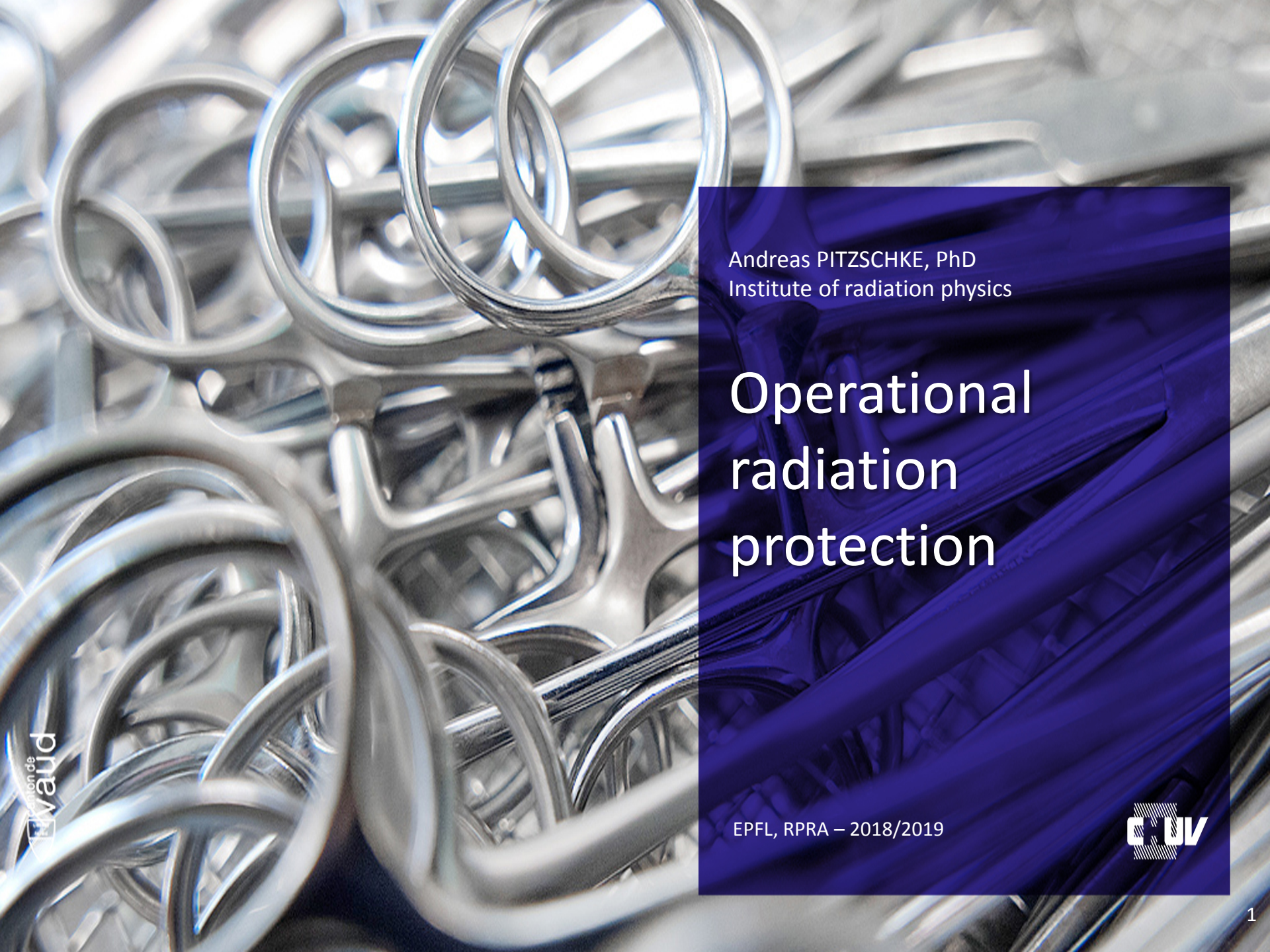


Andreas PITZSCHKE, PhD
Institute of radiation physics

Operational radiation protection

EPFL, RPRA – 2018/2019

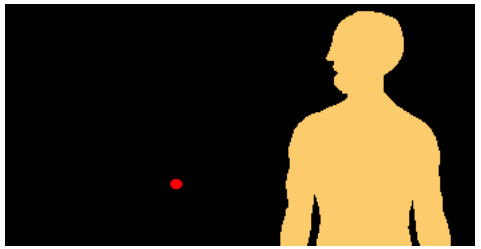
Course goals

- Describe strategies to reduce external exposure and the risk of internal contamination
- Know how to measure external exposure and contamination
- Understand the need of decontamination

Outline

1. External exposure
   - Strategies to minimize external exposure
   - Measuring external exposure

2. Internal exposure
   - Strategies to protect against internal exposure
   - Decontamination



Outline

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   - Strategies to minimize external exposure
   - Measuring external exposure

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   - Strategies to protect against internal exposure
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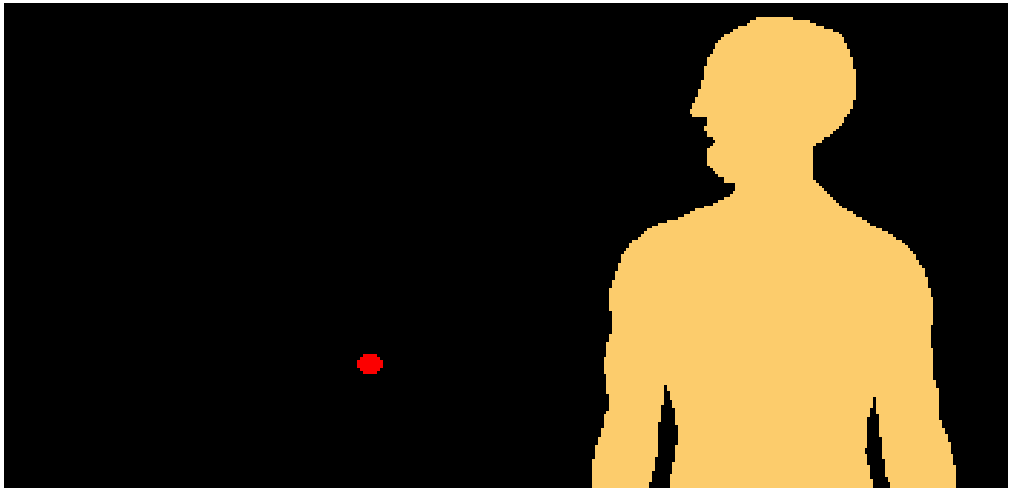
External exposure



An individual located near a source of radiation is subject to **external exposure**.

External exposure is essentially caused by gamma radiation. External exposure from alpha radiation can be overlooked.

