



**IAEA**

International Atomic Energy Agency

# Occupational Radiation Protection GSG7

## 5. Exposure of Workers in Existing Exposure Situations

GSG7 Section 5

# Presentation content

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Exposure arising from remedial actions in areas  
contaminated with radioactive material

Exposure to radon

Exposure to cosmic rays

# INTRODUCTION

## Introduction-existing exposure situations

- Due to **residual contamination**
  - From past activities (not subject to control)
  - After an emergency exposure situation
  - Includes exposures from contaminated commodities (food, drinking water, construction materials)
- From **natural sources**
  - NORM, radon and cosmic rays
- Includes **occupational exposures**
  - Workers carrying out remedial action
  - Workers exposed in the existing exposure situation

## Introduction-existing exposure

- Measures to prevent or reduce doses
- Remedial action
  - Removal of the source or reduction in activity
- Protective action
  - Action taken on the exposure pathway

# PROTECTION STRATEGIES

## Protection strategies

- Government responsibilities
  - Identify existing exposure situations of concern
  - Legal framework for management of exposures
    - Assignment of responsibility to relevant authorities (eg health, nuclear regulator etc)
    - Establish reference levels
    - Decision making regarding actions for exposure reduction
    - Specification of general principles
    - Involvement of interested parties

## Protection strategies

- Relevant authority responsibilities
  - Protection strategies appropriate to the risks
  - Ensure strategy defines objectives and reference levels
  - Evaluate actions and their effectiveness
  - Provide information to exposed individuals on health risks and how to reduce exposures



# JUSTIFICATION

## Justification

- ❑ Relevant authority should establish protection strategy for a particular existing exposure situation in accordance with the principle of justification.
- ❑ Only remedial/protective actions expected to yield a net benefit should be considered for inclusion in the protection strategy.
- ❑ Consider radiation risks, costs, and any other damage cause by taking the action
- ❑ Include exposures of workers engaged in any remedial actions

# OPTIMIZATION

## Optimization-general approach

- ❑ Relevant authority and others should ensure form, scale, and duration of actions are optimized
- ❑ Optimization is achieved by
  1. Evaluation of the existing exposure situation including potential exposures
  2. Identification of protection options
  3. Option selection
  4. Implementation

## Optimization-reference levels

- Set at a dose above which it would be inappropriate to allow exposures to continue:
  - Strategy should aim to reduce doses ALARA to below the reference level
- A tool to prioritise actions
  - Priority should be given to persons exposed above the reference level
- Normally in the range 1 - 20 mSv (effective dose)
  - For radon, annual average concentration in air
- Set by government or its assigned authority

## Optimization-reference levels

- The following should be taken into account
  - Nature of the exposure and the practicability of reducing it
  - Societal implications
  - Past experience
  - International guidance and good practice



**EXPOSURE FROM REMEDIAL ACTIONS  
IN AREAS CONTAMINATED WITH  
RESIDUAL RADIOACTIVE MATERIAL**

## Contaminated Areas- Application of System for Protection and Safety

- Occupational exposures to workers carrying out remedial actions should be managed as a **planned exposure situation**
- Workers exposed to residual radioactive material **who are not carrying out remedial actions** should be treated in the same way as members of the public



## Contaminated Areas- Protection strategies

Contaminated areas need to be monitored or surveyed by the relevant authority to determine reference levels

Relevant authority should establish criteria for assessing effectiveness of remedial measures and the end point

## Contaminated Areas- Organizational arrangements

- ❖ Arrangements should be as described in *Remediation Process for Areas Affected by Past Activities and Accidents* IAEA Safety Standards Series No WS-G-3.1
- ❖ **Roles and responsibilities**
  - Clearly defined in legal framework (eg for the protection of workers)
  - Identification of persons or organizations for providing resources

## Contaminated Areas- Organizational arrangements

### **Regulatory considerations**

- Legal framework should provide for protection of all persons and the environment
- Restriction on use or access may be required during and after remediation
- Other regulatory processes (eg health & safety, environmental protection, land management, food & water standards) should be applied

