

Rijksinstituut voor Volksgezondheid
en Milieu
*Ministerie van Volksgezondheid,
Welzijn en Sport*

DOSIS CONVERSIE COËFFICIËNTEN (DCC'S) VOOR EXTERNE STRALING EN INWENDIGE BESMETTING

Teun van Dillen

Leerdoelen

Na afloop van de scholing is de deelnemer op de hoogte van de **recente ontwikkelingen betreffende dosisconversiecoëfficiënten** voor:

- externe straling (ICRP 116 en ICRP 144);
- inwendige besmetting (inhalatie en ingestie, ICRP 130+).

Met aandacht voor de belangrijkste:

- ingrediënten van
- wijzigingen in
- gevolgen van

de nieuwe rekenmethodiek.



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Inhoud

1. Algemene inleiding
2. Externe straling (ICRP 116 en 144)
3. Inwendige besmetting
   (ICRP 130+)

Nascholing SBD, 25 november 2021 | Groningen | DCC's



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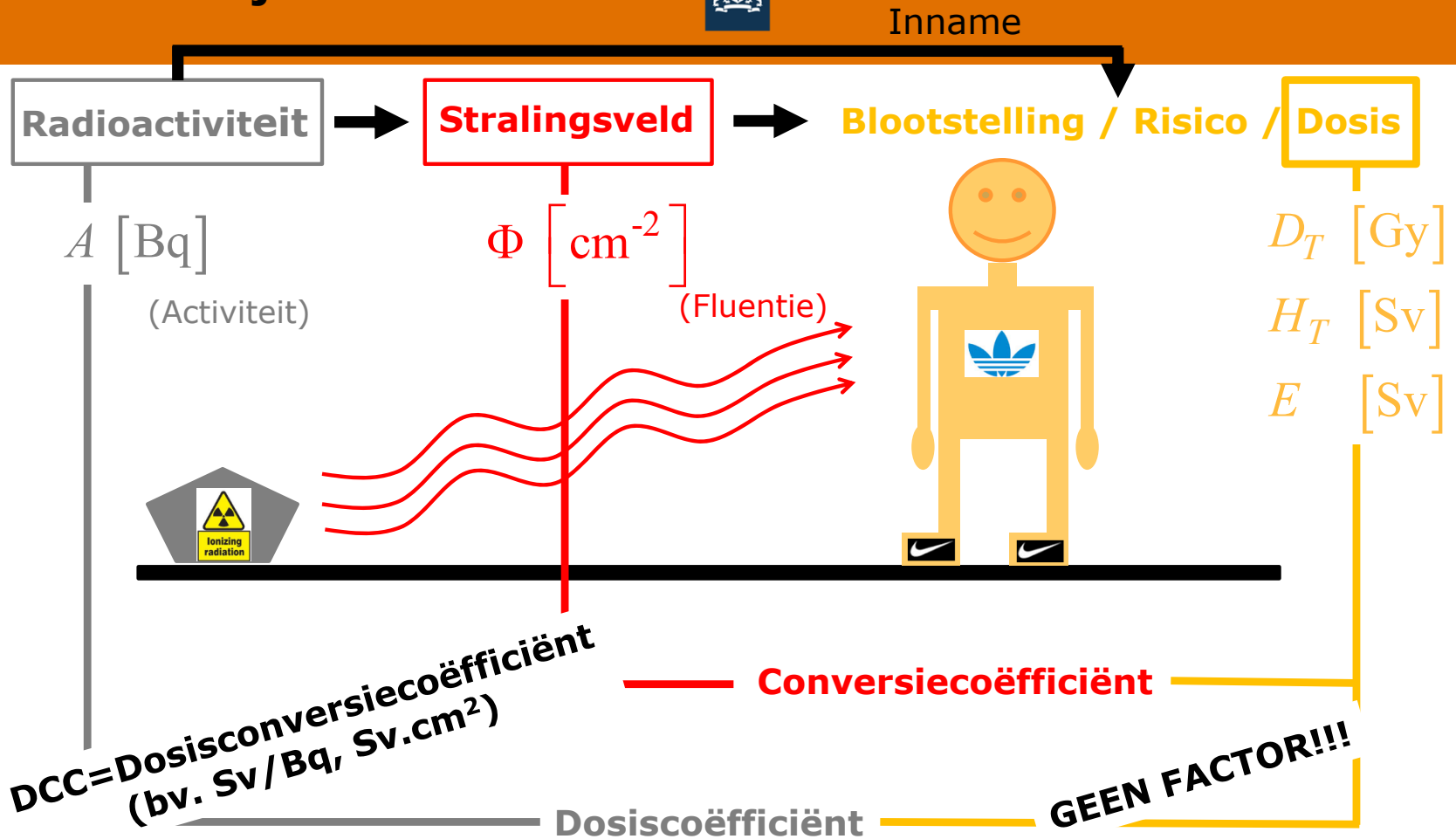
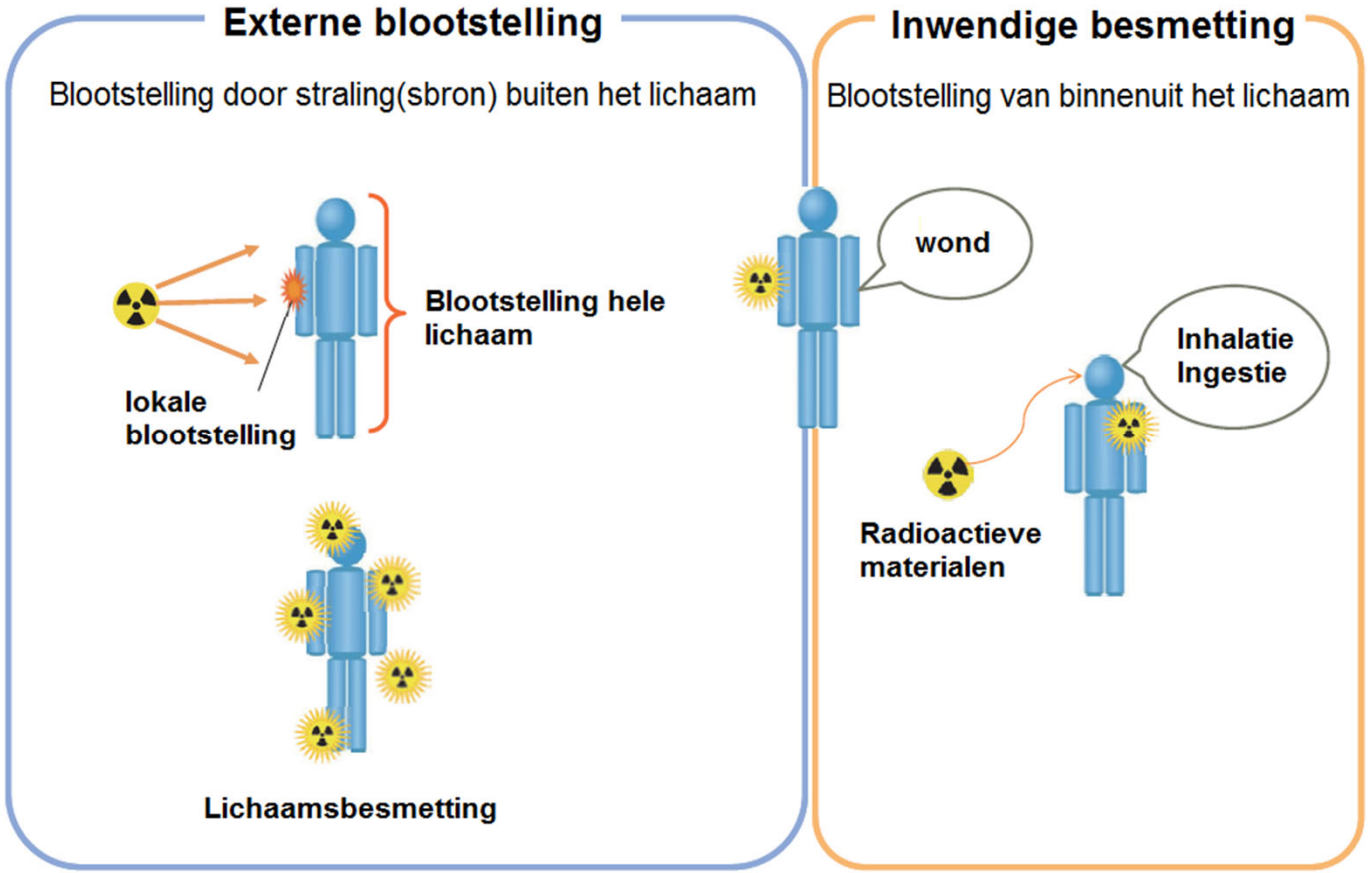
3. Inwendige besmetting
(ICRP 130+)

DCC's: wat zijn dat?



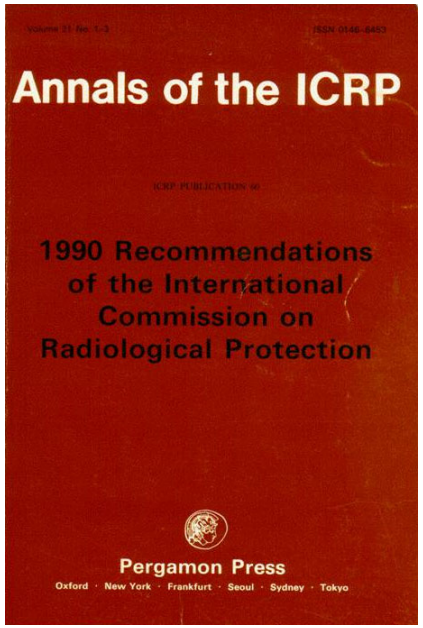
Typen blootstelling

Image adapted from following source:
Ministry of the Environment , Japan, website:
https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-01-01.pdf
Accessed: August 22, 2019



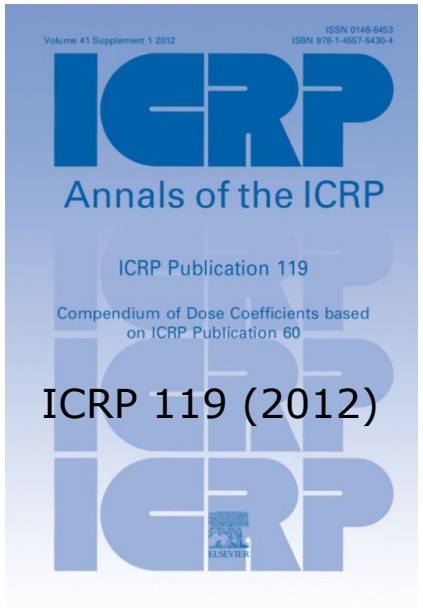
DCC's: waar te vinden?

Op basis van ICRP 60 (aanbevelingen uit 1990)



- Inwendige besmetting, werkers: ICRP 68 (1994)
- Inwendige besmetting, bevolking: ICRP 72 (1996)
- Externe straling, werkers (?): ICRP 74 (1996)

Compilatie (incl. correcties)



Nuclidespecifiek:
- Inhalatie, Ingestie
- Submersie

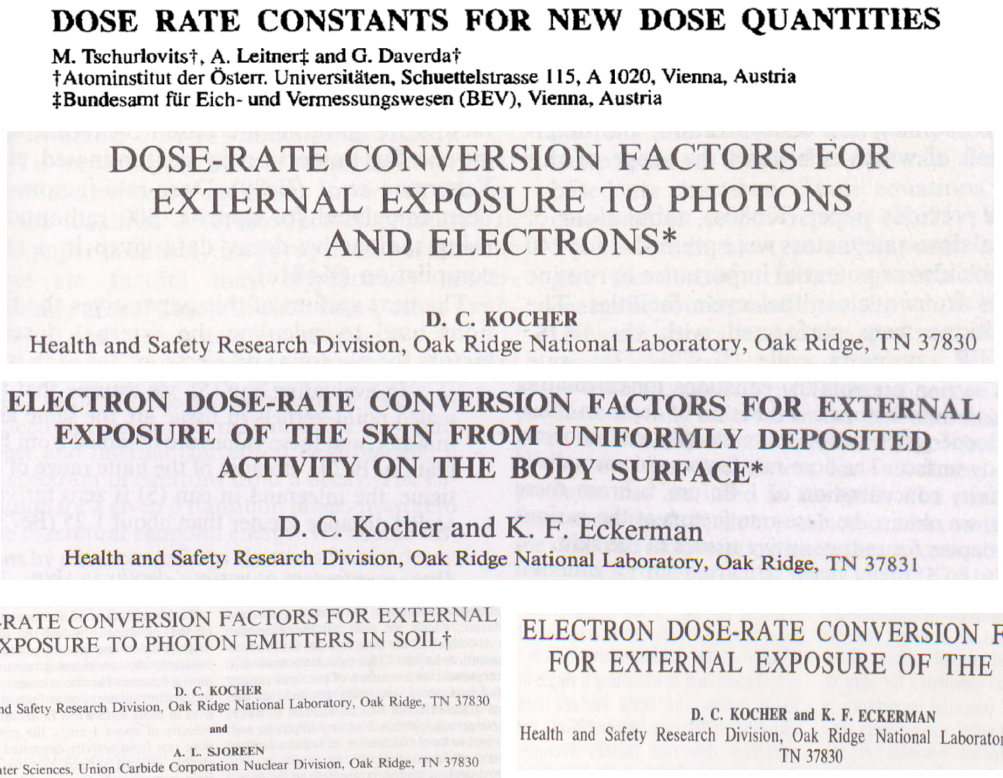
Energiespecifiek:
- Fotonen/neutronen: E/K_a en E/Φ
- Elektronen: D_{Huid}/Φ en E/Φ

https://www.autoriteitnvs.nl/onderwerpen/straling/standaarwaarden-en--relaties

Maar ook hier… (1)

Rapporten en wetenschappelijke literatuur





DOSE RATE CONSTANTS FOR NEW DOSE QUANTITIES

M. Tschurlovits†, A. Leitner‡ and G. Daverda†
†Atominstitut der Österr. Universitäten, Schuettelstrasse 115, A 1020, Vienna, Austria
‡Bundesamt für Eich- und Vermessungswesen (BEV), Vienna, Austria

DOSE-RATE CONVERSION FACTORS FOR EXTERNAL EXPOSURE TO PHOTONS AND ELECTRONS*

D. C. KOCHER
Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830

ELECTRON DOSE-RATE CONVERSION FACTORS FOR EXTERNAL EXPOSURE OF THE SKIN FROM UNIFORMLY DEPOSITED ACTIVITY ON THE BODY SURFACE*

D. C. Kocher and K. F. Eckerman
Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

DOSE-RATE CONVERSION FACTORS FOR EXTERNAL EXPOSURE TO PHOTON EMITTERS IN SOIL†

D. C. KOCHER
Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830
and
A. L. SJOREEN
Computer Sciences, Union Carbide Corporation Nuclear Division, Oak Ridge, TN 37830