External exposure

h: Dose/dose-rate factor per unit of source activity ((mSv/h)/GBq) at 1 m

T: Transmission factor of the shielding for the given radiation type and energy

$$H = A \cdot h \cdot \frac{1}{r^2} \cdot T \cdot t$$

H: Dose (mSv)

A: Source activity (GBq)

r: Distance to the radiation source (m)

t : Exposure duration (h)

Outline

1. External exposure
   - **Strategies to minimize external exposure**
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External exposure

Annex 3 of the **Radiological Protection Ordinance**

https://www.admin.ch/opc/en/classified-compilation/20163016/201806050000/814.501.pdf

Data for operational radiological protection, clearance limits, licensing limits and guidance values

Explanatory notes on the individual columns and a list of footnotes are given at the end of the table.

Radionuclide	Half-life	Type of decay/ radiation	Assessment quantities					Clearance limit	Licensing limit	Guidance values	
			e_{inh} Sv/Bq	e_{ing} Sv/Bq	h_{10} (mSv/h)/ GBq at 1 m distance	$h_{0,07}$ (mSv/h)/ GBq at 10 cm distance	$h_{c,0,07}$ (mSv/h)/ (kBq/cm^2)	LL Bq/g	LA Bq	CA Bq/m^3	CS Bq/ cm^2
1	2	3	4	5	6	7	8	9	10	11	12
H-3, OBT	12.32 a	β$^-$	4.10 E-11	4.20 E-11	<0.001	<1	<0.1	1.E+02	1.00 E+08	2.00 E+05	1000
H-3, HTO		β$^-$	1.80 E-11	1.80 E-11	<0.001	<1	<0.1	1.E+02	3.00 E+08	5.00 E+05	1000
H-3, gaz [7]		β$^-$	1.80 E-15		<0.001	<1	<0.1		3.00 E+12	5.00 E+09	
Be-7	53.22 d	ec / ph	4.60 E-11	2.80 E-11	0.008	<1	0.1	1.E+01	1.00 E+08	2.00 E+05	100
Be-10	1.51 E6 a	β$^-$	1.90 E-08	1.10 E-09	<0.001	2000	1.6	1.E+02	3.00 E+05	4.00 E+02	3

External exposure

$$H = A \cdot h \cdot \frac{1}{r^2} \cdot T \cdot t$$

Rules of protection against external exposure:

- Select an appropriate **source**
- Reduce exposure **time**
- Increase the **distance**
- Use **shielding**

Source selection

Act on the characteristics of the emitted radiation (**h**)

$$H = A \cdot h \cdot \frac{1}{r^2} \cdot T \cdot t$$

Act on the intensity of the source (**A**)

Use the **least penetrating radiation possible** which is compatible with the application goal:

Ex.: Iodine-125 (35 keV γ radiation) rather than Iodine-131 (360 keV γ radiation) for biological marking

Reduce the activity of the source

Ex : Immediate storage of the main solution following a dilution for use in chemistry or biology

Exposure time

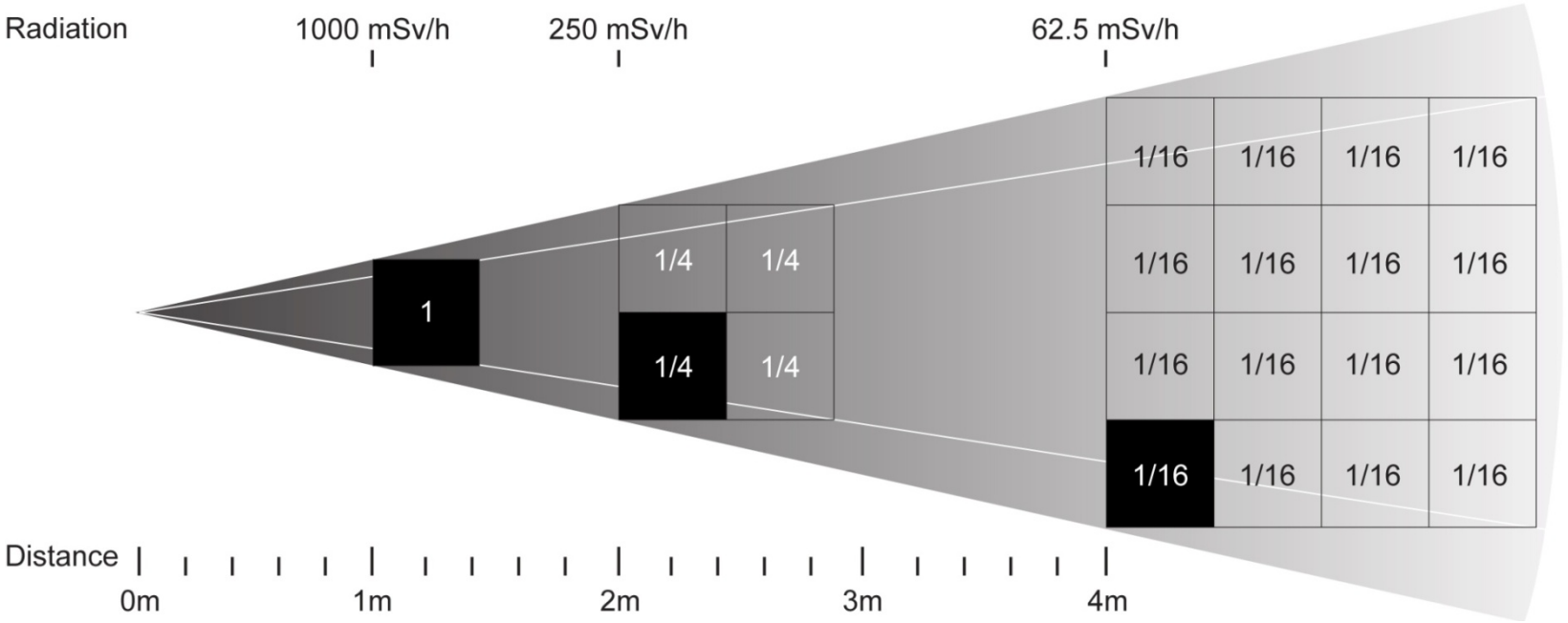
$$H = A \cdot h \cdot \frac{1}{r^2} \cdot T \cdot t$$

The shorter the exposure time, the smaller the dose.

Plan your work:

- practice of the manipulation without the source
- reduce any useless gestures, dead time and unexpected occurrences

Distance



Dose rate evolves as the inverse of the square of the distance to the source

Distance

Dose rate evolves as the inverse of the **square of the distance** to the source

$$\frac{H_1}{H_2} = \left(\frac{d_2}{d_1}\right)^2$$

Especially important at the first few centimeters:

Ex : 10 cm distance (tweezers) rather than 1 mm (finger contact) distance reduces the dose rate by a factor of 10’000.

