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Occupational Radiation Protection (GSG7)

8. Assessment of Occupational Exposure
GSG7 Section 7 and Appendix 1

Presentation content

- Assessment of external exposure
- Assessment of internal exposure
- Exposure assessment in emergencies
- Skin contamination
- Record of occupational exposure
- Assessment of exposure from NORM

ASSESSMENT OF EXTERNAL EXPOSURE

Monitoring programme

Doses received by workers from external exposure can be assessed by:

- ❑ Programme of individual monitoring
  - Provision of personal dosimeters
  - Dosimeters can be “active” or “passive”
- ❑ Workplace monitoring and occupancy

Individual monitoring

Why is individual monitoring required?

- Tool for control of worker exposure
- Comply with regulatory requirements
- Demonstrate doses are kept ALARA
- Risk assessment & planning
- Input into investigations
- Employee reassurance
- Epidemiology

Individual monitoring

- Prior radiological evaluation should determine whether individual monitoring is necessary
  - For any worker who usually works in a controlled area
  - For any who occasionally works in a controlled area and may receive a significant dose
- Where individual monitoring is performed, each worker should be issued with an integrating personal dosimeter
- Issued by a dosimetry service approved by regulatory body
- In many cases, a single dosimeter worn on trunk is adequate
  - Inhomogeneous radiation field?
  - Doses to the extremities, skin or lens of the eye?
- Suitable wear period

Workplace monitoring

Sites selected for workplace monitoring should be representative of worker occupancy

Number of monitoring instruments required depends on variation of dose rate with time and/or space

Frequency of routine monitoring of the workplace depends on occupancy factor and expected changes in radiation environment

- level of risk including the risk of failure of shielding or safety systems
  - variability of dose rates and related factors
  - where individual doses are assessed on basis of results monitoring should be continuous (installed monitors)

Choice of monitoring system

- Selection of personal dosimeter based on conditions in the workplace
  - type of radiation, energy and directional distribution
  - range of expected doses and dose rates
  - environmental conditions

Personal dosimeters-active & passive

- Active: electronic dosimeters, with display/ alarm/ **real time** capabilities

- Passive: requires processing to provide any information

Passive dosimeters

- Thermo luminescent dosimeters (TLDs)
- Optically stimulated luminescence (OSL)
- Radio photo luminescence (RPL)
- Film dosimeter

For neutrons

- Albedo dosimeters (thermal neutron detector + etched track detector)
- Bubble detector

Thermo luminescence dosimeter (TLD)

- Gamma, X and beta radiation
- Many different types of TLD – different phosphors, filters, number of elements
- Low cost

$H_p(10)$

$H_p(0.07)$

Extremity dosimeters

- Most dosimeters are designed to assess dose to the whole body
- Extremity dosimeters assess doses to skin, hands/ forearms, feet/ankles or lens of the eye
- Selection and use of extremity dosimeters should be optimized, taking into account practical considerations
  - Wear position
  - Sterilization requirements?

Extremity dosimeters

Eye dosimeters

- Monitoring of the lens of the eye particularly relevant for workers in medical sector and in nuclear facilities eg interventional radiologists and decommissioning
- Need to assess personal dose equivalent $H_p(3)$
- Dosimeters designed specifically for $H_p(3)$ not yet widely available
  - Measurement of $H_p(0.07)$ or sometimes $H_p(10)$ may provide estimate
- Where to wear it?
- Protective goggles or glasses can reduce dose efficiently

