IAEA
International Atomic Energy Agency

Occupational Radiation Protection (GSG7)

9. Engineered controls, administrative controls and personal protective equipment

GSG7 Section 9

Presentation content

- General considerations
- Engineered controls
  - Surface contamination control
  - Shielding
  - Ventilation and dust control
- Administrative controls
  - General
  - Surface contamination monitoring programme
  - Spillage of radioactive material and decontamination
- Personal protective equipment
- Special considerations for NORM

GENERAL CONSIDERATIONS

General considerations

- Where the physical design features of a facility do not provide sufficient shielding or containment, additional control measures will be required
- For example:
  - Ventilation systems
  - Fume hoods
  - Glove boxes
  - Manipulators
- Temporary engineered controls may be required during non-routine operations
- Monitoring of effectiveness of these controls is required

General considerations

Engineered controls and design features

↓

Administrative controls (systems of work)

↓

Personal Protective Equipment (PPE)

Use these first

Containment, ventilation, design for ease of decontamination (and shielding)

Use when engineered controls and admin controls are not sufficient to provide adequate protection

Where use of engineered controls is not sufficient alone to restrict exposures, consider admin controls

ENGINEERED CONTROLS
CONTROL OF SURFACE CONTAMINATION

Control of surface contamination

- Contamination control programme should be implemented to identify presence of surface contamination and prevent inadvertent transfer
- Contamination control programme will make use of design features and engineered controls, backed up by administrative controls and PPE as appropriate
- Physical design features are most important and may include:
  - design features aimed at containing radioactive material
  - Ventilation systems to reduce airborne contamination
  - Drainage systems for the transfer of contaminated liquid waste
  - Change barriers to control spread of contamination
  - Monitoring facilities at exits from contaminated areas

Control of surface contamination

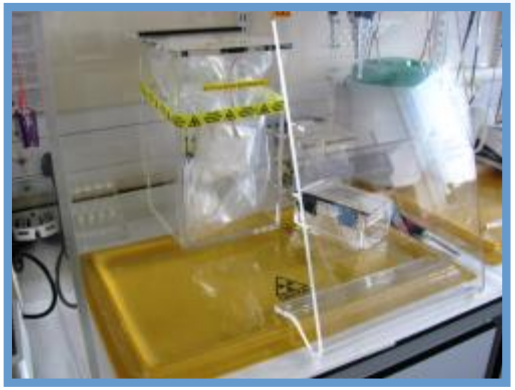
- Employer should provide washing facilities at exit from contaminated areas
  - Change barriers to control spread of contamination
  - Monitoring facilities
- Designed, monitored and maintained in accordance with regulatory requirements

Control of surface contamination

- Contamination build-up in facilities is an issue with long-lived radionuclides
- Identifying where contamination is coming from is important
- Special care and planning is required for operations likely to create contamination e.g. filter changing, and using temporary sumps and drains and hold-up tanks for contaminated liquids
- Removable coatings/layers and floor coverings may be used to protect the building from permanent contamination (but may increase radioactive waste)
- Fixing contamination in-situ may be appropriate but as much contamination as possible should be removed first

Graded approach to engineered controls

Simple containment



Basic engineered ventilation systems (fume hood)



Total containment systems (‘glove box’)



Low risk

High risk

Basic containment for low risk work

General purpose laboratory used for work with P-32



Drip tray to contain spills

Containers for contaminated items

Local shielding for beta radiation

Laboratory for medium risk work



Fume hood



Sealed floor

Surfaces easy to decontaminate

Change barrier

Fume hoods

- Partial containment
- Flow rate criterion e.g. minimum 0.5 m/s face velocity
- May impose operational limits (Bq) for radionuclides