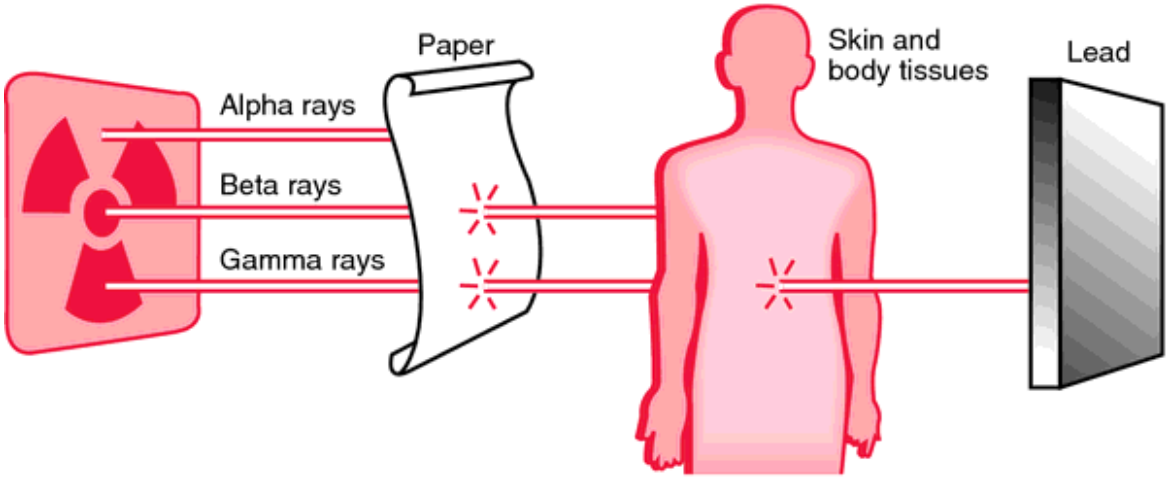
→ Use **tweezers** whenever possible!

→ Use telemanipulators

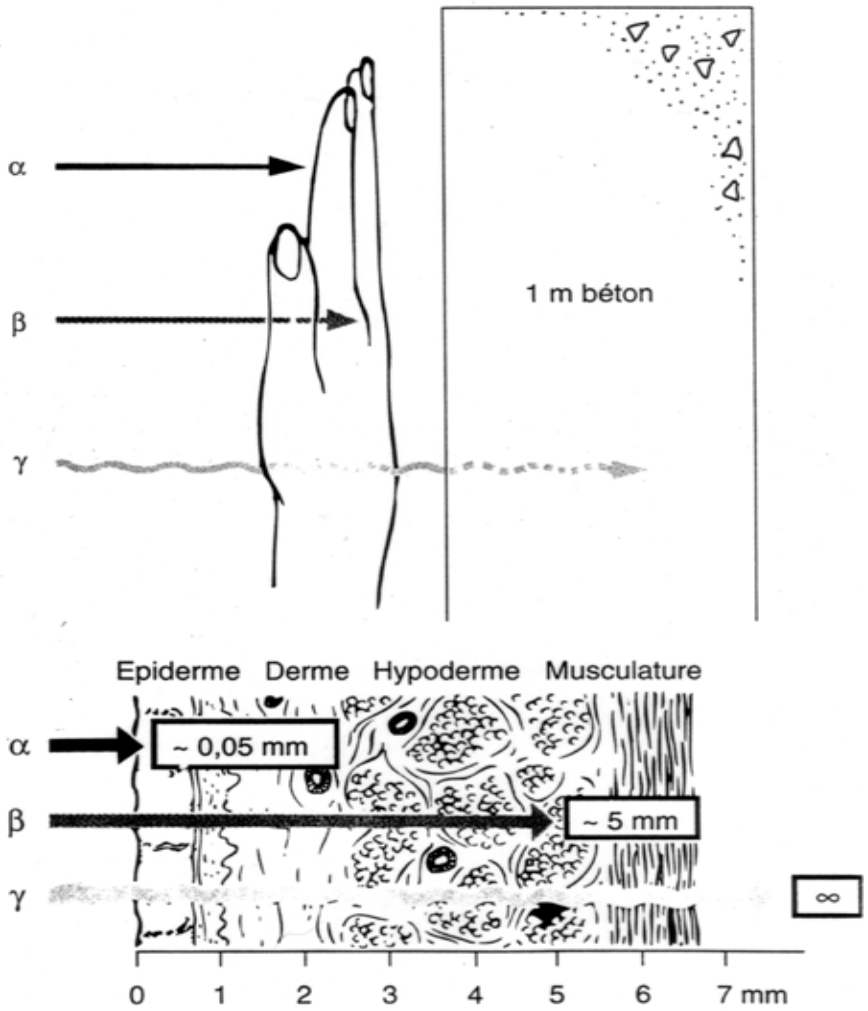
Shielding

Shielding

- α: Layer of the epidermis (70 µm) made up of dead skin cells, sheet of **paper**
- β: 1 cm of water, 1 cm-thick **plastic** screen $R_e\,[\mathrm{cm}] \cong \frac{E\,[\mathrm{MeV}]}{2}$
- γ: **Lead**, concrete $\tau = e^{-\mu x}$



