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STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

SCK•CEN ACADEMY
FOR NUCLEAR SCIENCE AND TECHNOLOGY

Decontamination and follow up of contaminated persons in Class I companies

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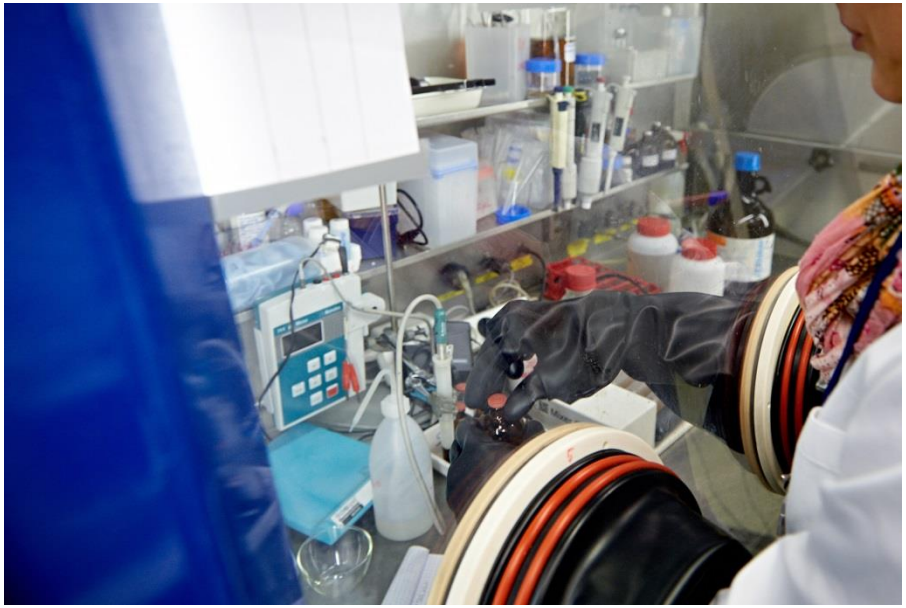
- Collective protective equipment:
  - Fume hoods
  - Glove boxes in underpressure
  - Hot cells/telemanipulators

- 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



Collective protective equipment

Prevention of contamination

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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

Radioisotope	T ½	Type of radiation
U-235 fissionable	704 000 000 y	α_1 = 4,36 MeV α_2 = 4,40 MeV α_3 = 4,42 MeV
U-238 not fissionable	4 468 000 000 y	α = 4,19 MeV

I.B Some fission products

Radioisotope	T½	Type of radiation
Kr-85	10,7 y	β_{max} = 0,69 MeV
Sr-90	28,15 y	β_{max} = 0,546 MeV ; β_{max} Y-90 = 2,228 Mev
Mo-99	66 h	β_{1max} = 0,436 MeV ; β_{2max} = 1,214 MeV
Ru-103	39,2 d	β_{max} = 0,226 MeV ; γ = 0,497 MeV
I-131	8 d	β_{max} = 0,606 MeV ; γ = 0,364 MeV
Te-132	78 h	β_{max} = 0,215 MeV ; γ_1 = 0,974 MeV ; γ_2 = 0,696 MeV ; γ_3 = 0,228 MeV
Cs-134	2,7 y	β_{1max} = 89 keV ; β_{2max} = 0,658 MeV γ_1 = 0,569 MeV ; γ_2 = 0,605 MeV ; γ_3 = 0,796 MeV
Cs -137	30,2 y	β_{1max} = 0,512 MeV ; β_{2max} = 0,57 MeV γ = 0,662 MeV

I.C Actinides formed in nuclear fuel (by neutron capture)

