National Institute for Radioelements

BASIC RADIATION PROTECTION TRAINING

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Goals

This presentation is intended to inform you of the dangers of radioactivity. It is organised around the three following topics:

1. Radioactivity – Basics
2. The interaction of ionizing radiation with (living) matter
3. Radiation Protection

The goal is for you to be fully aware of the phenomena in question and for you to become familiar with the rules and attitudes to adopt when you are in contact with radioactivity. You will also receive training in how to use the radiation protection equipment at the entrances and exits to controlled areas. Finally, you will be presented with the means of protection which are made available to you when you are in controlled areas.

Please therefore read this presentation carefully. After each chapter, a revision point indicates the essential information to be memorised. The boxes are used to give additional information to those people who wish to know more.

At the end of this presentation, a list of useful links is also presented.

After having studied this information, you will be asked to answer a quiz (multiple-choice questions) which will determine whether you are authorised to enter IRE & IRE ELiT's controlled areas.

1. Radioactivity – Basics
2. The interaction of ionizing radiation with matter
3. Radiation Protection

Sign: DANGER RADIOACTIVITY

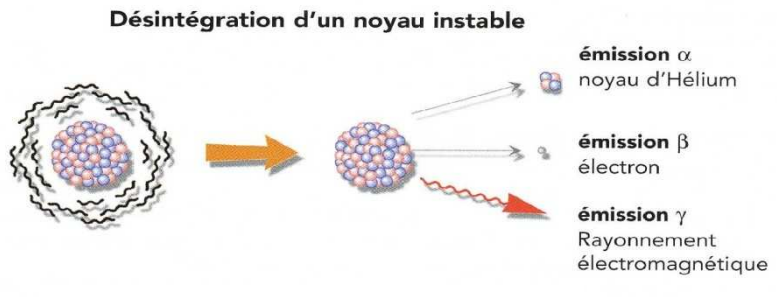
Radioactivity

Radioactivity is a totally natural phenomenon.

A radioactive atom is composed of a unstable nucleus (= which has too much energy). This nucleus becomes stable by ejecting this excess energy in the form of **ionizing radiation** (=nuclear disintegration).

The three main types of ionizing radiation are:

- Alpha rays (α)
- Beta rays (β)
- Gamma rays (γ)



Therefore, radioactive material emits energy spontaneously (i.e. humans are unable to do anything about this phenomenon).

The dangers of radioactivity

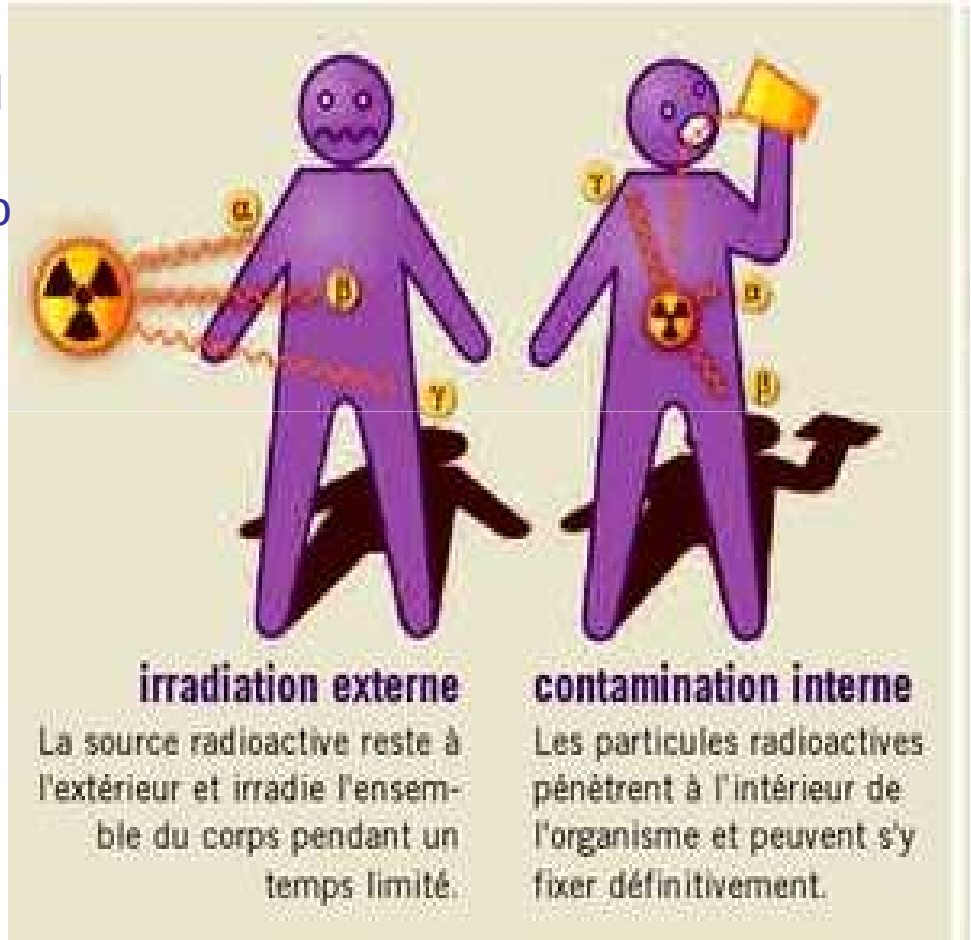
Ionizing radiation is potentially highly dangerous to Humans. It is painless and completely imperceptible by our five senses, even if we are fatally exposed to it!!!

