IAEA Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources

Intervention for Chronic and Emergency Exposure Situations

Assessment and Response during Radiological Emergency



Dose Assessment Overview

Lecture

Introduction

- This lesson provides various methodologies for calculating doses and dose rates based on the type of sources or radioactive materials involved and the circumstances of the emergency situation
- The Radiological Assessor may also find the formulas and tables in this section useful in developing protective action recommendations for the Emergency Manager during the early stages of an emergency situation when information regarding the radiation source or material is readily available

Content

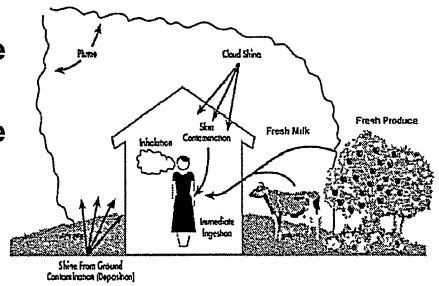
- Pathways of exposure
- Estimation of effective dose
  - Point source
  - Line source and spill
  - Ground contamination
  - Skin contamination
  - Inhalation
  - Ingestion
- Summary
- Problems

Overview

- In the event of a radiation emergency exposure of emergency workers or members of the public may occur
- Exposure may be external or internal and may be incurred by various pathways
- The various routs by which individuals may be exposed will determine the method to estimate the effective dose

Pathways of Exposure

- External exposure
- Internal exposure



Total Effective Dose

- Take into account all dominant routes by which individuals were exposed in an accident and sum up the contributions

$$E_T = E_{ext} + E_{inh} + E_{ing}$$

- E_T = total effective dose
- E_{ext} = effective dose from external radiation
- E_{inh} = committed effective dose from inhalation
- E_{ing} = committed effective dose from ingestion

Dosimetric Information

- Direct readings from personal dosimeters
- Dose assessments from personal dosimeters such as film badges or TLDs
- In case of inhalation: nose blows should be taken using material suitable for assessing the activity removed
- In case of ingestion: the need to collect urine and faecal samples should be considered
- The need for whole body or thyroid monitoring should be considered

Doses From External Radiation

- Where direct means of assessing doses is available, principally the use of personal dosimeters for external exposure, this should be used
- If external doses are not measured directly they must be assessed by another means

Point Source

- **Possible input data**
  - Activity of the point source
  - Distance from the point source
  - Exposure duration
- **Output**
  - Effective dose
  - Dose rate
  - Distance to a point source
  - Activity

Point Source

- **The effective dose**

$$E_{ext} = \frac{A \cdot CF_6 \cdot T_e \cdot (0.5)^{\frac{d}{d_{1/2}}}}{X^2}$$

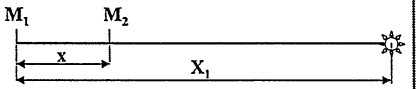
- **The dose rate**

$$\dot{D} = \frac{A \cdot CF_7 \cdot (0.5)^{\frac{d}{d_{1/2}}}}{X^2}$$

Point Source

- **The distance**

$$X_1 = \frac{x}{1-\sqrt{a}} \qquad a = \frac{\dot{D}_1}{\dot{D}_2}$$



- **The activity**

$$A = \frac{\dot{D}_1 \cdot X_1^2}{d^{\frac{d}{d_{1/2}}}}$$

Line Source (Pipe)

- **Input**
  - Source activity
  - Distance from the source
  - Time of exposure
- **Output**
  - External effective dose
  - Dose rates
  - Source activity from dose rate measurements
- **Effective dose**

$$E_{ext} = \frac{\pi \cdot CF_6 \cdot A_1 \cdot T_e}{X}$$

- **Dose rate**

$$\dot{D} = \frac{\pi \cdot CF_6 \cdot A_1}{}$$

- **The activity**

$$A_1 = \frac{\dot{D} \cdot X}{}$$

Spill

- **Effective dose**

$$E_{ext} = 2\pi \cdot CF_6 \cdot A_s \cdot T_e \cdot \ln\frac{X^2 + R^2}{X^2}$$

- **Dose rate**

$$\dot{D} = 2\pi \cdot CF_7 \cdot A_s \cdot \ln\frac{X^2 + R^2}{X^2}$$

- **The activity**

$$A_s = \frac{\dot{D}}{2\pi \cdot CF_7 \cdot \ln\frac{X^2 + R^2}{X^2}}$$

Ground Contamination

- Effective dose from exposure to ground contamination can be assessed based on:
  - Comprehensive radionuclide concentrations on ground
  - Based on ambient dose rates
  - Based on marker radionuclide concentration levels
- **Input**
  - Radionuclide concentrations on ground
  - Ambient dose rate
- **Output**
  - Effective dose from deposition

