Supporting occupational health and wellbeing professionals

Knowledge and Skills Guidance for an Occupational Physician with a Specialist Interest in **Radiation Medicine** (OPSIRM)

Nuclear Industry Ionising Radiation Occupational Health Professionals (NIIROPs)

A SOM Special Interest Group

BACKGROUND

The protection of employees working with ionising radiation presents a unique set of challenges for the occupational health physician. An understanding of radiation medicine in addition to that covered within the Faculty of Occupational Medicine curriculum is essential to enable the occupational health physician to understand the risks, provide appropriate health surveillance, advise on incident management, and comply with safety standards. In addition to the requirements of an appointed doctor (IRR 2017), occupational health physicians working in the nuclear industry will frequently be required to participate in an on-call rota to provide emergency advice in the event of radiation contamination or a radiation incident and should therefore be appropriately trained and competent to do so.

Whilst radiation accidents are rare, an occupational physician working in the nuclear sector should be fully cognisant with international guidelines and be competent to respond if such an event were to happen.

The management of radiation accidents is challenging. Radiation occupational health physicians play a key role in the ability to respond appropriately to such an event including triaging affected individuals, prompt diagnosis of radiation casualties and advising on the urgent initiation of specific treatment and management. They also have a key role in emergency planning and the liaising and coordination of management in the wider multi-disciplinary team that would be involved in the response, including with the radiation protection team, nuclear physicists, public health authorities and other physicians involved in the care of individuals.

Until this point there has been no agreed guidance on the required knowledge and skills for occupational health physicians working in the radiation industry out with the requirements to deliver classified radiation worker medicals, yet there would be an expectation that they would be adequately trained in order to assess fitness for work both with ionising radiation but also considering the demands of any emergency response roles and to respond to a radiation incident. The aim of this document is to provide guidance as to the knowledge and skills that should be held by occupational health physicians working in the nuclear sector.

Occupational Physician with a Specialist Interest in Radiation Medicine (OPSIRM): Requirements

1. The Occupational Health Physician must hold a minimum of the DOccMed, although it is preferable they will hold MFOM/FFOM.
2. Full GMC registration with license to practice.
3. Qualifications and training sufficient for an appointment as an IRR Appointed Doctor.
4. Knowledge of the security, environmental and safety considerations of working on a nuclear licensed site or with radioactive material as well as the demands of responding to any potential emergencies in that environment.
5. Radiation Physics/Medicine Knowledge to enable an understanding of ionising radiation, including the principle of dose, management of acute radiation syndrome and decontamination. To understand the effects and management of a radiation incident.
6. Documentary evidence of suitable training and participation in appraisal incorporating radiation medicine work.
7. Experience of working in the Radiation industry as an Occupational Health Physician.
8. Partake at least annually in CPD for radiation medicine.

LEARNING OUTCOME 1

Basic Physics of Ionising Radiation

The OPSIRM *should* understand the fundamental principles of radiation physics and an awareness of wider principles as listed below. They *should* be aware of sources of radiation and understand the interactions of radiation with matter.

Syllabus

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
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/Poisson, Gaussian, log-normal); scatter diagram; student T test; Chi square, regression; correlation; practical application to counting; curve fitting by least square methods
Charged Particle Radiation	Heavy particles (alpha, proton nuclei) Energy transfer mechanisms, ionization and excitation, scattering nuclear interaction; range–energy relationship

Professional Capabilities

OPSIRMs should have a good understanding of:

- the structure of the atom and identify the basic constituents of the nucleus
- how atoms are grouped into elements in accordance with their atomic number, and how these elements are arranged in the periodic table
- the concept of isotopes of a specific element
- the process of ionisation and the mechanisms by which an atom is ionised
- modes of decay and the types of radiation emitted (alpha, beta, positron emission, gamma, neutrons)
- the differences in how the types of radioactivity interact with matter/materials
- the unit of radioactivity, the concept of half-life and the law of radioactive decay
- the properties of neutrons
- the concept of nuclear fission.

LEARNING OUTCOME 2

Radiation Quantities and Measurements

The OPSIRM *should* have an understanding and wider awareness of the radiometric, dosimetric and operational quantities of radiation and their measurement units as listed below enabling them to conduct basic calculations. The OPSIRM should understand how to operate monitoring equipment as well as the characteristics and limitations of different equipment and be able to analyse and interpret the monitoring data.

