; mitotic dysfunction, cell death; consequences of cell death; consequences of cell damage, DNA repair; cell sensitivity; radiosensitizers and protectors; chromosome aberrations as biological indicator of dose	Lecture notes [3]
III.2. Deterministic effects	**Effects of whole body irradiation** General dose-response curve; threshold; severity; acute radiation syndrome; haematopoietic system; gastrointestinal tract; central nervous system **Effects of partial body irradiation** Skin (erythema, ulceration, effect of radiation type and radiation quality); thyroid, lung, eye lens; gonads; threshold doses; effect of fractionation and dose rate; case histories (accidental exposures)	Lecture notes [2, 3]
III.3. Stochastic somatic effects	Stochastic effects Cancer induction and development; sources of data: atomic bomb survivors, dial painters, medical exposures, miners, animal data Dose-response relationship; absolute and relative risk models; dose and dose rate effectiveness factors; ICRP risk factors, fatal and non-fatal cancers	Lecture notes [2, 3, 4, 5]
III.4. Stochastic hereditary effects	**Stochastic effects** Elementary genetics; natural mutations; production of gametes and damage to chromosomes (examples); gene mutations; sources of data: man and animals; concept of doubling dose; UNSCEAR and ICRP approach; ICRP risk assumptions: subsequent generations and severity	Lecture notes [2, 3, 4, 5]

Module	Content	References
III.5. Effects on the embryo and foetus	**Radiation effects** Sensitivity at different stages of development; brain development and retardation; induction of leukaemia and cancers	Lecture notes [2, 3, 5]
III.6. Epidemiological studies and issues	**Epidemiological studies** Statistical requirements, current types of studies; association and confounding factors, power and precision; prospects and pitfalls	Lecture notes
III.7. The concept of radiation detriment	**Radiation detriment** Need for an aggregated measure of harm; tissue weighting factor w_T, effective dose; dose limits, concept of collective dose; approach adopted by ICRP; comparison of risks from different activities	Lecture notes [1, 4]

REFERENCES TO PART III

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Diagnosis and Treatment of Radiation Injuries, Safety Reports Series No. 2, IAEA, Vienna (1998).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safe Use of Radiation Sources, Training Course Series No. 6, IAEA, Vienna (1995).

[4] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the International Commission on Radiological Protection, Publication No. 60, Ann. ICRP **21** 1–3, Pergamon Press, Oxford and New York (1991).

[5] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION (UNSCEAR), Sources and Effects of Ionizing Radiation (1994 Report to the General Assembly), UN, New York (1994).

PRACTICAL EXERCISES TO PART III

No.	Practical exercise	Type
III-1.	Analysis of chromosomal aberrations	Demonstration
III-2.	Interpretation of epidemiological data	Case study
III-3.	Assessment of the risks associated with doses	Case study

PART IV: PRINCIPLES OF RADIATION PROTECTION AND THE INTERNATIONAL FRAMEWORK

Prerequisite: Successful completion of Parts I, II and III.

Objective: To become aware of the ICRP's conceptual framework and international recommendations on radiation protection and the safe use of radiation sources. To become acquainted with the role played by international organizations in radiation protection.

Module	Content	References
IV.1. Conceptual framework	**Conceptual framework**	Lecture notes
	The ICRP Basic Framework (types of exposure, control of radiation sources); brief review of quantities, including collective dose	[1, 5]
	The System of Radiological Protection in proposed and continuing practices:	
	Justification of a practice; optimization of protection with examples; individual dose limits	
	Potential exposures; dose and risk constraints	
	System of protection for intervention	
	Assessment of the effectiveness of the system of protection	
IV.2. The role of international organizations in radiation protection	**International organizations**	Lecture notes
	International Atomic Energy Agency (IAEA): Statutory functions; establishment and implementation of safety standards, legally binding instruments: Conventions	[1, 4, 5, 6]
	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)	
	Food and Agriculture Organization of the United Nations (FAO)	
	OECD Nuclear Energy Agency (OECD/NEA)	
	Pan American Health Organization (PAHO)	

Module	Content	References
IV.3. The development of safety culture	**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	Lecture notes [1, 2, 3]

REFERENCES TO PART IV

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Safety Culture, Safety Series No. 75-INSAG-4, IAEA, Vienna (1991).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Examples of Safety Culture Practices, Safety Reports Series No. 1, IAEA, Vienna (1997).