Optically stimulated luminescence (OSL) dosimeter

- Gamma, X radiation
- Some types of

$H_p(10)$

Radiophoto luminescence (RPL) dosimeter

- Gamma, X and beta radiation
- Best accuracy
- No fading

$H_p(0.07)$

Film dosimeter

Gamma, X and beta radiation

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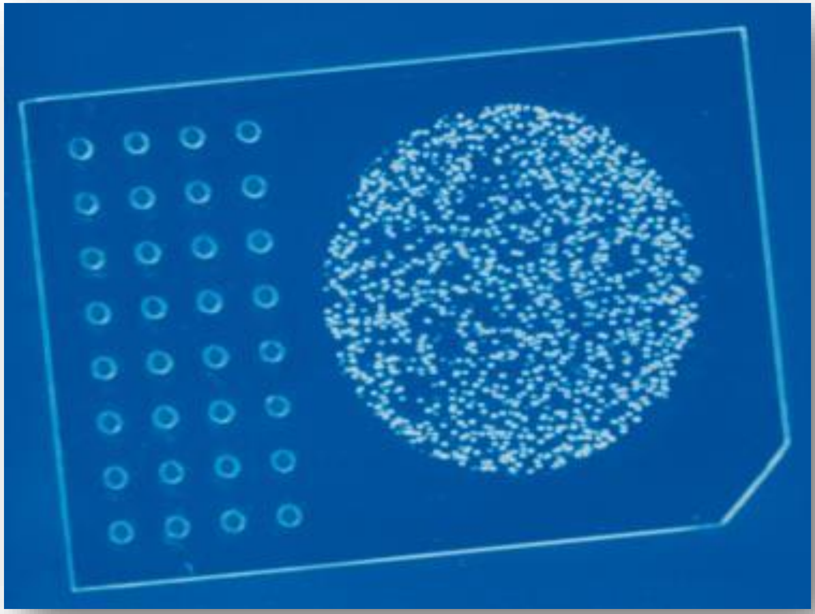
Neutron dosimeter (PADC)



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Active dosimeter

Can be used for day-to-day monitoring and control of dose

- ❑ The alarm function can be very useful in high dose rate area
- ❑ Poor performance in pulsed radiation fields

Wearing of dosimeters

Some assumptions

- Assume whole body is **uniformly exposed**
- Assume dosimeter **correctly samples** field experienced by wearer
- Relationship between measurable quantities (eg K_{air}, Φ) and E or H_T

Wearing position

- On trunk
- Best sampling for radiosensitive organs
- On chest (lung) or belt (gonads)
- Hand or finger
- Forehead?

Wearing of dosimeters

Interventional radiology: over or under apron?

- Wearing over apron can lead to excessive overestimates
- Wear one dosimeter under apron (can do pilot test wearing one over and one under)
- If any areas unshielded, eg thyroid?, wear another

Monitoring periods

- Established by management in consultation with QE or RPO and dosimetry service provider
- Routine doses – variable or predictable
- Likelihood & scale of accidental doses
- 2 – 13 weeks (typically 1 or 3 months)

Workplace monitoring system/instruments

- Selection of monitoring equipment should be done in consultation with the RPO and/or suitable qualified experts
- Monitoring equipment must be suitable to the task
- All monitors have an energy threshold (in keV). This is determined by the type of detector, the monitor casing and other factors. A particular issue when monitoring low energy x-rays.
- Only certain types of monitor can measure beta radiation
- The primary requirement is for **dose rate** monitoring (monitors scaled for microsievert or mSv per hour, etc.)
- Personal dosimeters are generally not suitable for workplace monitoring (measurement quantities different)

Practical monitoring challenges

- Mixed radiation fields
- Pulsed radiation fields
- Adventitious radiation
- Narrow radiation beams
- Direction (polar) response
- Response time
- Large area to be monitored
  - concentration

Testing of personal dosimetry systems

Type testing

- In accordance with relevant IEC/ISO standards

Performance testing

- Linking the routine calibration to national standards
- Ensures comparability between laboratories
- Three types of performance test:
  - Blind test, surprise test, announced test

Testing of personal dosimetry systems

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Routine testing

- Tests accuracy and precision of dosimetry system; carried out by dosimetry service
- Derive sensitivity, precision and accuracy are verified, usually for a single radiation type and energy
- Results should be followed up closely

Testing of workplace monitoring instruments

Type testing

- In accordance with relevant IEC/ISO standards

Tested before first use (pre-use test)

Periodic testing

- Monitoring equipment should be subject to periodic (at least annual) testing and calibration by a qualified service provider
- More frequent source checks, as necessary
  - carried out by end user

Approval of dosimetry services

- Regulatory body is responsible for authorization or approval of service providers for individual monitoring and for calibration services
- Re-assessed following any significant changes
- ADS (assessment) and ADS (records)

Interpretation of measurements

Personal dosimetry

- Aim to assess effective dose *E* and equivalent dose to tissues, H_T
- ICRU quantity $H_P(d)$ taken as estimator (d=10 mm for estimating *E,* 3 mm for H_T to lens of eye and 0.07 mm for H_T to skin / extremities

Workplace monitoring

- Use of suitable monitor together with appropriate occupancy data will provide adequate estimate of effective or equivalent dose