Syllabus

Radiometric quantities and interaction coefficients	Radiation field; fluence (rate); energy fluence (rate); cross section; mass attenuation coefficient; mass stopping power
Dosimetric quantities	Exposure (rate); concepts of dosimetry: energy imparted; absorbed dose (rate); linear energy transfer (LET); organ dose
Radiation protection and operational quantities	Radiation weighting factor wR; equivalent dose; tissue weighting factor wT; effective dose
Detectors	General properties of radiation detectors; detectors used for radiation protection purpose: principle of functioning, properties, operational features, main associated electronic components, measurement applications

Professional Capabilities

OPSIRMs should understand:

- the concepts of radiation field and fluence
- the quantities equivalent dose, effective dose, committed dose, committed effective dose
- dose limits and the recording of dose
- how radiation dose rate varies with the distance from sources of different geometries
- the principles of radiation detection and measurement
- the general principles of radiation detection and understand the concepts of energy efficiency, resolution, and limit of detection
- the basic principles of different methods of measuring radiation such as ionization chambers, Geiger–Müller tubes and scintillation detectors
- how to choose an appropriate monitor for a radiation hazard.

LEARNING OUTCOME 3

Biological Effects of Ionising Radiation

The OPSIRM *should* have a good understanding and 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 *should* understand models used for estimating risk coefficients for stochastic effects.

Syllabus

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)
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)
Oncogenesis	Animal models of radiation oncogenesis, atomic bomb survivors, dial painters, medical exposures, miners, and others
Dose-response relationship	Absolute and relative risk models; dose and dose rate effectiveness factors ; radiation-associated human tumours; 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
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
Effects on the embryo and foetus	Basic embryogenesis; tissue reactions: sensitivity at different stages of development; malformations; brain development and retardation; stochastic effects: induction of leukaemia and solid cancers
Epidemiological studies	Statistical requirements, current types of studies; methods of sampling to establish cohorts; association and confounding factors; power and precision; prospects and pitfalls
Radiation detriment	Need for an aggregated measure of harm; radiation weighting factor wR; tissue weighting factor wT, effective dose; concept of radiation detriment, collective dose; approach adopted by ICRP; risk comparison
Radionuclides in the Human Body	Radionuclides in the Human Body - the behaviour of radionuclides in the body including isotopes of tritium, caesium, strontium, iodine, radium, and plutonium; ICRP biokinetic and dosimetric models; dose calculations; doses to the embryo and foetus

Professional Capabilities

OPSIRMs should be able to:

- explain the concept and structure of cells
- describe the cell cycle and the process of division
- describe the DNA and chromosomal structures
- explain the mechanisms by which ionizing radiation damages DNA and know the major types of damage
- describe the DNA repair processes
- describe the evolutionary phases of radiation induced damage in an organism
- explain the factors that influence cellular and organ/tissue radiosensitivity
- define tissues reactions and distinguish early and late reactions in tissues and organs
- describe the factors that influence radiation sensitivity
- describe the causes of Acute Radiation Syndrome and how it is characterized
- list the main Acute Radiation sub-Syndromes
- give an overview of haematopoiesis and the influence of ionizing radiation on the hematopoietic system
- describe, in general terms, the two categories of effects of ionizing radiation on gastrointestinal physiology
- summarise cardio-neurovascular dysfunction in lethal irradiation
- explain what is meant by "localized" radiation exposure and the possible consequences of such exposure
- explain what characterizes Cutaneous Radiation Syndrome (CRS)
- explain what is meant by a "deterministic" or "stochastic effect" of ionizing radiation and summarize the relative risk of ionizing radiation for carcinogenesis
- summarise the early stages, and mechanisms, of oncogenesis and the main sources of data for the effects of radiation exposure on humans
- explain the concept of a risk factor
- explain the difference between somatic and hereditary effects of exposure to ionizing radiation and describe the sources of data for the hereditary effects in humans
- summarize the causes of hereditary effects
- provide an overview risk coefficient for hereditary effects and appropriate data resources
- summarise basic embryology and the varying sensitivity of the embryo and foetus at different stages of development
- explain the possible effects of prenatal exposure
- explain how epidemiology is used in radiation protection
- describe epidemiological parameters
- give an overview of several examples of epidemiological studies
- explain the concepts of tissue weighting factor, effective dose, and collective dose
- summarise the components of health detriment associated with stochastic effects
- specify the current dose limits for both occupational and public exposure and the rationale behind the values set.