ELECTRON DOSE-RATE CONVERSION FACTORS FOR EXTERNAL EXPOSURE OF THE SKIN*

D. C. KOCHER and K. F. ECKERMAN
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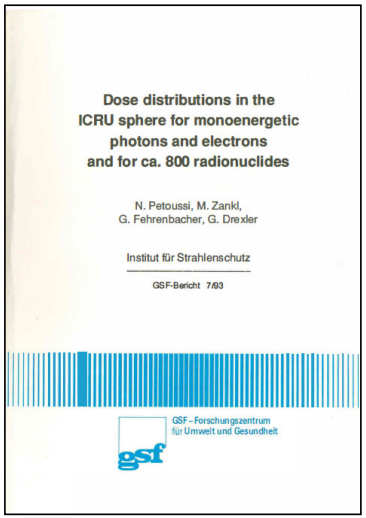
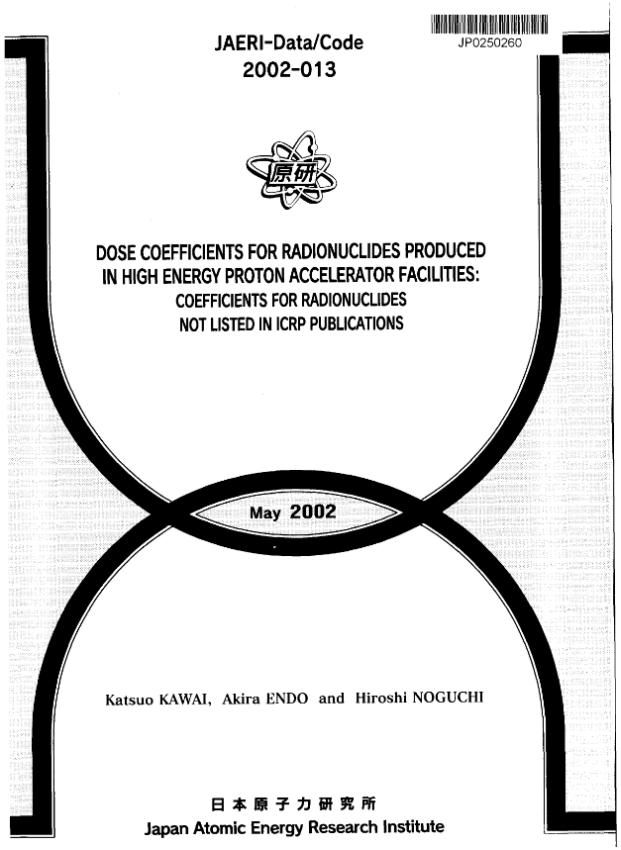


Maar ook hier… (2)



Ingestie en inhalatie (werkers en bevolking)

Ruim 300 extra radionucliden

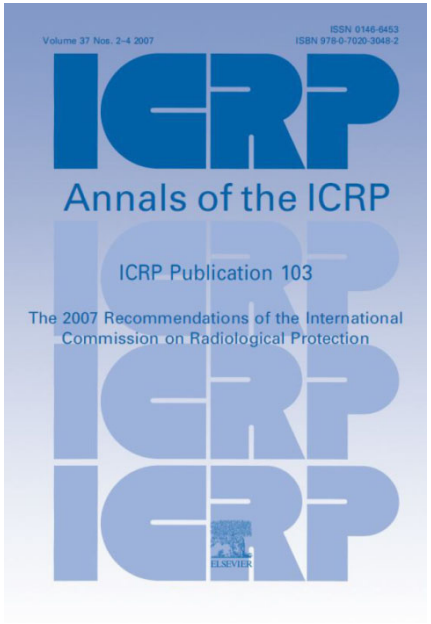
Op basis van ICRP 60 (aanbevelingen uit 1990)

Conform dosimetrische modellen ICRP

https://jopss.jaea.go.jp/pdfdata/JAERI-Data-Code-2002-013.pdf

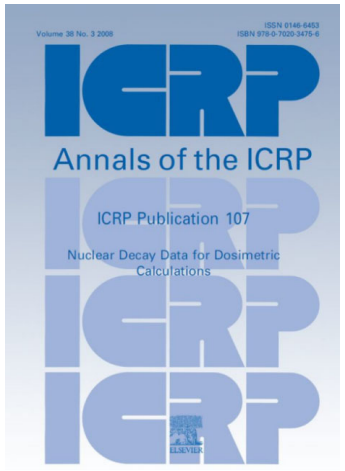
Waarom nieuwe DCC's?

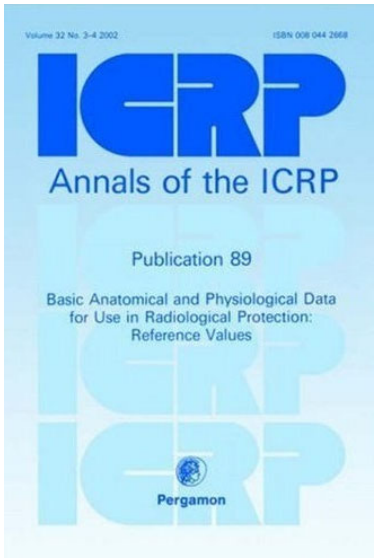
Nieuwe ICRP aanbevelingen uit 2007, onder andere:

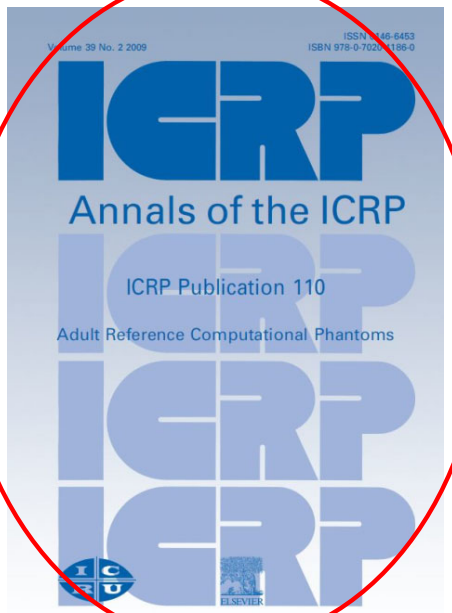


Nieuwe stralingsweegfactoren (neutronen, protonen)
Nieuwe set weefselweegfactoren

Maar verder ook:



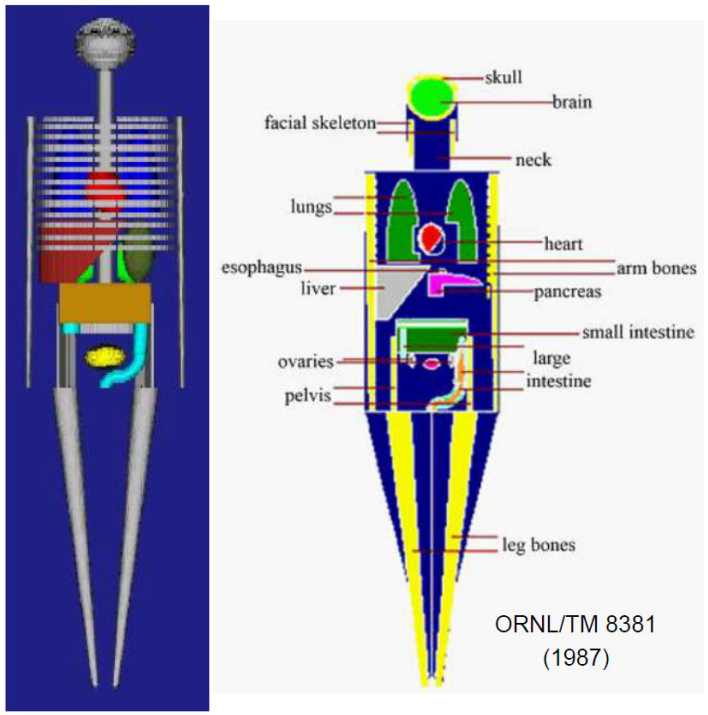




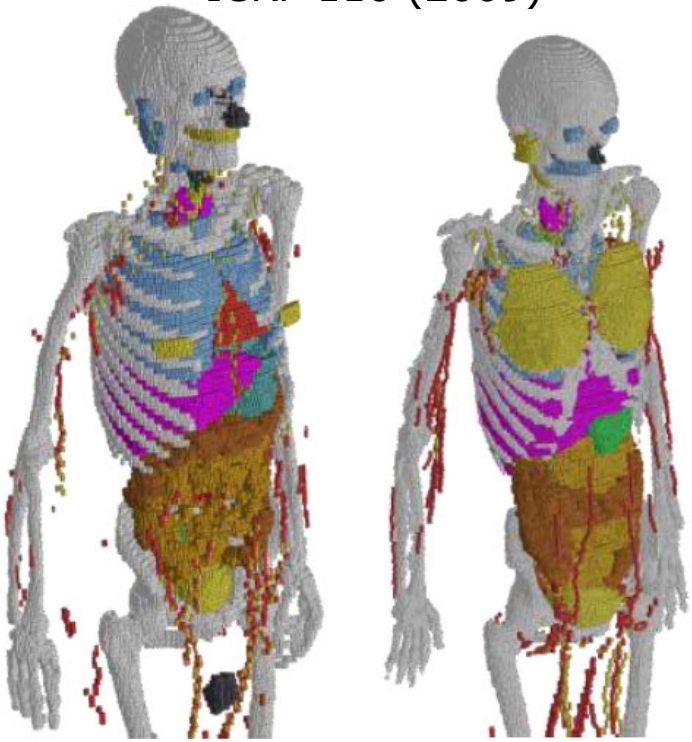
Fantomen (1)
Adult computational reference phantoms

Source images from:
presentations by Chan Hyeong Kim and Maria Zankl
ICRP symposium 2017, Paris, France
https://www.icrp.org/docs/icrp2017/4%20Kim%20Presentation.pdf
https://www.icrp.org/docs/icrp2017/3%20Zankl%20Presentation.pdf

Oud, jaren 80/90 (gestileerde fantomen),
ICRP 74/ICRU 57



Nieuw, voxel fantomen
ICRP 110 (2009)

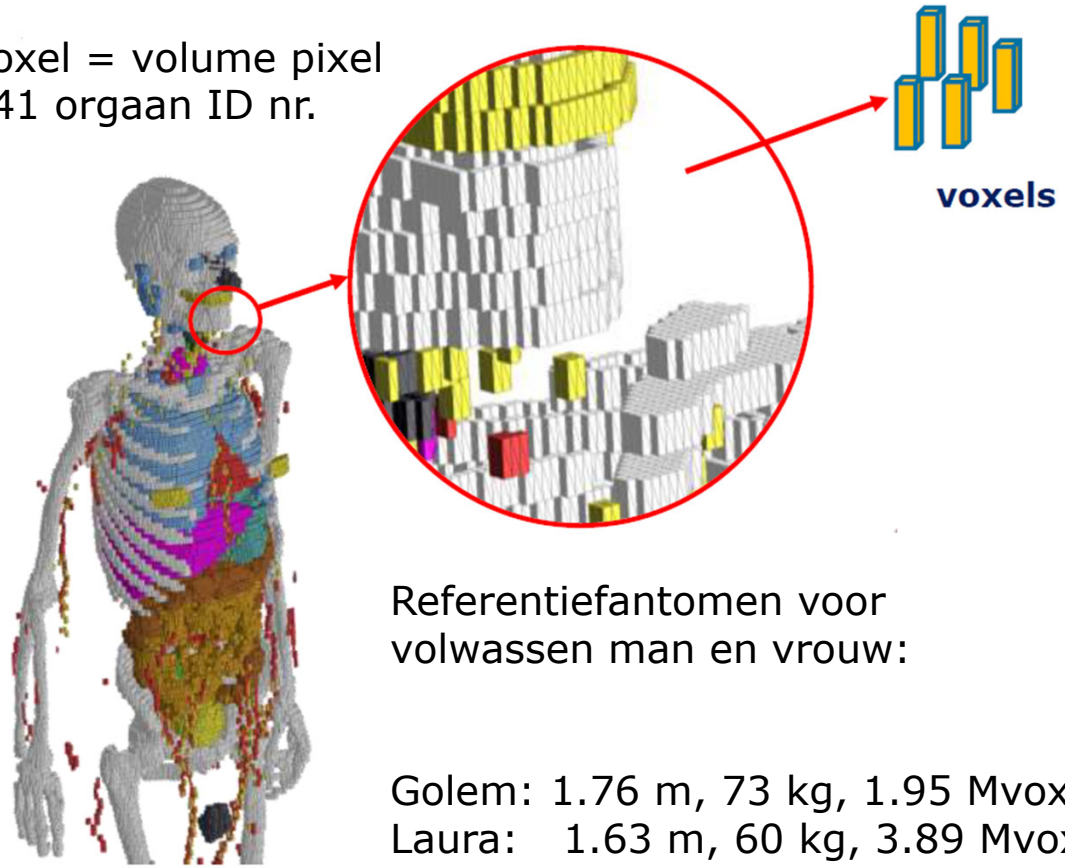


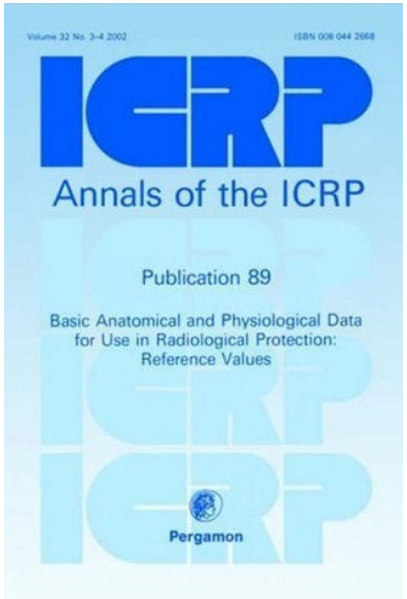
Ref. man: Golem Ref. vrouw: Laura

Fantomen (2)
Adult computational reference phantoms

Source image from presentation by Chan Hyeong Kim
ICRP symposium 2015, Seoul, South-Korea
https://www.icrp.org/docs/icrp2015/19%20Chan%20Hyeong%20Kim%202015.pdf

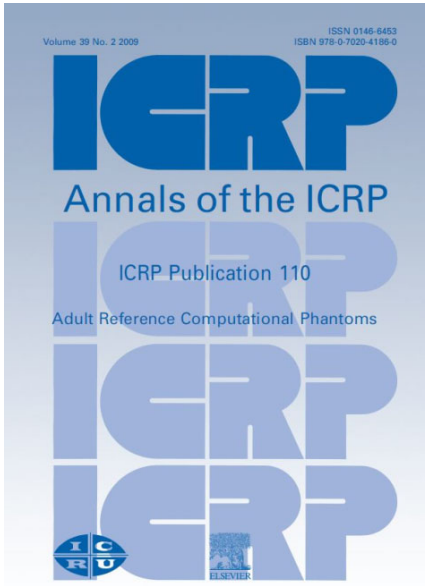
Voxel = volume pixel
141 orgaan ID nr.





Referentiefantomen voor volwassen man en vrouw:

Golem: 1.76 m, 73 kg, 1.95 Mvoxels
Laura: 1.63 m, 60 kg, 3.89 Mvoxels



Fantomen (3)
Adult computational reference phantoms

Beperkingen van de voxel fantomen:

1. Beperkte resolutie van de CT data/voxels

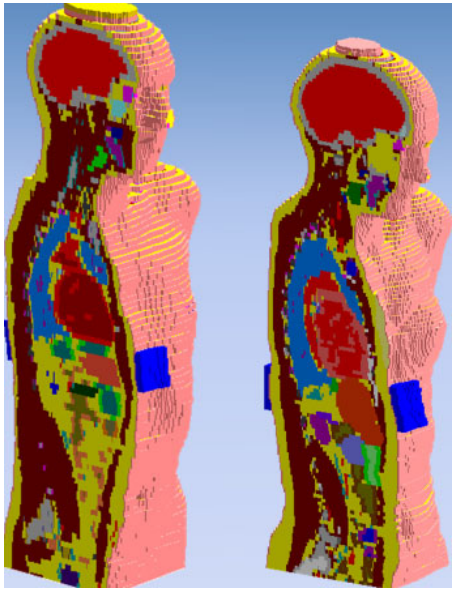
2. Kleine dimensies van de bepaalde weefsels.