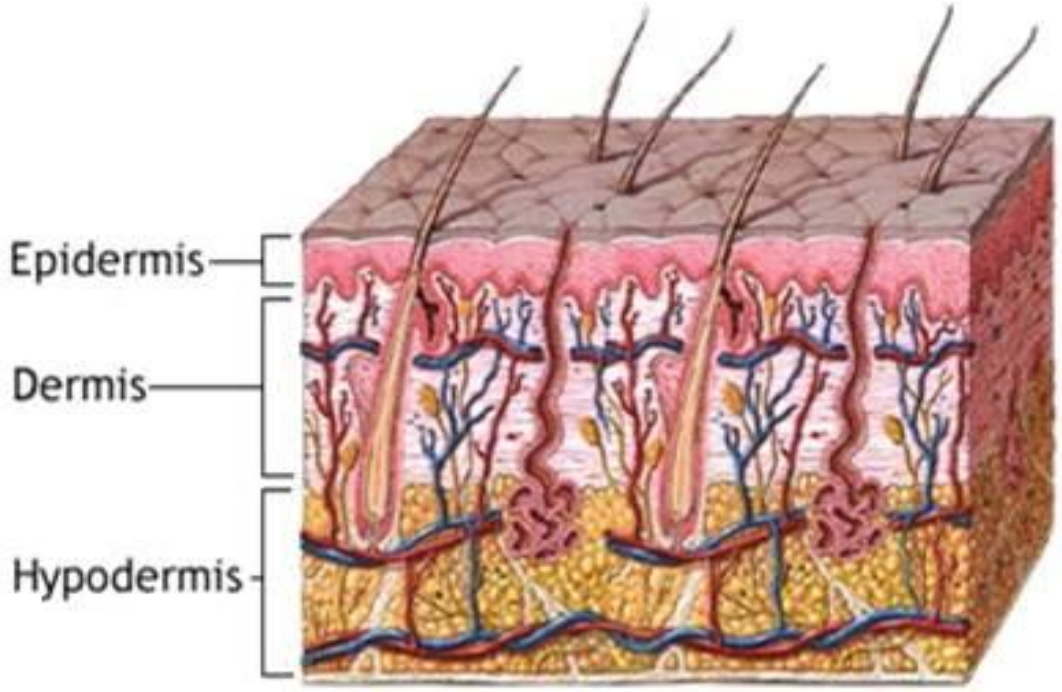
Radioisotope	T½	Type of radiation
Pu-239	24 100 y	α_1 = 5,16 MeV α_2 = 5,14 MeV α_3 = 5,10 MeV
Pu-240	6560 y	α_1 = 5,17 MeV α_2 = 5,12 MeV
Am-241	432 y	α_1= 5,48 MeV α_2 = 5,44 MeV γ = 59,6 keV
Cm-242	163 d	α = 6,1 MeV
Cm-244	18,1 y	α = 5,80 MeV

I.D Some activation products formed in reactor materials and activated corrosion products

Radionuclide	T½	Type of radiation
Fe-59	44,5 d	β_{1max} = 0,27 MeV ; β_{2max} = 0,46 MeV γ_1 = 1,10 MeV ; γ_2 = 1,29 MeV
Co-58	70,8 d	β^+_{max} = 0,475 Mev ; γ = 0,811 MeV
Co-60	5,3 y	β_{max} = 0,318 MeV γ_1 = 1,17 MeV ; γ_2 = 1,33 MeV
Zr-95	64 d	β_{1max} = 0,366 MeV ; β_{2max} = 0,399 MeV γ_1 = 0,72 MeV ; γ_2 = 0,76 MeV

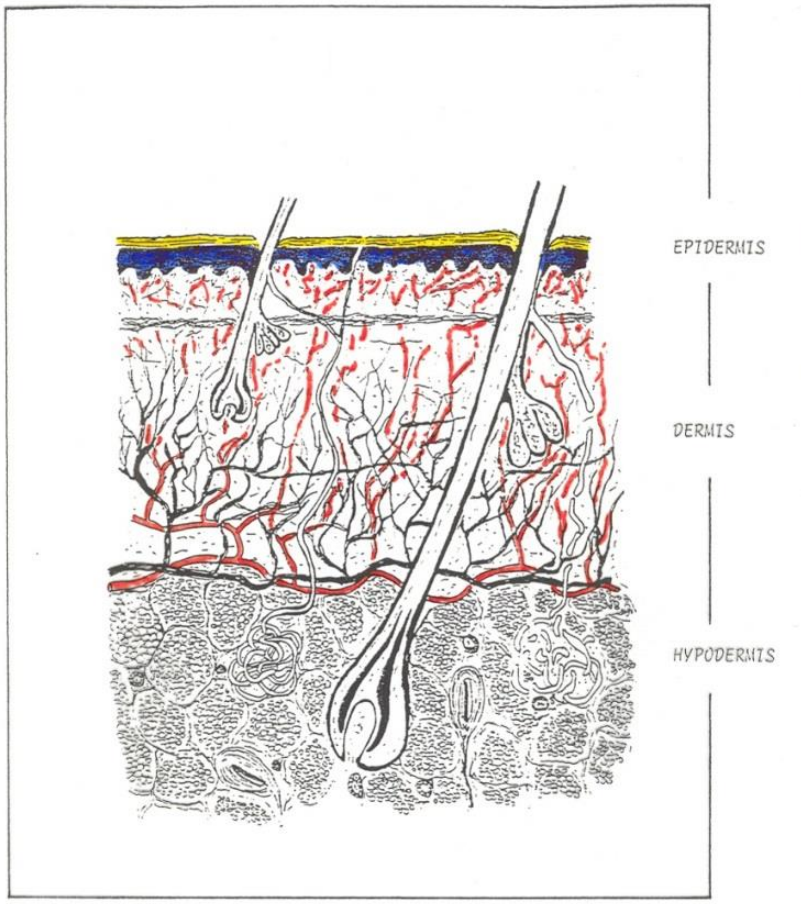
II.A (De)contamination of the intact skin

