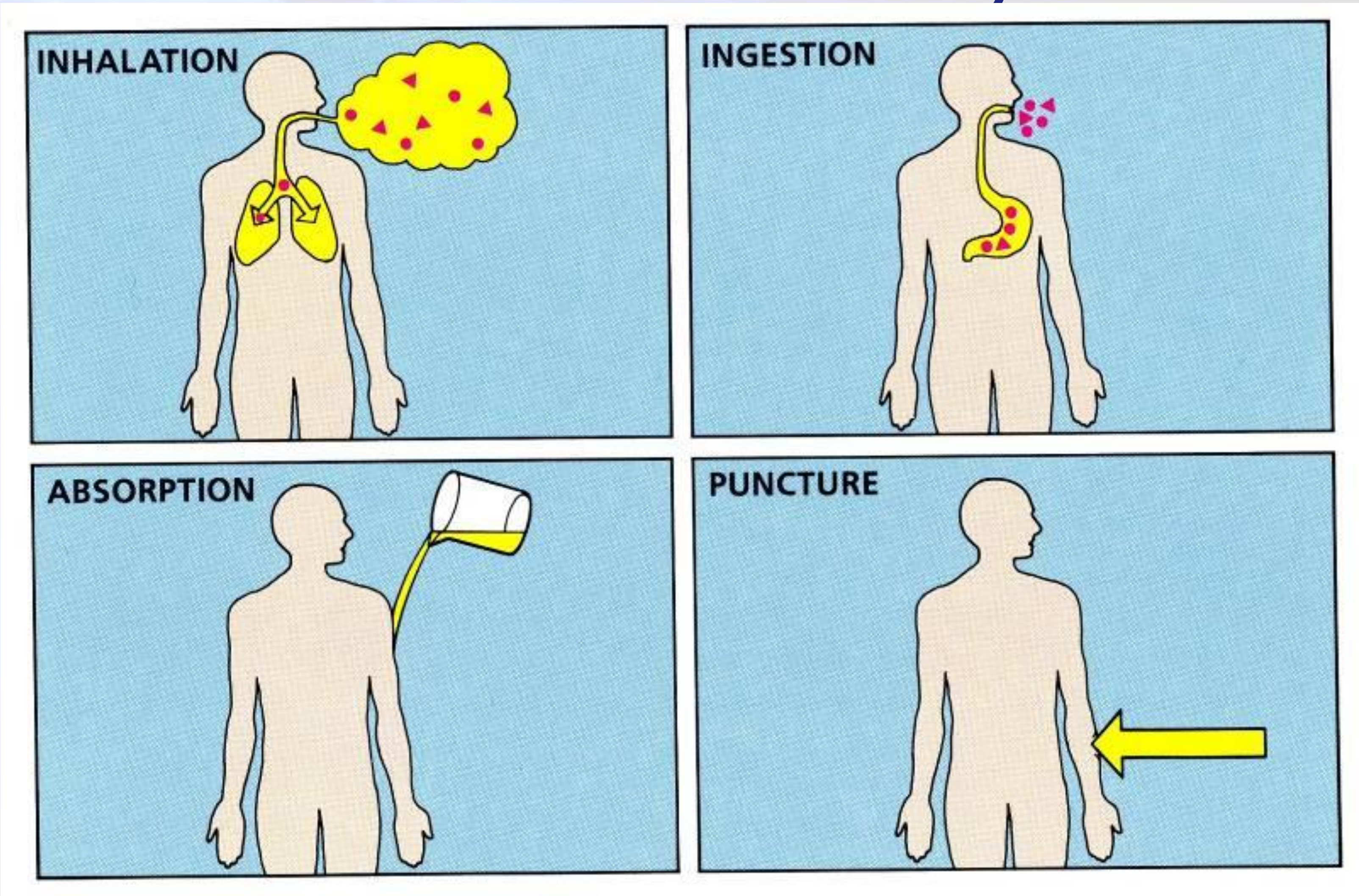
The Internal Radiation Hazard

- Routes of Entry
- Modelling and dose coefficients
- Methods of protection
  - facility design
  - containment
  - area designation
  - procedures
  - PPE
- Contamination monitoring
- Personal monitoring