Skelet:
- Rode beenmerg in mergholtes spongieus bot
- Endostale laag (50 µm)
  → Dosis-responsfuncties

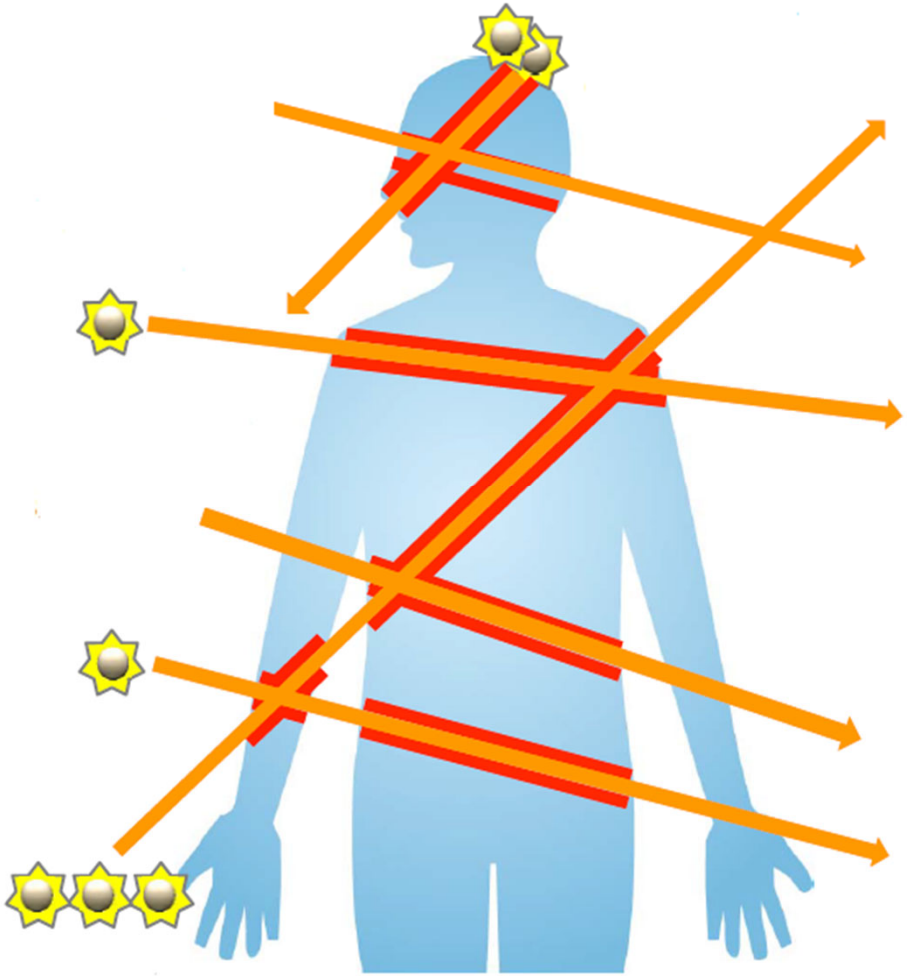
Ooglens
  → Gestileerd ooglensmodel (Behrens, et al.)

Basaalcellaag van de huid
  → Lokale huiddosis (diepte 50-100 µm)

Man: 2.137×2.137×8 mm^3



Source image from presentation John Harrison,
ICRP symposium 2015, Seoul, South-Korea
https://www.icrp.org/docs/icrp2015/03%20John%20Harrison%202015.pdf



Adapted from following source:
Ministry of the Environment , Japan, website:
https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-02-01.pdf
Accessed: September 13, 2019

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Externe straling

Image adapted from following source:
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https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-01-01.pdf
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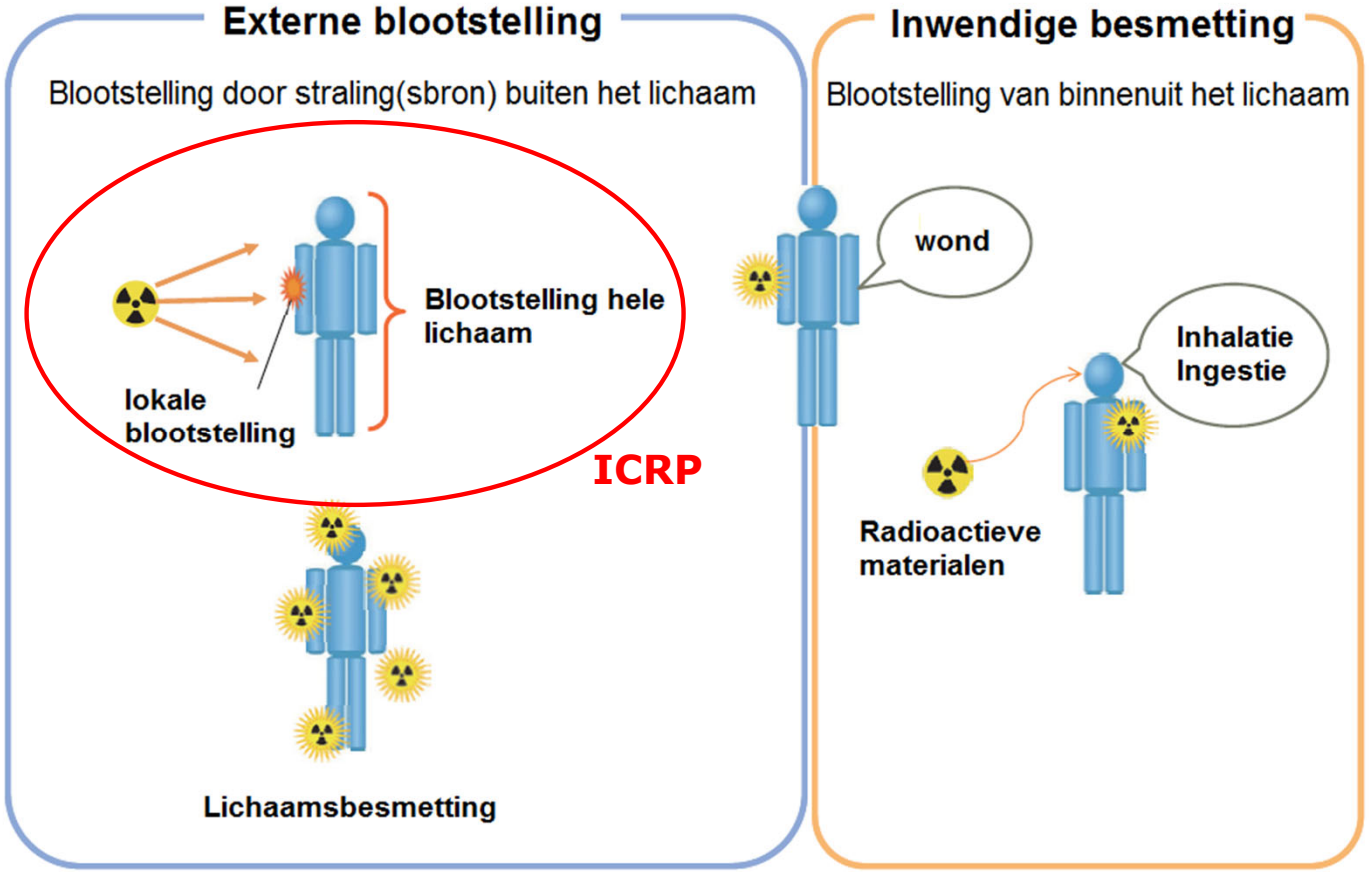
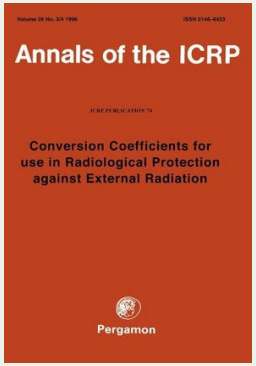
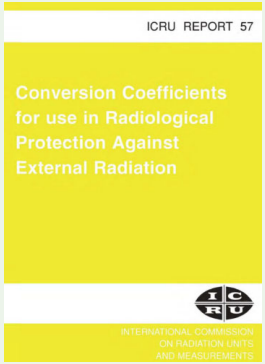
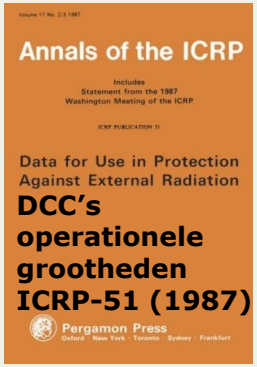


Oude DCC's o.b.v. ICRP-60 (1990)

ICRP Publicatie 74 (1996)
ICRU Rapport 57 (1997)







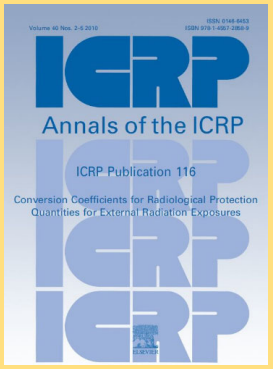
Compilatie Monte-Carlo berekeningen uit literatuur

Oude MIRD antropomorfe fantomen

Kermabenadering
(Geladen-deeltjes-evenwicht, gde)

Nieuwe DCC's o.b.v. ICRP-103 (2007)

ICRP Publicatie 116 (2010)



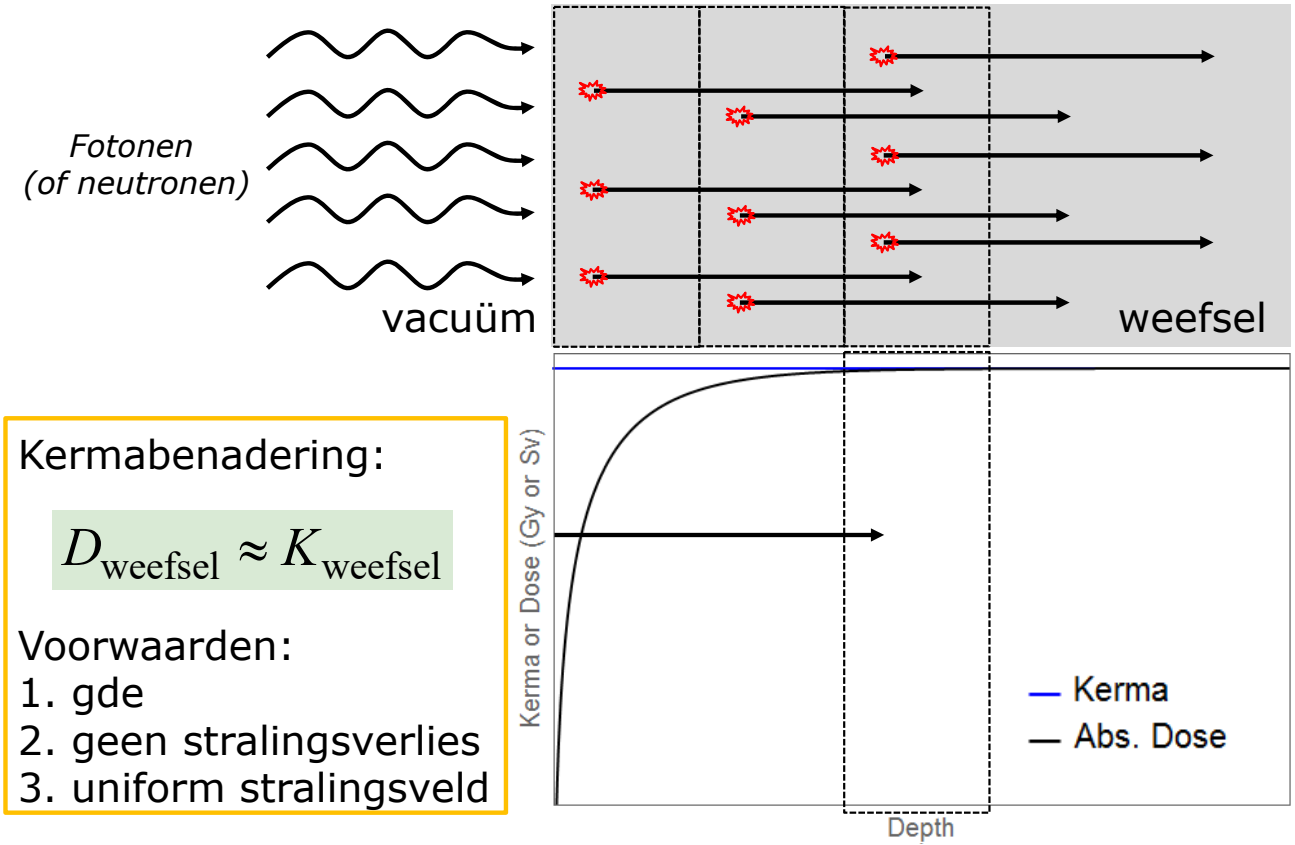
Geen nieuwe DCC's voor operationele grootheden (nieuwe berekeningen uit literatuur)

Monte-Carlo berekeningen speciaal voor dit rapport

Nieuwe voxel fantomen

Secondary charged-particle tracking
(géén kermabenadering)

Kermabenadering onder geladen deeltjes evenwicht

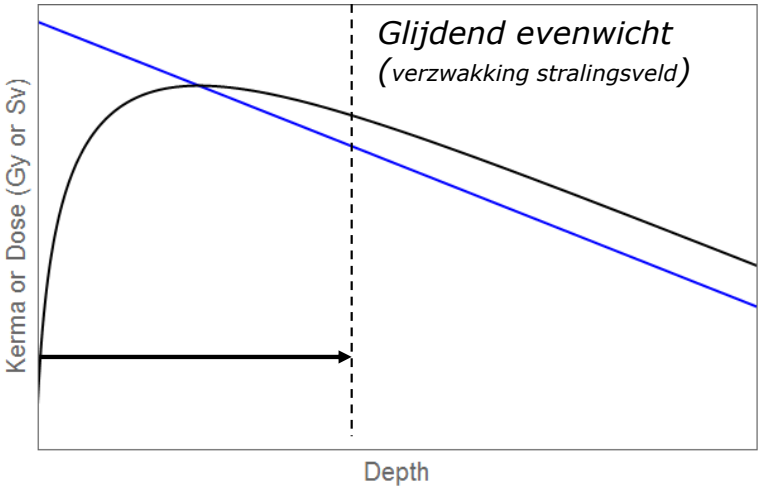


Kermabenadering:

$$D_{\text{weefsel}} \approx K_{\text{weefsel}}$$

Voorwaarden:
1. gde
2. geen stralingsverlies
3. uniform stralingsveld

Meer realistische situatie:

