Radiation Protection (II)

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Dose Limits

- Dose limits for radiation workers are:
  - Whole or large parts of the body: 20 mSv/year.
  - Individual organs:
    - Eye: 150 mSv/year.
    - Skin, hands and feet: 500 mSv/year.
  - For pregnant women the dose to the fetus are not allowed to be larger than 1 mSv for the remaining part of the pregnancy.
- An institution which perform radioactive work is required to ensure that the work does not expose anybody outside the institution for more than 0.25 mSv/year.

ALARA

- ALARA means "As Low As Reasonable Achievable"
- The therm implies that even if you are allowed to receive a dose of 20 mSv per year, you should always seek to keep it as low as possible.
- This implies that you should examine your work routines and equipment with an eye on reducing the dose exposure as much as possible.

Personnel Dosimetry

- To keep control with the dose received, each person working in a radiation environment is required to carry a dosimeter.
- This is a device which measures the accumulated dose.
- Formerly the most common dosimeter was a photographic film sensitive to radiation or some variation of an electroscope.
- Today the most common dosimeters is based on thermoluminescence crystals or electronic units.

TLD

- Many crystals, including CaF_2 containing Mn as an impurity, and LiF, emit light if they are heated after having been exposed to radiation.
- The amount of light emitted is directly proportional to the energy absorbed from the radiation. I.e. proportional to the radiation dose.
- TLDs respond quantitatively to X-rays, γ rays, β rays, electrons and protons over a range that extends from about 0.1 mGy to about 1000 Gy.
- LiF TLDs are approximately tissue equivalent, since the effective atomic number of the LiF phosphor is 8.1, while the effective atomic number of soft tissue is about 7.4.

ThermoLuminescence Dosimeter = TLD

Personnel Radiation Monitoring

- The measurement period should be between 1 and 3 months, depending on the radiation level and the risks involved.
- The dosemeter should be worn in such a way that it gives a representative picture of the radiation exposure.
- Both penetrating and non-penetrating radiation should be measured.
  - For penetrating radiation the whole body limit is 20 mSv/y.
    - Penetrating radiation is measured behind 10 mm of soft tissue and is referred to as "HP(10)".
  - For non-penetrating radiation the dose limit is 500 mSv/y.
    - non-penetrating radiation is measured behind a skin thickness of 0.07 mm.

Penetrating radiation = Gjennomtrengende stråling
Soft tissue = Bløtvev

Dosimeter is not needed if...

- If you only work with ^{3}H, ^{14}C or ^{35}S a dosimeter is not required, provided the amount of radioactivity is less than 40 MBq.
- This is because these are very low-energy β emitters.
  - They hardly registers on the TLD.
  - Their radiactive toxity is low.
- However, the normal safety precautions when working with radioactivity should be observed.

Classification of Laboratories

- The maximum limits of activity which one can use *without special permission* is given in the Norwegian law about "Radiation Protection and Use of Radiation" (lov om strålevern og bruk av stråling) (page 51-57).
- Any work which uses more activity than this needs to be performed special laboratories approved for radioactive work. These are classified into three categories: Type A, B and C.
  - Type C is for work with small amounts of radioactive substances
  - Type B is for moderate amounts.
  - Type A, commonly referred to as a "Hot-Lab", is for work with large amounts of radioactive substances.

Allowed Activity

Type	Permitted amount of activity which can be used for each experiment.	Example - maximum amount permitted
Unclassified	The maximum amount is listed in the appendix on page 51 in the Norwegian radiation protection law.	1000 MBq of ^{3}H 10 MBq of ^{14}C 100 kBq of ^{32}P 10 kBq of ^{137}Cs 10 kBq of ^{226}Ra
C	Up to 10 times the maximum amount which can be used in an unclassified laboratory.	1 MBq ^{32}P
B	Up to 10 000 times the maximum amount which can be used in a unclassified laboratory.	1 TBq ^{32}P
A	More than 10 000 times the maximum amount which can be used in a unclassified laboratory.	

Hot-lab

The picture is from a research lab in Jülich.

Risk related to exposure

- We differentiate between two main types of exposure: External and internal.

	Ekstern eksponering:	Intern eksponering:
Minst farlig	α-partikler	γ-stråler og nøytroner
Middels farlig	β-partikler	β-partikler
Mest farlig	γ-stråler og nøytroner	α-partikler

Internal exposure through skin

- Uptake of radioactivity through the skin (or in wounds) is easily avoided.
- Such uptake usually happens as a result of spill on unprotected skin or by handling contaminated equipment.
- Disposable gloves provides good protection in most cases.
  - The gloves must be resistant against the chemicals used.
  - If you spill on your gloves you shall *change them immediately*!
  - Use the monitor frequently to check your gloves for contamination.
- Safe working practices are important -avoid spill and splashing!
  - Work in trays with absorbing paper in the bottom.
  - Regularly check for contaminations.
  - Cover open beakers etc.
- Dedicated lab coats should be used. These should only be used for radioactive work and remind in the laboratory.

Special case: Tritium

- The tritium in many compounds, including water, tends to exchange with hydrogen in surrounding surfaces.
- Migration through plastic is therefore to be expected due to its high hydrogen content.
- Surgical gloves normally used for radioisotope work will protect the hands for only a few minutes after they are contaminated on the outside.
- Once the tritium has permeated the gloves, the perspiration inside offers an excellent environment for skin absorption. It is therefore important to change gloves frequently during an experiment and whenwever they may be contaminated.
- Bench paper and other protective covers must also be discarded as soon as possible due to their limited protective life.