It is therefore very important to:

- be aware of the warning signs
- be aware of the safety instructions and comply with them scrupulously
- wear means of protection

There are two ways that someone can be exposed to ionizing radiation:

- External radiation
- Internal and/or external contamination



The dangers of radioactivity

The risks of contamination are related to the physical form of the radioactive material:

- Gas: radioactivity can get into the body by breathing
  → **Internal contamination**

- Solid: radioactivity can be absorbed by breathing (if dust) or by ingestion.
  It can also be deposited on the skin
  →Internal and/or external contamination

- Liquid: radioactivity may also be ingested
  or deposited on the skin
  →Internal and/or external contamination

Contamination (internal or external) always causes irradiation

Radioactive materials handled at the IRE

The main radioactive elements (=radioactive isotopes) handled at the IRE are:

- Iodine-131 (gas or liquid) **HIGHLY RADIOTOXIC(*)**
- Xenon-133 (gas) **Slightly radiotoxic**
- Strontium-90 (solid) **HIGHLY RADIOTOXIC**
- Yttrium-90 (liquid) **Moderately radiotoxic**
- Molybdenum-99 (liquid) **Moderately radiotoxic**
- Tungsten-188 (solid) **HIGHLY RADIOTOXIC**
- Rhenium-188 (liquid) **Moderately radiotoxic**

(*) **Radiotoxicity**: Biological effect of a radioactive isotope when it is absorbed by humans

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Definitions

Radioactivity of a radioactive substance:

Number of nuclear disintegrations per second

Unit: Bq (Becquerel)

NB: A disintegration may emit several (types) of radiation

Old unit: Ci (Curie)
1 Ci = 37 GBq (37,000,000,000 Bq!!!)
= radioactivity of one gram of radium-226

Half-life $T_{1/2}$ (Radioactive decay):

Time needed for the radioactivity of a radioactive source to decrease by half → Radioactivity lessens over time

For a given quantity of material:
The smaller $T_{1/2}$, the more radioactive the source
The greater $T_{1/2}$, the stabler the source

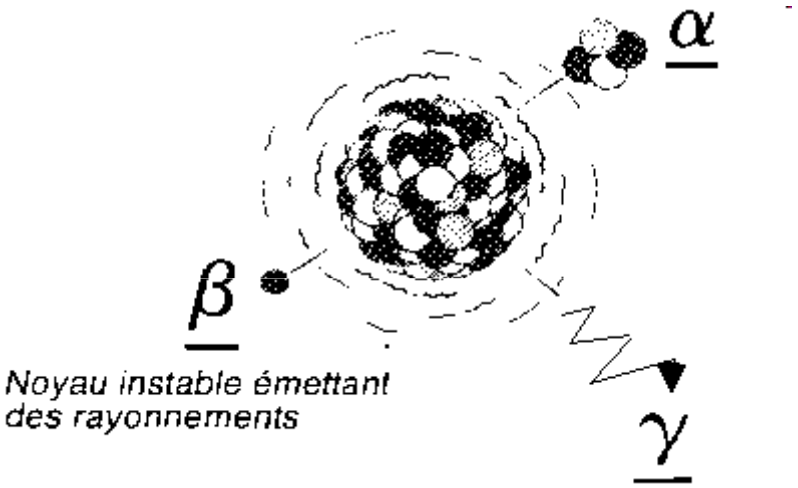
Examples:
- *Iodine 131: $T_{1/2}$ = 8 days*
- *Strontium-90: $T_{1/2}$ = 30 years;*
- *Xenon-133: $T_{1/2}$ = 5 days*

Illustration:
- *Iodine 131: $T_{1/2}$ = 8 days*

If today: A = 1000 Bq
In 8 days: A = 500 Bq /2
In 16 days: A = 250 Bq /2
In 24 days: A = 125 Bq /2
Etc.

The main types of ionizing radiation

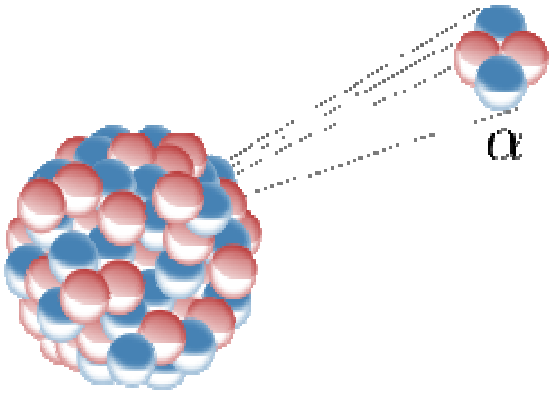
- **Alpha radiation (α)**
- **Beta radiation (β)**
- **Gamma radiation (γ)**



Ionizing radiation is invisible, imperceptible and painless.
However, it can be detected very easily with appropriate measuring systems (i.e. suited to the type of radiation: alpha, beta or gamma)

Alpha radiation

- The radiation consists of Helium nuclei
- High interaction → Stops over a short distance (4 to 5 cm of air)
- Suitable protective shield: a simple sheet of paper!!!