ASSESSMENT OF INTERNAL EXPOSURE

Monitoring programme

Objectives

Assess committed equivalent and effective doses and so demonstrate control of internal exposure

Aid design and operation of new facilities

Provide information after accidents

Monitoring programme

Assessment of doses received by workers from intakes of radionuclides based on results of individual monitoring using one or more of following:

a) Sequential measurement of radionuclides in whole body or in specific organs, ie thyroid
b) Measurement of radionuclides in biological samples, ie excretions
c) Measurement of activity concentrations in air samples collected using personal air sampling devices worn by worker or static air sampler

Routine monitoring

- Internal exposure monitoring should be carried out on a fixed schedule for selected workers
- Routinely only for workers employed in contamination controlled areas and only when there are grounds for suspecting significant intakes
- Other managerial reasons

Example of practices where internal exposure monitoring is necessary

From ICRP 78:

- Handling of large quantities of gaseous and volatile materials (e.g. tritium)
- Processing of plutonium and other transuranics
- Processing of thorium ores and the use of thorium compounds in quantity
- Milling and refining of high grade uranium ores
- Processing of natural and enriched uranium
- Production of large quantities of radionuclides
- Medical use of large quantities of iodine-131

Limitations on assessments

Internal exposure monitoring has certain limitations that should be considered in the design of monitoring programme

- Uncertainty about time of intake
- Route of intake
- Preceding intakes
- Biokinetics - which dose coefficient ?
- Inconsistency between methods eg. WBC vs bioassay
- Effect of blocking agents eg. stable iodine

Considerations

To determine the appropriate frequency and type of individual monitoring, the workplace should be characterized

- Radionuclides in use
- Chemical and physical form – particle size distribution
  - respiratory tract and biokinetic behaviour in body
- Rate of excretion and routes
  - Type of excretion samples needed and frequency of collection

Specific monitoring

Task related monitoring

- Not routine
- Provides information about a particular short term operation

Special monitoring

- Undertaken following known or suspected exposure, or loss of containment
- Accident situations
  - Urgent medical first aid takes priority
  - Steps taken to minimise immediate exposure (decontamination)
  - ‘Immediate’ assessment of intake

Methods of measurement

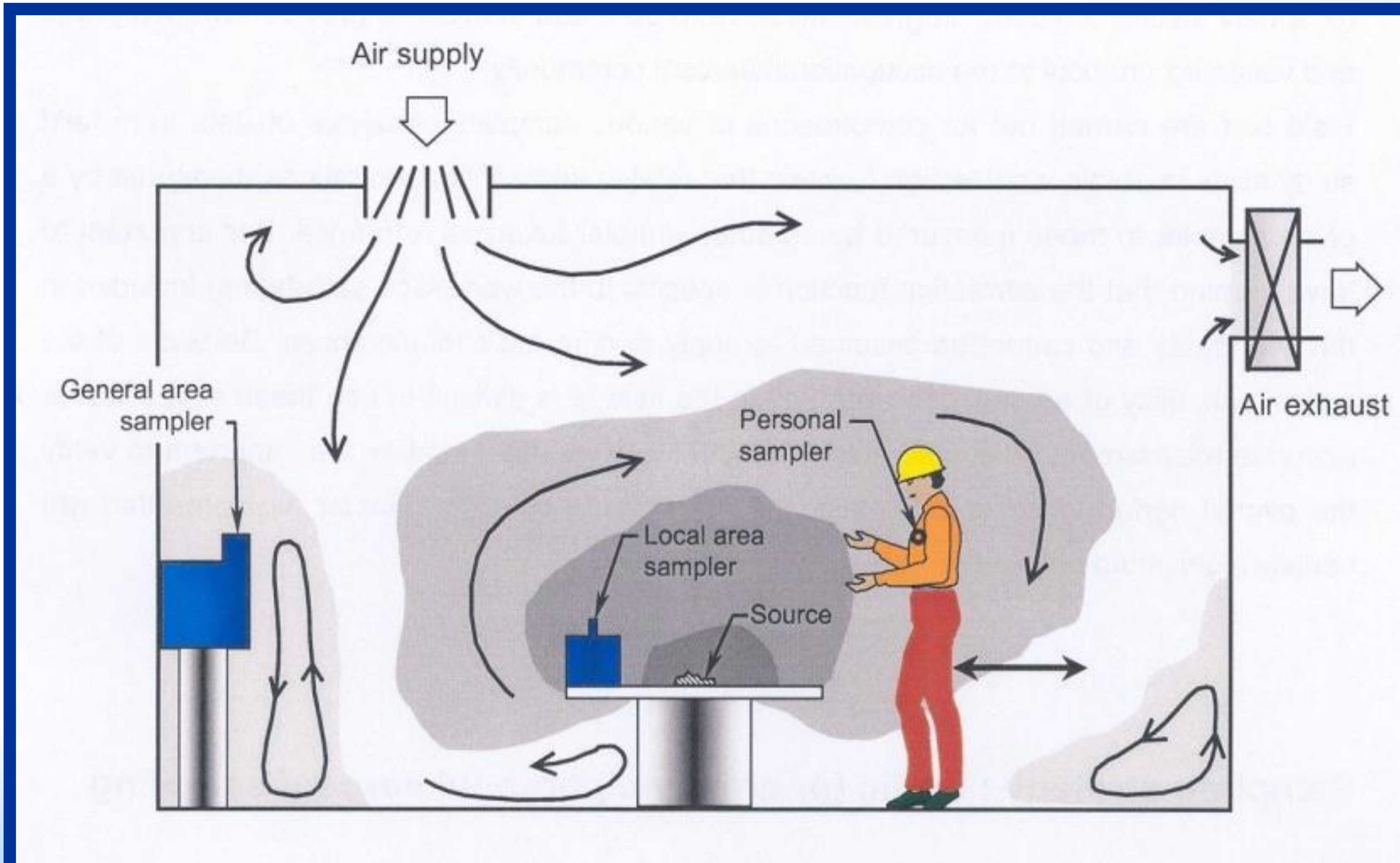
- Air sampling
- In-vivo measurements
- Excreta measurements
- Other biological samples