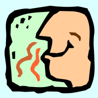
Internal exposure by swallowing

- Exposure by mouth usually happens due to activity being transferred from the hands to the mouth. This usually happen when you eat, drink or smoke.
- To reduce this risk, while in the laboratory it is absolutely forbidden to:
  - Eat,
  - Drink,
  - Smoke,
  - Chew chewing gum or
  - Put on makeup.

- Food and drink shall *not* be stored in the lab.
- Before you leave the area for radioactive work, gloves shall be thrown, your hands washed and the lab coat taken off.

Internal exposure by inhalation

- Airborne contamination is the most likely way for radioactivity to enter the body.
- Contrary to contamination on equipment or furniture, Airborne contamination will quickly be spread around the whole laboratory, and in the worst case the whole building.
- The risk of Airborne contamination is greatly reduced by using fume hoods or glove boxes.
  - All work with volatile compounds, aerosols, or dust/fine grained material *must* be performed in a fume hood or glove box.
  - Think through what will happen if the power is lost and the suction in the hood is lost.
  - The fume hood or glove box must have smooth surfaces, without any pores.
  - Keep fume hood neat and tidy!



External exposure

External exposure can effectively be reduced by control of three basic factors:

- Time.

- Distance.

- Shielding.

External Exposure - Time

- The radiation dose is directly proportional to the time the exposure to the source lasts.
- Thus, the easiest way to reduce the dose is to reduce the time you are exposed.
- You can reduce the time by:
  - Plan how to perform the experiment as quickly as possible.
  - Practice performing the experiment with "cold" reagents.
  - Label areas with strong radiation. In that way you and others can avoid this area when it is not strictly necessary to work there.

External exposure - distance

- The intensity of γ *radiation* from a point source is inversely proportional to the distance from the source.
- This do **NOT** pertain to α and β sources!!!
- Use long handling tools or other suitable equipment for handling strong sources.

Formula for calculation of the intensity reduction when the distance is increased:

$$I_b = I_a \cdot \frac{a^2}{b^2}$$

Here I_a and I_b is the intensity at distances a and b, respectively.

Radiation Field from β Sources

- The radiation dose from β particles close to a source is much larger than the dose from a corresponding γ source.
- This is because the β radiation will be stopped rather quickly, and thus also dispose of all its energy.
- A β particle may penetrate 1 cm into your hand and dispose 100% of its energy.
- γ radiation with the same energy would mostly go straight through your hand. Only about 2% of its energy would have been deposited.

Example

Radiation field from 37 MBq (1 mCi) ^{32}P

Avstand (cm):	Dosehastighet (μSv/time):
1	35000
3	3700
10	350
30	39
100	3,5

Dose from β contamination

- You will get β burns from skin doses of 300-1000 μSv.
- Such a dose you will get if you hold a ordinary plastic syringe with 37 MBq ^{32}P for one minute.
- If you had "held" the syringe at a distance of 10 cm, it would require a week to accumulate the same dose....
- Therefore, it is important to use syringe shields or other suitable protection when you handle syringes or pipettes with high amounts of high-energy β-emitters.
- For the same reason it is extremely important to use gloves which are not penetrated by the compounds used.

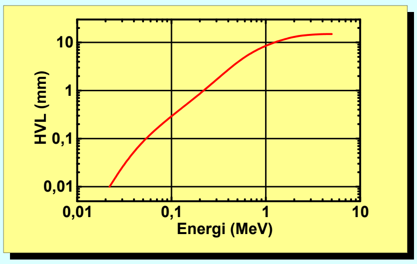
Examples

Dosehastighet fra en 37 MBq/cm² hudkontaminasjon		
E_β (MeV):	Nuklide:	mSv/time:
0,16	^{14}C, ^{35}S	17
0,25	^{45}Ca	45
0,48	^{59}Fe	64
0,61	^{131}I	69
0,96	^{198}Au	77
1,39	^{24}Na	80
1,71	^{32}P	54
2,27	^{90}Y	54

External exposure - shielding

- The intensity of γ radiation will be reduced by any type of absorber, but it can never be reduced to zero.
- Materials with a high Z absorbs more effectively than those with low Z.
- Therefore, Pb is most commonly used.
- The easiest way to calculate the necessary thickness of the shielding is by using "Half-Value-Layers" (HVL).
- HVL is the thickness of a given material required to reduce the radiation field by half.
- Notice that the HVL is a function of the γ-rays energy.

External exposure - shielding



To calculate the required shielding thickness the following formula can be used:

$$A_p = \frac{A_0}{2^n}$$

Where n is the number of HVLs, A_0 is unshielded activity, and A_p is shilded activity.

External exposure - shielding

- Since α and β sources deposit all their energy along a short path length, it's comparatively easy to shield effectively against such sources.
- To avoid excessive amounts of Bremsstrahlung one use low-Z materials like glass or plastic.
- Below is a table listing the maximum range of the β particles of some common sources:

Nuklide:		Maksimal veilengde (mm):		
	$E_{\beta,max}$ (keV):	Vann:	Lucite:	Glass:
^{14}C, ^{35}S	160	0,3	0,3	0,1
^{45}Ca	250	0,6	0,5	0,3
^{59}Fe	480	1,6	1,4	0,6
^{131}I	610	2,1	1,9	0,9
^{198}Au	960	3,6	3,3	1,5
^{24}Na	1390	5,9	5,4	2,5
^{32}P	1710	7,7	7,0	3,2
^{90}Y	2270	10,7	9,8	4,5