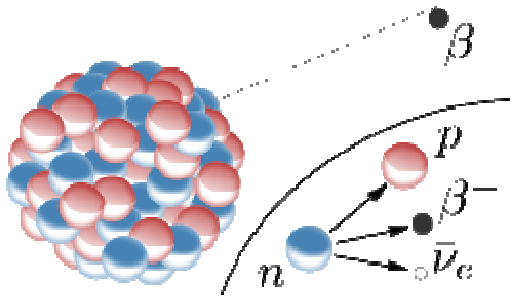


If **external contamination (or external irradiation)**, alpha radiation will "only" attack the skin. The other organs are protected because they are not exposed/irradiated (the alpha radiation does not reach the other organs)

BUT, **internal contamination** (the radioactive material gets into the body) is extremely **EXTREMELY DANGEROUS** because all the organs may be irradiated.

Beta radiation-

- The radiation consists of electrons
- Travels a few metres in the air and a few millimetres in solid matter
- Suitable protective shield: a sheet of aluminium or plexiglas (**especially not Lead**)



If external contamination (or external irradiation), beta radiation will mainly attack the skin. The other organs are relatively protected.

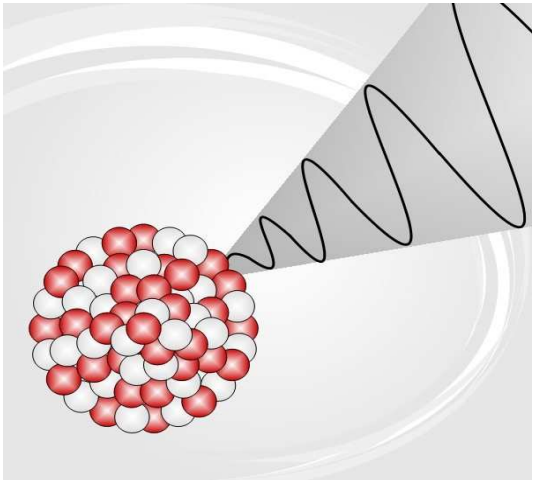
BUT, internal contamination is **highly dangerous** (but less so than alpha).

Gamma radiation (γ)

- The radiation consists of electromagnetic waves

  (similar to a light wave but which is invisible)

- Highly penetrating and travels tens of metres in the air and can pass through the whole body
- Suitable protective shield: Lead, reinforced concrete



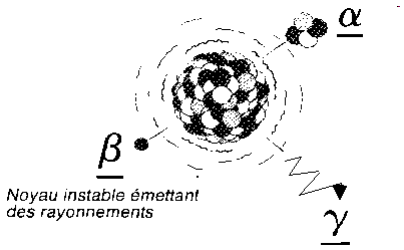
If external contamination (or external irradiation), beta radiation will reach all the organs.

Internal contamination is also highly dangerous, but is easily detectable

External irradiation in a controlled area is mainly caused by this type of radiation.

Part I: To memorise!!!

The main types of radiation



Radioactive decay

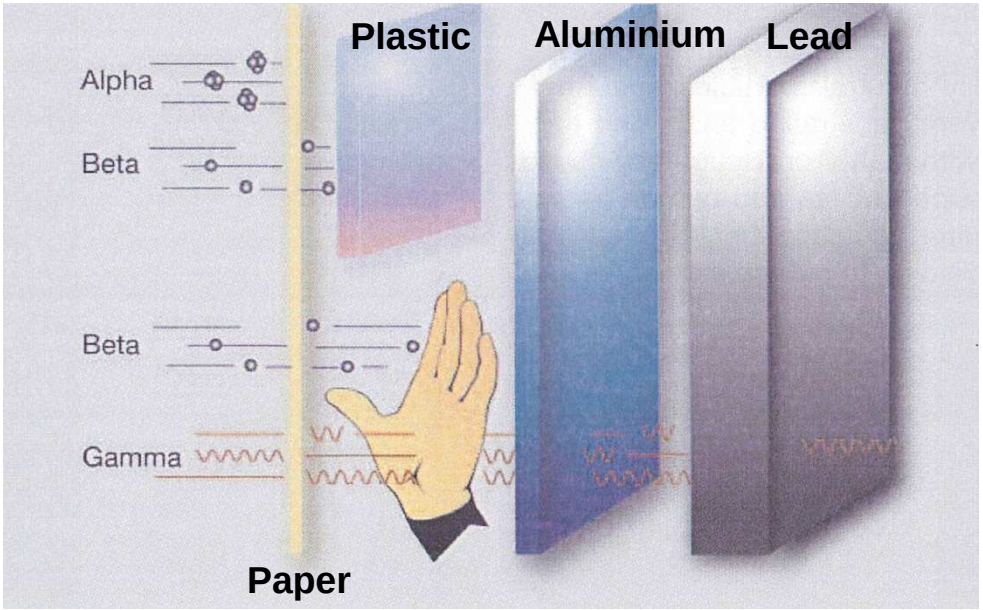
The dangers of radioactivity

> Irradiation

> Contamination

(internal and external)