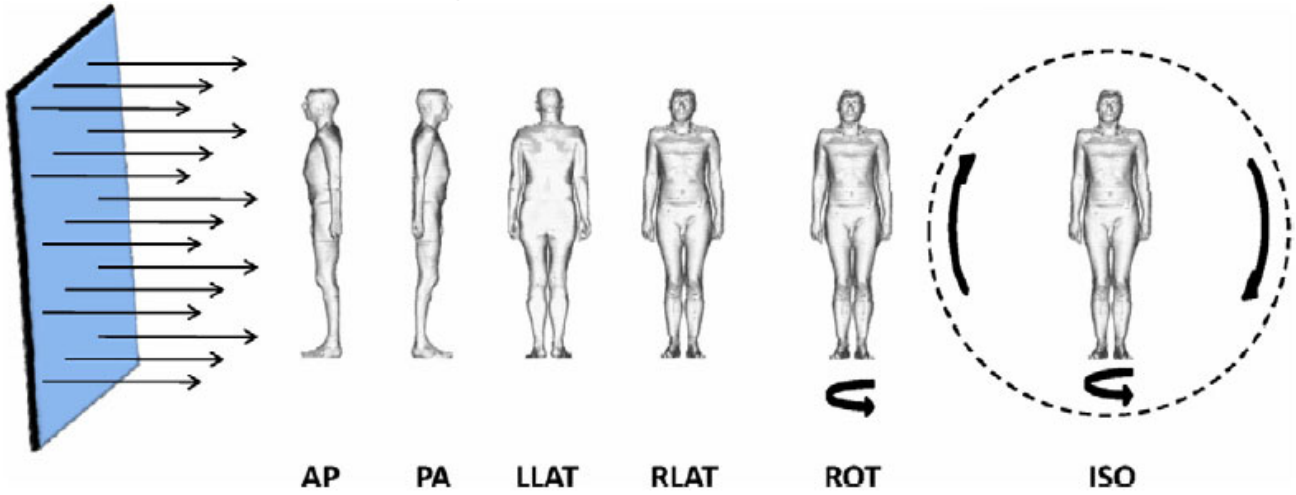


Nieuwe DCC's ICRP-116: Stralingsdeeltjes en bestralingsgeometrieën

Fotonen	Neutronen	Elektronen/ positronen	Protonen	Pionen (+/-)	Muonen (+/-)	Alfa deeltjes
10 keV – 100 GeV	1 meV – 10 GeV	50 keV – 100 GeV	1 MeV – 10 GeV	1 MeV – 200 GeV	1 MeV – 10 GeV	1 MeV/u – 100 GeV/u

NEW

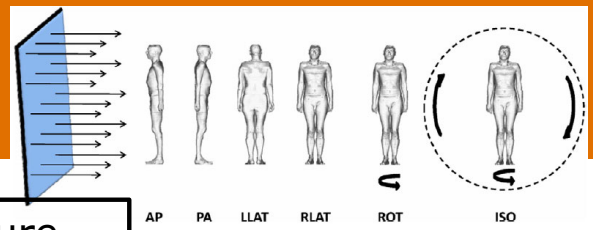
Geïdealiseerde stralingsvelden (werkers)
Brede bundels, monoënergetisch, in vacuüm



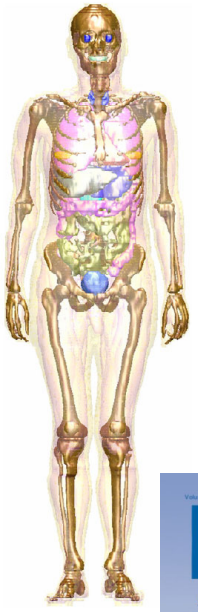
Source image from ICRP 116, Ann. ICRP 40(2-5) (Fig. 3.2, page 47)

Nieuwe DCC's ICRP-116: Rekenmethodiek

EGSnrc, FLUKA, PHITS, MCNPX, GEANT4



External exposure
(& Radionuclide intake)



Reference male

D_T^M Male phantom Absorbed dose

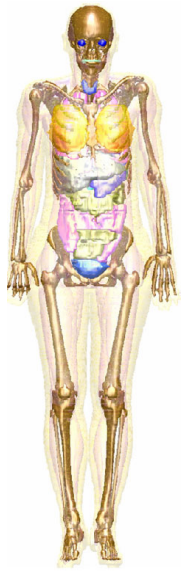
Female phantom Absorbed dose D_T^F

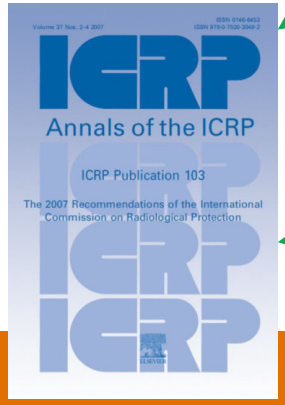
w_R

H_T^M Male phantom Equivalent dose

Female phantom Equivalent dose H_T^F

Reference female





Reference person

Sex-averaged equivalent doses $\langle H_T \rangle = \frac{1}{2}\left(H_T^M + H_T^F\right)$

w_T

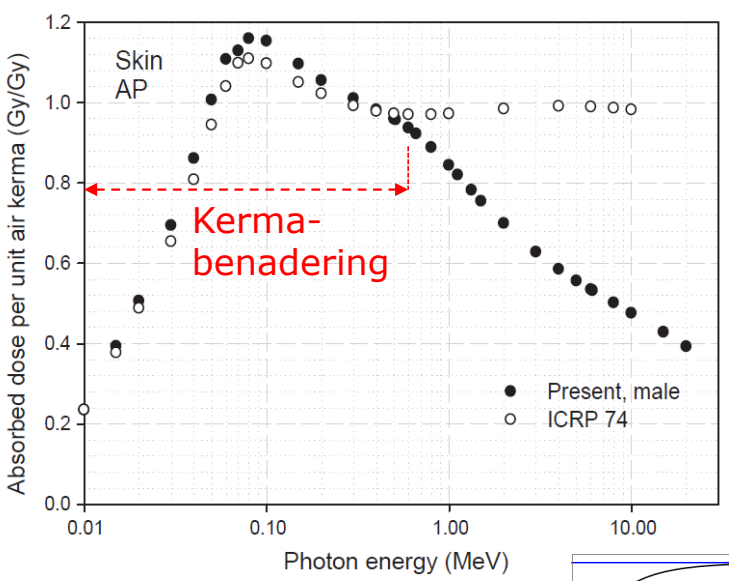
Effective dose $E = \sum_T w_T \langle H_T \rangle$

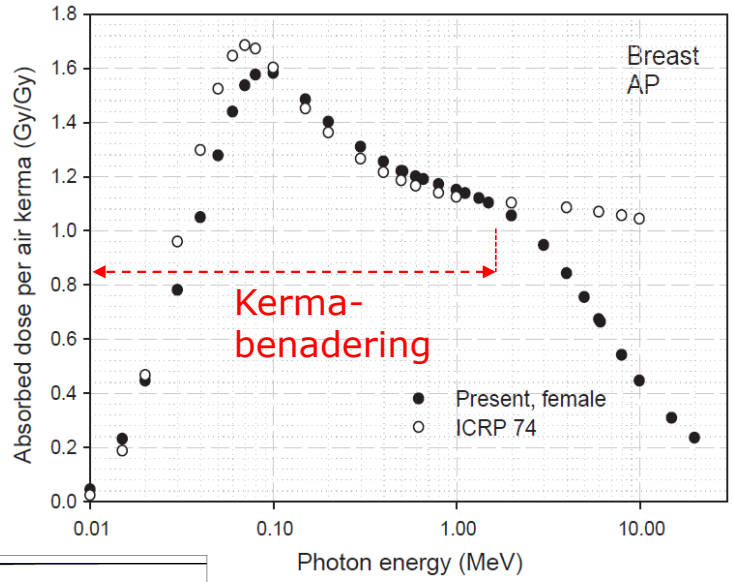
Source images from ICRP 116 (2010) Ann. ICRP 40(2-5) (Fig. 3.1, page 46)

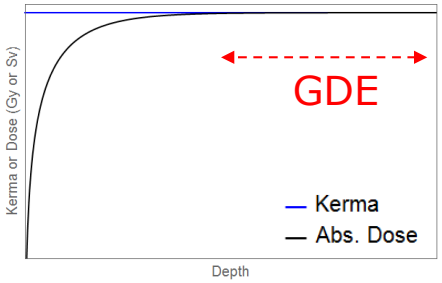
Resultaten fotonen Orgaandoses (1)

$D_T^{M,F}$

Organen aan oppervlak







Source of upper two figures: ICRP 116 (2010)
Ann. ICRP 40(2-5)
(Figs. 4.5 and 4.6, page 72)

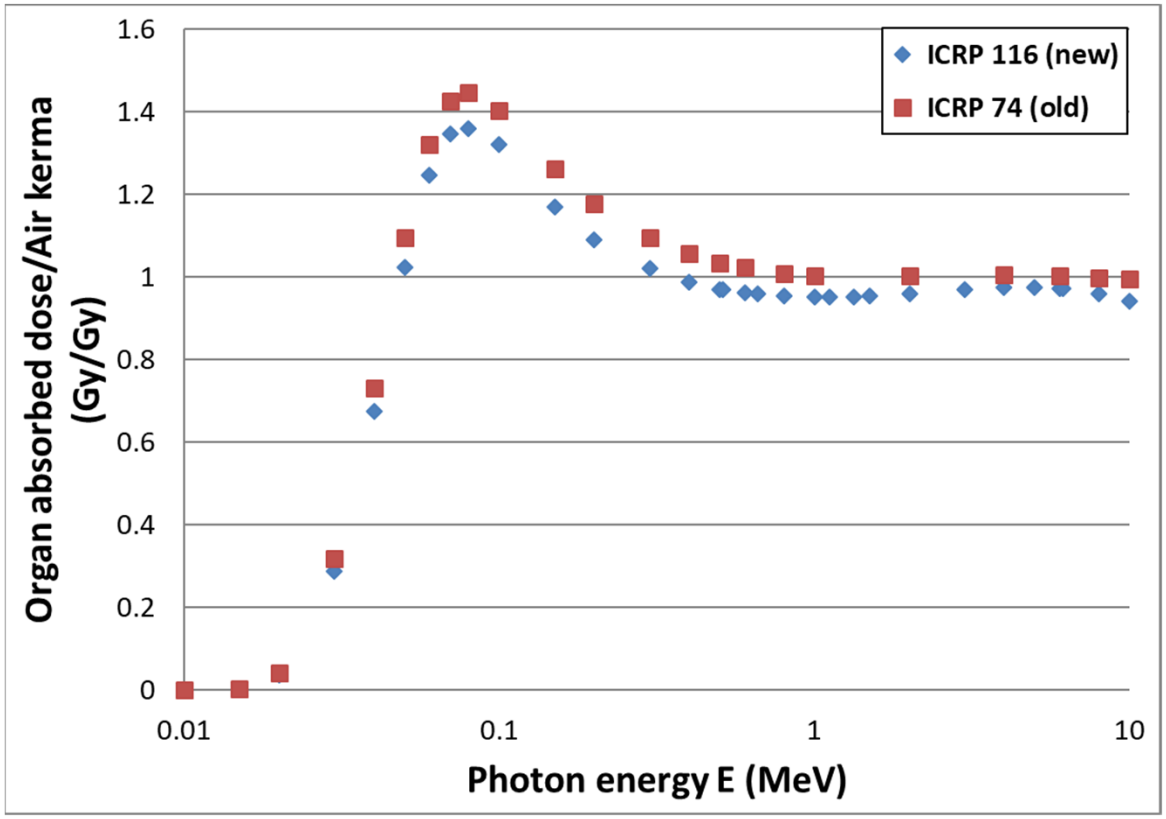
Tevens verschillen in:

- Anatomie
- Compositie organen
- Transportcodes

Resultaten fotonen Orgaandoses (2)

$D_T^{M,F}$

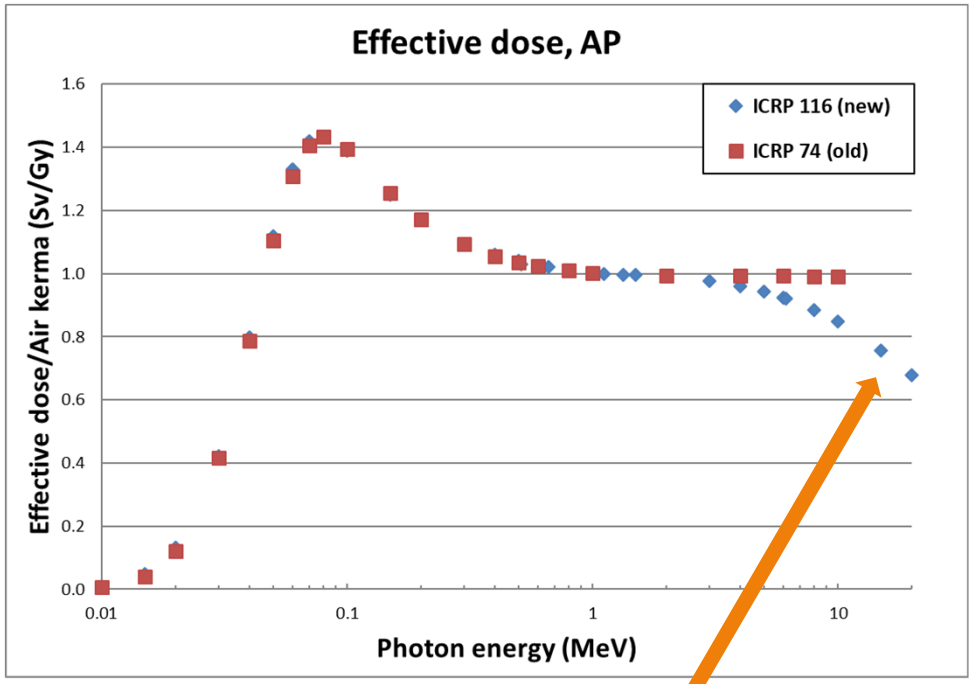
Diepe(re) organen: lever (AP)



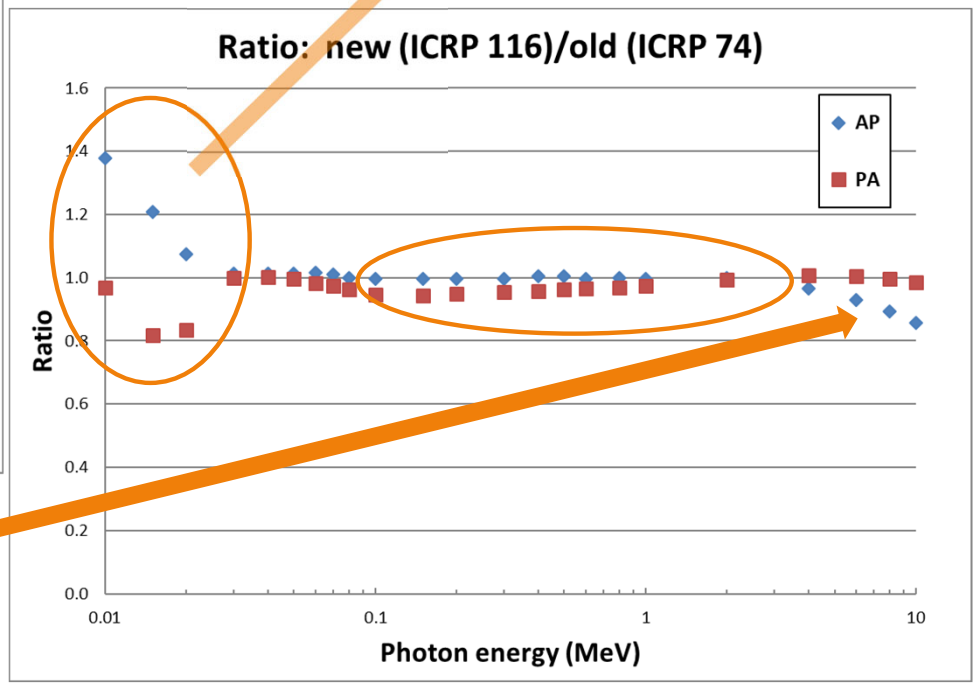
Kermabenadering OK in hele energiegebied