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PRACTICAL EXERCISES TO PART IV

No.	Practical exercise	Type
IV-1.	Description of the elements of the system of radiological protection and of safety culture for any given practice	Case study
IV-2.	Principles of protection and safety and national or international experience	Case study
IV-3.	Simple evaluation of safety culture for a given organization	Case study

PART V: REGULATORY CONTROL

Prerequisite: Successful completion of Part IV.

Objective: To become acquainted with the elements of a regulatory infrastructure for radiation protection and the safe use of radiation sources.

Module	Content	References
V.1. Legal framework for radiation protection and the safe use of radiation sources	**Legislative framework** Scope of basic legal framework Statutory base; enabling legislation **The Regulatory authority** Mandate of regulatory authorities; Responsibilities; organization; adequate resources; Training, qualification of staff; Advisory committees & consultants	Lecture notes [1, 3, 5, 7]
V.2. Regulatory system	**Regulatory system** The set of regulations (performance or prescriptive) Safety Requirements and Safety Guides System of notification, registration, licensing and control of radiation sources including criteria for waste storage and disposal; exemptions; clearance Responsibilities of licensees, registrants and employers Relationship between regulator and regulated; feedback National inventory of radiation sources; orphan sources; import, export, transport Safety assessment; compliance with the safety requirements; inspection; enforcement Training requirements Emergency preparedness; investigations of accident and management of emergencies Dissemination of information on protection and safety and communication with the public Co-operation between employers (sharing safety information, individual monitoring records, etc.)	Lecture notes [1, 2, 3, 4, 5, 7]
V.3. Assessment of effectiveness of the regulatory programmes	**Regulatory assessment** Methodology to assess the effectiveness: performance indicators, performance criteria Peer review	Lecture notes [5, 6]

REFERENCES TO PART V

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

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PRACTICAL EXERCISES TO PART V

No.	Practical exercise	Type
V-1.	Preparation of a conceptual regulatory framework for a country with a defined type and number of radiation sources	Case study
V-2.	Use of computer aided materials for an information system for a regulatory authority (for example, the IAEA Regulatory Authority Information System (RAIS))	Demonstration
V-3.	Study of the licensing process for an industrial or a medical practice	Case study
V-4.	Conduct of a safety review for a licence application for an industrial radiography facility or other type of practice	Case study
V-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
V-6.	Preparation of a press release by a regulatory authority on a topical issue	Case study

PART VI: ASSESSMENT OF EXTERNAL AND INTERNAL EXPOSURES

Prerequisite: Successful completion of Parts I–IV.

Objective: To be able to estimate the doses to individuals arising from both external and internal exposure.

Module	Content	Reference
VI.1. Assessment of occupational exposure due to external sources of radiation	**Dosimetric quantities (review)** The radiation weighting factor w_R in terms of unrestricted linear energy transfer in water; equivalent dose; tissue weighting factor w_T; effective dose; personal dose equivalent Hp (0.07) and Hp(10); the ambient dose equivalent H*(d) and the directional dose equivalent (H'(d)) **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 dosimeters 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 **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, noble gases; use of ambient dose equivalent and directional dose equivalent; dose rate meters for receptor free conditions calibrated for ambient and directional quantities	Lecture notes [1, 2, 4, 8, 9, 10, 11, 12, 15]

Module	Content	Reference
	Interpretation of measurements 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 **Calibration** Primary and secondary standards; sources used for calibration; calibration; Routine testing of equipment, performance testing, type testing **Quality assurance** Quality assurance procedures	
VI.2. Assessment of occupational exposure due to intakes of radionuclides	**Modes of intake** Inhalation (particle sizes, AMAD, determination of size distribution of aerosols), ingestion and absorption through skin or wounds; influence of specific activity and physicochemical state: retention in tissues, complexation, polymerization, etc. Special case of tritiated water and vapour: intake through skin of splashed water and of vapour and respiratory intake Intakes of radionuclides by workers; intakes of radionuclides by members of the public **Monitoring programme** Monitoring programme for exposure due to the intake of radionuclides Monitoring programme: need, design of a routine monitoring programme, methods of measurement, frequency of monitoring, reference levels, special monitoring Workplace monitoring: surface, air; the concept of DAC Direct methods for personal monitoring: principles; measurement geometry: whole body, thyroid, lung; methods of detection; measurement procedures Indirect methods for personal monitoring: 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)	Lecture notes [2, 3, 5, 8, 11, 12, 14, 15, 16, 17]