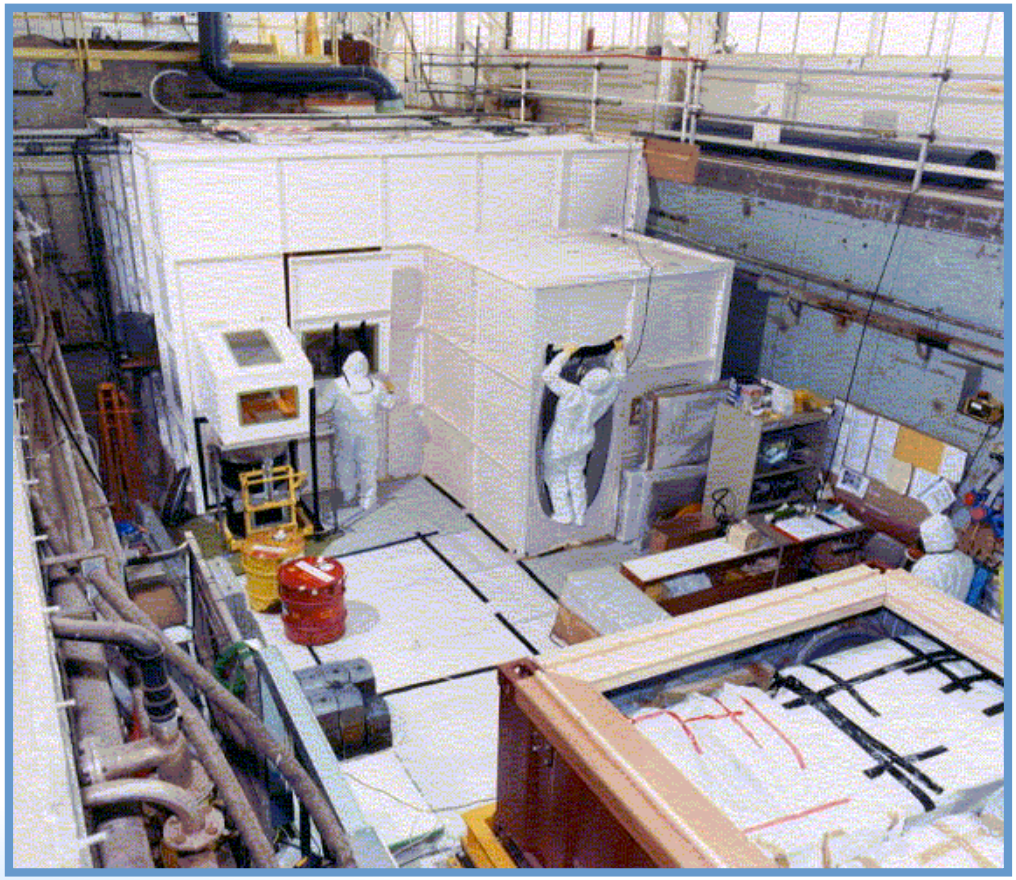


Glove boxes

- Engineered to provide high-level containment
- Access through gloved ports and ‘posting’ ports
- Gloves at risk of tear and puncture
- Under negative pressure (very low flow normally)
- Breach of containment results in inward flow velocity of at least 1 m/s produced automatically by high capacity extract system



Temporary containments

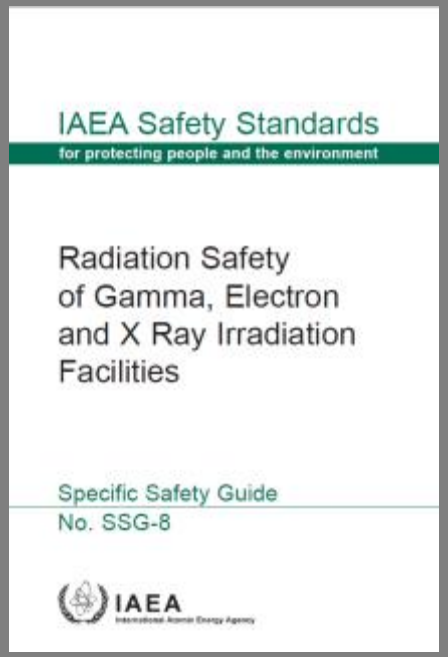


- PVC sheeting in ‘tents’ and modular containment systems
- Used for maintenance or decommissioning of active systems to limit the spread of contamination
- Require separate temporary ventilation (e.g. flexible ducting and must incorporate a HEPA filter)
- Use of strippable temporary coatings to protect floor and other areas