LEARNING OUTCOME 4

Assessment of internal and external exposures

The OPSIRM should have an awareness of different methods of measurement, monitoring, calculating, and interpreting the doses to individuals arising from internal or external exposure.

Syllabus

Monitoring programme for the workplace including the use of personal dosimeters	Routine, task related and special monitoring; fixed and portable monitors
Interpretation of measurements	Recording levels; evaluation of doses to whole body, extremities, and skin; an understanding of calculation of the effective dose caused by external exposure; routine, task related and special monitoring
Assessment of occupational exposure due to intakes of radionuclides	Modes of intake. Inhalation (particle sizes, determination of size distribution of aerosols), ingestion and absorption through skin or wounds. 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

Professional Capabilities

OPSIRMs should be able to:

- understand the radiological protection principles and how they are used in practice
- assess occupational exposure due to external sources of radiation
- describe the different types of personal dosimeter
- interpret dosimeter results
- identify the circumstances where dosimeter results may not provide an adequate estimate of dose
- specify the measurement techniques that can be used for accident dosimetry
- describe basic workplace monitoring principles
- describe the different types of personal dosimeters (film, thermoluminescent, optically stimulated luminescence, electronic).

LEARNING OUTCOME 5

Emergency exposure situations and emergency preparedness and response

The OPSIRM *should* understand the basic requirements for protection against emergency exposure situations. The system of emergency preparedness and response, including the basic requirements, principles, goals, planning basis, protective and other response actions, and public communication. They *should* also be aware of the arrangements that have to be in place for an effective and efficient response during a nuclear or radiological emergency.

Syllabus

Basic requirements and principles	**Basic Safety Standards requirements** 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 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 UK Domestic Regulation of Ionising Radiation (Ionising Radiations Regulation, Environmental Permitting Regulations and REPPIR)
Planning basis for emergency exposure situations	Assessment of hazards; emergency preparedness categories
Protection strategies for emergency exposure situations	Protection strategies for emergency exposure situations
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, reference levels to guide what action should be taken to protect workers/public
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

LEARNING OUTCOME 5

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
Medical response in emergency exposure situations	Medical response: responsibilities and management of medical response (pre-hospital and in hospital); triage priorities and triage systems; 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 first aid, psychological effects, and risk communications
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 for the key position's competencies within the emergency response organization; preparation, conduct and evaluation of emergency response exercises. Role of Government agencies in response to any incident
International arrangements	Role of IAEA in emergency preparedness and response; IAEA Safety Standards in emergency preparedness and response; IAEA Response and Assistance Network (RANET)

Professional Capabilities

OPSIRMs should:

- be able to demonstrate participation in a nuclear exercise. This exercise could be facility-based, location-based, or more broadly based including national exercises
- be able to show involvement in exercise planning
- be able to demonstrate practical participation in the techniques associated with use of PPE within a radiological emergency and be able to adequately demonstrate such use. This needs to include both the donning of PPE and the removal of contaminated PPE in a safe manner. Such a demonstration can be uploaded to the portfolio by use of video or be witnessed by a relevant nuclear professional
- be familiar with the commonest types of ionising radiation countermeasures used within the nuclear industry
- be familiar with the core publication NCRP 161 and its use
- be able to explain the importance of environmental monitoring and how it is achieved during nuclear incidents and emergencies and how that is used to guide the emergency response
- understand the psychological effects of radiation, both on victims, the emergency response teams, and the greater public
- be able to counsel on the risks of workplace radiation exposure
- be familiar with communications techniques used following a major incident and be able to effectively communicate risk in general terms at a wider population level https://srp-uk.org/professional-resources/general-guidance
- be able to convey to a receiving hospital team the difference quickly and effectively between an irradiated casualty and a contaminated casualty.

See also:
- Ionising Radiation Regulations 2017 (IRR17)
- Working with ionising radiation. Ionising Radiations Regulations 2017. Approved Code of Practice and guidance
- Guidance for appointed doctors on the Ionising Radiations Regulations 2017
- The Radiation (Emergency Preparedness and Public Information) Regulations 2019 Approved Code of Practice and guidance.

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