Module	Content	Reference
	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	
	Non-exponential retention; body model ICRP (standard man); gut model; lung model; age dependent models; entry through wounds and intact skin	
	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; dosimetric models of ICRP	
	Calculation of the organ contribution to the effective dose	
	Primary and secondary limits; Special case of radon and radon progeny	
	Software for internal dose calculation (characteristics and availability)	
	Calibration	
	Calibration of body counters; calibration of the biochemical techniques; intercomparison of radiochemical assays; standards; routine testing of equipment	
	Quality assurance	
	Quality assurance procedures	

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PRACTICAL EXERCISES TO PART VI

No.	Practical exercise	Type
VI-1.	Development of a routine monitoring programme (internal and external exposures)	Case study
VI-2.	Use of thermoluminescence dosimetry and film dosimetry for personal dose assessment	Demonstration
VI-3.	Interpretation of measurements made with a personal dosimeter	Case study
VI-4.	Demonstration of practical monitoring systems for areas, surfaces and air	Demonstration
VI-5.	Calibration of different dosimeters	Technical visit to a secondary standard dosimetry laboratory (SSDL)
VI-6.	Measurement of the radionuclide content of the body by whole body counting	Technical visit to a whole body counting facility
VI-7.	Measurement of radionuclides in urine samples	Laboratory exercise
VI-8.	Calculation of internal doses using ICRP models for acute and chronic exposure	Case study

PART VII: PROTECTION AGAINST OCCUPATIONAL EXPOSURE

Prerequisite: Successful completion of Parts I–V.

Objective: To be able to use the occupational radiation protection concepts in developing a radiation protection programme for any practice.

Module	Content	References
VII.1. Organization and management	**Radiation protection programme** Prior radiological evaluation and safety assessment; scope and structure of the radiation protection programme; responsibility and commitment of registrant, licensees and employers; responsibility of workers and others at the workplace; radiation protection organization; special administrative arrangements; infrastructure; role of the radiation protection officer; role of the qualified expert; lines of communication (internal, between employers, with regulatory authority); safety culture; quality assurance; emergency preparedness	Lecture notes [1, 4, 5, 6, 32]
VII.2. Methods of protection and the safe use of radiation sources; optimization	**Technical aspects of radiation protection against sealed and unsealed sources** General principles Time, distance and shielding; minimum number of sources; protection against contamination; house keeping; hierarchy in protective measures – infrastructure (design) and procedures **Safety and security of sources** Physical protection of sources and waste; leak testing, signs and tagging; conditioning; shielding; storage; decommissioning; emergency procedures **Features of facility design** 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; liquid effluent pipeline and decay control; fixed radiation monitors; warning signs; quality assurance; commissioning survey and regulatory review	Lecture notes [1, 2, 6, 10, 11, 14, 16, 17, 18, 32, 34]

Module	Content	References
	Personal protection	
	Protective clothing; respiratory protection; contamination control; decontamination	
	Administrative and procedural controls	
	Classification of areas	
	Controlled and supervised areas	
	Policies and procedures	
	Local rules and supervision; justification of practices and interventions, compliance with dose limits; record keeping and reporting	
	Optimization of radiation protection	
	Commitment to optimization; the optimization process; investigation levels; dose constraints; use of decision aiding techniques	
	Quality assurance	
	Routine assessment of management and technical performance; audits and review; feedback for improvements	
	Training	
	Induction training for new comers; specific safe working procedures; refresher training; communication skills	
VII.3. Individual and workplace monitoring	**Monitoring**	Lecture notes
	Purposes of monitoring	
	Individual monitoring for external and internal exposure	[1, 6, 7, 8, 13, 26, 27]
	Work place monitoring; choice of instrumentation and methods	
	Interpretation of results; record keeping	
VII.4. Health surveillance	**Health surveillance**	Lecture notes
	Objectives; responsibilities; medical examination of workers; content of training for the physicians; counselling; management of overexposed workers	[1, 6, 9, 28, 30]