ENGINEERED CONTROLS
SHIELDING

Shielding

- Can be an effective form of engineered control
- Should be considered in work involving:
  - X-radiation
  - Gamma radiation
  - Other high energy particles (including beta)
- Select shielding appropriate for the type of facility



Shielded containment system

- Very high levels of containment like glove boxes
- Heavily shielded with thick viewing windows and CCTV systems
- Operate using master/slave manipulators
- For high dose rate applications e.g. handling irradiated reactor fuel





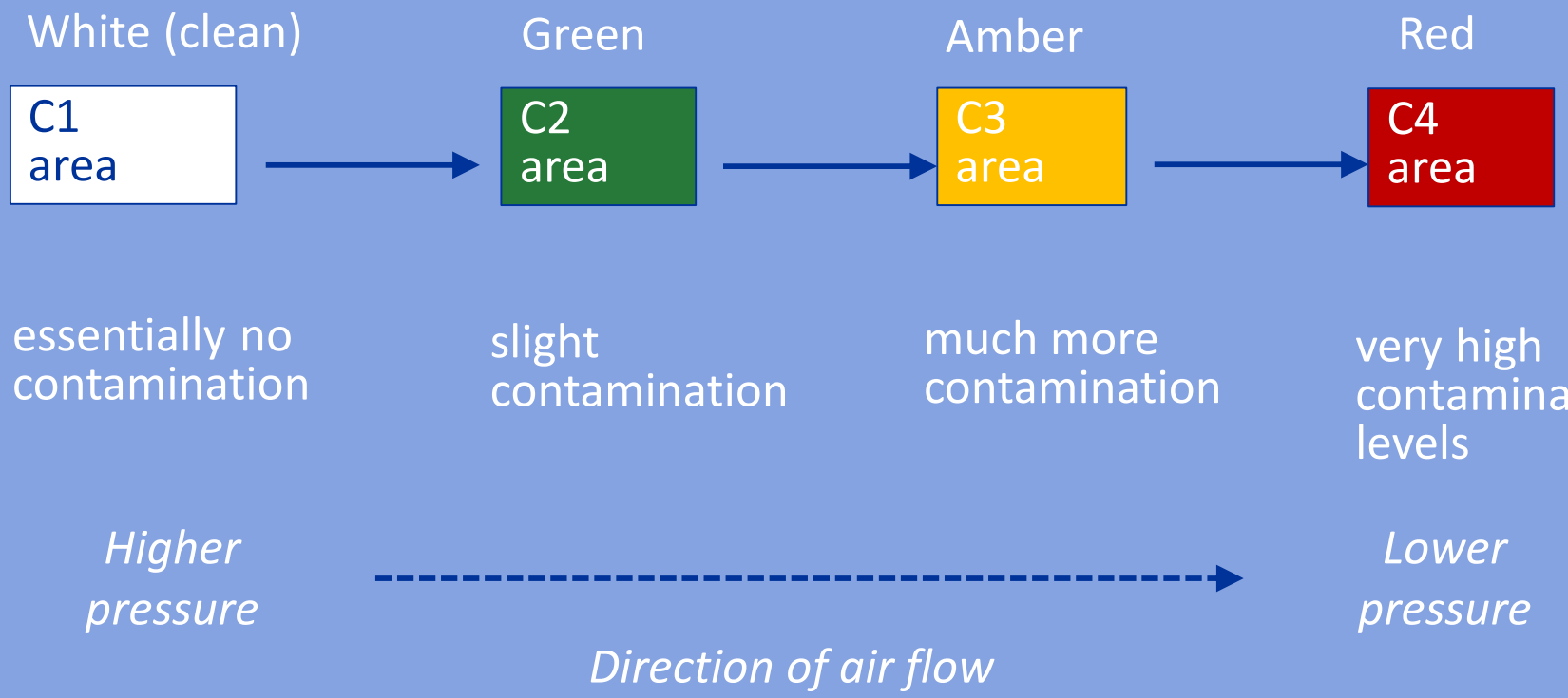
ENGINEERED CONTROLS
VENTILATION

Ventilation

- Primary requirement is to supply fresh air to the workplace and remove contaminants
- Control of airborne contamination can be achieved by:
  - maintaining adequate negative pressure
  - providing an adequate number of air changes
  - providing appropriate cleaning systems (*scrubbers, adsorbers, HEPA filtration*)
- Dedicated ventilation systems are always required to support (airborne) containment systems for radioactive materials including fume hoods and total containment systems