Tevens verschillen in:
- Anatomie
- Compositie organen
- Transportcodes

Resultaten fotonen
Effectieve dosis (3)

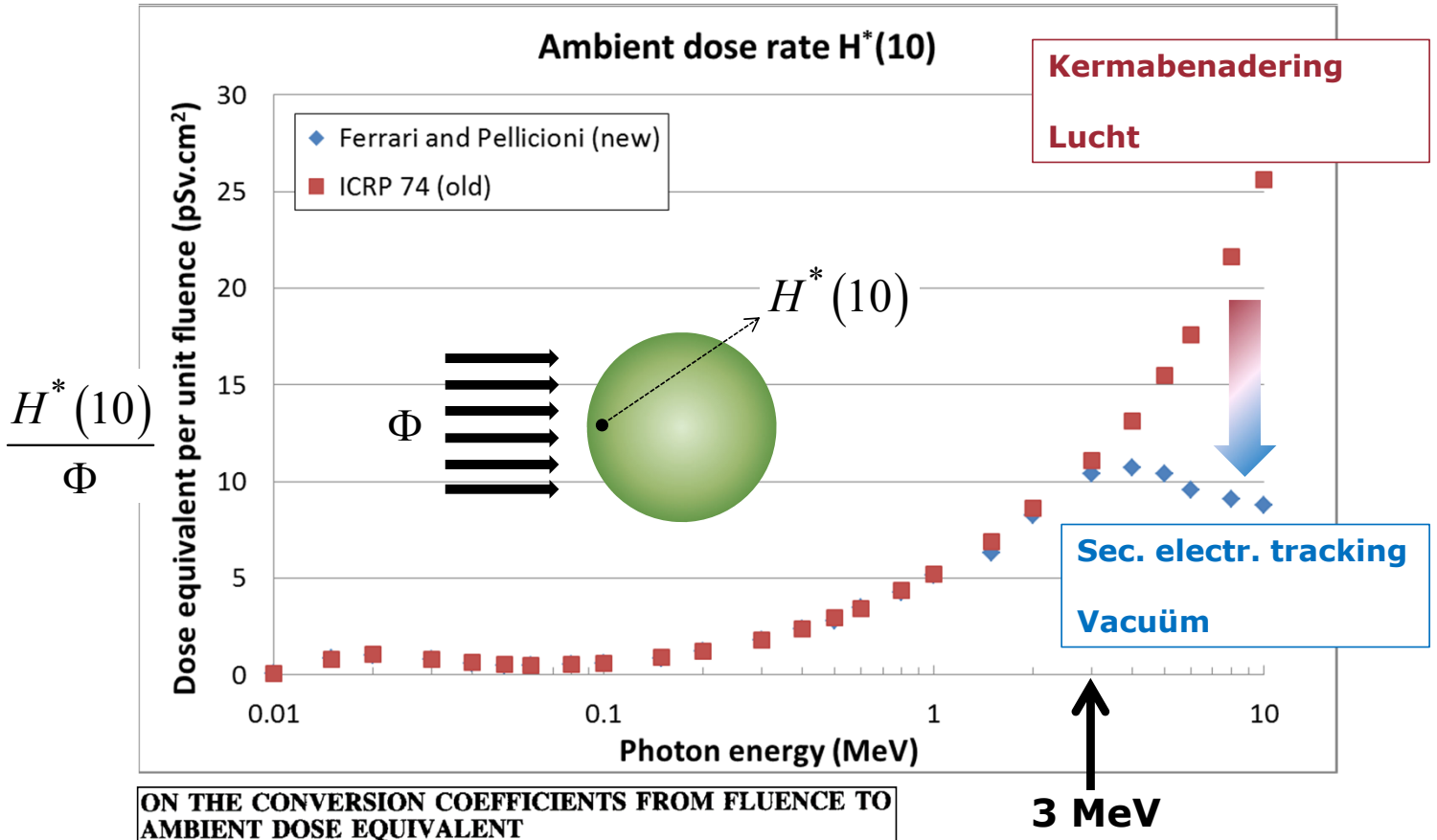


Verschillen in anatomie



Effect loslaten van de kermabenadering op de effectieve dosis

Resultaten fotonen (4)
Operationele grootheden

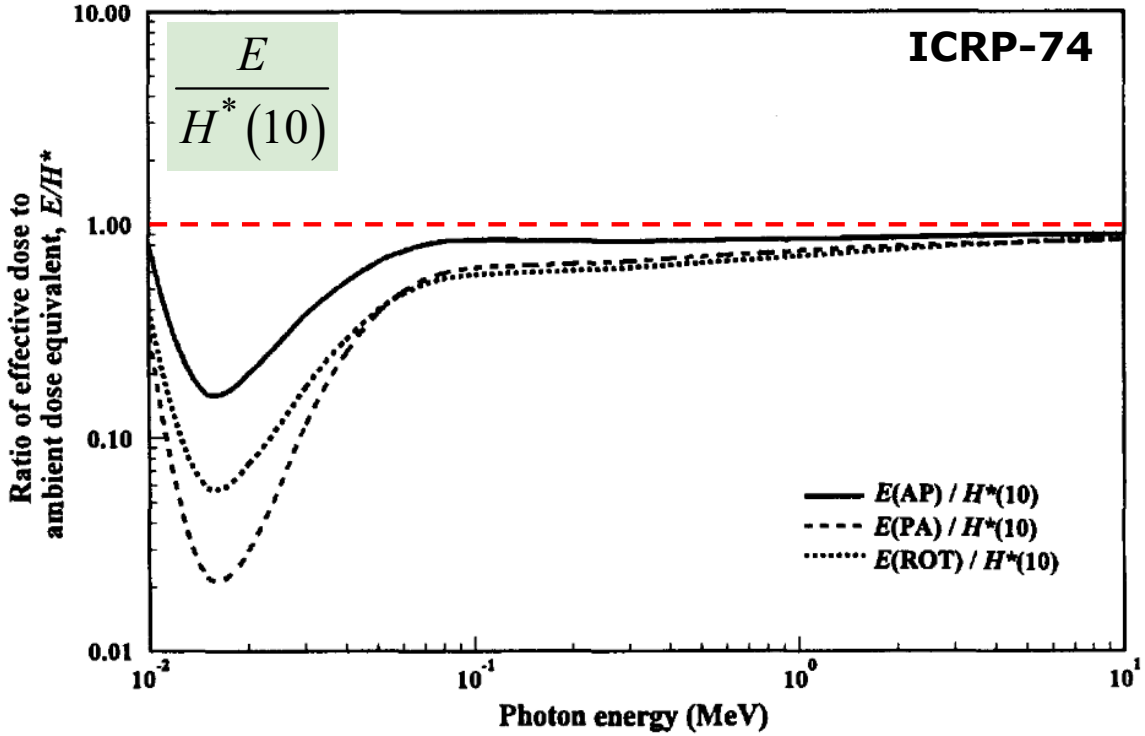


$$\frac{H^*(10)}{\Phi}$$

ON THE CONVERSION COEFFICIENTS FROM FLUENCE TO AMBIENT DOSE EQUIVALENT

A. Ferrari† and M. Pelliccioni‡
†INFN, Sezione di Milano, Via Celoria 16, 20133 Milano, Italy
‡INFN, Laboratori Nazionali di Frascati, 00044 Frascati, Italy

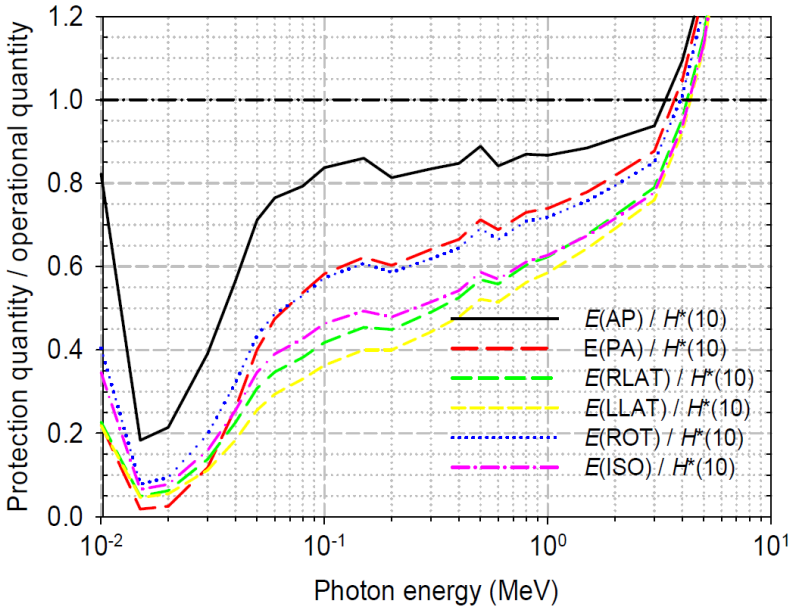
Resultaten fotonen (5)
E/H*(10) - oud



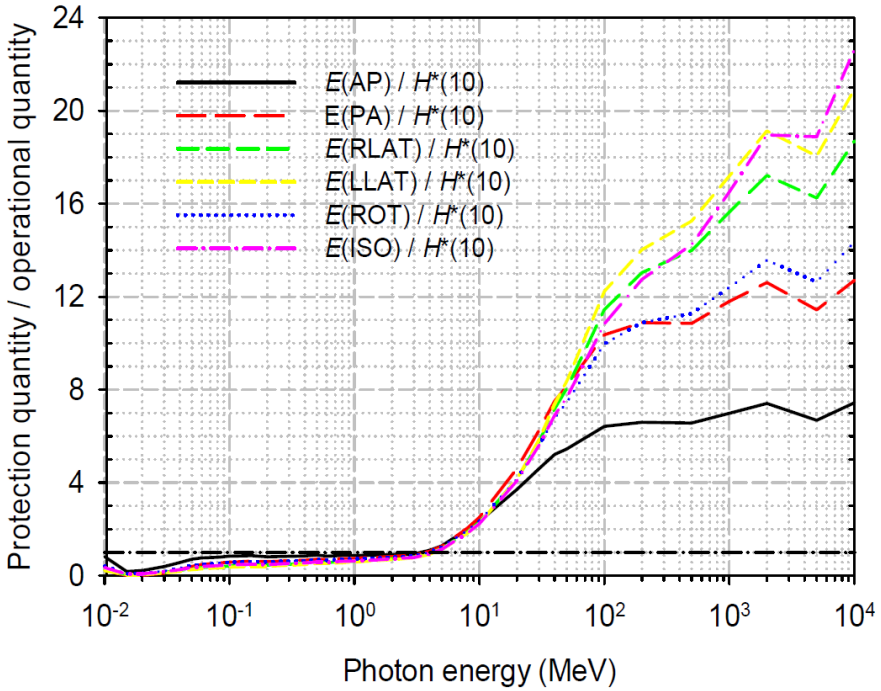
$H^*(10)$ en E via "kermabenadering"

Source images from ICRP 74 (1996)
Ann. ICRP 26 (3-4)
Figure 55, page 97

Resultaten fotonen (6)
E/H*(10) - nieuw



$$\frac{E}{H^*(10)}$$



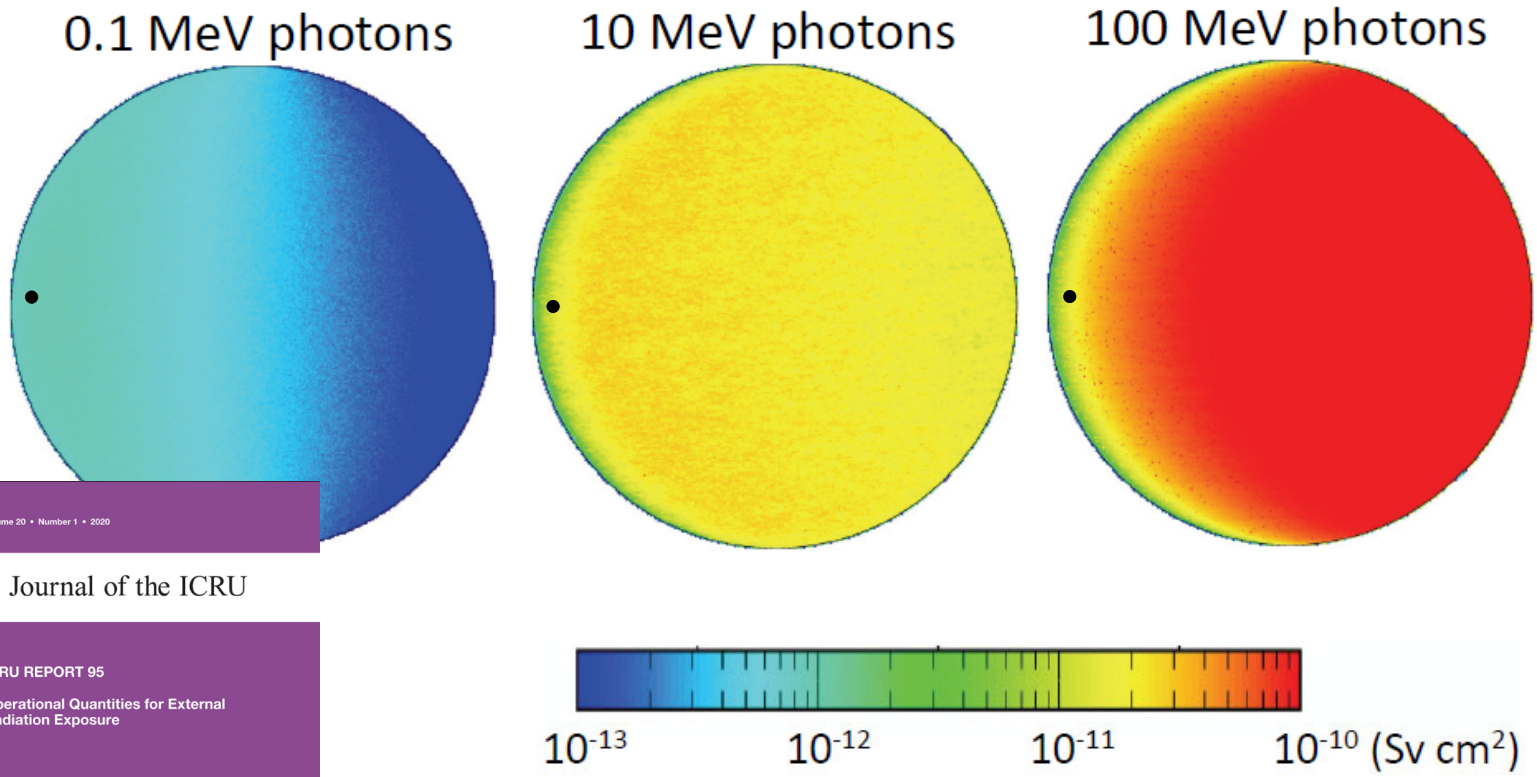
E en $H^*(10)$ via "secondary electron tracking"