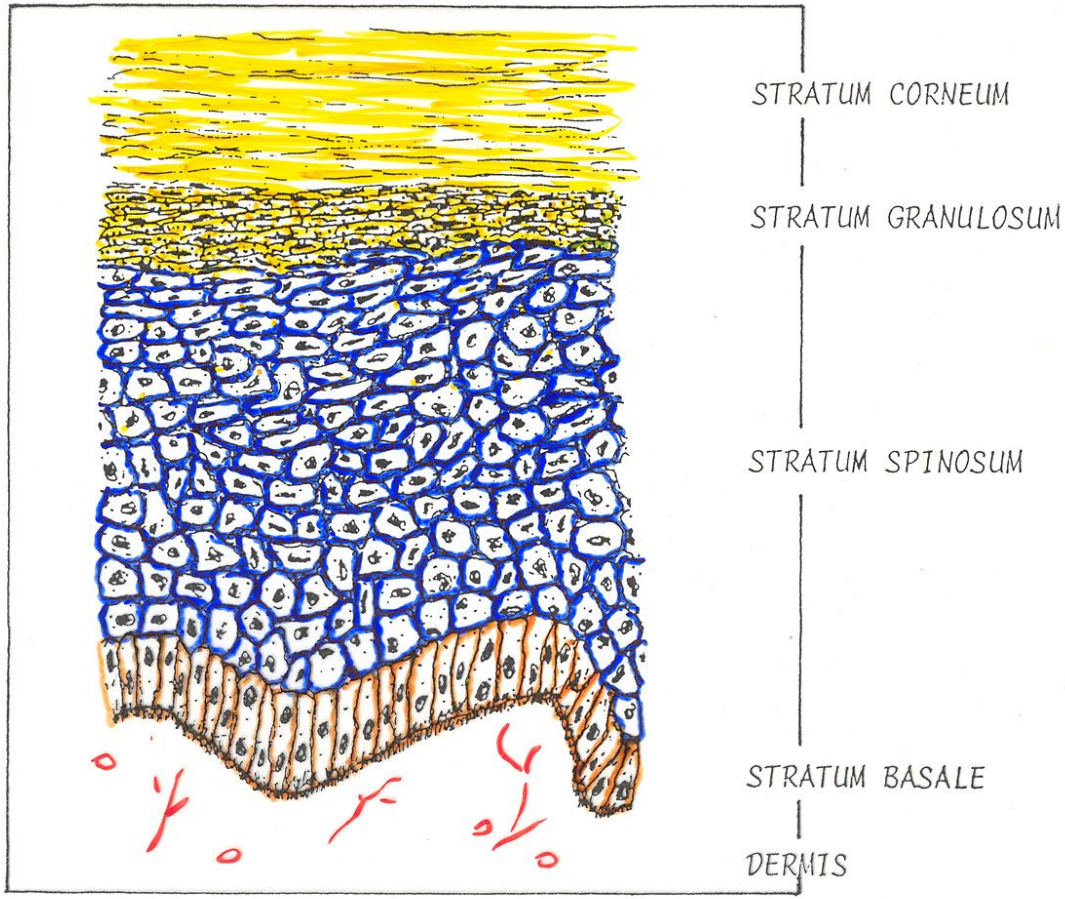
- Contamination: some radionuclides (^{3}H, *I,…) can penetrate the intact skin!
- Contamination/irradiation: most dangerous are β- emitters!
  (Partial) absorption in basal cell layer → eventually β-burns