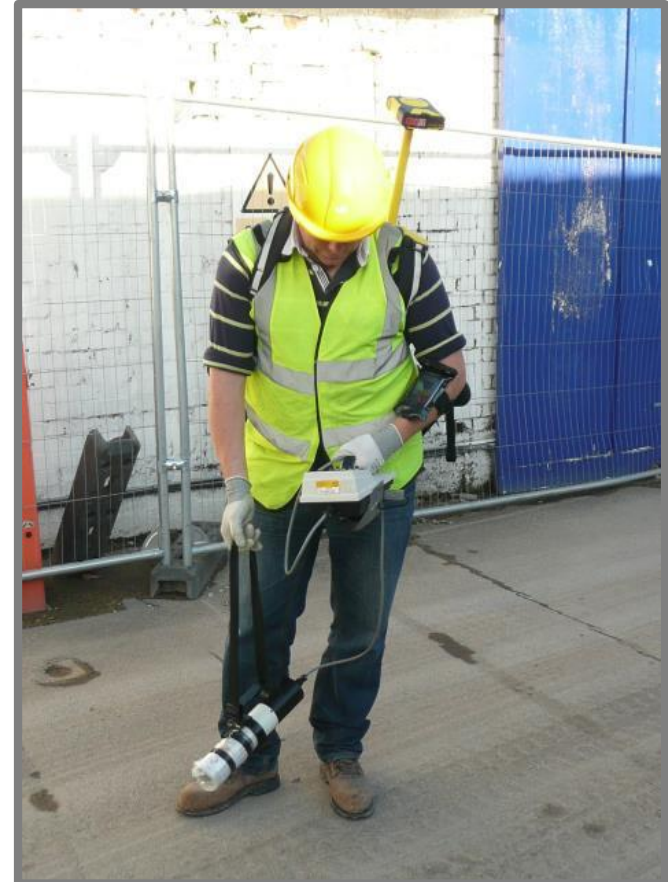
## Contaminated Areas- Remediation programme

- Prior radiological evaluation
- Preparation and approval of a remediation plan
- Remediation activity
- Management of radioactive waste
- Remediation plan should consider protection of workers including
  1. Nature and extent of the contamination
  2. Exposure pathways
  3. Assessing doses to individual workers
  4. Health and safety issues including PPE

# Contaminated Areas- Remediation programme

## Site characterization survey

- Determined by conditions, extent of contamination and resources
- Suitable instruments and techniques
- Instrument calibration
- Gamma measurements/mapping
- Sampling (eg soil, airborne material, groundwater, biota, etc.)
- Recording of data



# Contaminated Areas- Remediation programme

- ❖ Actions should be optimized taking into account reference levels, views of relevant parties and the health of present and future generations
- ❖ Justification should consider
  - Reduction of individual and collective doses
  - Reduction in anxiety of persons affected
  - Financial costs
  - Societal and economic costs
  - Health and environmental impacts
  - Disruption

## Contaminated Areas- Remediation programme

### Optimization should consider

- Approach as for planned situations
- Nature, scale, and duration of remedial actions
- Radiological impacts on individuals and the environment
- Non-radiological impacts
- Management of radioactive waste

### Remediation plan should include

- Monitoring programme
- Record keeping arrangements...