Protective shields



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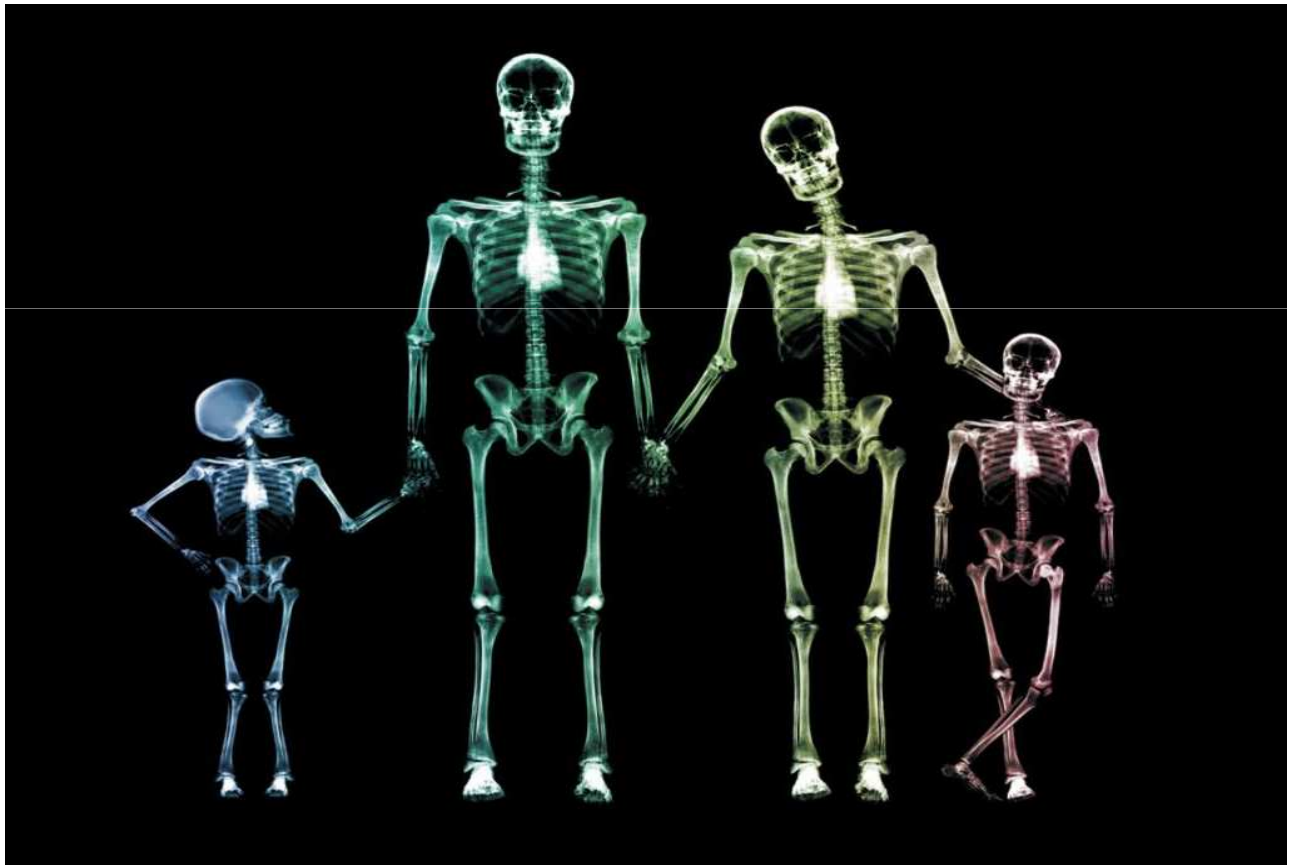
1. Radioactivity – Basics
2. The interaction of ionizing radiation with matter
3. Radiation Protection



Radiation - Material Interaction

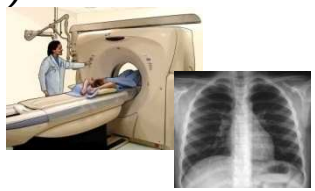
Radioactive material emits energy in the form of ionizing radiation.
If Humans are exposed to this radiation, then its will cause cell damage (deactivation) and result in a risk to the health of the person (see below).

To assess this risk, a magnitude is used (**the effective dose**) whose unit is the **Sievert (Sv)** which quantifies the effect of the energy that has been deposited in the body of the person exposed to the radiation

The **dose rate** is also used which can be seen as the equivalent of a speed. For example, a dose rate of 10 µSv/h means that in 1 hour, the person will have absorbed 10 µSv, in 2 hours: 20 µSv, in 3 hours: 30 µSv etc. In practice, the **µ**Sv is used to speak of dose rate and the **m**Sv for annual doses.

A few orders of magnitude:

- *Dose limit for occupationally exposed persons: 20 mSv/year (0.020 Sv/year)*
- *A scan of the abdomen: 10 mSv (0.001 Sv)*
- *A chest X-ray: 0.5 mSv (0.0005 Sv)*
- *High dose thresholds: 500 mSv (0.5 Sv) absorbed in a short time*
- *A lethal dose: 8 to 10 Sv absorbed in a short time*



Effective dose vs Contamination

Contamination = undesirable presence, at a significant level, of radioactive substances on the surface or inside the body.