Epidermis

- Energy of α-emitters is absorbed in (dead) cells of the epidermis





II.A (De)contamination of the intact skin

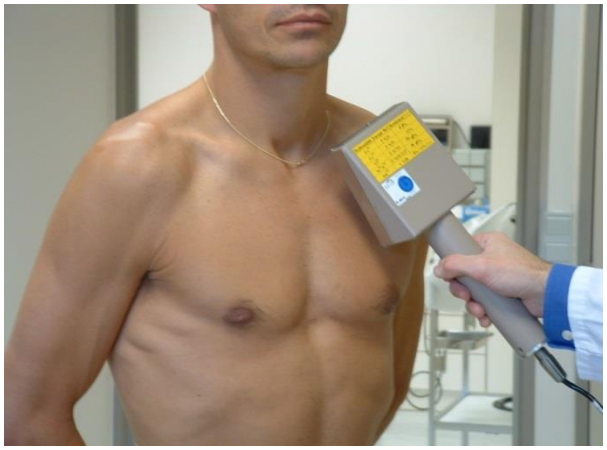
Depth of the basal cell layer	
Head and trunk	± 40 µm
Arms and legs	± 50 µm
Dorsal surface of hands and feet	± 150 µm
Palmar surface of hands and plantar surface of feet	± 300 µm

II.A Decontamination of the intact skin

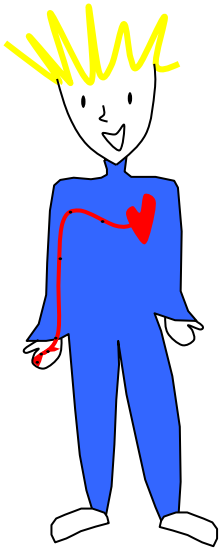
- Usually no problem if discovered in time
- In most cases: use of tepid water + detergents
- Can be problematic: acids, alkalines, iodine,…
- Peeling creams, depilatory creams

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 α-contamination!
- Registration of decontamination procedure and measurement results on an individual basis: medico-legal importance!



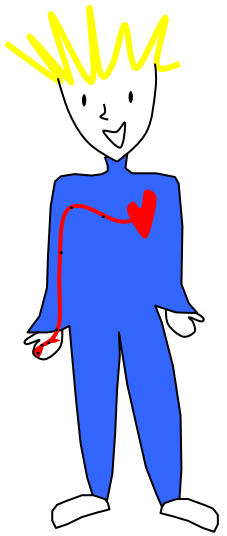
II.B Decontamination of wounds and burns



- 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

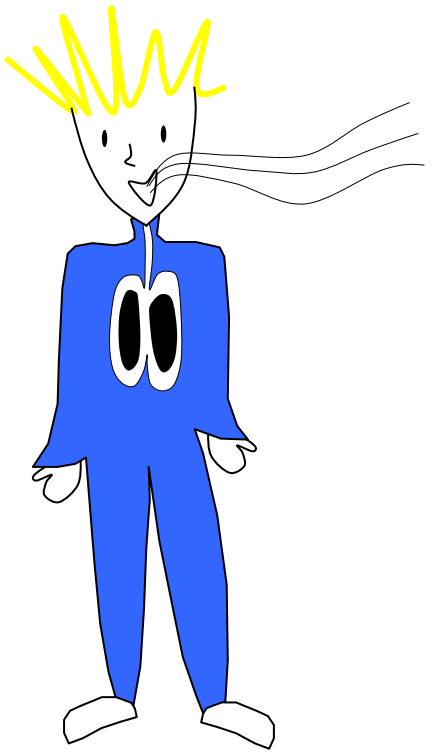


II.B Decontamination of wounds and burns

- 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 measuments (rinse fluids, bandages, blood drops…)
- Dosimetry of internal contamination: urine sampling, wound counting, total body counting, faecal analyses…

