PAM2001
Radiation Protection

In This Lecture…

Regulations
- IRR
- Dose-equivalent Limits

Implementation
- Radiation Protection Advisers & Supervisors
- Local Rules
- Personnel Monitoring

Radiation Protection

"Maintain a working environment where levels of ionizing radiation pose minimal acceptable risk"

Revision: Stochastic Effects

- Probability of effect occurring is governed by laws of chance
- Therefore, greater the dose the greater the probability of effect occurring
  - No safe dose limit - ALL doses carries some risk
  - Severity of effect is not related to dose
- Cancers & Genetic effects

Revision: Deterministic Effects

- Severity increases with dose
- Usually threshold below which no effect occurs
- Erythema, epilation,

Regulations

Radiation Protection

Based on three general principles…

1. Every practice resulting in an exposure to ionizing radiation should be justified by the advantages it produces
2. All exposures should be kept *as low as reasonably achievable* (ALARA)
3. The sum of the doses should not exceed specified limits

Ionizing Radiation Regulations

- Since joining EEC British radiation protection policy has become centralised from Brussels
- New document IRR 1999
- Contains fundamental requirements needed to control exposure of radiation workers, patients & public

Dose-Equivalent Limits

- Since IRR 1999 *Dose-equivalent limits* replace *maximum permissible dose*
- Limits set on Risk-Benefit basis
- Limits are NOT a boundary between safety & danger
- Reflect levels of risk comparable to other activities with acceptable risk

Risk Factor

$$r = \frac{\left(\dfrac{\text{number of cases}}{\text{size of population}}\right)}{\text{Dose equivalent received by population}}$$

- Units: Sv^{-1}

Example

The Risk factor for radiation-induced leukaemia is estimated to be $2X10^{-3}$ Sv^{-1}

If each member of a population of 1 million receives a 1 Sv dose how many leukaemias will occur?

Answer: 2000

1 Sv ~50,000 chest X-rays

Dose-Equivalent Limits

- Socially acceptable risk of various occupations 10^{-5} to 10^{-6} per year
- Assume the average risk ~10^{-5} per year
- Total risk factor for all stochastic effects if 10^{-2} Sv^{-1}
- Apply to risk factor equation
  - Calculate Annual Dose-Equivalent Limit
  - Annual Dose-equivalent Limit ~ 1 mSv

How the Regulations are Implemented

Radiation Protection Advisers & Supervisors

- RPA – suitably qualified & experienced
- Advises employers as to observance of IRR 1999 and all other aspects of safe use of ionizing radiation
- RPA must be consulted on points listed in section 33.11.1 Cloke
- RPAs also involved in selection of RPS

Local Rules

- Employers have legal responsibility to provide written local rules in every department where employees work with ionizing radiation
- Rules must be brought to the attention of employees
- RPAs write rules, RPSs ensure they are followed

Local Rules

- Should Contain:
  - Names of RPAs and RPSs
  - Details of restricted areas
  - Procedures and protocols for department
  - Contingency plans

Personnel Monitoring

- Measures dose received by radiation workers
- Scrutinise policies formulated by RPA
- Allows RPA & RPSs to identify and council individuals receiving higher doses

- Three Main Methods

1. Film Badge
2. TLD
3. Pocket Dosemeters

Film Badge Method

- Based on optical density increases with amount of radiation received by film
  - Controlled calibration, processing & analysis leads to dose estimation of dose received

- Filters (Plastic, Tin and Aluminium) used to distinguish between β-particles, low- and high-energy X-rays or γ-rays

Film Badge Method

Specifications

- Minimum Reportable Dose
  - (0.10 mGy)
- Useful Dose Range
  - (0.10 mGy - 5 Gy)
- Photon Energy Response
  - 5 keV - 3 MeV
- Beta (MAX) Energy Response
  - 1.71 MeV - 5 MeV