Contamination is characterised by its activity (Bq)

Contamination always causes irradiation (when a person is contaminated, they irradiate themselves and the people around them)

But being irradiated does not mean being contaminated (a person is not radioactive when they are irradiated)

An **irradiation** expresses the effect of the energy deposited by ionizing radiation (α, β or γ) in the matter. This is referred to as **effective dose** (**Sv**)

The dose rate (Sv/h) expresses a scale of risks.

A few orders of magnitude:

- *Average value in controlled areas of the IRE: 3 µSv/h (0.000003 Sv/h)*
- *A flight in Concorde (15 km altitude): 10 µSv/h*
- *A long-haul flight (10 km altitude): 5 µSv/h*
- *Himalayas: 1µSv/h*

The dangers of radioactivity

External radiation:

- It is instantaneous
- Effective dose is measured with a dosimeter that is worn on the chest.

Contamination:

- Internal:

  > by ingestion of radioactive particles

  > or by breathing them in

The contamination remains in the body until the radioactive elements decay and their natural elimination by the body

- **External:**

  > deposit on the skin

Dose Limit

Occupationally exposed person:

Whole body (legal limit) **At the IRE (dose constraint)**	20 **10**
Organs individually	500
Crystalline	150
Skin (beta dose)	500
Extremities (hands, arms, etc.)	500

Limits in mSv over 12 consecutive sliding months

Person of the general public:

Whole body	1
Organs individually	NA
Crystalline	15
Skin (beta dose)	50
Extremities (hands, arms, etc.)	NA

Limits in mSv per calendar year

These limits do not take into account medical exposure and natural radioactivity

Health Risks

For high doses:

The effects are predictable

For low doses (occupational hazard):

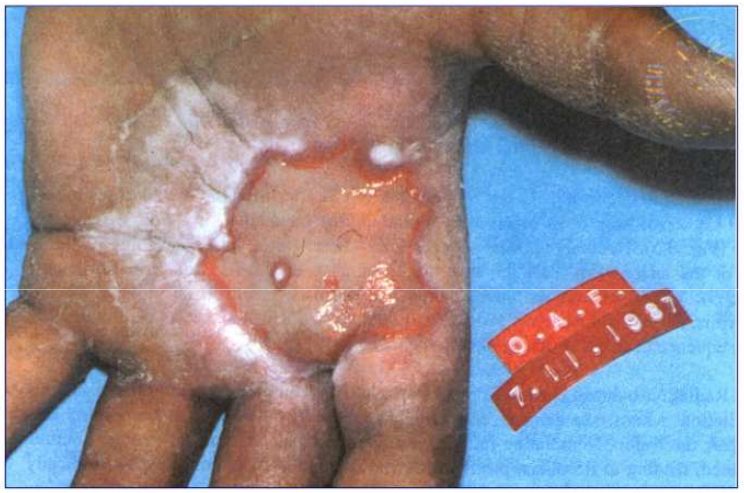
The effects are unpredictable

Health Risks

Predictable effects:

(Burns, skin peeling, vomiting, fever, coma, convulsions, death!)

- Existence of a threshold (~500mSv)
- Exposure to high doses
- The effects are proportional to the dose
- Appear in the **short** term
- Depend on the irradiated area
- *Treatment of a predictable effect does not give protection against the emergence of unpredictable effects later*



Burn caused by an alpha radioactive source

Health Risks

Unpredictable effects:

(Cancer, leukaemia)

- These effects concern exposure at low doses (occupational hazard)
- No fixed lower threshold (precautionary principle)
- The probability of occurrence is proportional to the dose
- Appear in the **long** term (> 10 years)
- *May result in the long-term from an acute irradiation*

Risk factor: 5% per absorbed Sievert to produce a fatal cancer induced by radiation.

- 10 mSv/year 5 in 10,000 chance of getting a fatal cancer
- Mortality rate of the population by cancer: 25-30 %

Part II To memorise!!!

Definition of effective dose

> Quantifies the effect of the energy that has been deposited in the body

The dangers of radioactivity

> contamination and irradiation

The possible health consequences

> Depend on the effective dose
> In the short and long terms

The dose limits

> legal limit: 20 mSv/year
> internal limit at the IRE: 10 mSv/year

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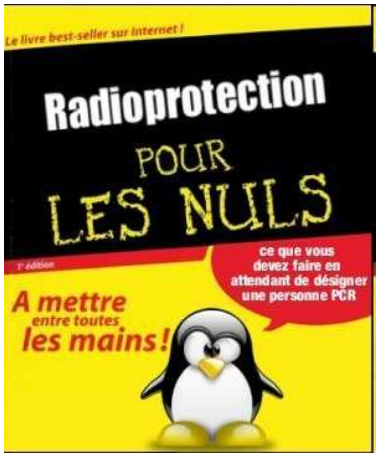


Prevention of the contamination

Goals:

- Avoid contamination of the worker, equipment and tooling, . . .
- Avoid the spread of the contamination outside the controlled areas and into the environment.

