



Principles of Radiation Protection

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Objective

Protection of man and his environment from unnecessary radiation exposure without eliminating the beneficial application of radiation and radioactive materials

Main Aim

Prevent deterministic effects and limit the probability of stochastic effect to acceptable level

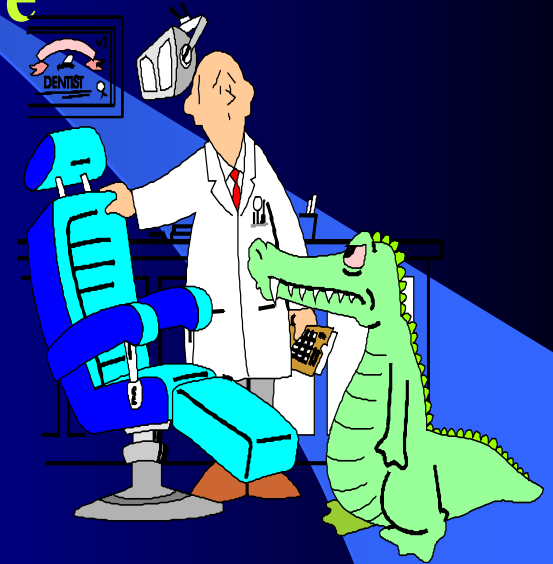
Radiation Protection Systems

Three principles used in radiation protection systems:

- Justification of a practice
- Optimization of dose - **ALARA**
- Dose Limitation

JUSTIFICATION of practice

- ⊕ A practice is *justified* only when there is a net positive benefit
- ⊕ *COST BENEFIT ANALYSIS*
- ⊕ Compare alternative methods/techniques which do not involve the use of ionizing radiation



OPTIMIZATION of Radiation Protection

- ALARA -As Low As Reasonably Achievable,
social & economic factors taken into account

Radiation Protection Systems

Optimization of Dose

- A key component of the system is that all necessary exposures be kept As Low As Reasonably Achievable, social & economic factors taken into account. The concept of 'ALARA' and 'optimization of protection' are identical.
- A wide range of techniques is available.

Example, QC & maintenance program is to reduce the number of rejected diagnostic films and in turn, to reduce the dose presently incurred by nursing staff, radiographer and patients.

Radiation Protection Systems

Optimization of Dose

- ALARA principles :
 - Choice of materials and equipments
 - Choice of specific technique and working procedures (best procedure)
 - Use of personnel protective equipment (PPE)
 - Proper monitoring system (well maintained and calibrated equipment)
 - Proper engineering & administrative control etc.

Mobile shielding and leaded aprons play an important protective role in certain applications.



Radiation Protection Systems

Dose Limit

Dose limit is used to apply controls on each individual's accumulation of dose and is not a line of demarcation (borders) between "safe" and "dangerous",

Dose limit is apply for occupational exposure only, **excluding** dose received **from natural radiation and medical exposure**

Dose limits are similar for men and women except pregnant women.

Radiation Protection Systems:

Dose Limit

To prevent **deterministic effects**:

equivalent dose < 500 mSv except eye < 150 mSv

To limit the occurrence of **stochastic effect**:

effective dose, H_E is limited by an annual limit of 20 mSv

$$H_E = \sum W_T H_T$$

where: W_T : weighting factor
 H_T : dose equivalent

Tissue or organ	W_T
Gonad	0.20
Bone marrow, lower large intestine, lung, stomach	0.12
Bladder, breast, liver, oesophagus, thyroid	0.05
Bone surface, skin	0.01

Radiation Protection Systems

Annual Dose Limits (ADL)

There are different categories of dose limits for:

- ▶ radiation workers
- ▶ female pregnant workers
- ▶ members of the public
- ▶ Apprentices and students
- ▶ planned special exposures

Radiation Protection Systems

ADL *Radiation Worker/Staff*

Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 – Effective on 15 Feb 2010

Occupational exposure shall be controlled so that their total dose does not exceed:

Effective Dose for worker

20 mSv/yr in a calendar year

Dose Equivalent :