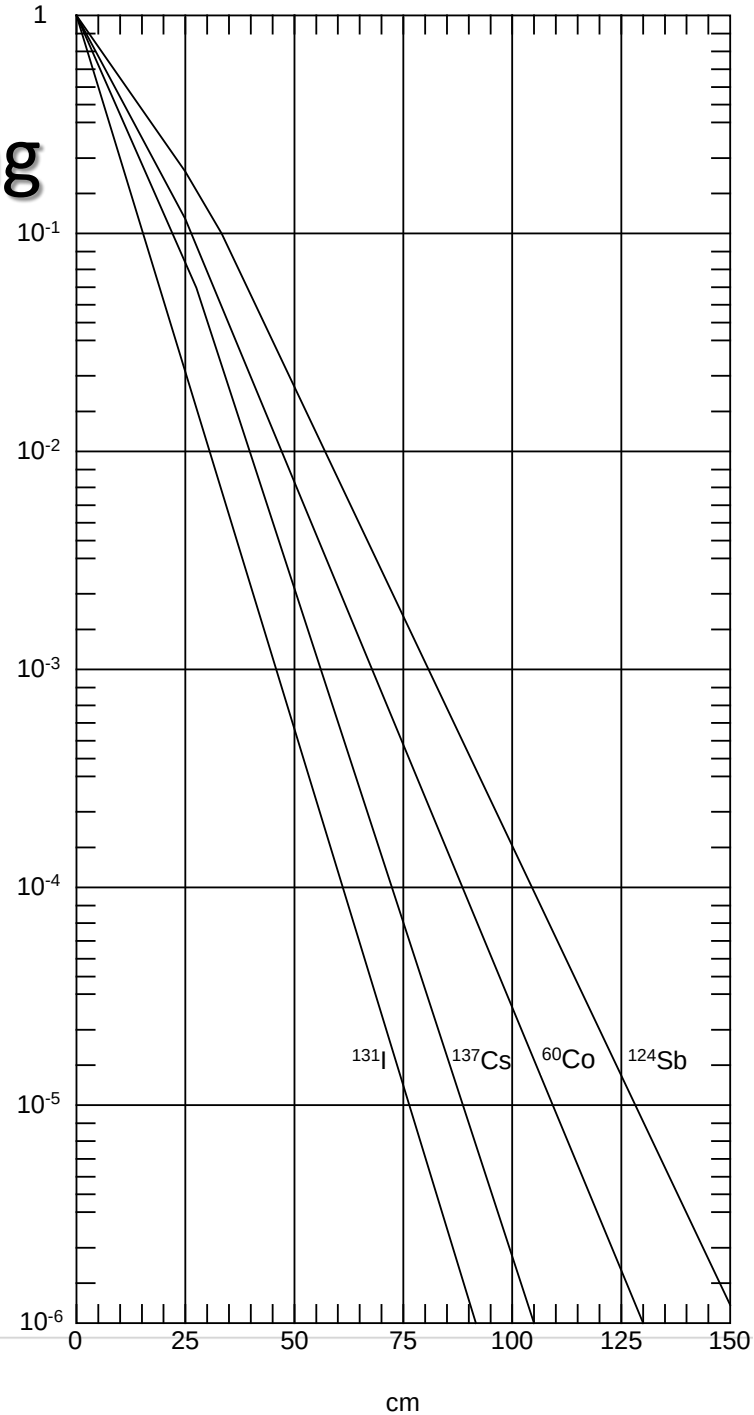
Shielding

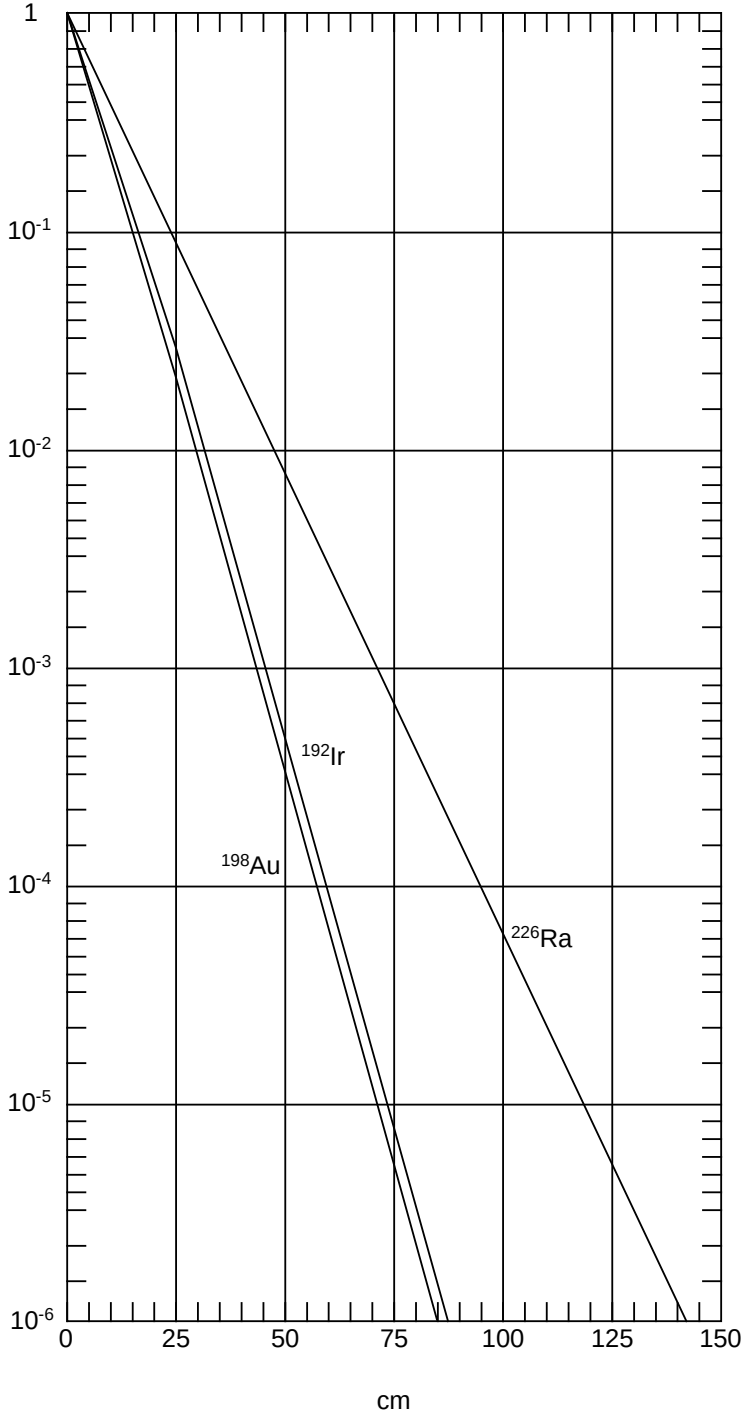


Energie de rayonnement 1 MeV

Shielding

Radiation transmission of **concrete** for various radionuclides
(ρ = 2.35 g/cm3)