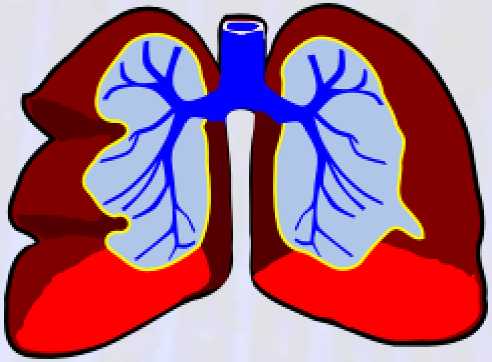
Routes of Entry



Note that only some nuclides e.g. tritium can be absorbed through the skin
Puncture – can be accidental – wounds or intentional – medical treatment e.g. I-131 for overactive thyroid
Will concentrate on inhalation and ingestion

Inhalation

- From airborne contamination
- Proportion of radioactive material is deposited in the lungs and remainder is exhaled



- Some of the material in the lungs is brought up and swallowed
- Some is absorbed directly from the lungs into the bloodstream and goes to target organs

Ingestion

- From contamination on foodstuffs, hands etc
- Some will be absorbed into the bloodstream and goes to target organs
- Remainder will be excreted in faeces

Modelling

- Dose received is dependent on:
  - Specific radionuclide
  - Intake pathway
  - Chemical and physical form
  - Particle size
- Effective decay constant in the body

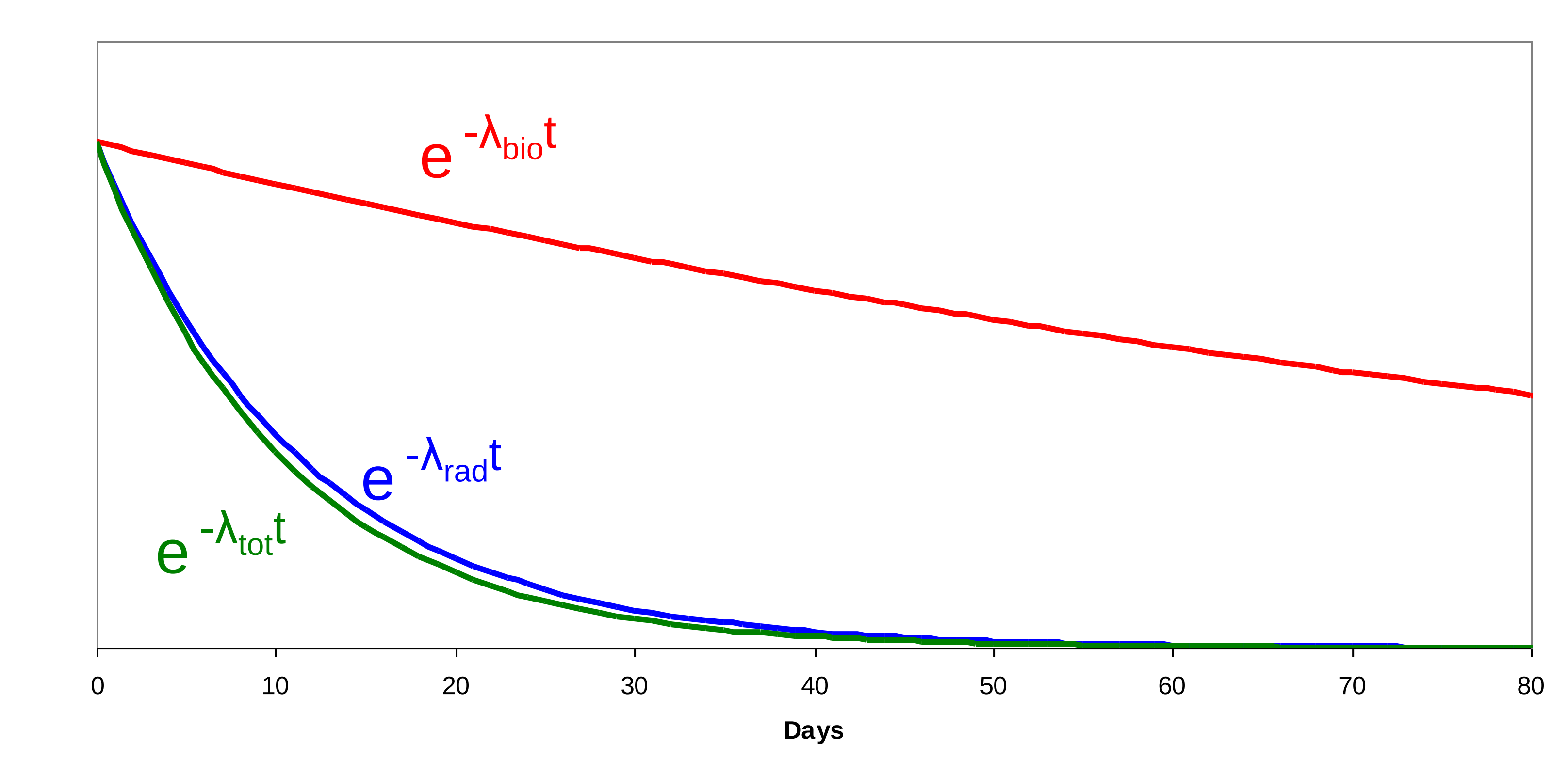
$$\lambda_{eff} = \lambda_{rad} + \lambda_{bio}$$