ICRU bol in vacuüm

Ferrari and Pellicioni, 1994

Source images from ICRP 116 (2010)
Ann. ICRP 40(2-5)
(Fig. 5.2, page 118)

Resultaten fotonen (7)
Operationele grootheden





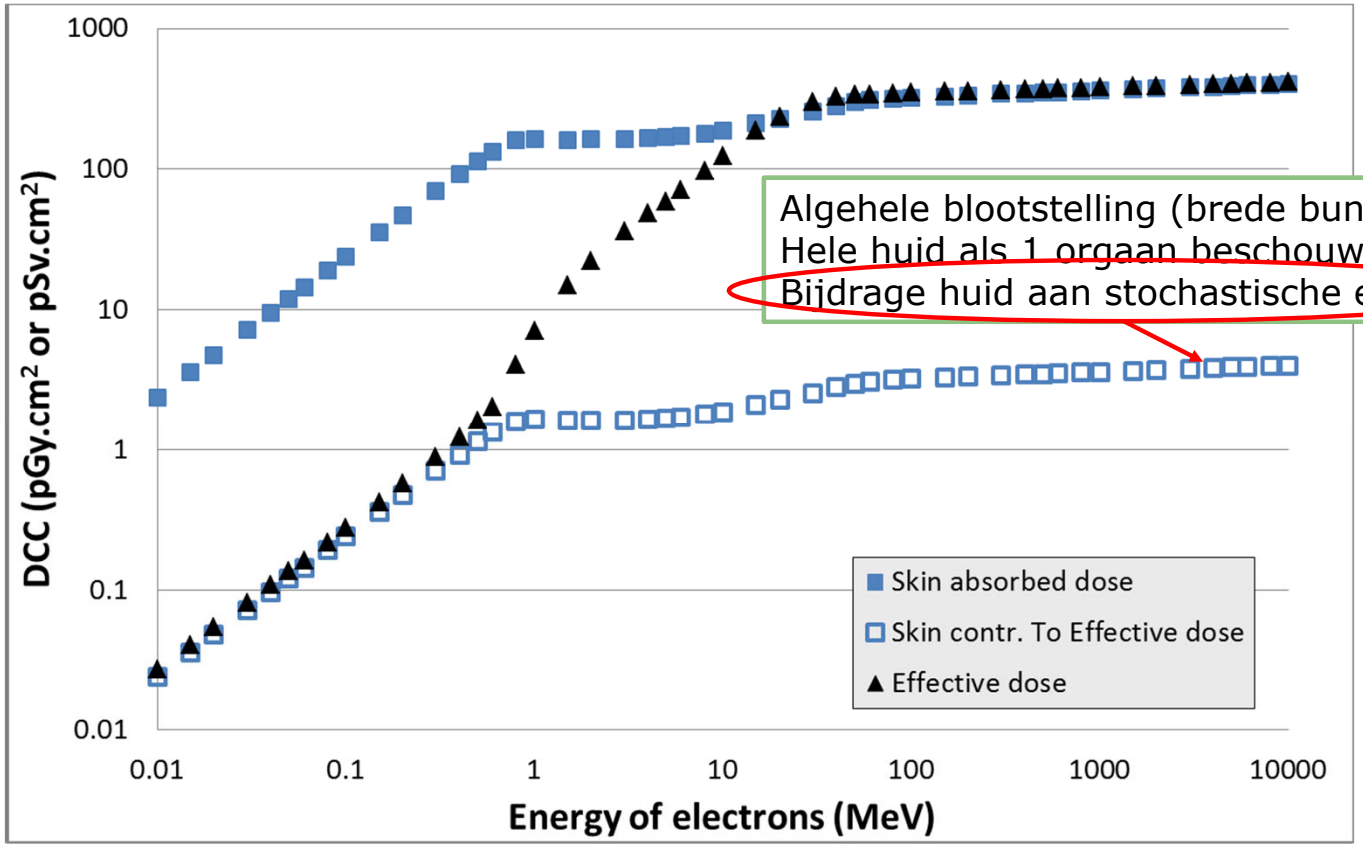
Introductie van nieuwe operationele grootheden

Source images from presentation Akira Endo, ICRP symposium 2015, Seoul, South-Korea
https://www.icrp.org/docs/icrp2015/18%20Akira%20Endo%202015.pdf

Resultaten elektronen (1)
Huiddosis

$$\frac{D_{Skin}}{\Phi}$$

AP

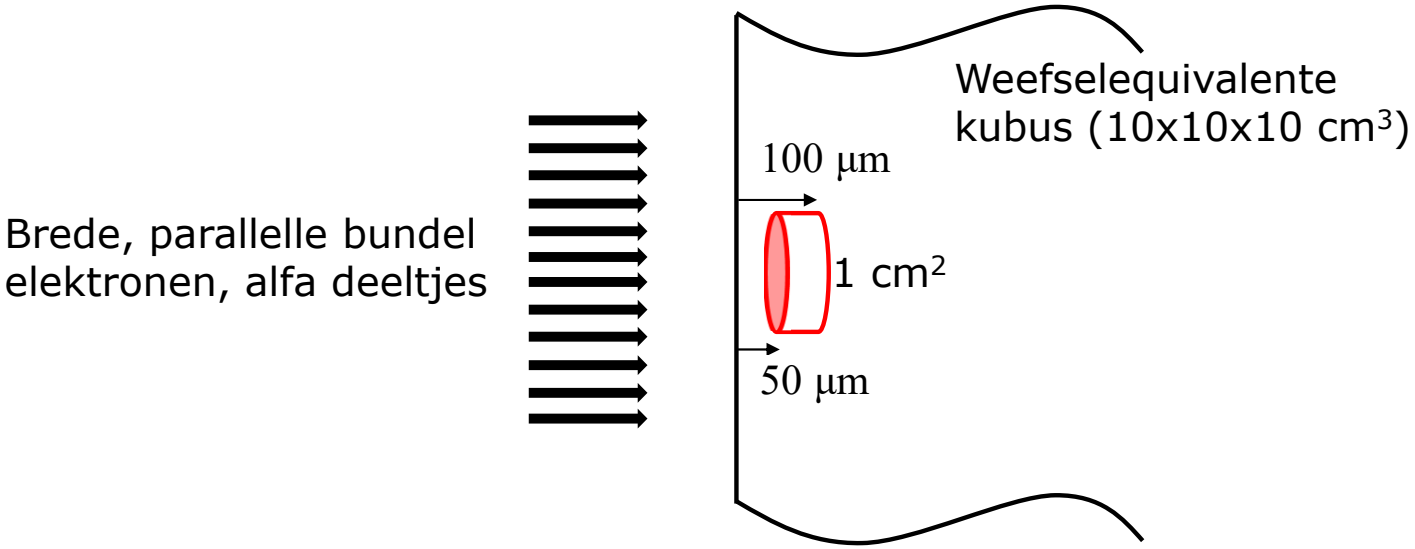


Algehele blootstelling (brede bundel)
Hele huid als 1 orgaan beschouwd
Bijdrage huid aan stochastische effecten

Data from ICRP 116 (2010)
Ann. ICRP 40(2-5)
Supplementary material

Resultaten elektronen (2)
Lokale huiddosis

ICRP-116: Lokale geabsorbeerde huiddosis voor partiële blootstelling

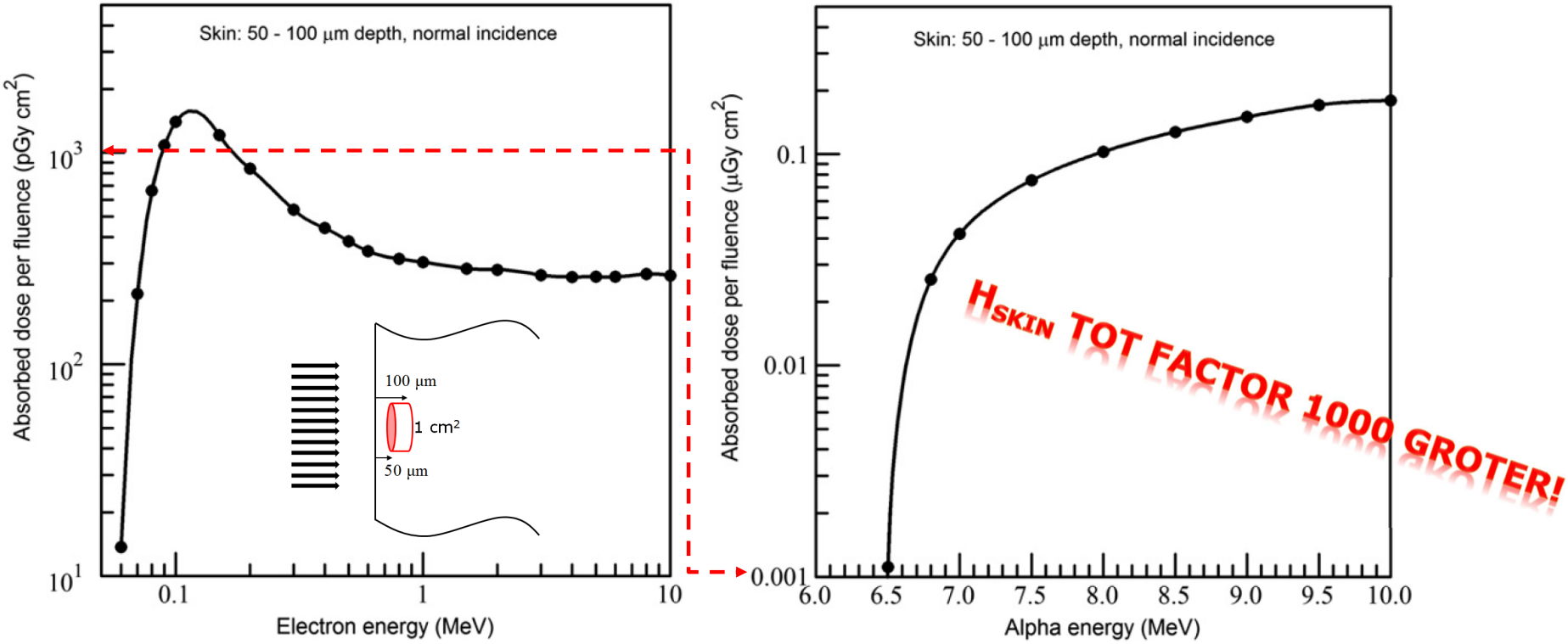


Lokale geabsorbeerde huiddosis (dus gemiddeld over 1 cm² huid) gebruiken voor toetsing aan huiddosislimieten

Resultaten elektronen (3)
Lokale huiddosis

Source images from ICRP 116 (2010)
Ann. ICRP 40(2-5)
(Figs. G.1 and G.2, page 249)

Lokale, **geabsorbeerde** huiddosis



Samenvatting ICRP 116

Update/uitbreiding van ICRP 74 en ICRU 57:
groter energiegebied, meer deeltjes

Op basis van ICRP-103 (nieuwe w_R en w_T)

Voxel fantomen (ICRP-110)

Specifieke dosimetrie voor skelet, ooglens en huid

Loslaten van de kermabenadering

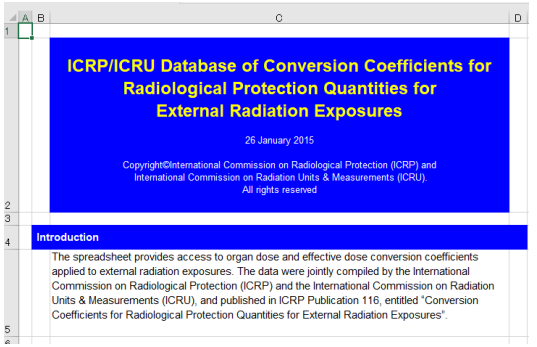
→ Fotonen: $H^*(10)$ is conservatieve schatter voor E tot 3 MeV

Gevolg: nieuwe operationele grootheden (ICRU Rapport 95, 2020)

Nieuwe grootheid: lokale huiddosis → **Alfa stralers!**

Deeltjes- en energiespecifieke waarden, niet nuclidespecifiek

WERKERS
(BEROEPSMATIGE BLOOTSTELLING)


ICRP/ICRU Database of Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures

26 January 2015

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Introduction

The spreadsheet provides access to organ dose and effective dose conversion coefficients applied to external radiation exposures. The data were jointly compiled by the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units & Measurements (ICRU), and published in ICRP Publication 116, entitled "Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures".

ICRP 116, supplementary material:
ICRP116-DB-v2.xls

Externe bestraling bevolking (Environmental exposure)

ICRP Publicatie 144 (2020):
DCC's voor externe blootstelling t.g.v. radionucliden in het milieu

- op en in de grond (groundshine)
- in de lucht (submersie)
- in water (immersie)

Externe bestraling van leden van de bevolking

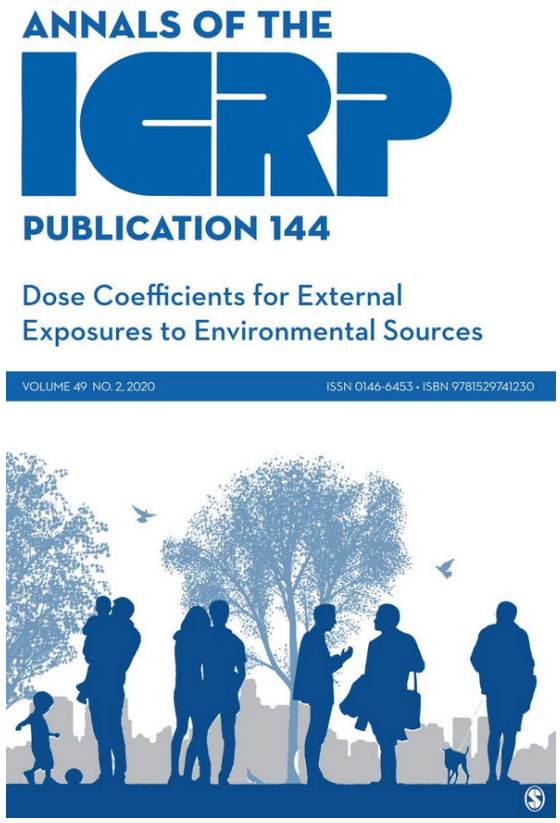
Referentie individuen: baby, 1, 5, 10, 15 jaar en volwassene