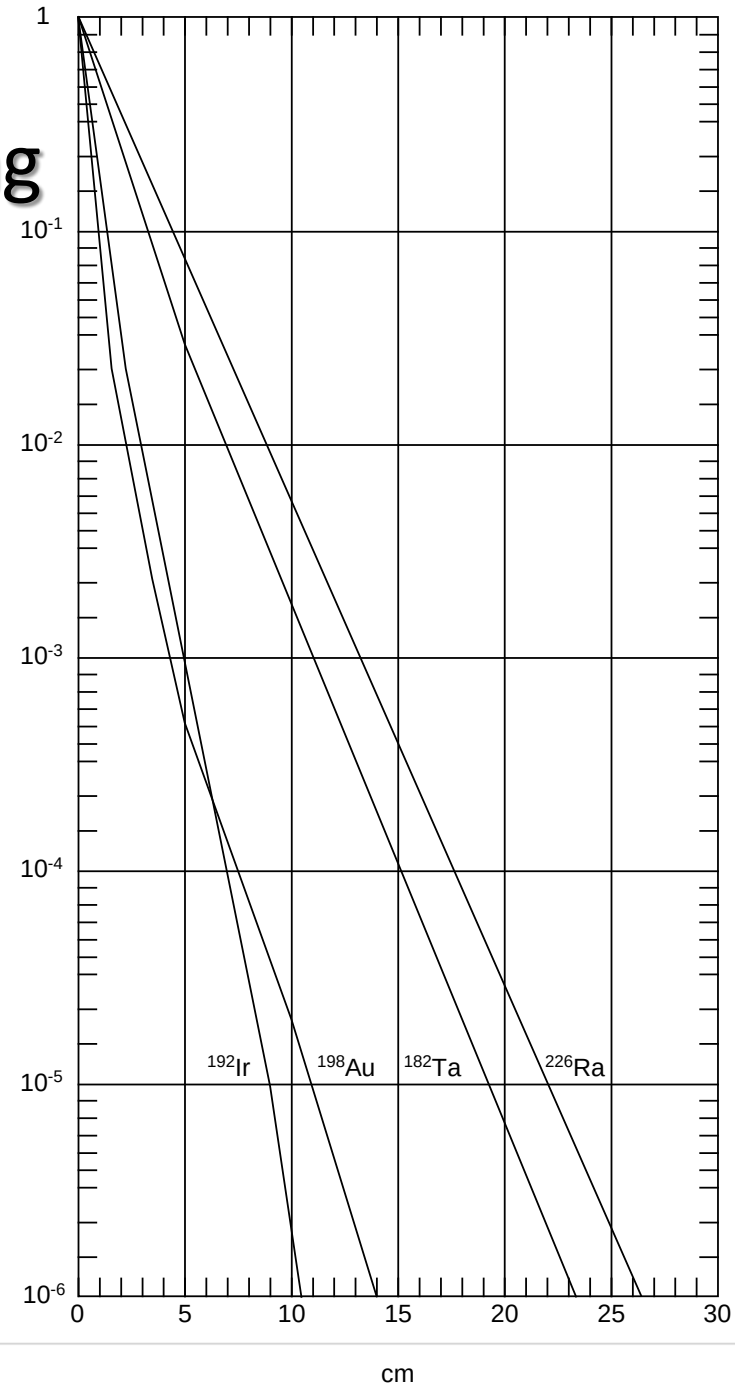


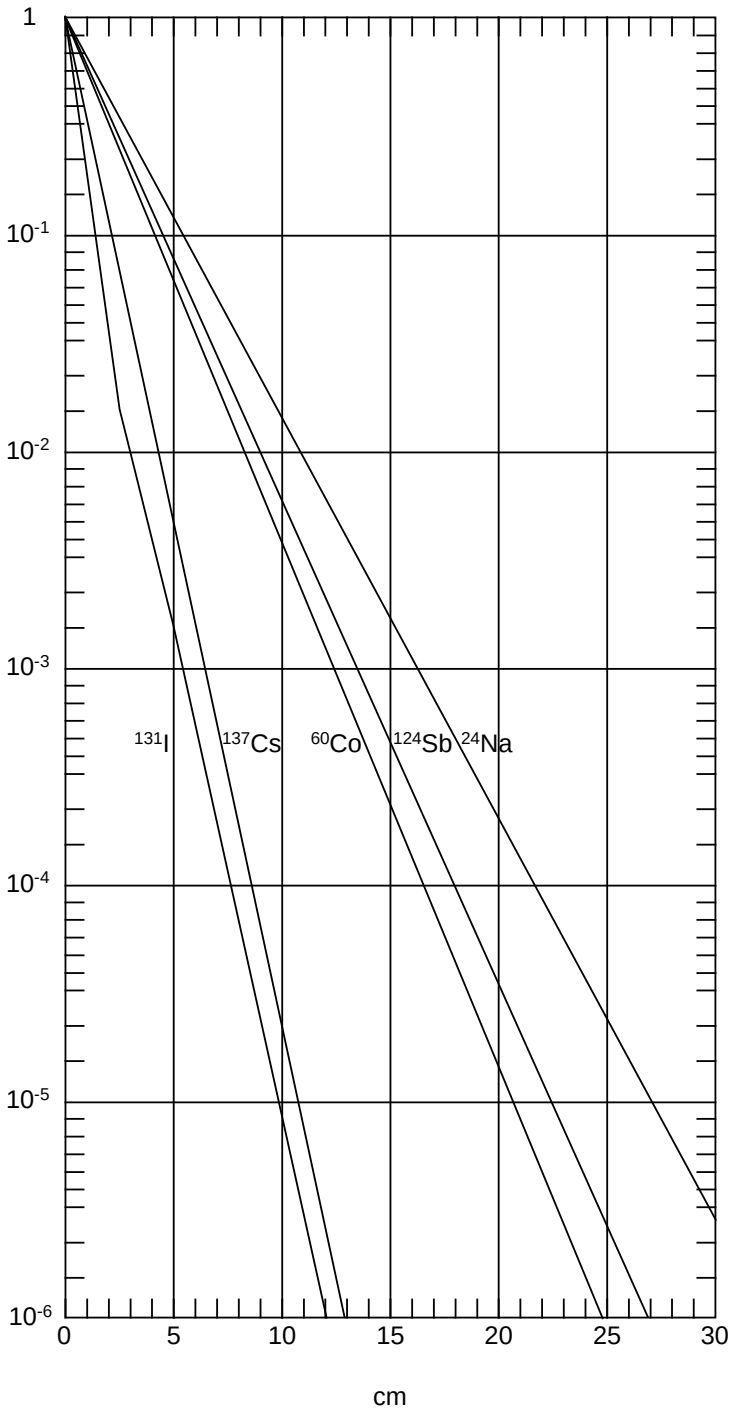


canton de vaud

Shielding

Radiation transmission of **lead** for various radionuclides (ρ = 11.35 g/cm3)





Outline

1. External exposure
   - Strategies to minimize external exposure
   - **Measuring external exposure**

2. Internal exposure
   - Strategies to protect against internal exposure
   - Decontamination

Personal dosimetry

Personal dosemeter to measure the individual dose

Passive personal dosemeter:

- monthly reading
- doses ≥ 50 µSv

Active personal dosemeter:

- immediate reading
- alarm
- doses ≥ 1 µSv

Passive ring dosemeter:

- monthly reading
- doses ≥ 100 µSv

Ambient dosimetry

Ambient dose rate meter to measure the ambient dose rate

Portable measuring device

- Standard equipment in a laboratory
- Alarm at high dose rates / cumulated dose
- For dose rates ≥ 0.1 µSv/h

Stationary measuring device

- Equipment for strategic points
- Data can be recorded if necessary
- Alarm at high dose rates / cumulated dose
- For dose rates ≥ 0.1 µSv/h

Outline

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Internal exposure

Internal exposure occurs following a contamination.
The radiation source is present **inside** the organism.