Module	Content	References
VII.5. Potential exposures	**Potential exposures** Safety assessment of structures, systems, components and procedures related to protection and safety including modifications of such items Documentation of safety assessments Accident prevention, mitigation and management, design provision and quality assurance for control of potential exposures; investigations of accidents, incidents and abnormal exposures and follow-up with corrective action	Lecture notes [1, 3, 15, 29, 33, 35]
VII.6. Protection against occupational exposure 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; specific regulatory requirements; basic requirements for safety (design and use 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	Lecture notes [10, 11, 18, 25, 34]
VII.7. Protection against occupational exposure in industrial irradiators and accelerators	**Industrial irradiators and accelerators** Overview of industrial irradiators and accelerators; organizational responsibilities; basic requirements for safety. specific regulatory requirements; 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	Lecture notes [18, 22, 23, 34, 37, 38, 39]
VII.8. Protection against Occupational Exposure in the Use of Nuclear Gauges	**Nucleonic gauges** Overview of gauging devices; organizational responsibilities; basic requirements for safety; safety associated to the equipment; radiation protection programme; protection of the workers	Lecture notes [18, 24]
VII.9. Protection against occupational exposure in the use of tracers	**Radiotracers** Overview of tracer uses; organizational responsibilities; basic requirements for safety; radiation protection programme. Control of effluents; protection of the workers	Lecture notes [18]

Module	Content	References
VII.10. Protection against occupational exposure in well logging devices	**Well logging** Overview of well logging devices; organizational responsibilities; basic requirements for safety; radiation protection programme; protection of workers	Lecture notes [18]
VII.11. Protection against occupational exposure 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. Control of effluents; protection of workers	Lecture notes [18]
VII.12. Protection against occupational exposure in diagnostic radiology	**Diagnostic radiology** Overview of diagnostic radiology; classification of the equipment: general and specialized radiology , basic requirements for safety; safety associated to the equipment (IEC standards); shielding; radiation protection programme; protection of the workers	Lecture notes [18, 31, 36]
VII.13. Protection against occupational exposure in nuclear medicine	**Nuclear medicine** Overview of nuclear medicine. Radionuclides used in nuclear medicine; basic requirements for safety; safety in diagnostic applications (in vivo and in vitro); safety in therapeutic applications; radiation protection programme; protection of the workers	Lecture notes [18, 21, 31, 36]
VII.14. Protection against occupational exposure in radiotherapy	**Radiotherapy** Overview of radiotherapy. Radiation sources and equipment used in brachytherapy and teletherapy, basic requirements for safety; safety requirements on radiation sources and equipment (IEC and ISO) for radiotherapy; radiation protection programme, protection of the workers	Lecture notes [12, 18, 19, 20, 31, 34, 36]
VII.15. Protection against occupational exposure 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 the workers	Lecture notes

Module	Content	References
VII.16. Protection against occupational exposure in mining and processing of raw materials	**Mining and processing of raw materials** Basic requirements for safety; ventilation; exclusion and exemption; radiation protection programme; protection of the workers	Lecture notes [1, 9]

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PRACTICAL EXERCISES TO PART VII

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 a department of nuclear medicine of a hospital	Technical visit
VII-4.	Preparation of an organizational chart and highlights of a radiation protection programme in a hospital (radiotherapy, diagnostic radiology or nuclear medicine) and in an industrial facility (industrial radiography or irradiator)	Case study
VII-5.	Shielding calculations for an X ray facility	Exercise
VII-6.	Application of the 'as low as reasonably achievable' (ALARA) principle for occupational exposure	Case study
VII-7.	Leak testing of sealed sources	Laboratory exercise
VII-8.	Use of personal protective equipment	Demonstration
VII-9.	Choice of a personal dosimeter and monitoring instruments	Demonstration
VII-10.	Preparation of a laboratory to work temporarily with unsealed sources	Simulation
VII-11	Monitoring a workplace for external radiation; selection of instrumentation; interpretation of results	Simulation
VII-12.	Monitoring a workplace for surface and air contamination; use of gross alpha and beta measurements and gamma spectrometry	Simulation
VII-13.	Decontamination of surfaces	Laboratory exercise
VII-14.	Determination of individual dose due to air contamination	Case study
VII-15.	Management of personal dose records, dose reduction measures, special monitoring, follow-up measures	Case study
VII-16.	Comparison of predicted doses to personnel on the basis of workplace monitoring with the results of individual monitoring in mixed radiation fields	Case study

PART VIII: MEDICAL EXPOSURES IN DIAGNOSTIC RADIOLOGY, RADIOTHERAPY AND NUCLEAR MEDICINE

Prerequisite: Successful completion of Parts I–VI.

Objective: To be able to apply the radiation protection principles to medical exposure. To understand the concepts used to calculate the dose to patient and to carry out quality assurance procedures.