Air flow between zoned contamination areas

- Design should ensure flow from ‘clean’ to ‘contaminated’ areas (example of zoning system)



Ventilation

- Fresh air supplied by primary ventilation system may not be adequate in some workplaces
- In these cases, auxiliary ventilation can be supplied through flexible ducts
- Ducts should be positioned to avoid recirculating contaminated air
- Functioning of primary and auxiliary ventilation systems must be ensured
- This should include a programme of inspection and maintenance

Ventilation

- For effective operation of primary and auxiliary systems, need:
  - a safe intake of clean air (from outside) via intakes located well away from discharge points
  - aim to achieve desired flow rate through the work areas (*not so high as to cause settled dust to be resuspended*)
- For higher risk scenarios:
  - stand-by systems may be required
  - real-time indication of system performance may be required
- If system fails, is changed or is shut down, monitoring to confirm effective operation should take place before workers return to the workplace

Filtration

- Where filtration of contaminants is required it is best to have the primary filter as close to the source as possible
- Larger secondary filters may be located downstream nearer to discharge points to provide additional protection
- Filters must be selected and installed according to the required standards - they should be of high efficiency particle collection type (HEPA)
- Filters should be changed before the performance of the ventilation system is degraded unacceptably
- Exhausts from portable air handling systems, including vacuum cleaners should be equipped with HEPA filters or other suitable adsorbers

‘Safe change’ filter changing system





In higher risk situations filter changing requires special procedures which could include temporary containments

Ventilation in underground mines- additional considerations

- Ventilation is of crucial importance in underground mines
- Workers may be exposed to radon and airborne dust containing NORM
- Design of ventilation system should be part of mine planning process
- Should ensure good air quality and minimize build-up of radon/dust
- Design of ventilation systems complex and requires special skills
- Usual to appoint a qualified Ventilation Officer
- See paragraph 3.177 of DS453 for Ventilation Officer's duties

Ventilation in underground mines- additional considerations

- Primary ventilation system should ideally be operated continuously
- Employer should take measures to deter entry to any unventilated areas in the mine
- Local operating instructions should specify actions to be taken if ventilation system fails
- Avoid locating work stations in return airways or areas of high external radiation (*operator booths with filtered air supply may be needed*)

ENGINEERED CONTROLS
DUST CONTROL

Dust control

- Usually a legal requirement for non-radiological reasons in operations involving potential for significant dust generation, eg:
  - mining
  - mineral processing
- For these operations, a programme of sampling and control of airborne dust should be established, including:
  - suppression of dust, at source or using other means
  - dilution of dust by means of frequent air changes (*but take care not to cause settled dust to be resuspended*)
  - filtering of air before discharge to the environment

ADMINISTRATIVE CONTROLS
GENERAL

The hierarchy of controls measures

Engineered controls and design features

↓

Administrative controls (systems of work)

↓

Personal Protective Equipment (PPE)

Use these first

Containment, ventilation, design for ease of decontamination (and shielding)

Where use of engineered controls is not sufficient alone to restrict exposures, consider admin controls

Use when engineered controls and admin controls are not sufficient to provide adequate protection

General considerations

- Where use of engineered controls alone is not adequate in restricting exposures, administrative controls need to be considered
- Administrative controls include:
  - work authorizations
  - restrictions or controls on access
  - written procedures to minimise transfer of contamination
  - local rules
  - training

Control of access

- Control of access may be necessary to:
  - inform workers of status of area and potential hazards
  - ensure workers are provided with correct PPE
- Indications of contamination status should be displayed
- Exit of workers and equipment from area should be controlled