Internal exposure

The risk of contamination linked to radioactive substances directly depends on their **physical state**:

- Gas and aerosol
- Liquid
- Solid

Outline

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Source selection

Parameters	Optimization
Type of emitter and radiation energy	Less dangerous radiation and the lowest energy
Activity of the source	Minimum activity compatible with the planned application
Half-life	Shortest half-life compatible with the planned application
Chemical forms	Chemical forms which are the most quickly eliminated by the body

Protection through structures

Protection through structures

LA – Authorization limit

Authorization or licensing limit is the activity of a substance above which an authorization/license is needed for handling an unsealed source

1x LA leads, by inhalation of the substance, to a committed effective dose of 5 mSv.

Data for operational radiological protection, clearance limits, licensing limits and guidance values

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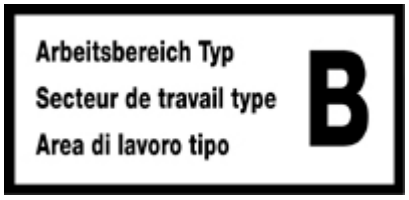
Radiological Protection Ordinance:
https://www.admin.ch/opc/en/classified-compilation/20163016/201806050000/814.501.pdf

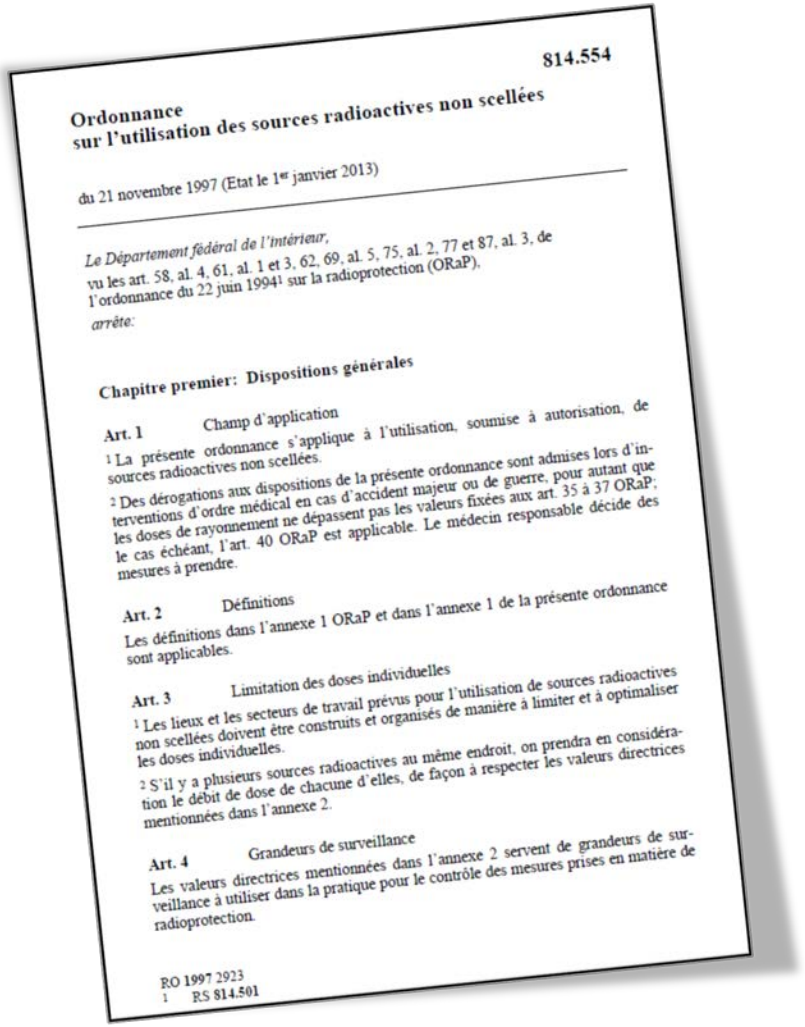
Protection through structures

Goal of the working area: **Confine the radioactive substance**

Type	Maximum activity
Normal	1 LA
Type C	100 LA
Type B	10’000 LA
Type A	>10’000 LA (in accordance with authorization)



Protection through structures



814.554

Ordonnance
sur l'utilisation des sources radioactives non scellées

du 21 novembre 1997 (Etat le 1er janvier 2013)

Le Département fédéral de l'intérieur,
vu les art. 58, al. 4, 61, al. 1 et 3, 62, 69, al. 5, 75, al. 2, 77 et 87, al. 3, de l'ordonnance du 22 juin 1994[1] sur la radioprotection (ORaP),
arrête:

Chapitre premier: Dispositions générales

Art. 1 Champ d'application

[1] La présente ordonnance s'applique à l'utilisation, soumise à autorisation, de sources radioactives non scellées.

[2] Des dérogations aux dispositions de la présente ordonnance sont admises lors d'interventions d'ordre médical en cas d'accident majeur ou de guerre, pour autant que les doses de rayonnement ne dépassent pas les valeurs fixées aux art. 35 à 37 ORaP; le cas échéant, l'art. 40 ORaP est applicable. Le médecin responsable décide des mesures à prendre.

Art. 2 Définitions

Les définitions dans l'annexe 1 ORaP et dans l'annexe 1 de la présente ordonnance sont applicables.

Art. 3 Limitation des doses individuelles

[1] Les lieux et les secteurs de travail prévus pour l'utilisation de sources radioactives non scellées doivent être construits et organisés de manière à limiter et à optimaliser les doses individuelles.

[2] S'il y a plusieurs sources radioactives au même endroit, on prendra en considération le débit de dose de chacune d'elles, de façon à respecter les valeurs directrices mentionnées dans l'annexe 2.

