Decontamination and follow up of contaminated persons in Class I companies

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I. The most important contaminants in Class I undertakings (nuclear reactors)

II. Decontamination principles after contamination of intact skin, wounds /burns, and after inhalation and ingestion accidents

III. Dosimetry

IV. Concluding remarks
Prevention of contamination

- Collective protective equipment:
  - Fume hoods
  - Glove boxes in underpressure
  - Hot cells/telemanipulators

- Personal protective equipment (PPE):
  - Gloves, lab coat, overall, overshoes
  - Half-face and full-face masks with P3 cartridges
  - Overpressure suits with external air supply
Collective protective equipment
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Personal protective equipment
I. The most important contaminants in Class I undertakings (nuclear reactors)

- A. NUCLIDES PRESENT IN NON IRRADIATED NUCLEAR FUEL
- B. FISSION PRODUCTS
- C. ACTINIDES FORMED IN NUCLEAR FUEL
- D. ACTIVATION PRODUCTS FORMED IN REACTOR MATERIALS
## I.A Nuclides originally present in non irradiated nuclear fuel

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>$T^{\frac{1}{2}}$</th>
<th>Type of radiation</th>
</tr>
</thead>
</table>
| U-235 fissionable    | 704 000 000 y            | $\alpha_1 = 4.36 \text{ MeV}$  
                           |                          | $\alpha_2 = 4.40 \text{ MeV}$  
                           |                          | $\alpha_3 = 4.42 \text{ MeV}$  |
| U-238 not fissionable| 4 468 000 000 y          | $\alpha = 4.19 \text{ MeV}$  |
## I.B Some fission products

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>$T_{\frac{1}{2}}$</th>
<th>Type of radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kr-85</td>
<td>10,7 y</td>
<td>$\beta_{\text{max}} = 0,69$ MeV</td>
</tr>
<tr>
<td>Sr-90</td>
<td>28,15 y</td>
<td>$\beta_{\text{max}} = 0,546$ MeV ; $\gamma_{-90} = 2,228$ MeV</td>
</tr>
<tr>
<td>Mo-99</td>
<td>66 h</td>
<td>$\beta_{1\text{max}} = 0,436$ MeV ; $\beta_{2\text{max}} = 1,214$ MeV</td>
</tr>
<tr>
<td>Ru-103</td>
<td>39,2 d</td>
<td>$\beta_{\text{max}} = 0,226$ MeV ; $\gamma = 0,497$ MeV</td>
</tr>
<tr>
<td>I-131</td>
<td>8 d</td>
<td>$\beta_{\text{max}} = 0,606$ MeV ; $\gamma = 0,364$ MeV</td>
</tr>
<tr>
<td>Te-132</td>
<td>78 h</td>
<td>$\beta_{\text{max}} = 0,215$ MeV ; $\gamma_{1} = 0,974$ MeV ; $\gamma_{2} = 0,696$ MeV ; $\gamma_{3} = 0,228$ MeV</td>
</tr>
<tr>
<td>Cs-134</td>
<td>2,7 y</td>
<td>$\beta_{1\text{max}} = 89$ keV ; $\beta_{2\text{max}} = 0,658$ MeV ; $\gamma_{1} = 0,569$ MeV ; $\gamma_{2} = 0,605$ MeV ; $\gamma_{3} = 0,796$ MeV</td>
</tr>
<tr>
<td>Cs-137</td>
<td>30,2 y</td>
<td>$\beta_{1\text{max}} = 0,512$ MeV ; $\beta_{2\text{max}} = 0,57$ MeV ; $\gamma = 0,662$ MeV</td>
</tr>
</tbody>
</table>
### I.C Actinides formed in nuclear fuel (by neutron capture)

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>T½</th>
<th>Type of radiation</th>
</tr>
</thead>
</table>
| Pu-239       | 24 100 y    | \( \alpha_1 = 5,16 \text{ MeV} \)
|              |             | \( \alpha_2 = 5,14 \text{ MeV} \)
|              |             | \( \alpha_3 = 5,10 \text{ MeV} \) |
| Pu-240       | 6560 y      | \( \alpha_1 = 5,17 \text{ MeV} \)
|              |             | \( \alpha_2 = 5,12 \text{ MeV} \) |
| Am-241       | 432 y       | \( \alpha_1 = 5,48 \text{ MeV} \)
|              |             | \( \alpha_2 = 5,44 \text{ MeV} \)
|              |             | \( \gamma = 59,6 \text{ keV} \) |
| Cm-242       | 163 d       | \( \alpha = 6,1 \text{ MeV} \) |
| Cm-244       | 18,1 y      | \( \alpha = 5,80 \text{ MeV} \) |
I.D Some activation products formed in reactor materials and activated corrosion products