150 mSv/yr to the lens of the eye

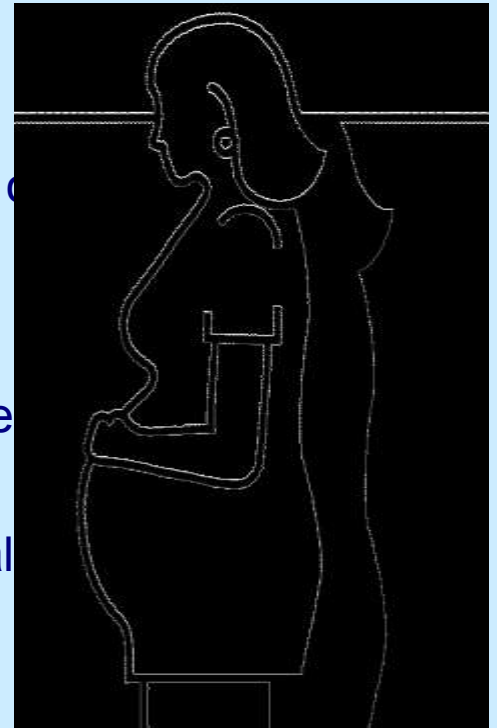
500 mSv/yr to skin, hands and feet

Radiation Protection Systems

FEMALE STAFF (Occupationally Exposed)

Embryo or fetus is radiation sensitive, notify Licensee of a pregnancy ASAP.

BSS 8(5) Where a female worker is pregnant, the dose to the foetus accumulated over a period of time between confirmation of pregnancy and the date of delivery shall not exceed 1mSv..



Radiation Protection Systems

ADL for members of public

Application	ADL (mSv)
Dose limit for the whole body exposure	1
Equivalent dose for lens of the eyes	15
Equivalent dose for the skin	50

ADL for apprentices and students (16 – 18 yrs)

Application	ADL (mSv)
Dose limit for the whole body exposure	6
Equivalent dose for lens of the eyes	50
Equivalent dose for the hand, feet and skin	150

Dose limit in special circumstances

- (1) Apply to the appropriate authority (AELB) for a temporary change in the dose limit requirement for specified workers. Licensee shall comply with any procedures, information as specified by the AELB).
 - ❑ extension of the averaging effective dose to not more than 10 consecutive years, and the effective dose shall not exceed 20 mSv per year averaged and not exceed 50 mSv in any one calendar year,
 - ❑ Plan exposure shall be reviewed when the dose accumulated by any worker reaches 100 mSv;
 - ❑ a change in the limit on average effective dose per year to a value not exceeding 50 mSv for a period of not more than five consecutive years, subject to a limit of 50 mSv in any one calendar year. -(Suatu perubahan dalam had bagi purata dos berkesan bagi setiap tahun hingga suatu nilai yang tidak melebihi 50 mSv bagi suatu tempoh yang tidak melebihi lima tahun berturut-turut, tertakluk kepada suatu had 50 mSv dalam mana-mana satu tahun kalendar).

Classification of Areas

- **Clean Areas**

Exposure is unlikely to exceed 1/10 ADL , no special arrangements are necessary.

- **Supervised Areas**

Occupational exposure conditions are kept under review (likely to exceed 1/10 but not exceeding 3/10 of ADL). Specific protective measures and safety provisions are normally not necessary.

- **Control Areas**

Exposure exceeds 3/10 of ADL . Entry limited to authorized personnel. Appropriate safety and signaling systems to restrict access. Subjected to regular medical examination, routine monitoring and training.