Module	Content	References
VIII.1. Scope and responsibilities	**General principles** Diagnostic and treatment purposes; registration of professionals; licensees; role of medical practitioner; role of qualified expert in medical physics **Training** Workers to be trained; content of the training programmes; updating of programmes; refresher training	Lecture notes [1, 2, 4, 7, 8]
VIII.2. Justification of medical exposures	**Justification of medical exposures** Identification of alternative techniques; evaluation of the detriment; criteria for the justification of exposure (difference between diagnostic and treatment practices)	Lecture notes [1, 8]
VIII.3. Optimization of protection for medical exposures	**Design considerations for equipment** Radiation safety; international requirements (standards (IEC, ISO) for radiation generators and radioactive sources) Basic technical characteristics; regular review and maintenance; factors affecting dose to the patient **Determination of a dose to the patient** Specific correction factors for the determination of absorbed dose in water for photon and electron beams; determination of the dose in nuclear medicine, diagnostic radiology and radiotherapy: determination by assessment; determination by measurement; comparison with reference levels **Operational considerations** Optimization of dose distribution in treatment (planning of physical treatment); minimizing exposures of patients (difference between diagnostic and treatment practices); mobile equipment versus fixed equipment; exposure of women in reproductive capacity; use of organ shielding	Lecture notes [1, 5, 6, 7, 8]

Module	Content	References
	Guidance levels for the patients Guidance levels for the patient specified by professional bodies on the basis of relevant surveys (in diagnostic and radiotherapy); dose constraints (persons exposed for medical research purposes) and comforters; ethical review committee for experiments; activity in patients to be discharged from treatment in nuclear medicine	
VIII.4. Quality assurance	**Comprehensive specific quality assurance programmes** Pre-use testing; periodic control (physical and clinical parameters); periodic quality audit and review **Calibration of sources and equipment** Traceability to secondary standard dosimetry laboratory (SSDL); quantities used for calibration; criteria used for calibration of different types of equipment (radiotherapy equipment, sealed and unsealed sources); standards **Records** Identification of the information to be recorded related to the type of medical exposure	Lecture notes [1, 7]
VIII.5. Accidental exposures in medical applications	**Accidental medical exposures** Identification and investigation of accidental medical exposures; report to the regulatory authority; lessons learned and feedback into operation	Lecture notes [1, 3]

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PRACTICAL EXERCISES TO PART VIII

No.	Practical exercise	Type
VIII-1.	Determination of doses to patients	Case study
VIII-2.	Optimization of doses to patients in diagnostic radiology	Case study
VIII-3.	Optimization of doses to patients in nuclear medicine and radiotherapy	Case study
VIII-4.	Measurement of the absorbed dose in the body for a unidirectional exposure to cobalt-60 using a phantom and thermoluminescence dosimetry detectors	Laboratory exercises
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

PART IX: EXPOSURE OF THE PUBLIC DUE TO PRACTICES

Prerequisite: Successful completion of Parts I–VII.

Objective: To become aware of the various pathways by which the public might be exposed to radiation as a result of practices and methods for determining doses.

Module	Content	References
IX.1. Sources of exposure of the public	**Natural sources of exposure (review)** Terrestrial sources (potassium-40, uranium, thorium, radon); exposure to cosmic and cosmogenic radiation; geographic variation **Human made sources of exposure (review)** Fallout from atomic bomb tests; effluent discharges; transport; consumer products; etc.	Lecture notes [13]
IX.2. Responsibilities and organization	**Responsibilities** Responsibilities of licensees and registrants; regulatory authorities; regulations; inspection; monitoring; reporting; adequate records; emergency planning; communication with the public; physical protection and the safe use of sources; registry and periodic physical inventory of sources; control and disposal of spent sources; control of visitors	Lecture notes [2]
IX.3. 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	Lecture notes [3, 4]

Module	Content	References
IX.4. Safety of radioactive waste management	**Radioactive waste management**	Lecture notes
	Sources of radioactive waste, waste types, waste classification, waste characterization	[5, 6]
	Principles of radioactive waste management, basic technical management options: dilute and disperse, concentrate and contain, storage for decay and clearance from control	[2, 5, 7]
	Waste minimization	[8]
	Pre-disposal waste management: collection, segregation, treatment, conditioning, secure storage	[5, 9, 10, 11]
	Control of effluents: approach to regulatory control, establishing authorized discharge levels	[2, 12]
	Management of disused sealed sources: technical options and safety aspects	[13, 14, 15]
	Management of waste from decommissioning	[9, 16]
	Solid waste disposal: disposal options for different waste types, safety principles and technologies for assuring long term safety, safety assessment methods	[7, 17, 18]
	Management of waste from uranium and thorium mining and milling	[19]
	Management of NORM waste	
	Cleanup of contaminated areas	[20, 21]