II.C (De)contamination after inhalation accidents

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



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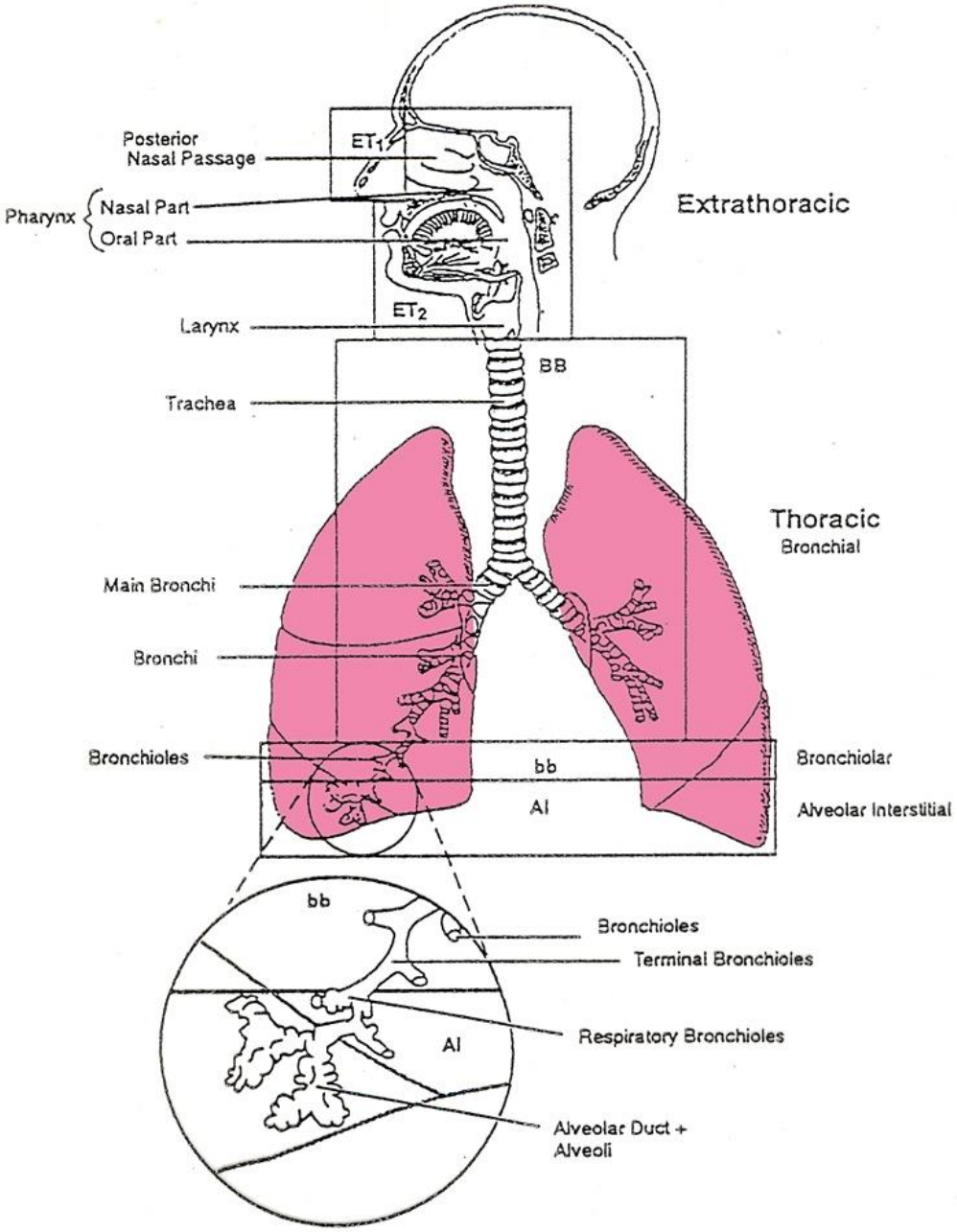
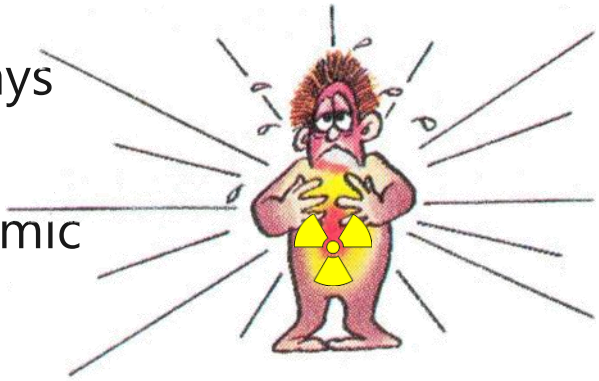