λ_{rad} = radioactive decay constant, λ_{bio} = biological decay constant

- Effective half life in the body $\frac{1}{t_{eff}} = \frac{1}{t_{rad}} + \frac{1}{t_{bio}}$

Some elements target specific organs e.g. iodine to thyroid, strontium to bones. Others e.g. hydrogen (tritiated water) are distributed throughout the body

Elimination Curve for I-131



Biological half life ≈ 80 days
Radiological half life ≈ 8 days

Methods of Protection

- Eliminate use
- Minimize activity
- Containment
- Procedures
- Use of personal protective equipment (PPE)
- Good housekeeping

Facility Design

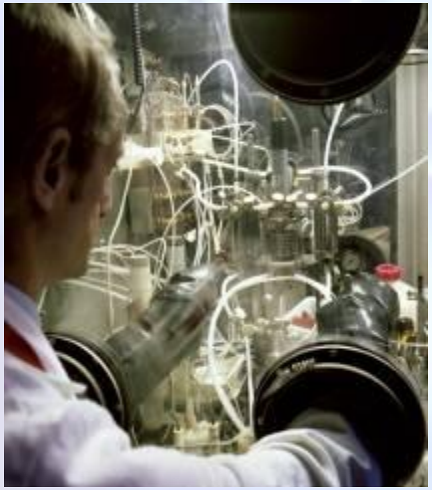
- New facilities should be designed to be easily decontaminated
  - Good clean finish with no gaps in which contamination can accumulate
  - Coverings at all angles to walls, ceilings to walls and floors to walls
  - Non porous materials – gloss paint, sheet PVC
  - Work surfaces made of non-porous materials e.g. melamine, PVC, stainless steel

Facility Design

- Air flow from low contamination to high contamination
- Ventilation, use of HEPA filter units etc
- Gaseous discharges – location of discharge
- Containment
- Work being done within the facility
- Decommissioning