Prevention & Protection:

- Containment of non-sealed sources within an enclosure (static containment)
- Ventilation of facilities and of the controlled area: Dynamic containment of the radioactivity
- Real-time measurement of any contamination of the air + alarms
- If necessary: protective overalls or respirator:
  - Airborne particles (aerosols): 3M paper mask
  - Iodine: Full face mask with charcoal filter
  - Tyvek overalls if risk too high

- Air extraction during the work and cleaning of the workplace after the various operations.
- Control of non-contamination of equipment used before putting away (call to an R.P. agent on 9333)
- Check of oneself at the "hand-foot" monitors or at the whole body monitors on leaving the controlled area

Prevention of the contamination

Ingestion:

- No eating, drinking or smoking in controlled areas
- Pay attention to "habitual" behaviour such as:
  - Placing objects/hands in contact with the mouth
  - Wiping perspiration with gloves
- Preventive measures:
  - Workplace hygiene
  - House Keeping

Through breathing:

- Preventive measures:
  - Ventilation of rooms + depression cascade (collective protection)
  - Air extraction of the work area
  - Real-time measurement of the concentration of radioactive gases (collective protection)
  - Wearing of appropriate breathing protection (personal protection)

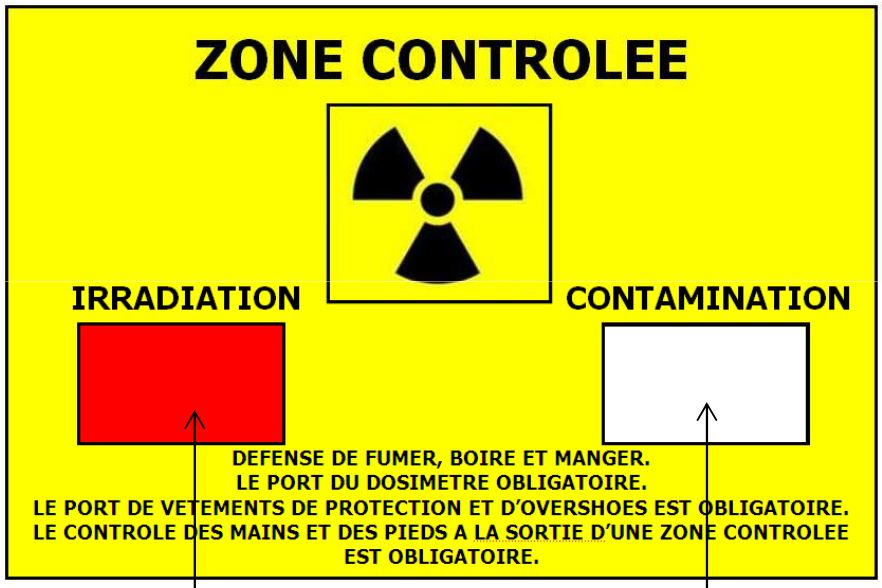
Through the skin:

- Via open wounds
- Move any person with an open wound away from the controlled area.
- If injured in a controlled area, leave and call 9333

Reminder of the conditions for obtaining permission to work under ionizing radiation

- Be at least 18 years old
- Obtain safety approval issued by the AFCN (for the B6 and B17 controlled areas)
- Medical fitness to work under ionizing radiation
  - Undergo a medical examination by a doctor approved by the AFCN
  - Do not have any open wounds. If in doubt, consult the occupational doctor
  - Not have undergone a medical examination during which a radioactive product has been injected
  - Not be pregnant; if suspected, talk to one's employer (or one's supervisor at the IRE) and to the occupational doctor
- Be informed about the dangers of radioactivity, and the risks to health
- Know the radiation protection basic standards and the rules of good practice
- Know the meaning of the warning signs
- Know the workstation's emergency instructions
- Obtain one's legal and electronic dosimeter

Controlled Area Signs

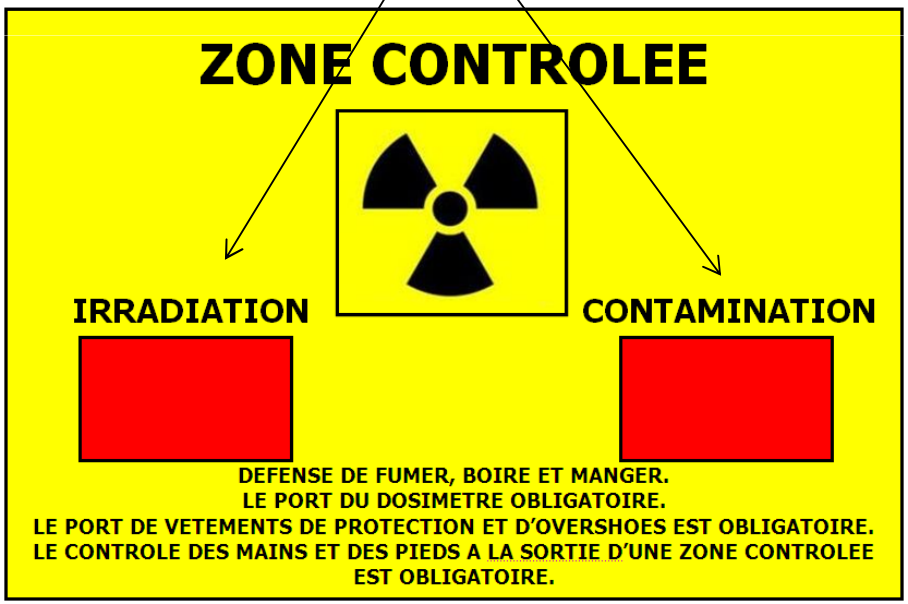


Radiation risk

No risk of contamination

Radiation risk

AND contamination



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Personal protective equipment in controlled areas