Protection Against Radiation Hazards

Three (3) Principles

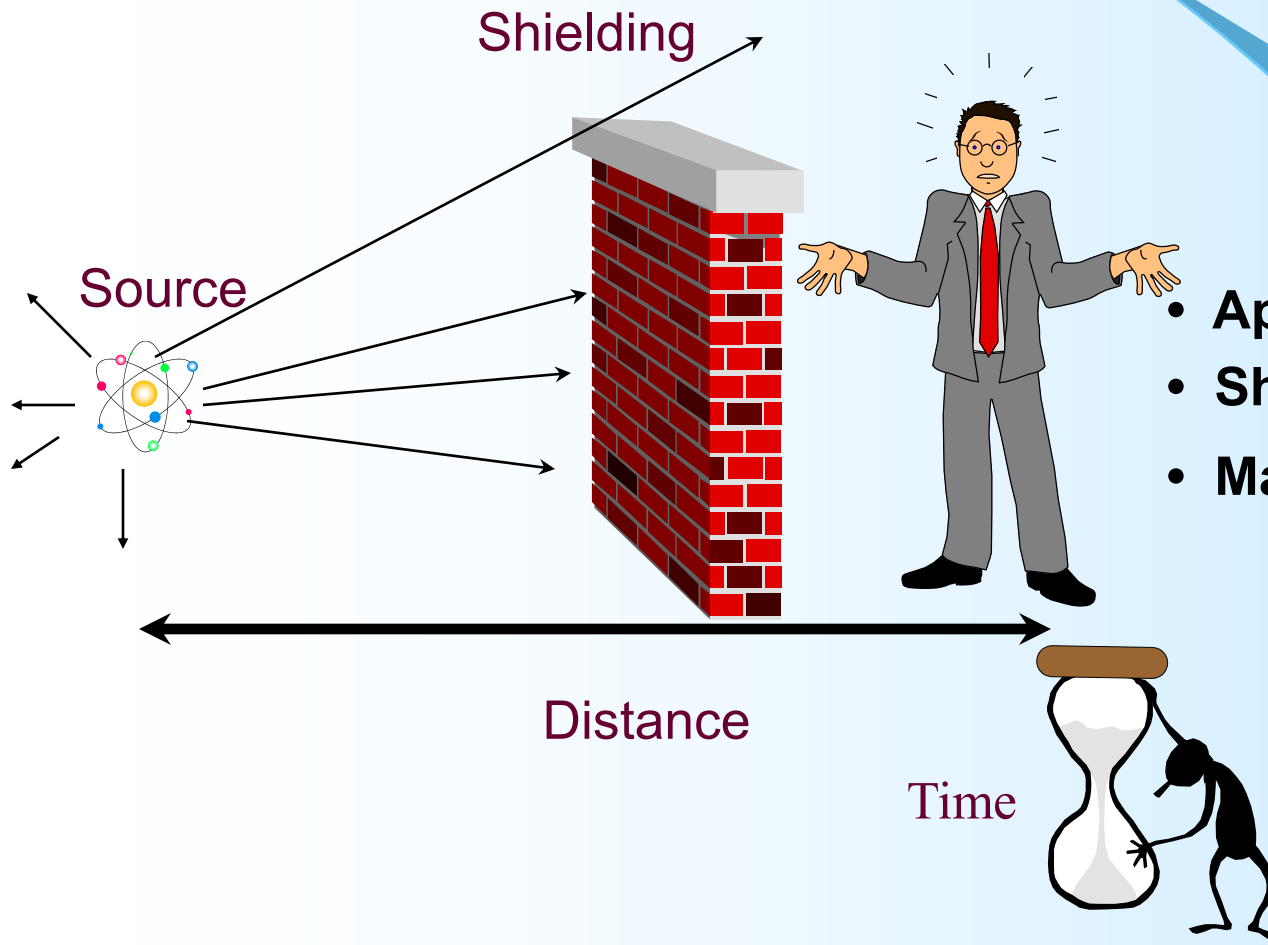
1. Remove or reduce hazard
 - Use minimum radioactive material
 - Choose least hazardous radioactive material & best procedure
 - Good waste disposal.... etc
2. Guard the Hazard
 - Prevent release of radioactive material
 - Use fume cupboards, gloves boxes, hot cells, sealed containers, lead bricks, lead pots as appropriate
 - Radiation level outside work area < permissible level
3. Guard the Worker
 - Choose correct materials, instruments and facility
 - Provide regulations, working procedures, operating instructions, emergency procedures... etc
 - Protective equipment and clothing

External Radiation Hazards

Protection from external radiation hazards

- Minimum activity required
- Maximum distance
- Shortest time
- Appropriate shielding
- Regular area check

Protection Against External Radiation Exposures



- Appropriate **S**hielding
- Shortest **T**ime
- Maximum **D**istance

SHIELDING



The shielding materials & thickness depend on:

- i. Type of radiation
- ii. Activity of the radioactive source
- iii. Energy of radiation

Alpha lose energy rapidly in passage through matter and hence do not penetrate far. No shielding is required.

Beta radiation requires shielding of low atomic number (Z) materials such as perspex, aluminum and thick rubber are most appropriate for the absorbance of beta particles.

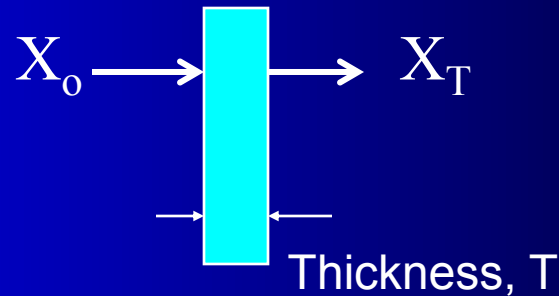
Gamma and x-ray, the high density materials such as lead and concrete are good and normally used for shielding this type of radiations.