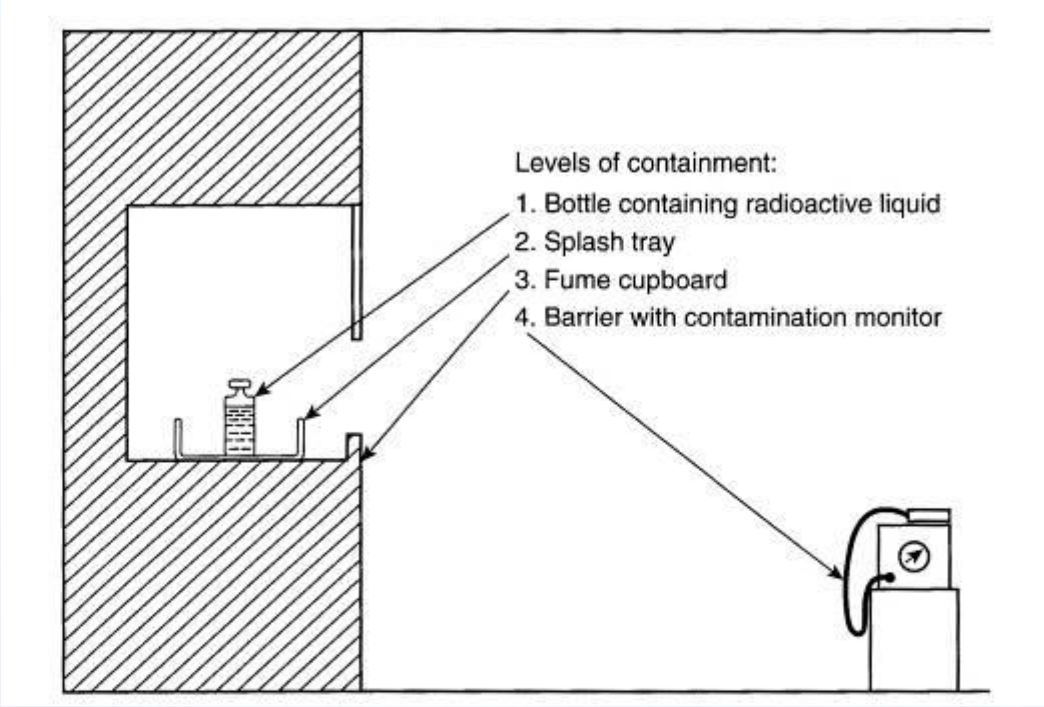
Containment

- Fume cupboards
- Glove boxes
- Bespoke containment e.g. ModuCon™ Modular Containment System
- Tented structures



Containment

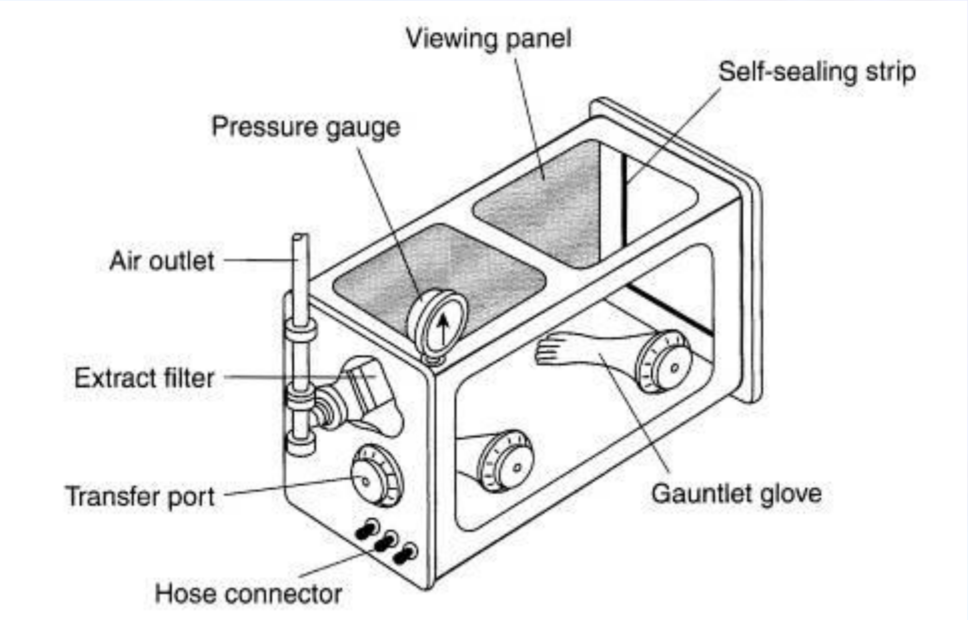
- Facilities should be design with various levels of containment where practicable, especially if the radiation risks are significant



Schematic diagram showing four levels of containment

Containment – Glove Boxes

- Mainly used when working with alpha or beta emitters
- Maintained at lower pressure relative to main work area so that air flows inwards if a leak develops
- Filtered inlet and extract air