II.C Decontamination after inhalation accidents

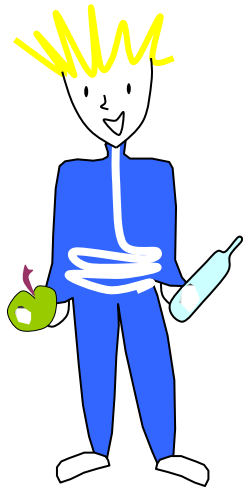
- SPONTANEOUS DECONTAMINATION for larger unsoluble particles (mucociliary clearance + faecal excretion)
- Very fine aerosol of unsoluble α–emitters: eventually pulmonary lavage in case of severe contaminations
- Soluble compounds:
  - Chelation therapy (e.g. DTPA);
  - Dilution therapy (e.g. stable iodine);
  - Diuretics + diuresis ↑

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



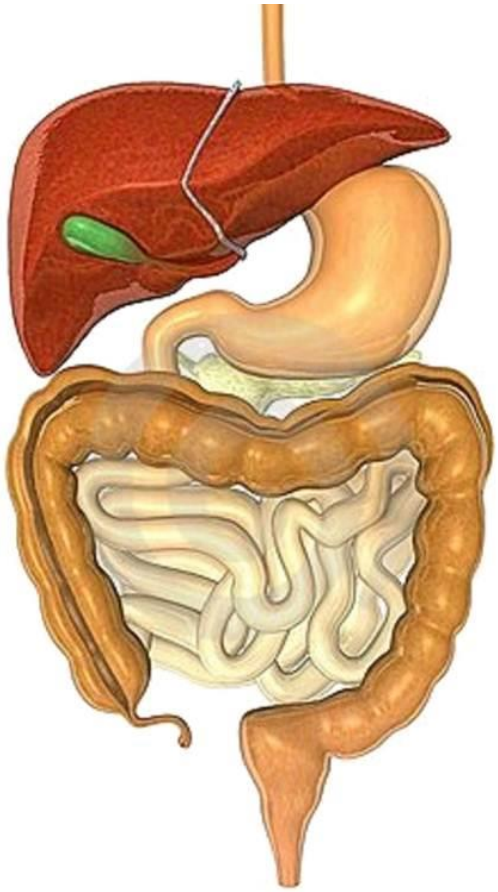
- DIRECT CONTAMINATION
  - very rare/nearly impossible at work (prevention)



- 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

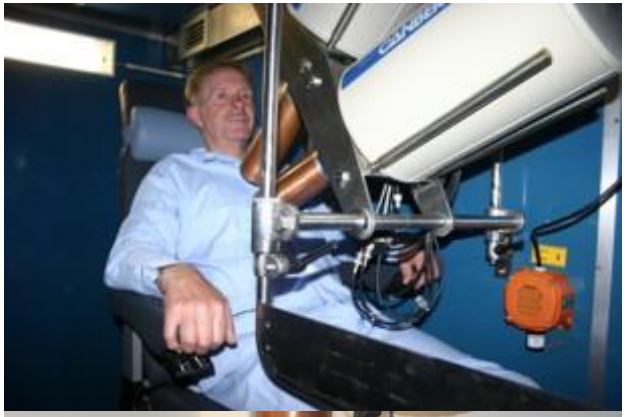
- (gastric lavage)
- speeding up transit time gastrointestinal tract
- decreasing resorption:
  - isotopic dilution: *I → stable iodine
  - *Cs → R/Prussian blue (cuts enterohepatic cycle)
  - *Ra and *Sr →R/Alginates or $MgSO_4$