## Record keeping arrangements

**Description of activities**

**Monitoring programme data**

**Occupational health and safety records**

**Type and quantity of radioactive wastes**

**Environmental monitoring data**

**Financial expenditure**

**Involvement of interested parties**

**Continuing responsibilities for the site**

**Location of remediated areas and residual contamination**

**Areas with restrictions and conditions**

**Lessons identified**



# Contaminated Areas- Remediation programme

Reporting procedures for abnormal conditions to relevant authority

Parties to be involved in planning, implementing, and verification

Remediation plan and radiological evaluation should be submitted to relevant authority

Licence or registration may be required

# Contaminated Areas- Remediation programme

## Implementation of remedial actions

### Responsible person or organization:

- Protection and safety of all aspects (eg transport, processing, storage and disposal etc)
- Making and submitting safety and environmental assessments to relevant authority



# Contaminated Areas- Remediation programme



## Employers should:

1. Prepare and implement safety procedures
2. Apply good engineering practice
3. Ensure staff are trained, qualified and competent
4. Integrate protection and safety into management systems
5. Cooperate with contractors ON safety

# Contaminated Areas- Remediation programme

## Implementation of remedial actions (cont.)

### Relevant authority should

- carry out inspections,
- review procedures, monitoring programmes & results
- take enforcement action for non-compliances

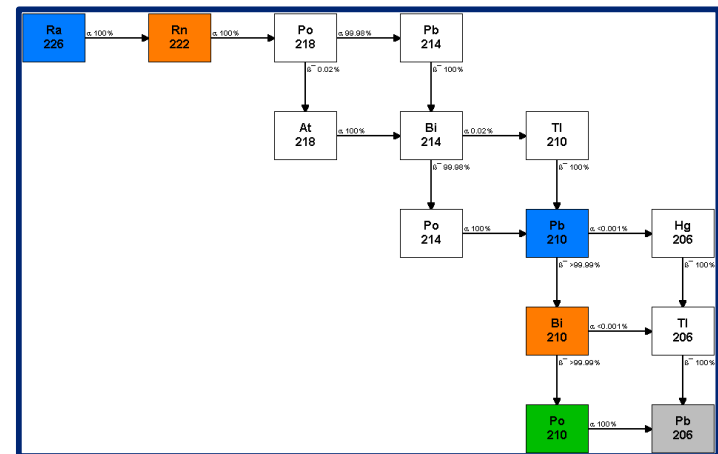


## EXPOSURE TO RADON

# Radon- exposure pathways

Rn-222 results from decay of natural uranium in rocks

- Escapes to air
- Half-life 3.8 days
- Dissolves in ground water, but ingestion of radon from ground water unlikely to be of concern
- High concentrations in enclosed spaces
- Exposure to lung by breathing in air containing radon and its progeny



## Buildings

- Alpha dose to lung mainly from progeny attached to condensation nuclei and dust
- Exposure to Rn-220 (from Th-232) unlikely to be of concern
- Accumulates in buildings arising from underlying soil
- Temperate area buildings are at low pressure drawing in soil gas
- Some radon can arise from building materials or from water supplies

## Buildings(cont.)

- Concentrations differ due to local geology, climate, construction, ventilation and domestic habits
- Indoor radon average concentration values vary from 7 to 200 Bq/m<sup>3</sup>.
- High background areas 100 to 2700 Bq/m<sup>3</sup>
  - >80 000 Bq/m<sup>3</sup> reported



# Radon concentration

## Underground workplaces

- High concentrations in mines, tunnels, basements, and underground car parks, water treatment facilities, caves and spas
- Reported radon concentrations:
  - 200 to 7000 Bq/m<sup>3</sup> in tunnels
  - 20 to 20 000 Bq/m<sup>3</sup> in caves and mines
  - Higher values in underground uranium mines

## System for protection and safety

- Occupational exposure to radon is normally an existing exposure situation
- Occupational exposure is generally only a concern in enclosed workplaces such as underground mines

## Radon-identifying workplaces

- Government should gather information to identify workplaces in radon prone areas and have national action plans
- Geographical and geological considerations useful to identify relevant areas
- Radon measurements in workplaces or dwellings identify radon prone areas

## Exposure to radon-action plan

- National indoor radon action plans should
  - Provide means for identifying exposures in workplaces
  - Ensure information is provided to employers, workers and the public
  - Share findings and understanding of radon, health risks and how to reduce exposure
- Action plans should identify measures to address radon in existing and future workplaces
- Radon prone buildings can be identified by their design or construction