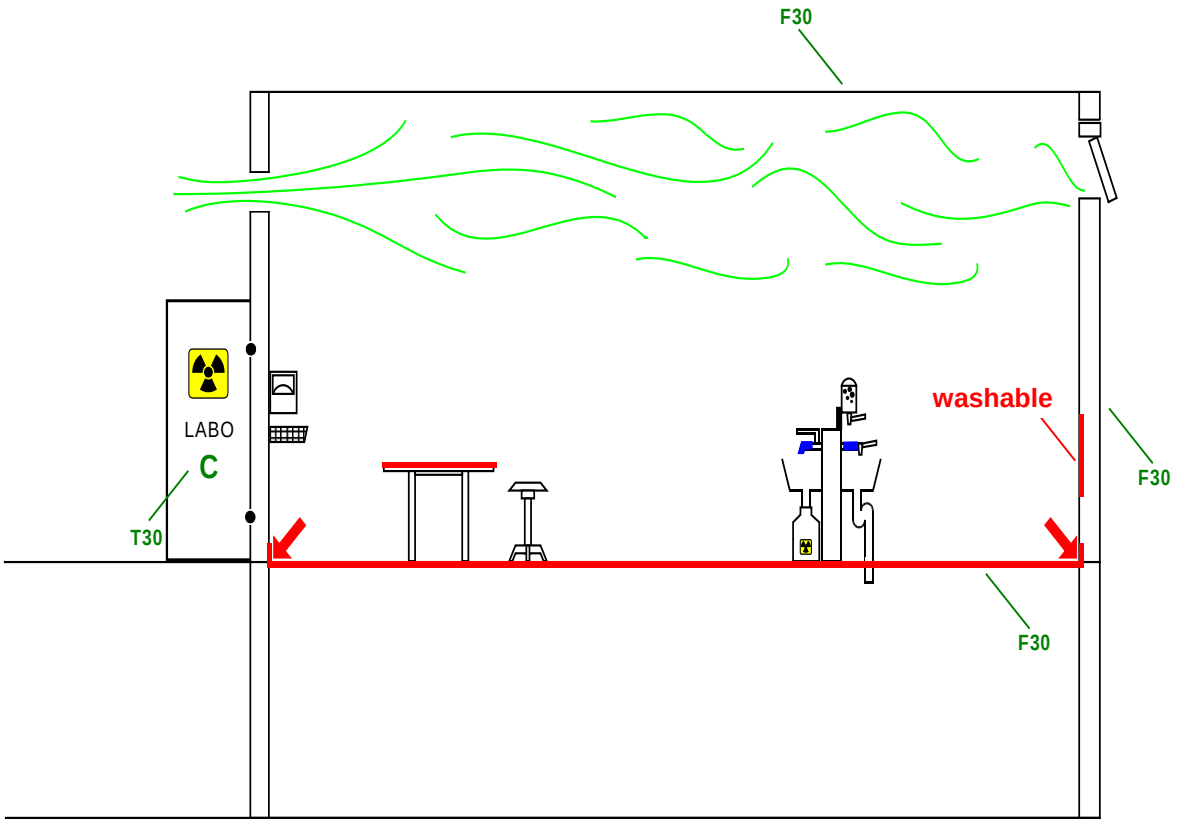
Art. 4 Grandeurs de surveillance

Les valeurs directrices mentionnées dans l'annexe 2 servent de grandeurs de surveillance à utiliser dans la pratique pour le contrôle des mesures prises en matière de radioprotection.

RO 1997 2923
1 RS 814.501

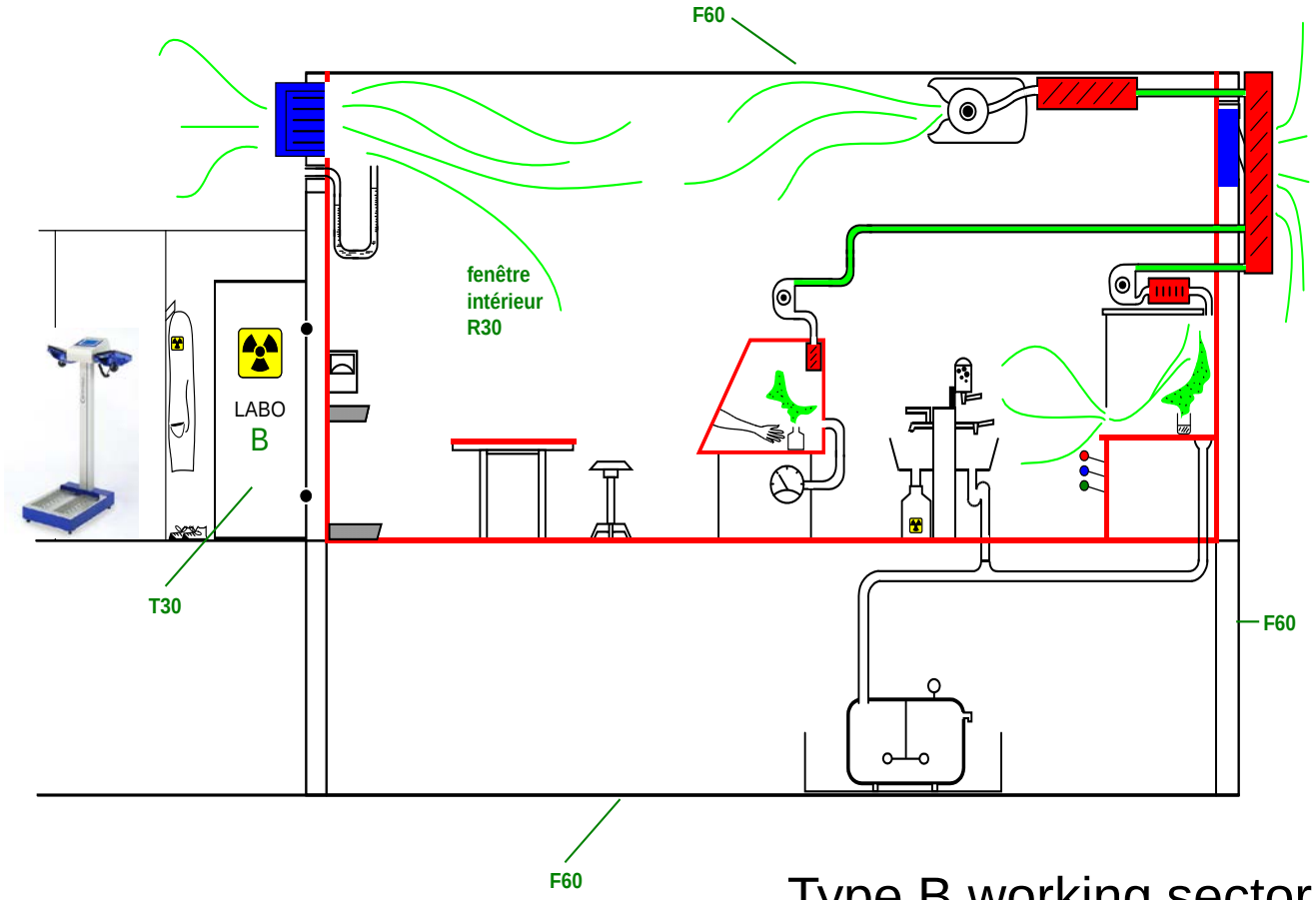
Ordinance on the use of open sources of radiation