Film Badge Method

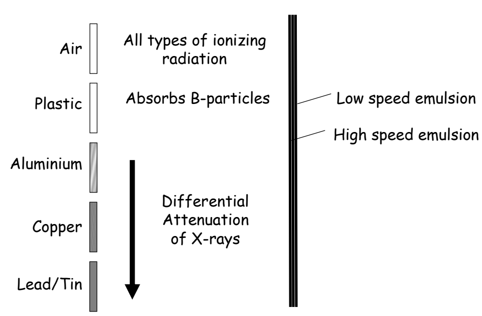
Light proof envelope
Double sided film
- Fast – Normal
- Slow – High dose

Radiation reaches the film after penetrating five different filter areas:

•Open window
•Plastic
•Aluminum
•Copper,
•Lead/Tin Alloy

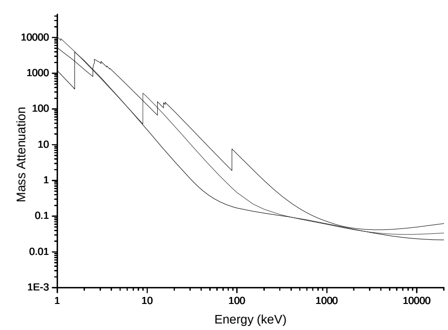
A complex algorithm is deployed to analyze the results on a film of these filter areas and report dose.

Filters Used to Estimate Dose

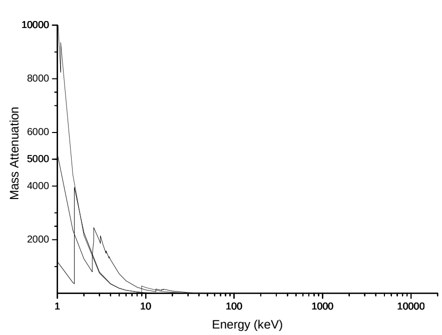


Film Badges used in nuclear industry contain an extra Cadmium/lead filter to estimate exposure from thermal neutrons

Differential attenuation of X-rays



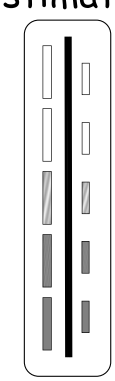
Differential attenuation of X-rays



Filters Used to Estimate Dose

Filters on reverse of badge are often different size/shape

Exposure through back indicates much higher dose as radiation has passed through worker



Film Badge Method

- Advantages
  - Permanent record of received dose
  - Easy to handle
  - Low tech processing
- Disadvantages
  - Delay between reading and exposure
  - Film is expensive and not reusable
  - Poor sensitivity – some of new dose limits do not show on film

TLD Method

Typical Specifications

- Minimum Reportable Dose
  - (0.05 mGy)
- Useful Dose Range
  - (0.05 mGy - 5 Gy)
- Photon Energy Response
  - 5 keV - 6 MeV
- Beta (MAX) Energy Response
  - 0.778 MeV - 5 MeV

TLD Method

Two TLD discs

- Thin disc: 40 mg cm^{-2}
- Open window
- Measures skin dose
  - B & low energy X-rays

- Thick disc: 90 mg cm^{-2}
- Under 700 mg cm^{-2} plastic dome
- Whole body dose
  - High energy X-rays

(Physical thickness of material obtained by dividing density)

TLD Method

- Advantages
  - Often more sensitive to low doses than film
- Disadvantages
  - Delay between reading and exposure

Pocket Dosemeters

- Real-time dose monitoring
- Digital display of dose rate
- Set audible alarm for preset dose rates
- Download data onto PC

Pocket Dosemeters

- Typical Specifications
- Minimum Reportable Dose
  - (1 μGy)
- Useful Dose Range
  - (1 μGy - 10 Gy)
- Photon Energy Response
  - 50 keV - 6 MeV

Pocket Dosemeters

- Advantages
  - Very sensitive
  - Monitors dose rate
- Disadvantages
  - Expensive

Choice of Monitor

- RPA decides on most appropriate method
- Assess risk of receiving unexpected high dose