Module	Content	References
IX.5. Environmental dose assessment	**Environmental assessment** Environmental dispersion and transfer routes (atmospheric, terrestrial, aquatic), exposure pathways for humans, critical groups, assessment models, individual and collective dose assessment, committed effective dose per unit intake as a function of age	[22]
IX.6. Source and environmental monitoring	**Environmental monitoring** Monitoring at source: external radiation and liquid and gaseous effluents, verification of compliance with discharge limits Environmental monitoring: atmosphere, water bodies, foodstuffs, other environmental indicators, verification of compliance with derived environmental reference levels, survey techniques Application to different sources: nuclear power plants, waste facilities, including repositories, mining and milling, tailings, contaminated land	[2, 23]
IX.7. Consumer products	**Consumer products** Definition; justification; optimization (including type testing); responsibilities of manufacturer and supplier; prior authorization; guidance for users; labelling	Lecture notes [2]

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PRACTICAL EXERCISES TO PART IX

No.	Practical exercise	Type
IX-1.	Procedures for transport of material: characterization of materials and selection of optimum type of package	Case study
IX-2.	Packaging of radioisotopes for transport	Laboratory exercise
IX-3.	Preparation of shipping documents for transport by road and air	Laboratory exercise
IX-4.	Collection and segregation of waste: monitoring, preliminary conditioning and labelling	Laboratory exercise
IX-5.	Visit to a waste treatment facility and a waste management facility	Technical visit
IX-6.	Listing of the components of an environmental monitoring programme for a given installation	Case study
IX-7.	Preparation and measurements of environmental samples: air, soil, water and foodstuffs	Laboratory exercise
IX-8.	Interpretation of the results of an environmental monitoring programme	Case study

PART X: INTERVENTION IN SITUATIONS OF CHRONIC AND EMERGENCY EXPOSURE

Prerequisite: Successful completion of Parts I–VII and Part IX.

Objective: To develop an awareness of the causes and consequences of situations of chronic exposure, and of radiological and nuclear accidents and approaches to mitigate their consequences.

Module	Content	References
X.1. General principles and types of events	**Principles for intervention** Chronic exposure situations: types - radon, residual contamination, etc.; remedial action plans; action levels Nuclear and radiological accidents: nuclear reactor accident; accident with radiation sources, accident outside the country with transboundary effects; nuclear powered satellites and re-entry; history of past accidents; lessons learned	Lecture notes [1, 4, 5, 13, 19–29]
X.2. Basic concepts for emergency response	**Emergency response** Concepts and objectives of emergency response; principles of intervention, including intervention levels; protective actions and operational intervention levels; emergency response strategies; generic response organization	Lecture notes [1, 2,17]
X.3. Basic concepts for emergency preparedness for a nuclear accident or radiological emergency	**Emergency preparedness** Concepts and objectives of emergency preparedness; emergency planning categories; planning areas and zones; planning levels and responsibilities; planning elements for emergency preparedness; integrated planning concepts; personal protective equipment and devices; training; exercises	Lecture notes [2, 3, 6, 8, 18]
X.4. Developing a national capability for response to a nuclear accident or radiological emergency	**Implementation of emergency response plans** Step by step approach to developing and implementing emergency response plans and procedures; identification and assignment of critical tasks; concept of operations; national emergency response plan Checklists of emergency preparedness; considerations for radiological and nuclear accidents: infrastructure elements; functional elements	Lecture notes [8, 9]