Measurement methods have limits of detection arising from natural background, statistical fluctuations in counting rates and factors related to sample preparation and analysis (ISO standards 11929 and 28218)

Air sampling

- Personal Air Sampler (PAS) where practicable
- Static Air Sampler (SAS) results used in *some* situations
- Total inhalable dust

Air sampling



In-vivo measurements

- Three types
  - whole body monitor
  - organ monitor
  - wound monitors
- Direct assessment of activity
- Photon emissions only
- Equipment considerations
  - detectors
  - shielding
  - geometry and phantom calibration

Whole body monitoring

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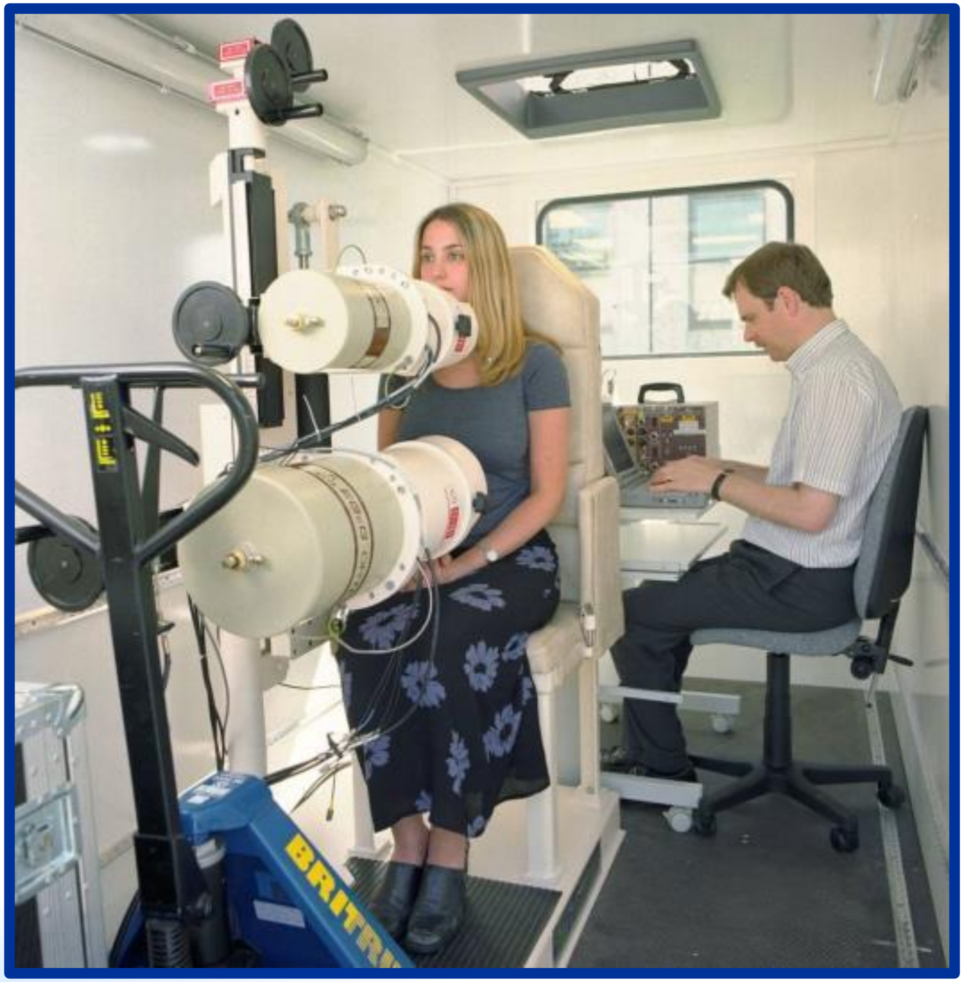