Orgaandoses (man en vrouw) en effectieve dosis

Maar ook: dosistempi voor luchtkerma K_a en $H^*(10)$

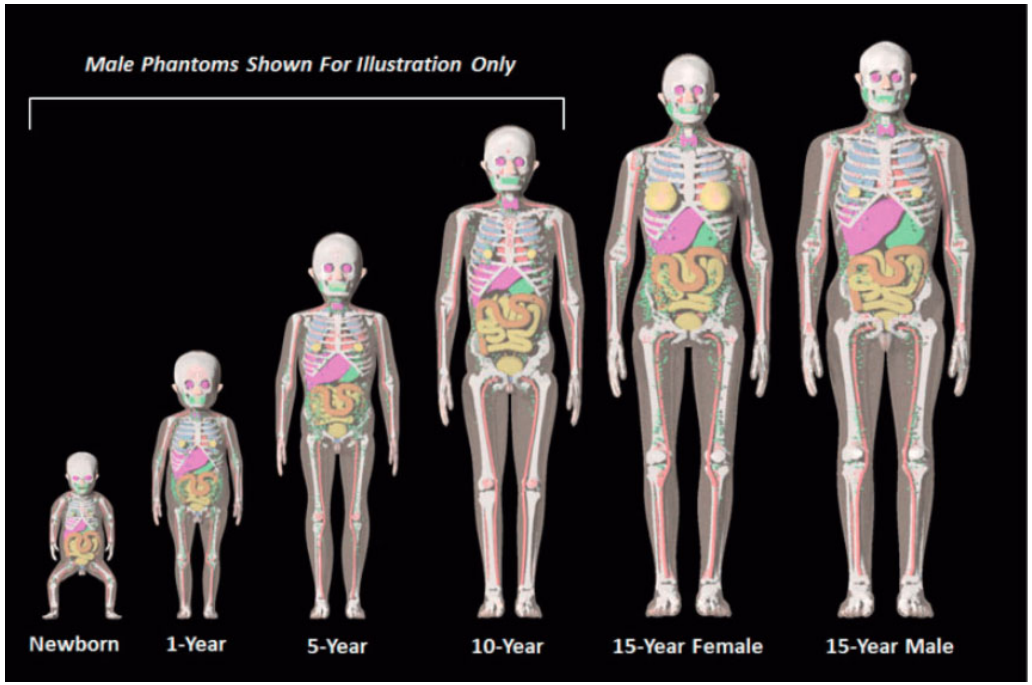
Monoënergetische fotonen en elektronen

Nuclidespecifieke DCC's (1252 radionucliden)

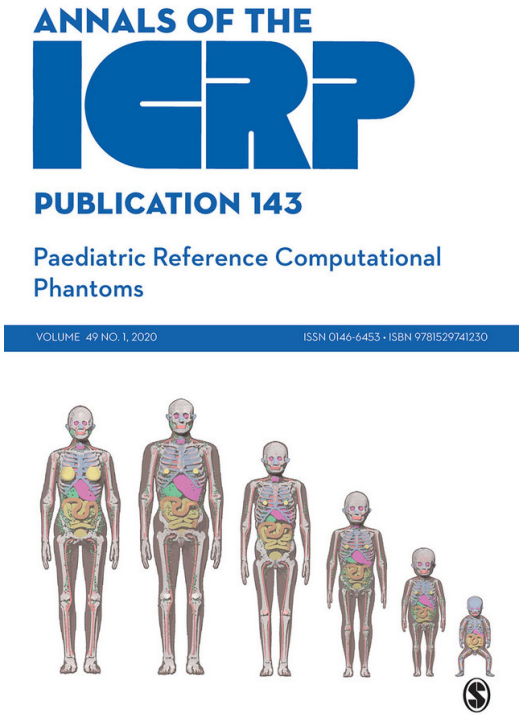


Externe bestraling bevolking
Voxel fantomen voor kinderen

ICRP Publicatie 143 (2020):
Pasgeborenen en kinderen van 1, 5, 10 en 15 jaar (M en V)
Hoge resolutie: 55 Mvoxels (computeranimatie technieken)

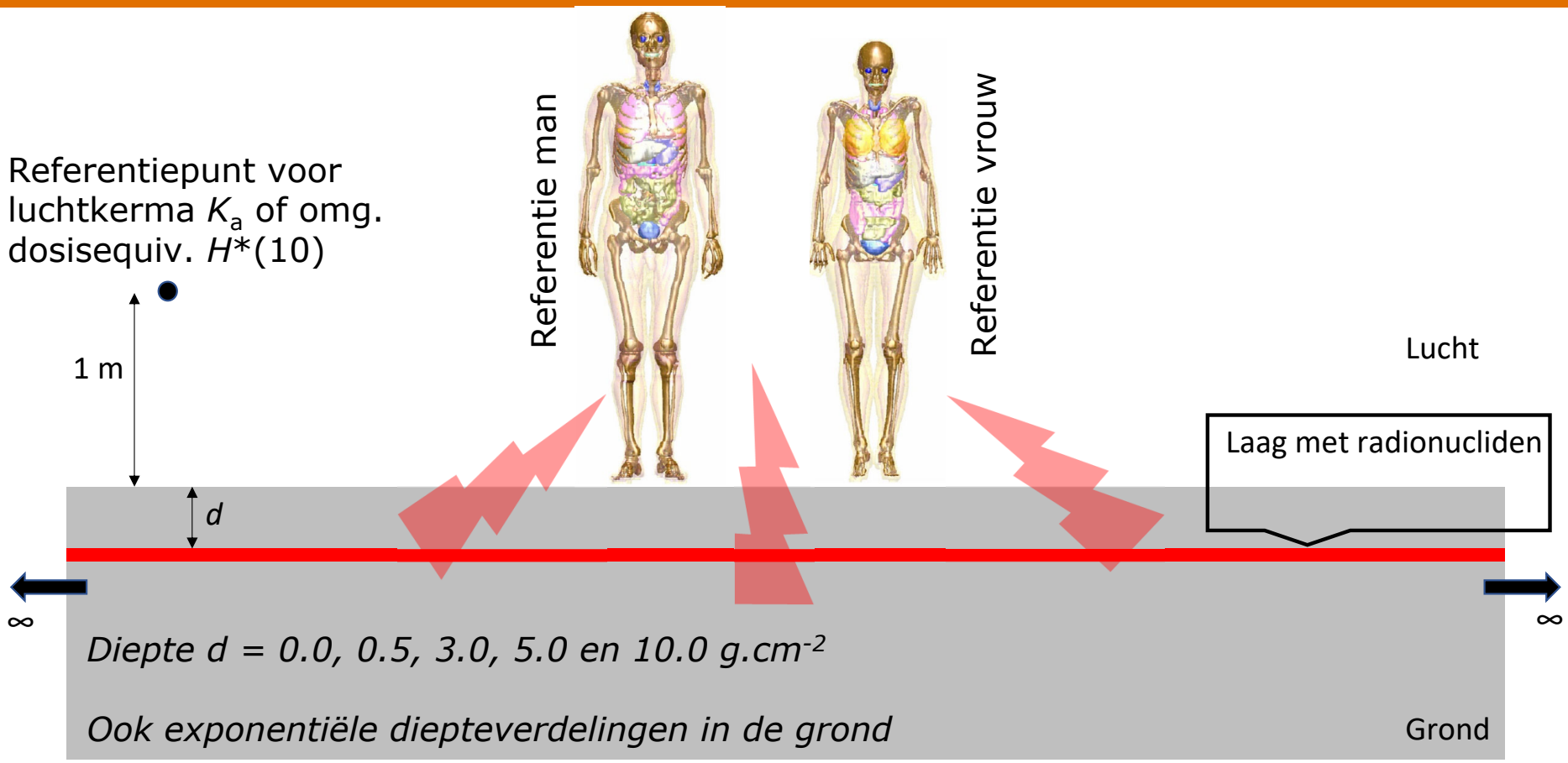


Source image from ICRP Publ.143, Ann. ICRP 49(1), 2020; Fig. 3.3 page 30



- Externe bestraling (ICRP Publ. 144)
- Inwendige besmetting

Externe bestraling bevolking
Grondbesmetting



Source of phantom images from ICRP 116 (2010)
Ann. ICRP 40(2-5)
(Fig. 3.1, page 46)

Externe bestraling bevolking
Alle scenario's

Effective Dose Rate Coefficients

I-131 T1/2: 8.02070 d Decay Mode: B-

Adult	15 yr	10 yr	5 yr	1 yr	Newborn	h*	k	Depth
Air Submersion: Effective Dose Rate Coefficient (nSv/h per Bq/m3)								
5.63E-02	5.88E-02	6.08E-02	6.47E-02	6.63E-02	6.91E-02	1.14E-01	8.25E-02	
Ground Plane: Effective Dose Rate Coefficient (nSv/h per Bq/m2)								
1.36E-03	1.41E-03	1.51E-03	1.70E-03	1.94E-03	2.31E-03	2.29E-03	1.75E-03	0.0 g.cm-2
8.25E-04	8.62E-04	9.26E-04	1.02E-03	1.10E-03	1.23E-03	1.57E-03	1.17E-03	0.5 g.cm-2
4.59E-04	4.79E-04	5.10E-04	5.55E-04	5.80E-04	6.26E-04	9.18E-04	6.73E-04	3.0 g.cm-2
1.89E-04	1.98E-04	2.11E-04	2.29E-04	2.39E-04	2.56E-04	4.11E-04	2.92E-04	10 g.cm-2
Exponential Ground Distribution: Effective Dose Rate Coefficient (nSv/h per Bq/m2)								
8.71E-04	9.10E-04	9.78E-04	1.08E-03	1.18E-03	1.32E-03	1.64E-03	1.23E-03	0.5 g.cm-2
7.61E-04	7.95E-04	8.53E-04	9.38E-04	1.01E-03	1.12E-03	1.45E-03	1.08E-03	1.0 g.cm-2
5.93E-04	6.19E-04	6.63E-04	7.27E-04	7.77E-04	8.54E-04	1.15E-03	8.55E-04	2.5 g.cm-2
4.55E-04	4.75E-04	5.08E-04	5.55E-04	5.91E-04	6.46E-04	9.00E-04	6.63E-04	5.0 g.cm-2
3.21E-04	3.35E-04	3.58E-04	3.91E-04	4.14E-04	4.50E-04	6.46E-04	4.73E-04	10.0 g.cm-2
2.07E-04	2.17E-04	2.31E-04	2.52E-04	2.67E-04	2.89E-04	4.24E-04	3.09E-04	20.0 g.cm-2
1.16E-04	1.21E-04	1.30E-04	1.42E-04	1.49E-04	1.62E-04	2.41E-04	1.75E-04	50.0 g.cm-2
8.59E-05	8.99E-05	9.59E-05	1.05E-04	1.11E-04	1.19E-04	1.80E-04	1.30E-04	100.0 g.cm-2
Water Immersion: Effective Dose Rate Coefficient (nSv/h per Bq/m3)								
2.08E-04	2.16E-04	2.28E-04	2.49E-04	2.64E-04	2.84E-04			

Note:
h* is the ambient dose equivalent rate coefficient (nSv/h per Bq/m3 or Bq/m2)
k is the air kerma rate coefficient (nGy/h per Bq/m3 or Bq/m2)

$H^*(10)$ en K_a tempo

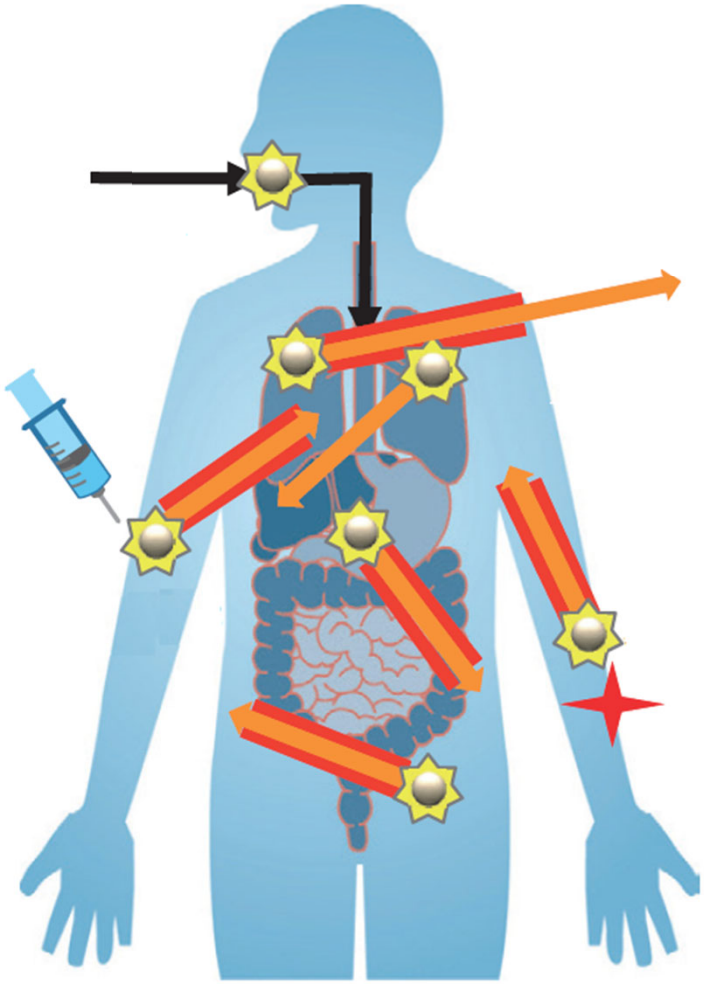
Submersie: nSv/h per Bq/m^3

Grondbesmetting:
nSv/h per Bq/m^2



Immersie: nSv/h per Bq/m^3

Screenshot: EDC_Viewer, ICRP



Adapted from following source:
Ministry of the Environment , Japan, website:
https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-02-01.pdf
Accessed: September 20, 2019

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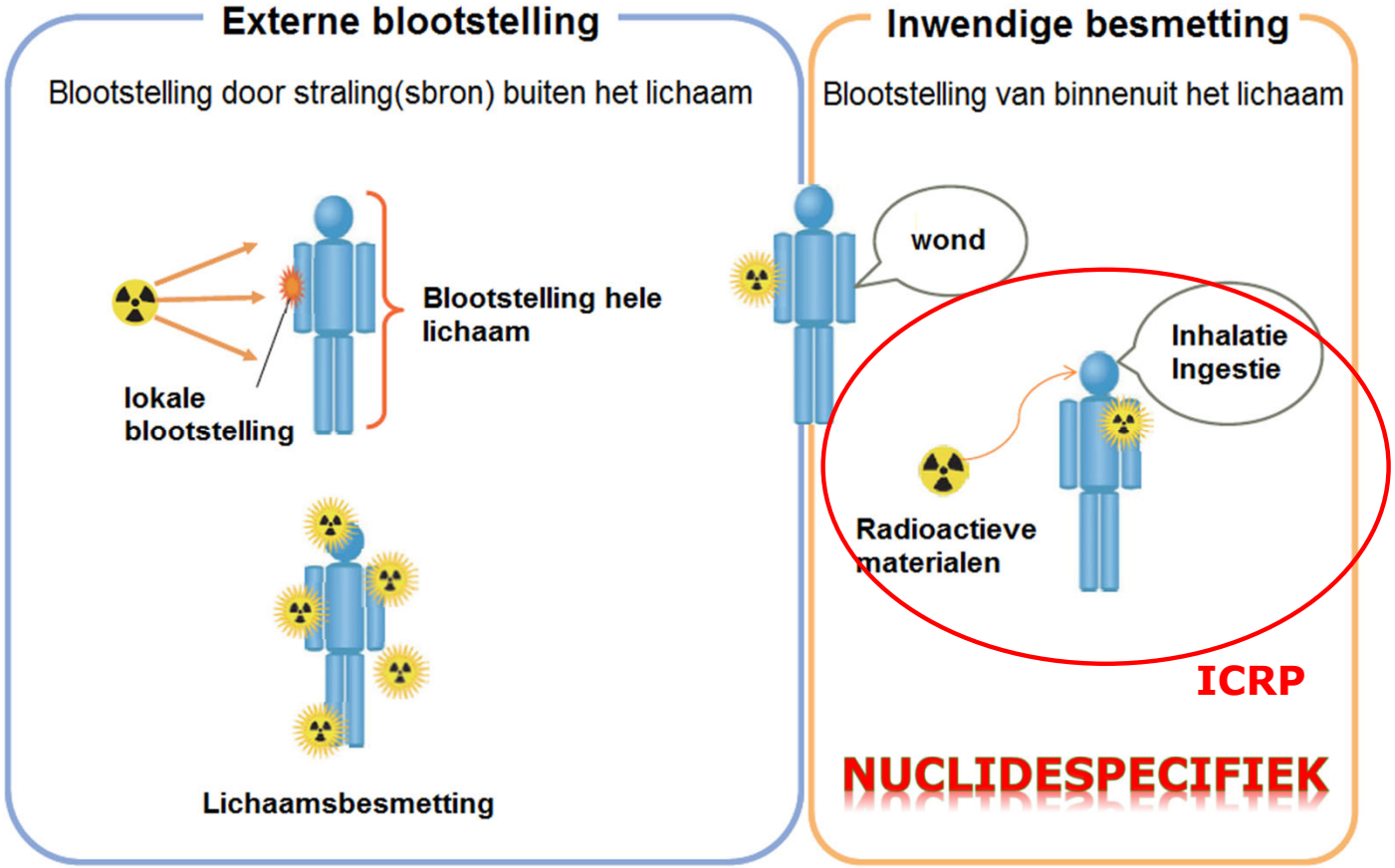
en Milieu
*Ministerie van Volksgezondheid,
Welzijn en Sport*