Schematic diagram of a glove box

Area Designation

- Uncontrolled (non-active)
  - No potential for radioactive contamination
- Supervised Contamination
  - Low potential for contamination but need to keep under review
- Controlled Contamination
  - Contaminated to greater or lesser extent and requiring appropriate precautions and protection measures

Procedures

- Radiation safety arrangements (rules) for working in contamination areas
  - No eating, drinking, smoking
  - Wounds to be covered before entering areas
  - Wounds sustained in area to be reported immediately and treated accordingly
- Barrier procedures
- Work procedures
- Pre work safety talks

Use of PPE

- Selection should be based on nature and amount of contamination and also the working environment
- Low risk – lab coat, overshoes and gloves
- Medium risk – coveralls, overshoes (taped), respiratory protection
- High risk – pressurised suits

Contamination Monitoring

- Instruments need to be sensitive, generally use scintillation materials e.g. zinc sulphide for alpha, plastic phosphorus for beta
- Consist of a probe attached to a ratemeter - measure in counts per second (cps)
- Need to know conversion factors to go directly from cps to $Bqcm^{-2}$ when direct monitoring
- Beta probes respond to gamma radiation

Smear Surveys

- Used to:
  - Detect very low levels of contamination
  - Monitor for contamination in an area of high radiation background
  - Monitor for nuclides that are difficult to detect using direct methods e.g. H-3, C-14
  - Establish if contamination is loose or fixed
  - Monitor areas that are inaccessible with instruments

Smear Surveys

- If a filter paper is smeared over a specific area e.g 300 cm^2 or 1000 cm^2 and then counted in a detecting system of known efficiency the surface contamination level can be calculated

$$\text{Contamination Level (Bqcm}^{-2}\text{)} = C_c \times \frac{100}{E_c} \times \frac{1}{A} \times \frac{100}{E_F}$$

where

C_c = background corrected count rate (cps)

E_c = percentage efficiency of the counting system

A = area smeared (cm^2)

E_F = percentage pick up by paper, usually 10%

Air Monitoring

- Carried out in areas where airborne contamination may occur e.g. by:
  - Disturbing surface contamination
  - Allowing liquid contamination to dry out
  - Carrying out dry, dusty operations e.g. cutting, grinding

Air Monitoring

- If a known volume of air is sampled and the sample paper is counted in a detecting system of known efficiency the particulate airborne contamination level can be calculated

$$\text{Contamination Level (Bqm}^{-3}\text{)} = C_c \times \frac{100}{E_c} \times \frac{1}{V}$$

where

C_c = background corrected count rate (cps)

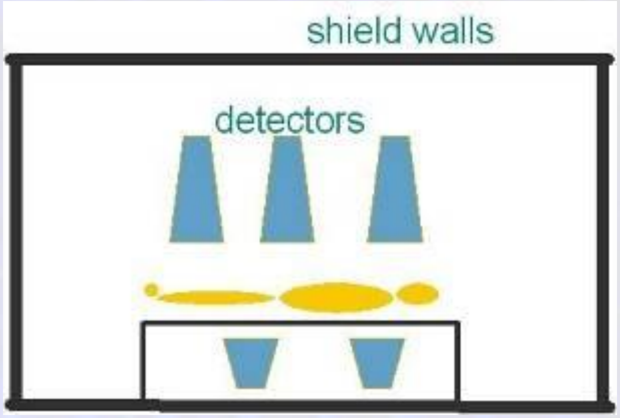
E_c = percentage efficiency of the counting system

V = volume sampled (m^3)

Personal Monitoring

- May need to do in addition to area monitoring if:
  - the dose per unit intake is high e.g. plutonium
  - a nuclide is difficult to detect by monitoring
  - there is a significant risk that individuals could receive an intake
  - there has been an accident

Personal Monitoring



- Whole body monitoring for gamma emitters e.g. Co-60
- Can also target specific organs e.g. thyroid counter for I-131
- Excretion (urine or faecal) monitoring for alpha/beta emitters e.g. Pu-239
- Personal air sampling
- Can also take nasal swabs following a suspected intake