Some therapeutics

Medication	Posology	Radionuclide(s)
Alginates	start 10 g/d 4 g/d as maintenance therapy	Ba, Ra, Sr,…
Chlorthalidone	start 1 - 2x 100 mg/d evtl. 50 mg/d as maintenance therapy	^{3}H, Na , K, Ru,…
Ca-/Zn-DTPA	1 g/d	Transuranics, Lanthanides, Mn, Pb, Co, Y, Zr, Ru, Cf, Cr, Ir, Np, Th, Cm…
Stable Iodine	100 mg/d (adult)	I
$MgSO_4$	10 - 15 g/d	All, especially Sr en Ra
Prussian blue	3 x 1 g/d	Cs, Tl, Rb
$NaHCO_3$	2 - 8 g/d	U
$Al(OH)_3$	6 g/d	F, Hg, K, P, Po

Some therapeutics

- **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)**

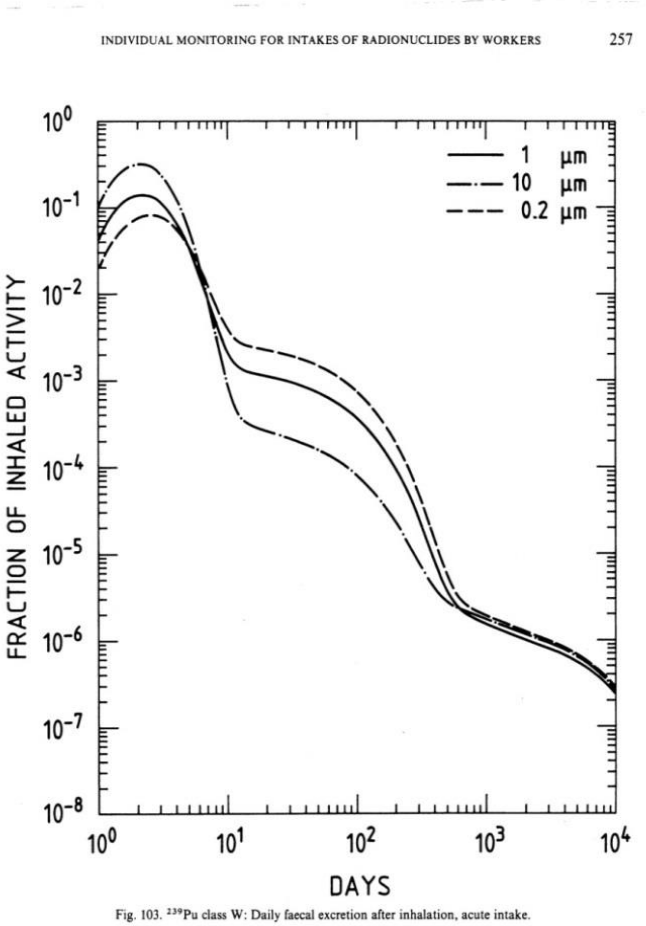
e.g.: for M-type aerosol (AMAD = 5 µm)

D1: daily faecal excretion = 11 % of intake

D2: daily faecal excretion = 15 % of intake

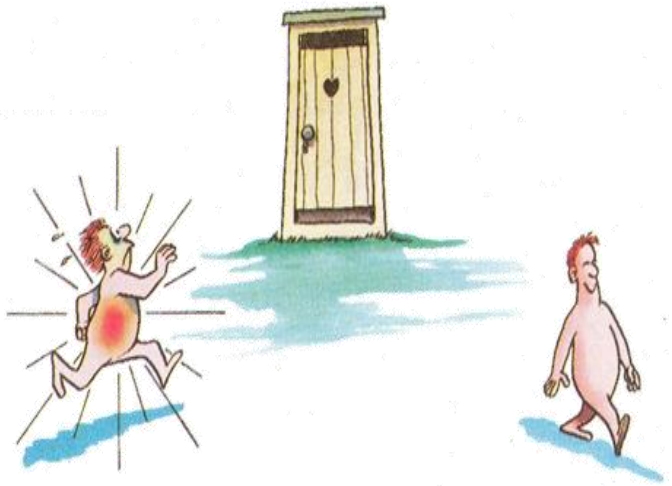
D3: daily faecal excretion = 8 % of intake

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

IV. Concluding remarks

- **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)

Radionuclide	Total activity (Bq)
Uranium	~ 1
Radium-226	~ 1
Thorium	~ 0,1
Potassium-40	3 000 - 5 000
Polonium-210	~ 40
Carbon-14	~ 3 500
Tritium	20 - 40
Rubidium-87	~ 500
Total	**7 000 - 9 000**

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