Whole body monitoring

Lung monitoring

Excreta monitoring

- Urine
- Faeces
- Nose blows etc
- Exhaled breath

Interpretation of measurements and dose assessment

- Intake of radionuclides and resulting committed effective dose assessed from results of monitoring measurements
- Dose coefficient
  - Effective dose arising from unit activity
  - Derived using ingestion and inhalation models
  - Values depend on intake pathway, chemical form and particle size
- Air concentrations
  - PAS or SAS
  - Exposure times
  - Breathing rates
- Radon progeny exposure

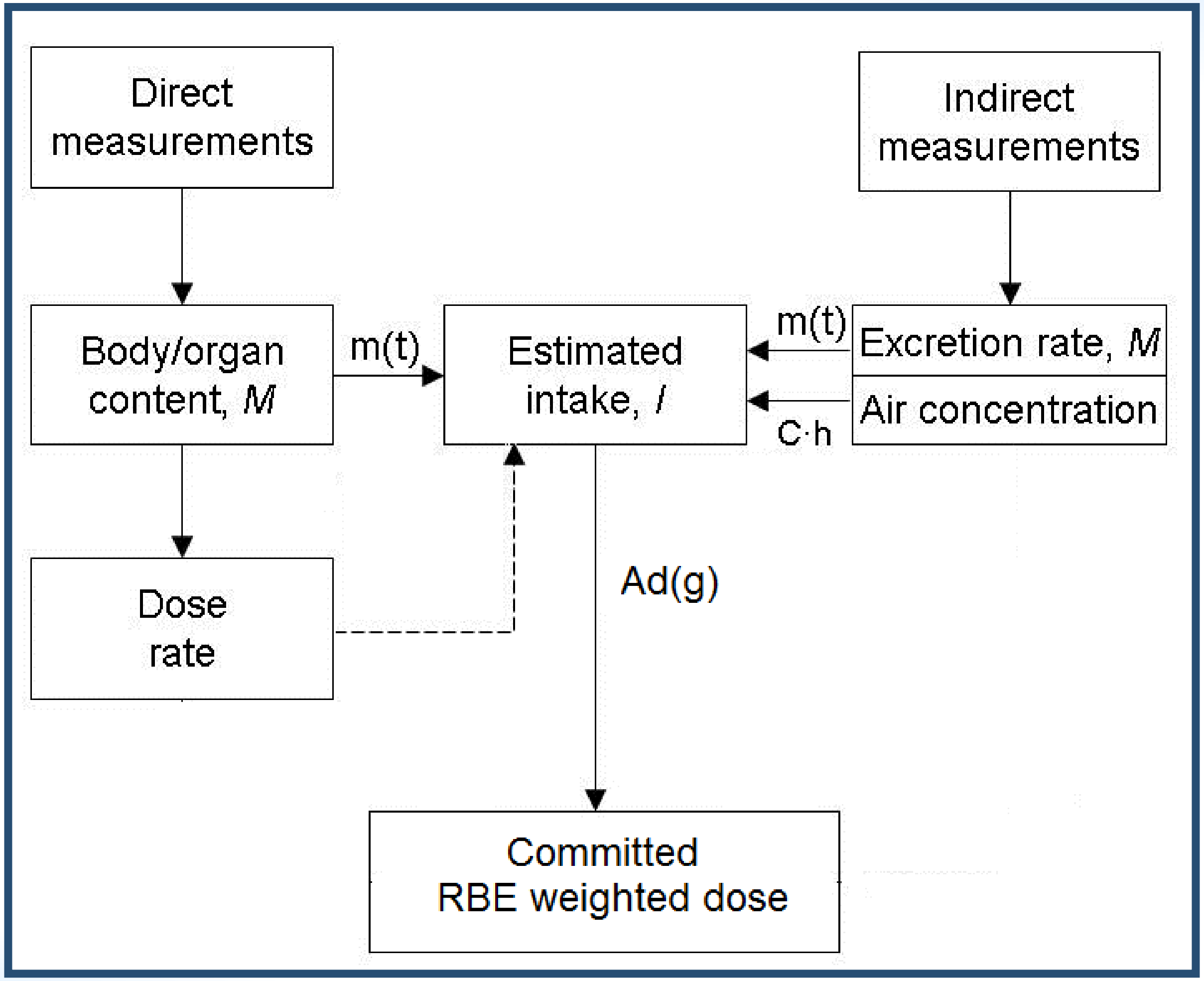
EXPOSURE ASSESSMENT IN EMERGENCIES

Exposure assessment in emergencies

- Assessment of exposures as a result of an accident or incident may begin by using data from personal and workplace monitors
- Choice of personal dosimeter depends on type of radiation and on information that is needed for determining the RBE weighted absorbed dose AD_T for tissue T
- Wearing of warning (alarm) dosimeters (or dose rate monitors) can be effective in preventing serious exposures
- Retrospective dosimetry techniques
  - chromosome aberration analysis, electron spin resonance, numerical analysis

Exposure assessment in emergencies

Framework for assessment of internal doses from monitoring measurements in emergencies



SKIN CONTAMINATION

Skin contamination

Contamination of the skin leads to external exposure and potentially internal exposure

- Depends on radionuclide(s), chemical form, activity conc.
- Principle objectives for monitoring and assessment:
  - Compliance with dose limits, avoidance of deterministic effects
  - Initiate and/or support medical examinations and interventions following an overexposure
- Monitoring
  - Contamination is non-uniform
  - Routine monitoring interpreted as average equivalent dose over 100 cm^2 (compared against derived limit, ie in Bq/cm^2)
  - For high levels of contamination dose averaged over 1 cm^2 (inaccurate)

RECORDs OF OCCUPATIONAL EXPOSURE

Record of keeping for individual monitoring

- Individual occupational exposure record linked uniquely to relevant worker
- Results of dose assessments for external exposure, and internal exposure, where relevant, for each monitoring period