These consist of the following:

- T-shirt, shirt or buttoned-up tennis shirt
- Cotton trousers falling onto the shoes
- Safety footwear + overshoe (if the person does not have controlled area safety footwear)
- Fastened apron

NO HIGH HEELS

- If in work clothing
  - White clothing of the controlled area
  - Controlled area safety footwear
- Wear one's identification and access badge **VISIBLY**
- Wear one's dosimeters (legal and electronic) at the level of the chest **VISIBLY**
- Possibly: protective overalls or respirator

Protection means - The three basic rules

- **Distance:**

The dose rate decreases significantly with distance (= with the inverse of the square of the distance)

For example:
- From 1 mm to 1 m: Distance multiplied by 1,000.

→ **DDD divided by 1,000,000 !!!**

- From 1 m to 2 m: Distance multiplied by 2.

→ **DDD divided by 4**

- **Time:**

Minimise the exposure time

- **Protective shields suited to the type of radiation:**

Alpha Radiation: a layer of a few cm of air or a sheet of paper
Beta Radiation: Aluminium, plexiglas.
Gamma Radiation: Lead, concrete,

Detection Means

Electronic Dosimeter (<u>is worn only at chest level and visibly</u>)
Measures the dose [µSv] and the dose rate [µSv/h]
Emits audible and visual alarms
-> If alarm: make the process safe and leave + phone 9333

Legal dosimeter (at chest level and visible)
Measures the dose absorbed monthly
ATTENTION: Calculation and monitoring of the dose; No alarm
To be placed in the rack at the end of the day because a control dosimeter records the background noise which will be subtracted from all the others

Hand-Foot Monitor
Measures the contamination present on the hands and feet
Mandatory control on leaving controlled areas

Whole Body Monitor
Measures the contamination present over the whole surface of the body
Mandatory control on leaving the B6 controlled area
If contaminated: call 9333

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Detection Means

G64

Measures the dose rate [µSv/h] prevailing in the room
Emits audible and visual alarms
If alarm: make the process safe and evacuate the laboratory + call 9333

iCAM

Measures the contamination of the air (Measures particles suspended in the air)
(Measures iodine and rare gases depending on the location)
Emits audible and visual alarms
If alarm: make the process safe and evacuate the laboratory + call 9333

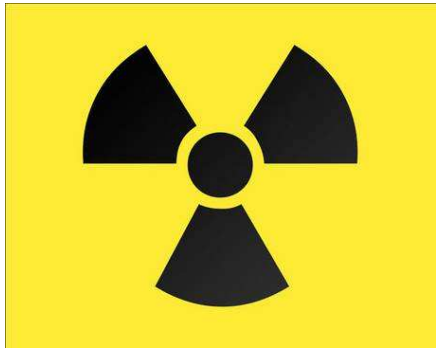
TAM

Measures the contamination of the air (Measures radioactive noble gases)
Emits a visual and sound radiological alarm
If alarm: make the process safe and evacuate the laboratory + call 9333

Anthropogammameter

Allows the detection of any internal contamination by gamma-ray emitting isotopes
Available in the medical department

Warning Signs

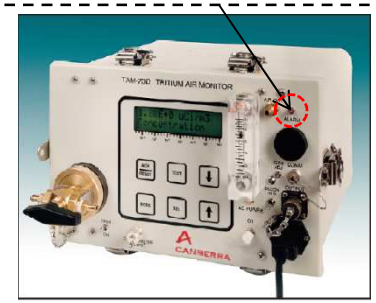


Warning for ionizing radiation

This sign is displayed:
- At each entrance to a controlled area
- On the doors of rooms in which radioactive substances are stored
- On containers in which radioactive substances are stored
- On any contaminated object

Red Flashing Light + audible alarm: Radiological Alarm

→ Evacuation of the room



Air contamination measurement systems:
On the left: measurement of radioactive particles suspended in the air
On the right: measurement of radioactive noble gases

Dose rate measuring system

Procédure d'entrée en zone contrôlée:

Porter son dosimètre et son badge d'accès.
Mettre des chaussures de zone ou des overshoes

SCP.P01.MO015, V2,
date d'application 01/06/2008

M. Bleus, Resp. SCP
01/06/2008

Use of Hand-Foot Monitor

MANDATORY before leaving a controlled area

Ensure your hands and your feet are correctly placed before the position detectors

If detection of a slight contamination of the hands

- Warn an R.P agent: 9333
- Wash with soap and water
- Water temperature: Lukewarm
- Do not rub too hard so that the contaminants do not penetrate the skin **(use of a brush prohibited)**

If detection of contamination of the feet

- Warn an R.P agent: 9333
- Go to the sink and remove the contaminated shoe (or the overshoe)
- Do not put your foot on the floor
- Using the brush provided, lightly rub the shoe under slowly running water.

New non-contamination measurement:

- If still contaminated: call **9333 AND DO NOT LEAVE THE AREA.**
- Otherwise: **Leaving of area allowed** except at B6 where use of the whole body monitor is mandatory. Place the overshoe in the "non-contaminated" compartment located at the exit of the area.