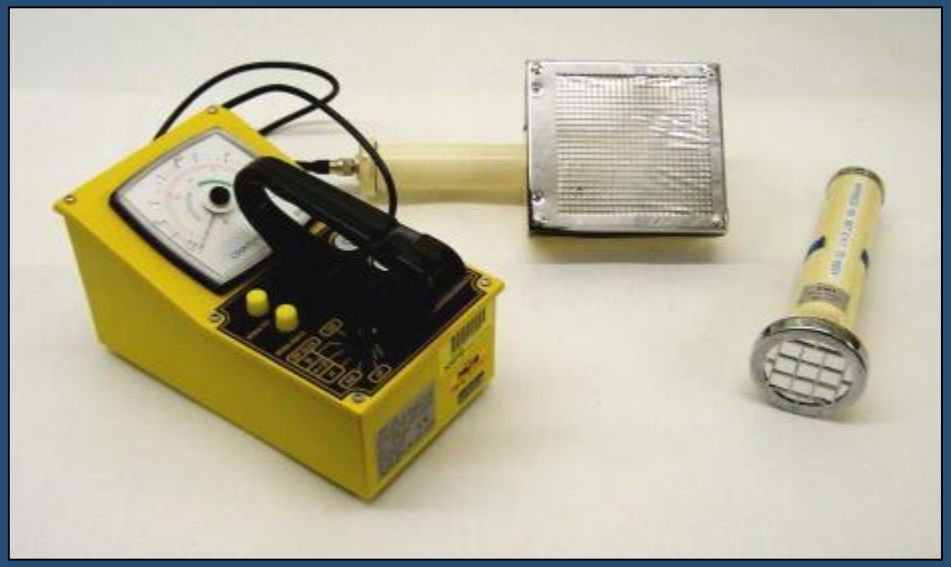
Job rotation

- Job rotation may be considered as an administrative control to restrict individual exposure, but only:
  - in workplaces with potential for high levels of exposure
  - where no other practicable means of control are available
- Use of this method should be kept to a minimum
- Job rotation should never be used as a substitute for use of appropriate methods of individual exposure control

ADMINISTRATIVE CONTROLS
SURFACE CONTAMINATION MONITORING

Surface contamination monitoring

- Contamination monitoring programme should be put in place to verify effectiveness of surface contamination control measures
- Instruments and techniques used should be appropriate for the types, levels and energies of radioactive materials used
- Suitable instrument should be available wherever unsealed radioactive materials are used
- Guidance on selection of appropriate monitors given in Chapter 9 of DS453 (Paragraphs 9.36 to 9.40)



Surface contamination monitoring

- Instruments must be regularly maintained and calibrated
- This should include:
  - test before first use
  - routine test at annual intervals
  - after any repair that may have affected performance
- Test should be carried out by qualified expert to determine:
  - detection efficiency for relevant radionuclides
  - operating voltage for interchangeable detectors
  - linearity of response
- Test certificate should be provided
- Routine checks should be carried out by user (batteries, response to check source)

Surface contamination monitoring



- Contamination monitoring programme should include routine monitoring of:
  - Benches
  - Floors
  - Protective clothing
  - Equipment
  - Hands
  - Transport packages

Indirect methods for surface contamination monitoring

- Some low energy emitters such as H-3 and Ni-63 cannot be reliably detected by hand-held monitoring equipment
- May also be a problem with rough or difficult to access surfaces
- 'Wipe' or 'swab' or 'smear' sampling can be used
- Assess removable contamination

Use of removal factor if seeking to quantifying contamination as Bq/cm^2



ADMINISTRATIVE CONTROLS

SPILLAGE AND DECONTAMINATION

Spillage of radioactive material

- Employer should ensure that procedures are provided for dealing with spillages, including:
  - clean-up procedures
  - restriction of access to the affected area
  - monitoring of affected persons
  - advice from RPO or Qualified Expert
  - management of waste arising
  - notifications to relevant authorities
- Any spill should be cleaned up as soon as practicable to minimise spread of contamination