Neutron, any high hydrogen content materials (< 1 MeV) and water, wax, paraffin (> 1 MeV)

SHIELDING CONCEPT

For X and γ -rays:

$$X_T = X_o e^{-\mu T}$$



X_o = Dose rate before shielding

X_T = Dose rate after shielding

T = Shielding thickness

μ = mass attenuation coefficient

Half Value Layer, HVL

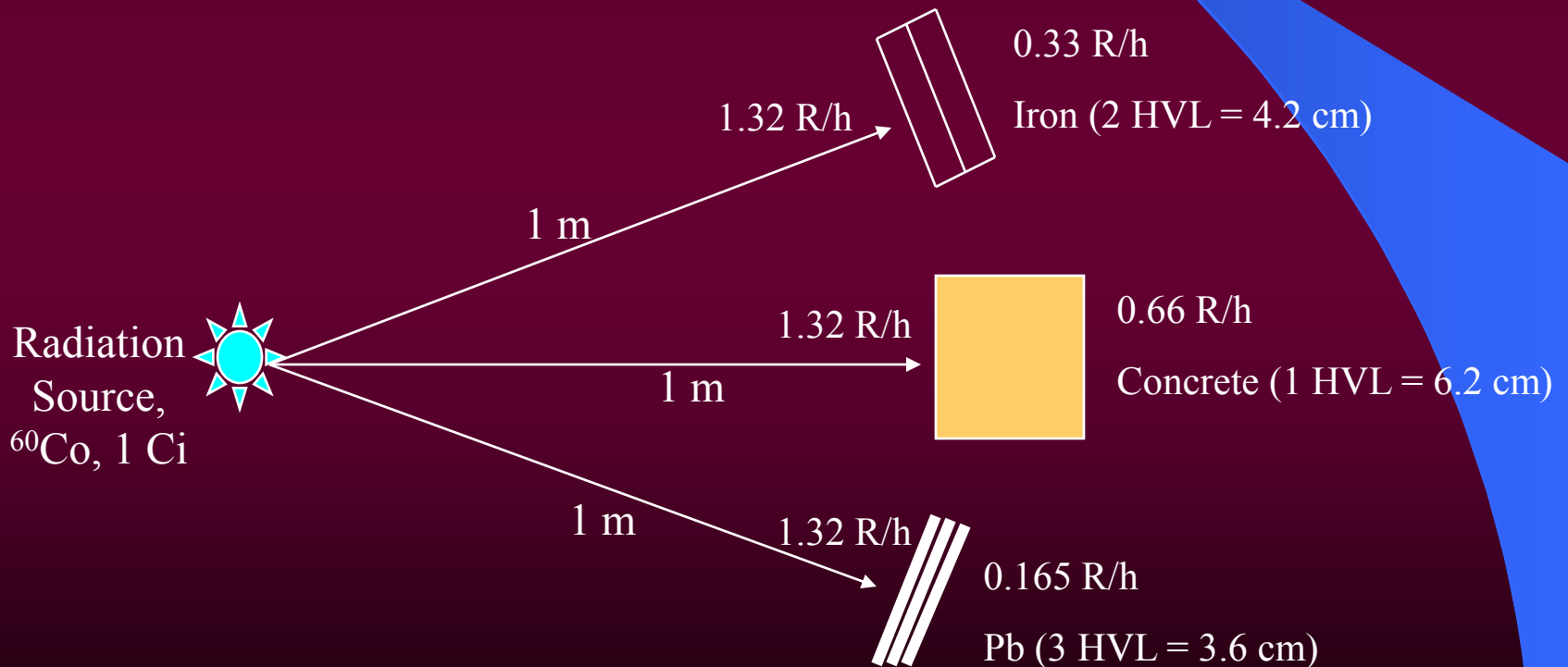
Shielding Material and Thickness (cm)		Source	
		Ir-192	Co-60
Concrete	TVL	14.74	22.86
	HVL	4.82	6.85
Steel	TVL	2.90	7.36
	HVL	0.87	2.20
Lead	TVL	1.62	4.11
	HVL	0.48	1.24
Tungsten	TVL	1.09	2.62
	HVL	0.33	0.79
Uranium	TVL	0.93	2.29
	HVL	0.28	0.69

HVL: Thickness of a shielding material required to reduce the intensity of the beam to the half of its initial value.

SHIELDING

Half-value layer (HVL)

Thickness of shielding material that reduces the dose rate to half of original



Example:

HVL for Cs-137 is 6.5 mm. of lead. What is the thickness of lead needed to reduce the dose rate from 40 mR/hr to 2.5 mR/hr ?

$$\text{No. of HVL, } 2^n = \frac{\text{Dose rate before shielding}}{\text{Dose rate after shielding}}$$

$$= 40 / 2.5 = 16$$

$$n \ln 2 = \ln 16 \Rightarrow n = \ln 16 / \ln 2 = 4$$

Therefore, thickness required = $n \times \text{No. of HVL}$
= $4 \times 6.5 = 26 \text{ mm. of lead}$

Question:

A lead shield is used to block ^{60}Co radiation field of $96 \mu\text{Sv/hr}$. Calculate the final dose rate after passing through 6.2 cm lead. Given, HVL for lead in ^{60}Co is 1.24 cm.