- Notional doses, estimated doses
- Separate records relating to use of extremity dosimeters
- Establishment of national dose registry
- Records retained for at least 30 years after cessation of the work and at least until worker attains age of 75

Record of keeping for workplace monitoring

- Important to record data that:
  1. demonstrates compliance with regulations
  2. identifies significant changes to working environment
  3. includes details of radiation surveys eg date, location, radiation levels, instruments used etc
  4. details any actions taken
- Maintain suitable record of calibration of monitoring equipment
- A retention period of 5 years is generally recommended for records of workplace monitoring and of the calibration of workplace monitoring instruments

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Appendix 1. Exposure of NORM Workers

Record of keeping for workplace monitoring

Exposure of workers to NORM

The only reliable way to assess occupational exposures from NORM is through a properly developed monitoring programme conducted in the workplace.

However:

- external gamma radiation and airborne dust are the main pathways
- doses are dependent on NORM activity concentrations
- it is possible to establish a broad indication of the expected dose if there is knowledge of the characteristics of the material and the work situation
- for use during the prior radiological evaluation as a prioritization tool

Relationship between Bq/g and mSv

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MATERIAL	Annual dose from gamma and dust (mSv per Bq/g)	
	Minimum	Maximum
Bulk quantity: orebody, stockpiles	0.02	0.4
Small quantity: Concentrates, scale, sludge	0.008	0.04
Pb-210 and Po-210	0.0006	0.03

Key messages

- Assessment of external exposure can be carried out using individual or workplace monitoring
- Selection of personal dosimeter should be based on conditions in the workplace
- Assessment of internal exposure may be required for certain practices and for selected workers
- Type of the internal monitoring depends on workplace conditions
- Records of individual exposure and workplace monitoring should be kept

QUESTIONS
AND
DISCUSSION