Decontamination of equipment

- Employer should provide facility and materials for the decontamination of equipment and workplaces
- Water is preferred decontamination agent
- Other cleaning agents should be selected based on:
  - effectiveness
  - restriction of access to the affected area
  - hazardous properties
  - amount of waste generated
  - compatibility with surface/items to be cleaned
  - ease of disposal
- Effectiveness of decontamination should be periodically reviewed

Personal decontamination

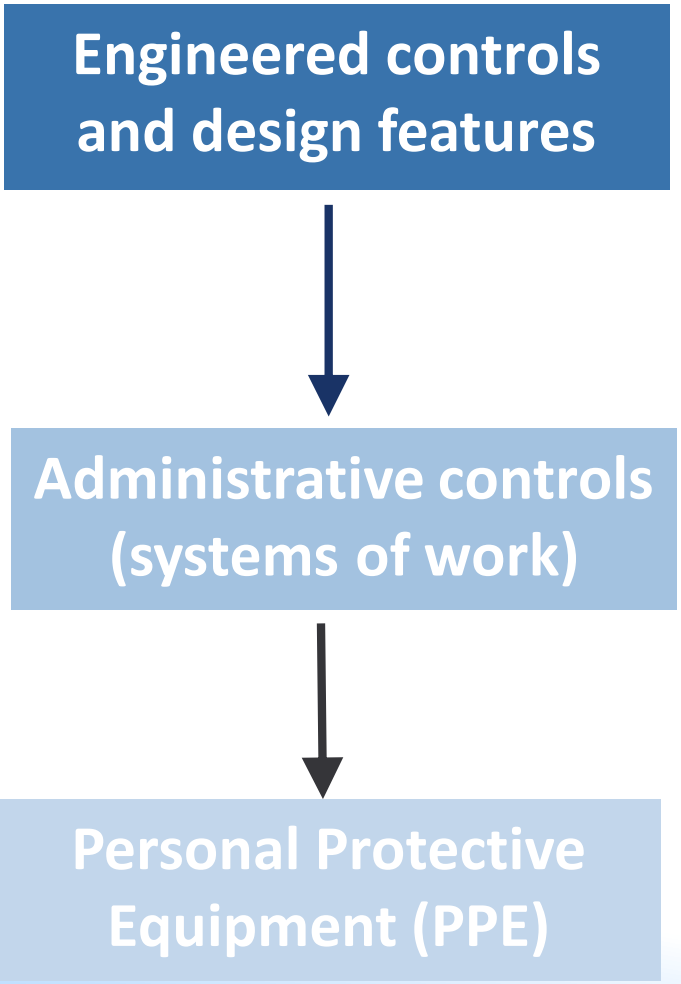
- Includes contamination of:
  - personal clothing
  - skin
  - hair
  - eyes
  - mucous membranes
  - wounds
- RPO should be informed if contamination detected
  - samples may need to be taken for dose assessment
  - Then begin decontamination process

Personal decontamination

- Decontamination by washing may not be effective in some circumstances
- In the event of serious contamination, medical advice must be sought immediately
- Medical assistance required for intrusive decontamination methods such as tissue removal
- Medical treatment of injuries takes precedence over radiological considerations (*but decontamination efforts should start as soon as practicable to prevent intakes*)
- Contaminated personal clothing should be laundered, monitored and either returned to owner or disposed of as radioactive waste

PERSONAL PROTECTIVE EQUIPMENT

The hierarchy of control measures



Use these first

Containment, ventilation, design for ease of decontamination (and shielding)

Where use of engineered controls is not sufficient alone to restrict exposures, consider admin controls

Use when engineered controls and admin controls are not sufficient to provide adequate protection

General considerations

- Control measures such as design features, engineered controls together with administrative controls and training should be used to maximum extent possible before relying on Personal Protective Equipment (PPE) for worker protection

- Where engineered controls and administrative controls are not sufficient, PPE should be provided

Personal protective equipment (PPE)

- Selection of PPE depends on the hazards involved in the work
- PPE should provide adequate protection and be comfortable and convenient to use
- Consideration should be given to possible increase in exposure due to additional constraints of the PPE
- Examples of PPE include:
  - protective clothing
  - reinforced clothing
  - ventilated suits
  - protective eyewear
  - respiratory protective equipment