Ground Contamination

- **Based on comprehensive radionuclide concentrations on ground**

$$E_{ext} = \sum_{i=1}^{n} C_{g,i} \cdot CF_{4,i}$$

- **Based on ambient dose rate**

$$E_{ext} = \dot{H}_g \cdot \frac{\sum_{i=1}^{n} C_{g,i}^{rep} \cdot CF_{4,i}}{\sum_{i=1}^{n} C_{g,i}^{rep} \cdot CF_{3,i}}$$

Ground Contamination

- **Based on marker radionuclide concentration levels**

$$E_{ext} = C_{g,i}^{sam} \cdot \frac{\sum_{i=1}^{n} C_{g,i}^{rep} \cdot CF_{4,i}}{C_i^{rep}}$$

- **Taking into account shielding and partial occupancy**

$$E^{po}$$

Air Immersion

- Input
  - Average concentration of radionuclides in air
  - Duration of exposure
- Output
  - Effective dose from external exposure to γ radiation from the plume
- Air immersion dose

$$E_{ext} = T_e \cdot \sum_i \bar{C}_{a,i} \cdot CF_{9,i}$$

Skin Contamination

- Input
  - Average surface concentration of radionuclides on the skin or clothing
- Output
  - Equivalent dose (beta) to the skin
- Skin beta dose

$$H_{s,i} = \bar{C}_{s,i} \cdot CF_{s,i} \cdot SF_b \cdot T_e$$

$$H_s = \sum_i H_{s,i}$$

Dose From Internal Contamination

- May arise from intakes of radionuclides, primary by inhalation or ingestion
- The dose depends on
  - The activity deposited in the body
  - The energy of the emitted radiation absorbed by the organ and
  - The mass of the organ at risk
- Internal doses can not be measured directly – they have to be assessed by some other means

Inhalation

- Input
  - Radionuclide concentrations in air
  - Inhalation duration
- Output
  - Committed effective dose from inhalation
  - Committed equivalent dose to the thyroid
- Committed effective dose from inhalation

$$E_{inh} = \sum_n \bar{C}_{a,i} \cdot CF_{2,i} \cdot T_e$$

- Committed equivalent dose to the thyroid

$$H_{thy} = \sum_n \bar{C}_{a,i} \cdot CF_{h,i} \cdot T_e$$

Ingestion

- Input
  - Radionuclide concentrations in food, water or milk
  - Radionuclide concentrations in soil
  - Time of intake
- Output
  - Committed effective dose from ingestion
- Committed effective dose from consumption of food or soil

$$E_{ing} = \sum_{i=1}^{n} C_{f,i} \cdot U_f \cdot DI_{f,i} \cdot CF_{s,i}$$

$$T_m = T_{1/2} \cdot 1.44$$

Summary

- Basic methodologies for assessing individual dose from external and internal exposure were discussed
- Remember
  - In general, doses to individuals cannot be measured directly; some combination of measurement and assessment is required
  - All dominant routes by which individuals were exposed should be taken into account

Where to Get More Information

- See references on cover page

Problem 1

A 150 MBq point source of Co-60 is located 2.0 m from you. What is the dose rate at your location?

Problem 2

A very long pipe contains 0.5 GBq/m of Cs-137. 5.0 m from a pipe a technician is working for 30 min. What dose he will receive?

Problem 3

An Ir-192 source was stuck in a radiography tube – unshielded. The dose rate measured at a certain point from the source was 0.65 mGy/h. 2.0 m closer in the "line of sight" the dose rate monitor showed 0.82 mGy/h. How far is the source?

Problem 4

In the air of the nuclear medicine laboratory the following concentration of I-131 was measured 250 Bq/m^3. Two technician were working in the laboratory for 3 hours. What is the committed equivalent dose to the thyroid? What is the dose from external exposure?

Problem 5

After Chernobyl accident the environment in Europe was contaminated mainly by Cs-134, Cs-137 and I-131. In one of the country the following levels of food contamination were measured:

Food	Cs-134 [Bq/L or kg]	Cs-137 [Bq/L or kg]	I-131 [Bq/L or kg]
Milk	160	330	2000
Meat	250	470	220
Vegetables	1100	2200	5600

Problem 5 - Cont'd

What is the committed effective dose to an adult if the food was consumed for 30 days?

Consumption data

Food	Consumption data [kg/d]
Milk	0.30
Meat	0.27
Vegetables	0.07