Answer:

Given 1 HVL for lead is 1.24 cm, therefore 6.2 cm of lead is equivalent to 5 HVL

$$2^n = \frac{I_o}{I_x}$$

$$2^5 = \frac{96}{I_x}, \quad \text{therefore } I_x = \frac{96}{32} = 3 \mu\text{Sv/hr}$$

Question:

If dose rate at a particular distance from ^{192}Ir radioactive source is $1000 \mu\text{Sv/hr}$, calculate the thickness of lead required to reduce the dose rate to $1 \mu\text{Sv/hr}$. Given for ^{192}Ir , TVL is 1.62 cm of lead.

Answer:

Using a formula:
$$10^n = \frac{I_o}{I_x}$$

$$10^n = \frac{1000}{1} = 10^3, \quad \text{therefore, } n = 3$$

Given 1 TVL for Ir – 192 is 1.62 cm ,

Therefore, 3 TVL is equal to $3 \times 1.62 \text{ cm} = 4.86 \text{ cm}$

TIME

$$\text{Dose} = \text{Dose rate} \times \text{Time}$$

Ir-192



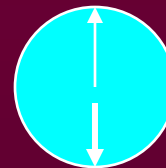
Doserate @ 1m
= 1.0 mSv/h



Exposure starts
at 12:00



$$1.0 \text{ mSv/hr} \times 3 \text{ hr} \\ = 3.0 \text{ mSv}$$



$$(1.0 \text{ mSv/hr} \times 3 \text{ hr}) \times 2 \\ = 6.0 \text{ mSv}$$



$$(1.0 \text{ mSv/hr} \times 3 \text{ hr}) \times 3 \\ = 9.0 \text{ mSv}$$

PROTECTION AGAINST INTERNAL HAZARD

Internal Dose

Intake - the amount of activity taken into the body.

Entry into the body can occur via:

- Inhalation (dust, gas or volatile materials)
 - Ingestion (contaminated food or water)
 - Wound (dust, solid or liquid materials)
 - Direct absorption (tritium)
-
- The limit of internal exposure resulting from the intake of radionuclide is based on the Annual Limit of Intake (ALI).
 - The ALI is the amount of a radionuclide (in Bq) which would give a harm commitment to the organs it irradiates equal to that resulting from whole body irradiation of 20 mSv in a year.

PROTECTION AGAINST INTERNAL HAZARD

- ⊕ All radiations are hazardous - α being the most toxic.
- ⊕ Ensure minimum quantity of radioactive material used
- ⊕ Conduct all operation in enclosure (fume hood/cupboard, hot cells)
- ⊕ Ensure good house keeping habit
- ⊕ Confined radioactive material spillage
- ⊕ Conduct periodic survey of areas to detect contamination
- ⊕ Practice first for new operation with dummy
- ⊕ Hand and foot must be monitored before exit the area

Personal Protective Equipment (PPE)

- is worn to reduce the risk of radiation exposure from internal radiation exposure and radioactive contamination.
- is the last line of defense in controlling risk.
- should only be used to complement other means of radiation hazard control already in place.

Examples of PPE/clothing include:

- ✓ Laboratory coat
 - ✓ Overall or boiler suit
 - ✓ Rubber gloves
 - ✓ Overshoes
 - ✓ Rubber boots
 - ✓ Breathing apparatus



(example - Pressurized clothing, SCABA + whole body suit (Self Contained Breathing Apparatus))

Conduct all operation in enclosure (fume hood/
cupboard, hot cells)



Safety Equipment and Facilities at the Place of Work

These equipments are used to reduce exposure and contamination.

Safety facilities include building design incorporating safety features to handle radiation and radioactivity.

Examples of such equipment and facilities are:

- *Remote-handling tongs*
- *Lead brick*
- *Liquid transfer system*
- *Radioactive containers*
- *Ventilated facility*



Safety Procedures and Surveillance

- a) Safety procedures must stress the importance of preventing inhalation, ingestion and penetration of radionuclides through the skin, and contamination of personnel and working areas in normal routine procedure and emergency situations.
- b) Having a safe working procedure does not guarantee its compliance. Surveillance of compliance and monitoring of radiation levels must be carried out periodically. Both visual surveillance and those using radiation monitoring and detectors must be used.



END OF TOPIC

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