## Radon-reference levels

- ❑ Appropriate reference levels should be established
  - Should not exceed  $1000 \text{ Bq/m}^3$ 
    - 10 mSv (equilibrium factor 0.4, occupancy 2000h)
  - Chosen carefully due to economic implications
  - Reference level for dwellings should be used for buildings with high occupancy by the public

## Remedial action in workplaces

- ❑ Measurements of radon concentrations by employers may be required
  - Require access to expert advice
  - National authorities may provide guidance on building practice
- ❑ Workplaces where reference levels are exceeded should be prioritised
  - In underground mines there can be large variations in space and time

## Exposure to radon-remedial action in workplaces



- ❑ If despite reasonable efforts radon concentrations cannot be reduced below reference levels, planned exposure situation requirements apply
  - Unlikely except in some mines

# Methods for reducing radon in buildings



- Sub-floor depressurization
- Sub-floor ventilation
- Floor sealing and membranes
- Increased ventilation
- Water treatment
- Removal of subsoil





# EXPOSURE TO COSMIC RADIATION

## Exposure to cosmic radiation-sources of exposure

- ❑ Galactic radiation from outside the solar system (mainly protons and helium ions)
- ❑ Solar radiation generated near the sun by magnetic disturbances; solar flares and coronal mass injections (mainly protons)
- ❑ Radiation from the earth's radiation belts (van Allan belts at 3000 km and 22000 km from the earth's surface)

## Exposure to cosmic radiation-sources of exposure

- Intensity reaching upper atmosphere
  - Reduced by earth's magnetic field
  - Varies with latitude; highest at the geomagnetic poles, lowest at the equator
  - Follows 11 year solar activity cycle; lowest when solar activity high
- High energy particles interact with the air generating a complex range of secondary particles. Ground level muons lead to greatest dose (80%)

## Cosmic Radiation- System for protection and safety

- Exposure at ground level cannot readily be controlled
- Occupational exposure of aircrew and space crew is an existing exposure situation
- Doses are self-limiting (eg set altitudes, controlled flight time, management of pregnant workers). Dose typically 10% of occupational dose limits

## Exposure of aircrew



- ❑ At commercial altitudes, radiation consists of neutrons (40 - 80% of dose), electrons, positrons, photons and protons
- ❑ Dose rate:
  - depend on altitude, latitude and solar cycle
  - doubles every 1830 m
  - Flying from Europe to USA dose rate is 4 – 8 mSv/h
  - Short-haul (lower altitude), average dose rate 3 mSv/h.
- ❑ Aircrew annual doses:
  - 1 – 3 mSv average
  - 3.5 – 6.5 mSv maximum

## Assessment of aircrew exposure

- Relevant authority to set reference level (5 mSv), dose assessment method and record keeping requirements
- Dose assessment if likely to exceed reference level
- Employer to assess doses (using computer codes) and keep records
- Manage pregnant aircrew as if a planned situation. Dose to foetus < 1 mSv

## Exposure of space crew

- Short low orbit missions doses 2 – 27 mSv
- Longer missions doses can reach 100 mSv
- Relevant authority to have framework for radiation protection of individuals in space
  - Reference levels for missions and career dose
  - Design features to optimize the dose
  - Monitoring to assess dose and changes in radiological conditions

## Key messages

- Authorities should ensure that protection strategies are put in place
- Only remedial/protective actions expected to yield a net benefit should be considered for inclusion in the protection strategy
- Reference levels should be set – tool to prioritize actions for optimization
- Occupational exposure to radon is generally only a concern in enclosed workplaces such as underground mines
- Remediation programme may be required
- Relevant authority should set reference levels for workers occupationally exposed to cosmic radiation



QUESTIONS  
AND  
DISCUSSION

## Exercise-Radon in workplaces

- How would you set a reference level for radon in workplaces in your country?
- A workplace arranges a radon survey. The results show that radon gas concentrations are **3x higher** than the reference level. What actions should be taken?