Protective clothing

- Employer should specify appropriate protective clothing in accordance with risk of internal and external exposure
- For example:
  - overalls or protective coats
  - head coverings
  - safety eyewear
  - gloves
  - impermeable footwear
  - aprons (*including lead shielded aprons where appropriate*)
- Employer should provide changing, washing and laundry facilities as appropriate
- Individuals should be trained and wear PPE provided

Protective eyewear for external radiation hazard

Suitable shielded glasses may be worn where dose to the lens of the eye is likely to be significant

If conventional safety glasses to be used for protection from beta radiation or soft X radiation, their shielding properties should be evaluated first

Area covered by glasses should also be considered

Protective clothing for contamination hazard

- Objectives:
  - prevent transfer of radioactive contamination onto the worker
  - need to consider other hazards eg. fire, chemical etc.
  - needs to be comfortable (especially if worn continuously)
  - needs to easy enough to be put on, use and take off (or worker may try to avoid using it)
- A graded approach is needed to match the level of risk and take into account the particular needs of the working environment and tasks undertaken

Protective clothing

- Outer clothing layer is more likely to be contaminated
- Protects inner clothing and equipment worn on the worker



Respiratory protective equipment (RPE)

- Employers should not rely on use of RPE to comply with individual dose limits
- RPE may be needed for emergencies, repair and maintenance and in special circumstances
- Should be used for limited and specified period of time only
- If levels of airborne contaminants exceed safe working levels specified by management, appropriate RPE should be worn
- Area should be monitored and workers withdrawn if safe working levels or dose limits could be exceeded



Respiratory protective equipment (RPE)

- Use of RPE should be supervised
- Employers should ensure that wearers are ‘fit tested’ and trained to use RPE
- Results of fit tests should be recorded
- Protection factors should be specified
- Wear period should not be so long as to discourage use of RPE
- Filter respirators should have low breathing resistance
- On supplied air RPE, air should be of respirable quality and in sufficient quantity to ensure leak free use

Respiratory protective equipment (RPE)

- Comfort and convenience of use should be considered as well as protection factor
- Powered air respirators or helmets with face shields are preferable for comfort, provided they ensure protection
- RPE should be cleaned, maintained and inspected regularly
- Records of inspections and repairs should be kept
- Frequency of testing depends on RPE type and environment in which it is used
- RPE should be checked before use and after cleaning



Removal of RPE in higher risk situations

- Significant risk of an intake during removal of RPE and PPE
- Needs support assistant/team also wearing PPE
- May put new respirator on the worker while removing rest of PPE
- Swabs and ‘nose-blows’ taken to check for contamination
- Must have emergency plan for dealing with a medical emergency in a highly contaminated area





SPECIAL CONSIDERATIONS FOR NORM

NORM in mineral processing etc.

- Typical concentrations of U-238 + Th-232 chains
- 1-10 Bq/g
- Relatively low external radiation dose rates
- Main radiological concern is internal exposure from dust
- First consideration should be containment (but complete containment often impractical)
- Usually necessary to control levels of dust in the workplace anyway
- Follow general principles of dust control

NORM in mineral processing etc.

- Design processes to minimise production of dust
- Suppress dust where possible (e.g. water sprays)
- Provide ventilation as close to the source as possible
- Good housekeeping - keep surfaces in the workplace clean to minimise re-suspension
- Control exposure from accumulated NORM during maintenance operations
- PPE may be required

Local ventilation system for NORM



NORM contamination monitoring

- Specially designed instruments may be needed
- Risk of fire or explosion – intrinsically safe equipment
- Cylindrical probes for monitoring inside pipes
- Calibrated using natural uranium/thorium standards if possible



Key messages

Engineered controls and design features

↓

Administrative controls (systems of work)

↓

Personal Protective Equipment (PPE)

Use these first

Containment, ventilation, design for ease of decontamination (and shielding)

Where use of engineered controls is not sufficient alone to restrict exposures, consider admin controls

Use when engineered controls and admin controls are not sufficient to provide adequate protection

QUESTIONS AND DISCUSSION