Module	Content	References
X.5. Overview of assessment and response in a radiological emergency	**Assessment of radiological emergency** Accident scenarios; generic response organization in a radiological emergency; emergency management; response at the scene: co-ordination of organizations involved; initial response; radiological response: source recovery; decontamination; removal of radioactive wastes; dose assessment overview: external and internal; lessons learned from Goiânia accident	Lecture notes [7, 11, 19, 20, 21, 22, 23, 25]
X.6. Overview of assessment and response in a nuclear reactor emergency	**Assessment of nuclear emergency** Events leading to a release from the core; releases from the core and to the environment; exposure pathways; protective actions; revision of operational intervention levels; lessons learned from reactor accidents (Three Mile Island, Chernobyl)	Lecture notes [9]
X.7. Monitoring in a nuclear accident or radiological emergency	**Emergency monitoring overview** Objectives; generic monitoring organization and strategy; small and large scale accidents; staff qualification; instrumentation; basic survey method during an emergency; quality assurance **Field radiation and contamination monitoring** Objectives; basic methods and techniques (plume survey; ground deposition survey; environmental dosimetry; source monitoring; surface contamination survey; aerial survey); field sampling: objectives; methods and techniques (sampling of air; soil; milk; human food; pasture; sediment) measurement techniques; gamma spectrometry (laboratory and in situ); gross alpha and beta measurements; radiochemical analysis **Radiation protection of monitoring teams** Objectives; personal protection guides; personal monitoring; simple decontamination techniques **Basic data evaluation** Methods; field monitoring data evaluation; radionuclide concentration data evaluation; mapping; link to operational intervention levels	Lecture notes [12, 15]
X.8. Medical management of radiation injuries	**Medical management** Responsibilities and management of medical intervention; the triage of victims; diagnosis and treatment; training of those involved in medical management of the victims (medical, paramedical staff); psychological effects	Lecture notes [1, 10, 14]

Module	Content	References
X.9. Communication with the public	**Communication** Communication with the public and other parties, including regulatory authority in neighbouring countries; objectives of communication with the public; spokesperson; preparation of message; communication methods and means; communication schedule; resources; training on communications	Lecture notes [16]
X.10. International co-operation	**International co-operation** Safety conventions and their implementation IAEA Emergency Response Network (ERNET)	Lecture notes

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PRACTICAL EXERCISES TO PART X

No.	Practical exercise	Type
X-1.	Measurement of radon in dwellings and comparison with action level	Laboratory exercise
X-2.	Response to a hypothetical accident: loss of a gamma radiography source	Case study
X-3.	Response to a hypothetical accident: environmental release of a substantial amount of radioactive material	Case study
X-4.	Estimation of the individual doses following an accidental overexposure	Case study
X-5.	Search for a lost source	Simulation
X-6.	Response to a hypothetical transport accident with radioactive material	Simulation
X-7.	Communication with the public and with information media after a hypothetical accident; press conference	Simulation

PART XI: TRAINING THE TRAINERS

Prerequisite: For the workshops: successful completion of Parts I–X.

Objective: To be able to organize and implement national training courses. To develop didactic skills.

Module	Content	References
XI.1. Training needs	**General considerations on persons to be trained and types of training** 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; trainers Classroom based training, distance learning, on the job training, refresher training; education at schools; radiation awareness programme for the public	Lecture notes [1, 2]
XI.2. Being a lecturer	**Being a lecturer** Building a structured learning session to meet objectives Differences between learning objectives and course content; defining learning objectives appropriate to participant background; building the learning scale step by step; choice of a teaching method; optimization of learning time to meet objectives **How to teach involving the group** Create a positive climate; motivating participants; enhance group discussions: do not speak and do yourself, encourage the participants discuss and work out problems themselves; solving difficulties with participants; conception of didactic material; adding value using visual aids; permanent assessment of the acquired notions	Lecture notes [3]

Module	Content	References
XI.3. Setting up a training course	**Course design** Aims and objectives, syllabus, lecture plans, course programme, lecture notes Selection of lecturers/instructors Course organization Course administration, facilities and equipment, selection of participants, pedagogical methodologies, preparation of demonstrations, practical exercises and case studies, field visits, preparation of examinations **Course evaluation** Results of the examination, participants and lecturers feedback, results of the evaluation, independent course audits	Lecture notes [3]

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PRACTICAL EXERCISES TO PART XI

No.	Practical exercise	Type
XI-1.	Preparation of a syllabus and programme for a training course on radiation protection and the safety for users	Case study
XI-2.	Suggested topics for presentation and discussion by the participants: – Occupational radiation protection in a given application of ionizing radiation – Safety assessment for licensing purposes for a given installation – Preparation of an inspection in a given installation – Medical application of sources of ionizing radiation and safety related aspects – Limitations and use of radiation protection instrumentation – Natural radioactivity and radiation exposure of the public – Conceptual planning to respond to a radiological emergency at a given installation	Presentations and workshops

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