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Use of Hand-Foot Monitors

MANDATORY before leaving the B6 controlled area

- Enter the whole body monitor via the barrier
- Stand facing the detection surfaces
- Move your feet forward and place your right arm into the apparatus
- Listen to the instrument's instructions (help with correct positioning)
- The detector head descends automatically with automatic shut off (do not lower your body!!!)
- The barrier closes! *The monitor begins measuring.*

Do not move…

- Turn round when the whole body monitor asks and place your left arm into the equipment
- The detector head automatically repositions itself and the apparatus begin another measurement.

Do not move…

- **If contaminated:**

The whole body monitor door remains closed and leaving the area is prohibited. Contaminated areas are shown on the screen. Call an R.P agent: 9333

- If not contaminated: The whole body monitor door opens and you may leave

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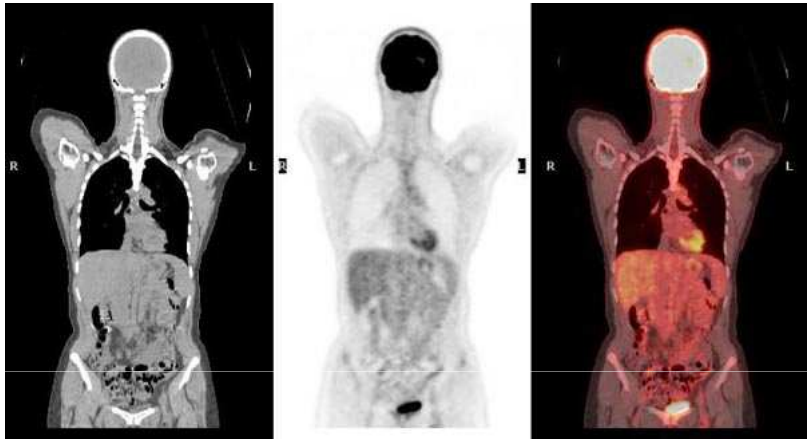
Use of Hand-Foot and Whole Body Monitors

Entry forbidden to controlled areas for any worker having undergone a medical examination during which a radioactive product has been injected

In fact, this person will be considered to be contaminated each time by our measuring equipment located at the exits of the controlled areas.

→ Impossible to know whether it is real contamination from your work in a controlled area or whether it comes from the "medicine" injected during your medical examination

→ Obligation to inform the occupational doctor



Obligation to inform (if possible in advance) one's IRE supervisor.

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Protection of pregnant women

In Belgium, as soon as the pregnancy is notified, a pregnant woman and her foetus are considered to be members of the public.

1 mSv for the whole body throughout the pregnancy

Lactation period:

- **ANY** risk of internal contamination must be avoided

-> as a precaution avoidance of controlled areas during this period.

- Exceptional exposure **PROHIBITED**

Part III: To memorise!!!

Individual protective equipment

> Controlled area clothing
> Breathing protection: paper mask, mask with charcoal cartridge

Collective protections against contamination

> Ventilation + depression cascade
> Air contamination measuring equipment
> Hand-Foot & Whole Body Monitors

Rules to comply with in controlled areas

> Always comply with the safety agents' instructions
> Comply with the instructions in the event of an alarm
> Do not eat, drink or smoke
> Do not undergo unnecessary exposure (one's presence in the area must be justified)

Signs in controlled areas

> Radioactive trefoil
> Area entry sign

Part III: To memorise!!!

Procedure for entering and leaving controlled areas

> Equipment for entering a controlled area (apron, dosimeters, etc.)
> Use of Hand-Foot and Whole Body Monitors

Use of dosimeters

> On the chest and visible with the identification badge

Controls to undergo on leaving controlled areas

> Check one's non-contamination: hand-foot & whole body monitors
> Check the non-contamination of objects that must be taken out of a controlled area

(the control is performed by a safety agent (R.P agent – Phone: 071/82 93 33)

Radioactivity detection means in controlled areas

> G64 = measurement of the dose rate in the laboratory
> Air contamination measurement system

Part III: To memorise!!!

Radiological alarm responses

> Make the current process safe (if applicable)
> Evacuation (questions are asked after evacuation)
> Warn a safety agent (R.P. agent – Phone: 071/82 93 33)
> If a safety agent supervises the evacuation operations of the room following an alarm and left to his discretion (only the assessment by the safety agent must be considered)

Protection of pregnant women

> Warn the occupational doctor
> Entry prohibited in a controlled area during pregnancy
> Avoidance of a risk of contamination, including during the lactation period

Medical examination with radioactive tracers

> Warn the occupational doctor
> Entry prohibited in a controlled area during pregnancy

Useful Links

In French:

- http://www.afcn.fgov.be/
- http://www.afcn.fgov.be/fr/page/video-radioactivite/1351.aspx?LG=1
- http://www.belv.be/
- http://www.cea.fr/jeunes/themes/la-radioactivite/la-radioactivite
- http://www.asn.fr/index.php/S-informer/Dossiers/Les-effets-des-rayonnements-ionisants
- http://www.asn.fr/index.php/S-informer/Publications/Fiches-d-information-du-public

In English:

- http://www.iaea.org/Publications/Booklets/RadPeopleEnv/pdf/radiation_low.pdf
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