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>$T_{1/2}$</th>
<th>Type of radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe-59</td>
<td>44,5 d</td>
<td>$\beta_{1\text{max}} = 0,27 \text{ MeV} ; \beta_{2\text{max}} = 0,46 \text{ MeV}$ $\gamma_1 = 1,10 \text{ MeV} ; \gamma_2 = 1,29 \text{ MeV}$</td>
</tr>
<tr>
<td>Co-58</td>
<td>70,8 d</td>
<td>$\beta^+_{\text{max}} = 0,475 \text{ MeV} ; \gamma = 0,811 \text{ MeV}$</td>
</tr>
<tr>
<td>Co-60</td>
<td>5,3 y</td>
<td>$\beta_{\text{max}} = 0,318 \text{ MeV}$ $\gamma_1 = 1,17 \text{ MeV} ; \gamma_2 = 1,33 \text{ MeV}$</td>
</tr>
<tr>
<td>Zr-95</td>
<td>64 d</td>
<td>$\beta_{1\text{max}} = 0,366 \text{ MeV} ; \beta_{2\text{max}} = 0,399 \text{ MeV}$ $\gamma_1 = 0,72 \text{ MeV} ; \gamma_2 = 0,76 \text{ MeV}$</td>
</tr>
</tbody>
</table>
II.A (De)contamination of the intact skin

- Contamination: some radionuclides (³H, *I,...) can penetrate the intact skin!
- Contamination/irradiation: most dangerous are β- emitters! (Partial) absorption in basal cell layer → eventually β-burns
Energy of $\alpha$-emitters is absorbed in (dead) cells of the epidermis
## II.A (De)contamination of the intact skin

<table>
<thead>
<tr>
<th>Depth of the basal cell layer</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and trunk</td>
<td>± 40 µm</td>
</tr>
<tr>
<td>Arms and legs</td>
<td>± 50 µm</td>
</tr>
<tr>
<td>Dorsal surface of hands and feet</td>
<td>± 150 µm</td>
</tr>
<tr>
<td>Palmar surface of hands and plantar surface of feet</td>
<td>± 300 µm</td>
</tr>
</tbody>
</table>
II.A Decontamination of the intact skin

- Usually no problem if discovered in time
- In most cases: use of tepid water + detergents
- Can be problematic: acids, alkalines, iodine,...
- Peeling creams, depilatory creams
II.A Decontamination of the intact skin

- Avoid physical and chemical damage to the skin!
- Objective = ALARA ...and sometimes accept remaining contamination (for some time)
- Use proper techniques for evaluation of $\alpha$-contamination!
- Registration of decontamination procedure and measurement results on an individual basis: medico-legal importance!
II.B  Decontamination of wounds and burns

- Decontamination of wounds = priority

- Stimulate bleeding; rinse wound with (sterile) physiological solution

- Impair venous return (in case of contaminated wounds on limbs with highly toxic radionuclides)
II.B Decontamination of wounds and burns

- Use of complexing agents (e.g. Ca-DTPA, Zn-DTPA,…)
- Excision or coagulation of insoluble compounds
II.B Decontamination of wounds and burns

- Treatment of burns eventually in burn units (rinsing wounds with complexing agents or adstringents)

- Serum in blisters of second degree burns = shielding for β-radiation component...

- Direct measurements of contamination: sometimes difficult → indirect measurements (rinse fluids, bandages, blood drops...)

- Dosimetry of internal contamination: urine sampling, wound counting, total body counting, faecal analyses...
Most dangerous in case of
- fine aerosols of
- $\alpha$ – emitters under
- soluble forms

The deposition depends on
- particle size
- particle density
- Most dangerous in case of fine aerosols of α emitters under soluble forms.

- The deposition depends on particle size and particle density.
II.C Decontamination after inhalation accidents

- **SPONTANEOUS DECONTAMINATION** for larger unsoluble particles (mucociliary clearance + faecal excretion)

- Very fine aerosol of unsoluble $\alpha$–emitters: eventually pulmonary lavage in case of severe contaminations

- **Soluble compounds:**
  - Chelation therapy (e.g. DTPA);
  - Dilution therapy (e.g. stable iodine);
  - Diuretics + diuresis $\uparrow$
II.D (De)contamination after ingestion accidents

- INDIRECT CONTAMINATION OF THE GASTROINTESTINAL TRACT:
  - mucociliary clearance of contaminated airways
  - secretions into the digestive tract after systemic resorption of soluble compounds

- DIRECT CONTAMINATION
  - very rare/nearly impossible at work (prevention)

- GREAT VARIATIONS IN RESORPTION
II.D (De)contamination after ingestion accidents