Protection through structures



Type C working sector

Protection through structures



Type B working sector

Means of personal protection

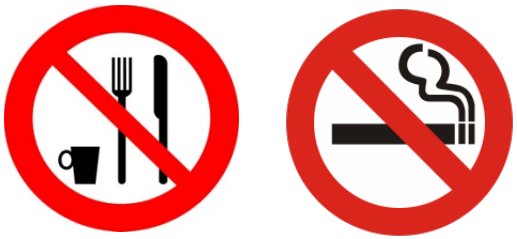
Goal of personal protection: Protect against **contamination**

Means of personal protection

Protection through working methods

Basic rules :

- Do not smoke, drink or eat in a laboratory where open sources are located
- Always use **gloves** when handling the source
- Take all necessary precautions to **avoid cuts** or other injuries
- Never use a pipette with the mouth



Protection through working methods

Contamination monitoring:

- Frequently monitor hand contamination
- **Periodically monitor** (and when finished with any work) surface contamination of working areas, shoes and clothing
- Never leave any contamination behind, wash hands as frequently as necessary
- Monitor the contamination of any object **leaving the working area**

Protection through working methods

Sources manipulation:

- Avoid working near the stock of a radioactive substance: put it away as soon as you have taken what you need for working
- Conduct any handling above a basin which can gather the substance if it disperses
- Prepare special containers for radioactive waste
- Label all radioactive products

Accident:

- Prepare response measures in the event of a contamination
- In case of an accident, react calmly and carefully, avoid spreading the contamination, call the radiation protection officer

Outline

1. External exposure
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   - **Decontamination**

Decontamination

CS – Surface contamination

The guiding value for surface contamination is the accepted limit value outside controlled zones.

1x CS leads, by inhalation or ingestion of the substance, to a committed effective dose of 0.5 mSv or, by skin contamination, to an equivalent skin dose of 50 mSv.

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Radiological Protection Ordinance:
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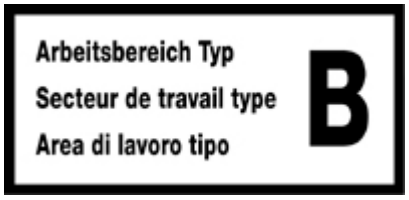
Decontamination

Goal of decontamination: **Avoid spreading** of radioactive substances and **minimize** internal and external **exposure**

Area	Maximum surface contamination
Public	1 CS
Controlled	10 CS (if fixed)



Measuring surface contamination

Measuring instrument: **Surface contamination monitor**

Measuring surface contamination

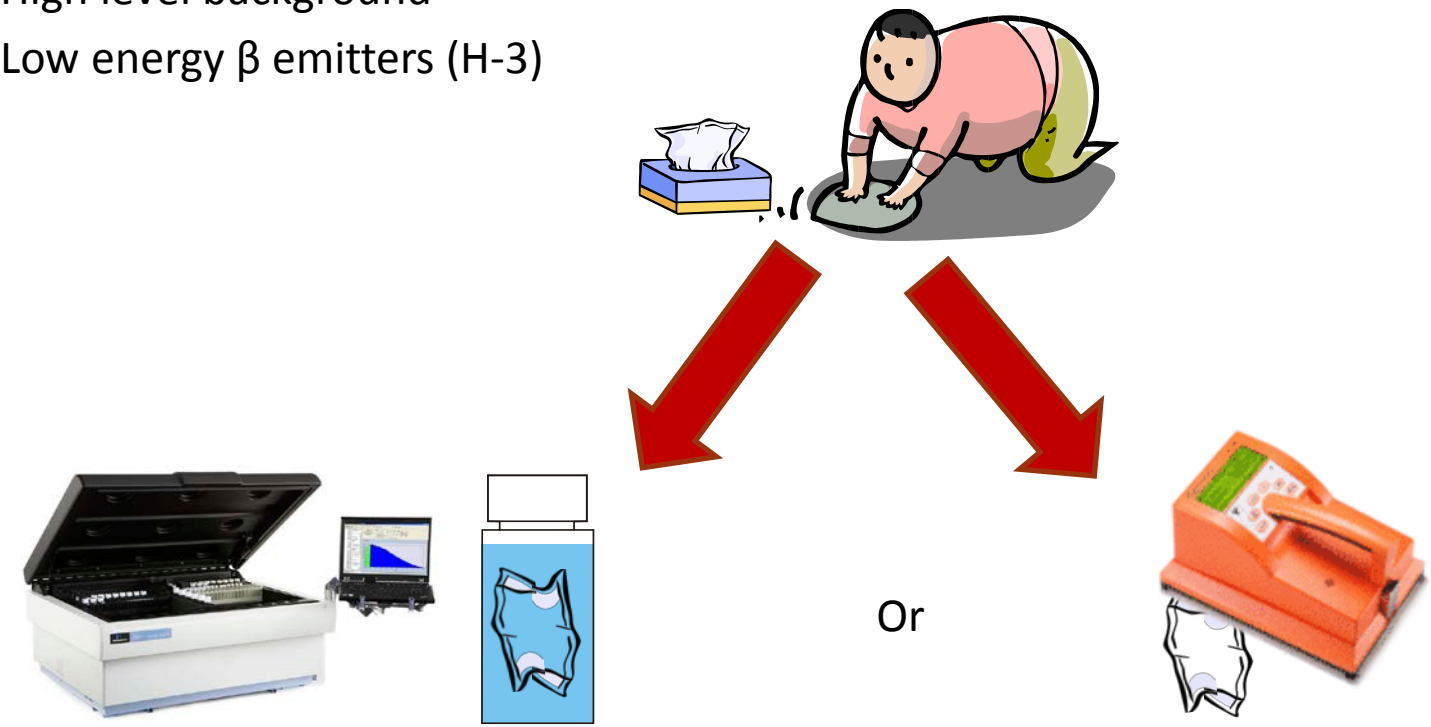
Direct method:

Measuring surface contamination

Indirect method:

Indication of the level of contamination using the wipe test:

- Surfaces that cannot be easily controlled
- High level background
- Low energy β emitters (H-3)



Decontamination techniques

Decontamination of surfaces:

- Wash-dry-measure-rewash-etc:
  1. Standard cleaning
  2. Chemical methods or electrochemical procedures (water, acids, bases, oxidants, reducers, etc)
  3. Physical procedures (aspiration, abrasion, ultrasound, etc)

Decontamination of people:

- Wash with mild soap, rinse with water
- If contamination of the eyes, ears or mouth → physician

Decontaminate as soon as possible

Course goals

- Describe strategies to reduce external exposure and the risk of internal contamination
- Know how to measure external exposure and contamination
- Understand the need of decontamination