- Resorption in gastrointestinal tract:
  - P: ± 80 %
  - Po: ± 50 %
  - Fe: ± 10 %
  - Zn: ± 50 %
  - Ra en Sr: ± 30 %
  - U: ± 2 %
  - Co: ± 5 - 10 %
  - Pu, Np: ± 10^{-4} - 10^{-6}
  - Cs, I, K, C: ± 100 %
II.D Decontamination after ingestion accidents

- (gastric lavage)

- speeding up transit time gastrointestinal tract

- decreasing resorption:
  - isotopic dilution: *I → stable iodine
  - *Cs → R/Prussian blue (cuts enterohepatic cycle)
  - *Ra and *Sr → R/Alginates or MgSO₄
## Some therapeutics

<table>
<thead>
<tr>
<th>Medication</th>
<th>Posology</th>
<th>Radionuclide(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alginates</td>
<td>start 10 g/d</td>
<td>Ba, Ra, Sr,...</td>
</tr>
<tr>
<td></td>
<td>4 g/d as maintenance therapy</td>
<td></td>
</tr>
<tr>
<td>Chlorthalidone</td>
<td>start 1 - 2x 100 mg/d evtl. 50 mg/d as maintenance therapy</td>
<td>$^3$H, Na, K, Ru,...</td>
</tr>
<tr>
<td>Ca-/Zn-DTPA</td>
<td>1 g/d</td>
<td>Transuranics, Lanthanides, Mn, Pb, Co, Y, Zr, Ru, Cf, Cr, Ir, Np, Th, Cm...</td>
</tr>
<tr>
<td>Stable Iodine</td>
<td>100 mg/d (adult)</td>
<td>I</td>
</tr>
<tr>
<td>MgSO$_4$</td>
<td>10 - 15 g/d</td>
<td>All, especially Sr en Ra</td>
</tr>
<tr>
<td>Prussian blue</td>
<td>3 x 1 g/d</td>
<td>Cs, Tl, Rb</td>
</tr>
<tr>
<td>NaHCO$_3$</td>
<td>2 - 8 g/d</td>
<td>U</td>
</tr>
<tr>
<td>Al(OH)$_3$</td>
<td>6 g/d</td>
<td>F, Hg, K, P, Po</td>
</tr>
</tbody>
</table>
Some therapeutics
III. DOSIMETRY

DIRECT MEASUREMENTS ($\beta\gamma$)

- LUNG COUNTING / TOTAL BODY OR CRITICAL ORGAN COUNTING / WOUND COUNTING
III. DOSIMETRY (ICRP 78)

**INDIRECT MEASUREMENTS (α/βγ)**

1. URINE ANALYSES (α/βγ)
2. FAECAL ANALYSES (α/βγ)

   e.g.: for M-type aerosol (AMAD = 5 µm)

   D1: daily faecal excretion = 11 % of intake

   D2: daily faecal excretion = 15 % of intake

   D3: daily faecal excretion = 8 % of intake

   D4: daily faecal excretion = 3.4 % of intake
IV. Concluding remarks/Summary

- Always try to reduce the spread of external and internal contamination and reduce the dose to the total body and critical organs by
  - decreasing the absorption
  - reducing the deposition in critical organs
  - stimulating the excretion

by means of chelation, isotopic dilution, increasing the intestinal transit, and increasing the urinary excretion
BECAUSE OF PSYCHOLOGICAL ASPECTS...:

- A given external *irradiation* dose is NOT identical to the same committed dose due to external/internal *contamination*!!

→ in case of contamination: compare the (residual) contamination with the natural contamination of well known things and the natural contamination of the human body
Natural radioactivity

- **Seawater**
  - 12 Bq/l

- **Corn**
  - 155 Bq/kg

- **Sugar**
  - 90 Bq/kg

- **Human body**
  - 120 Bq/kg
  - (~8500 Bq)

- **Concrete**
  - 500 Bq/kg

- **Brick**
  - 800 Bq/kg

- **Potatoes**
  - 150 Bq/kg

- **Milk**
  - 70 Bq/kg
## Natural radioactivity of the human body (adult male)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Total activity (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
<td>~ 1</td>
</tr>
<tr>
<td>Radium-226</td>
<td>~ 1</td>
</tr>
<tr>
<td>Thorium</td>
<td>~ 0.1</td>
</tr>
<tr>
<td>Potassium-40</td>
<td>3 000 - 5 000</td>
</tr>
<tr>
<td>Polonium-210</td>
<td>~ 40</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>~ 3 500</td>
</tr>
<tr>
<td>Tritium</td>
<td>20 - 40</td>
</tr>
<tr>
<td>Rubidium-87</td>
<td>~ 500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7 000 - 9 000</strong></td>
</tr>
</tbody>
</table>
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