Inhoud

1. Algemene inleiding
2. Externe straling (ICRP 116 en 144)
3. **Inwendige besmetting (ICRP 130+)**

Inwendige besmetting

Image adapted from following source:
Ministry of the Environment , Japan, website:
https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-01-01.pdf
Accessed: August 22, 2019

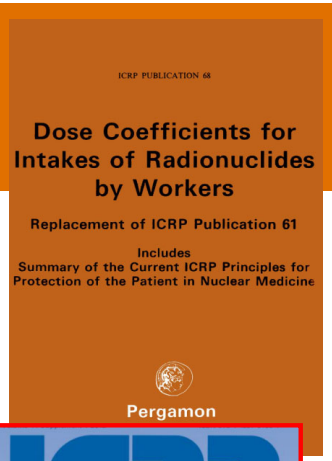


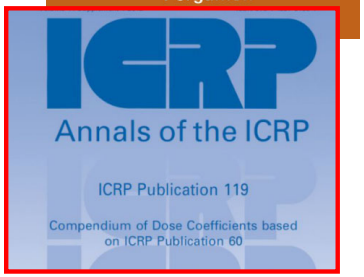
Oude DCC's werkers

DCC's inhalatie en ingestie

ICRP Publicatie 68 (1994) o.b.v. ICRP-60 (1991)

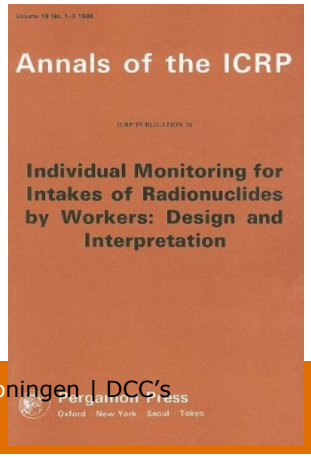
Compilatie in ICRP 119 (2012)





Interpretatie bioassay data / opzet monitoring programma

ICRP Publicatie 54 (1989)
ICRP Publicatie 78 (1997)



Nieuwe DCC's werkers ICRP 130 (2015)

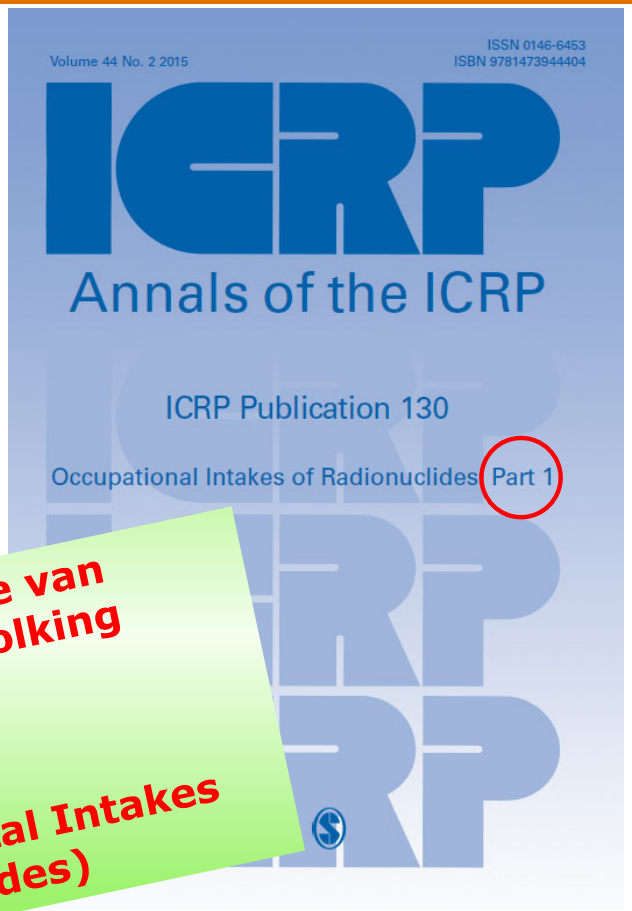
OIR series: Occupational Intakes of Radionuclides

Deel 1:

Introductie
Beschrijving van de:

- Biokinetiek
- Dosimetrie

Monitoring methoden
Bioassay data



Ook voor update van DCC's voor bevolking

"EIR Series"

(Environmental Intakes of Radionuclides)

Deel 2-5:

DCC's
Specifieke modellen

2) H, C, P, S, Ca, Fe, Co, Zn, Sr, Y, Zr, Nb, Mo, Tc — ICRP-134

3) Ru, Sb, Te, I, Cs, Ba, Ir, Pb, Bi, Po, Rn, Ra, Th, U — ICRP-137

4) Lanthaniden en Actiniden — ICRP-141

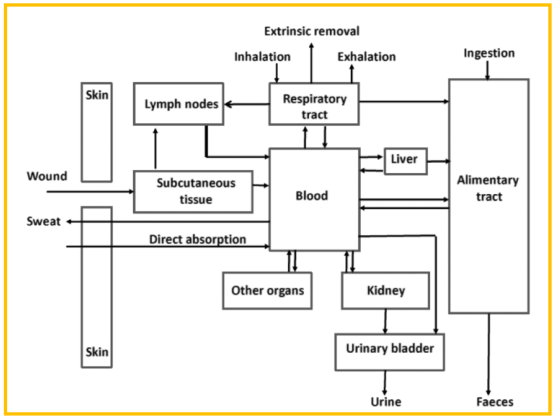
5) F, Na, Mg, K, Mn, Ni, Se, Mo, Tc, Ag,.. — ICRP-??

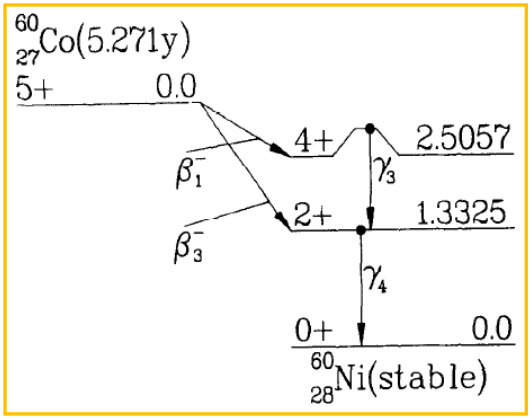
Ingrediënten voor inwendige DCC's

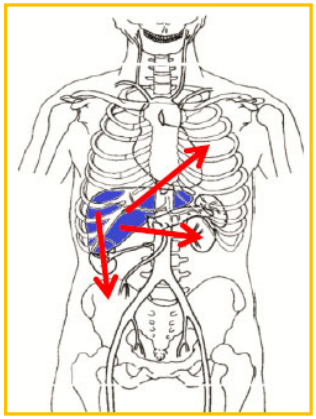
Inname en systemische biokinetische modellen

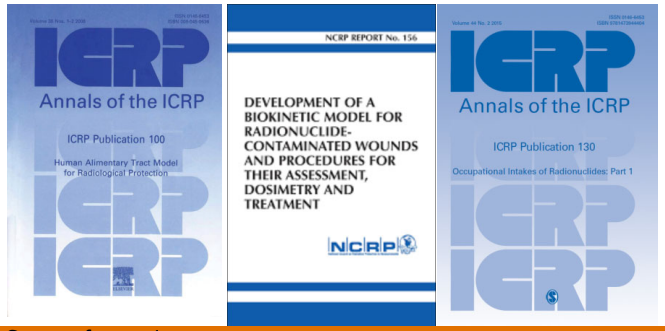
Nucleaire vervaldata radionucliden

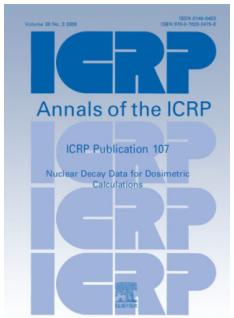
Referentiefantomen stralingstransport

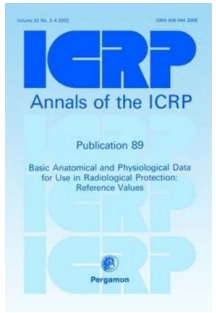


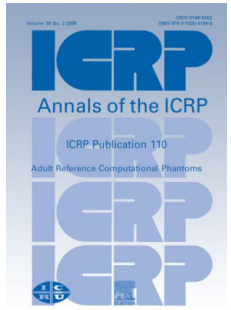










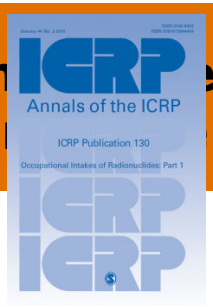


Source of upper images:
Left: ICRP 130 (2015), Ann. ICRP 44(2), Fig. 3.1 page 57
Middle: ICRP 38 (1983), Ann. ICRP 11-13, page 63 (superseded by ICRP 107)
Right: Presentation W.E. Bolch, ICRP symposium 2015, Seoul, South-Korea (https://www.icrp.org/docs/icrp2015/17%20Wesley%20Bolch%202015.pdf)

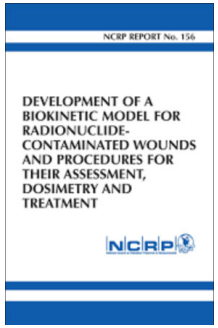
Generieke biokinetische model (ICRP 130)

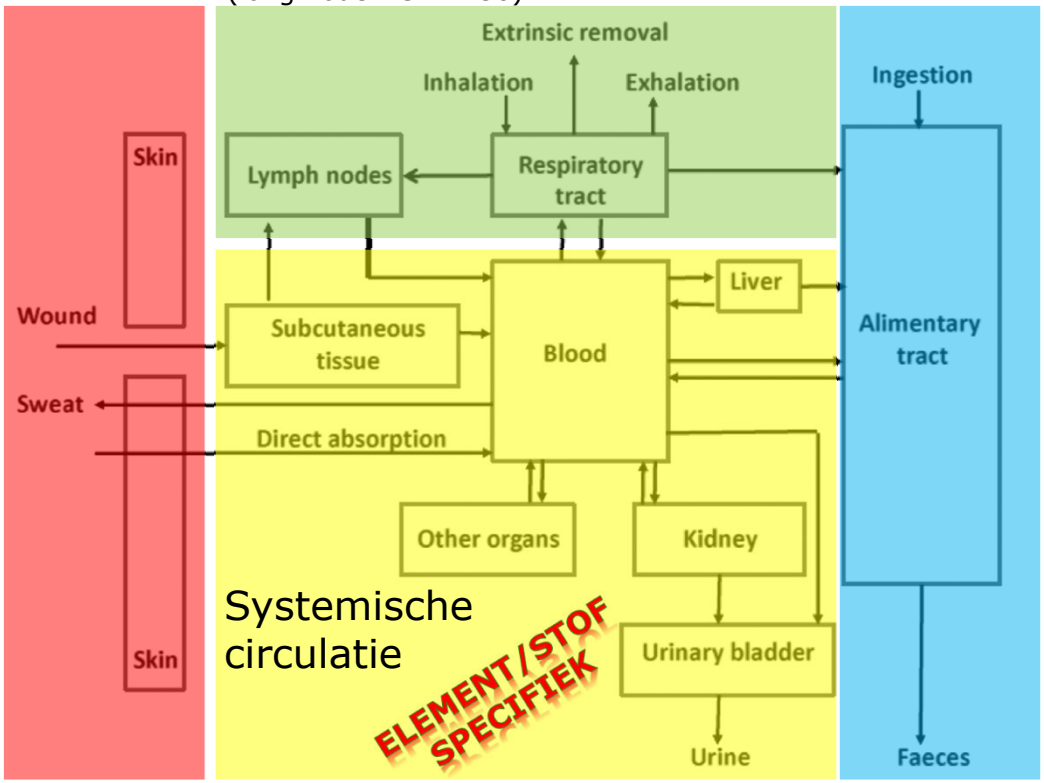
In … en systemische ci…

HRTM, Inhalatie,
ICRP 66 met aanpassingen
(longmodel ICRP-130)

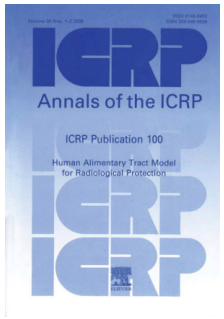


Wondmodel
NCRP-156



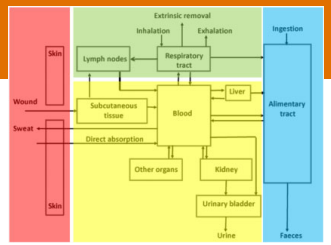


HATM
Ingestie
ICRP 100
(Spijsvertering)

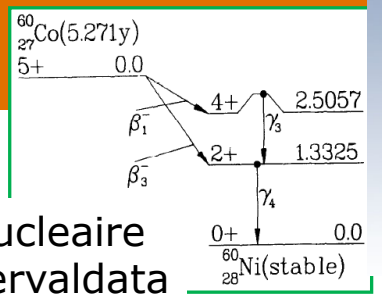


Source image from ICRP 130 (2015)
Ann. ICRP 44(2)
(Fig. 3.1 page 57)

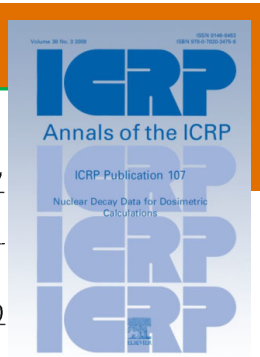
Route naar DCC's (1)



Biokinetische modellen



Nucleaire vervaldata



Inname (ingestie, inhalatie)

Verdeling over weefsels/organen

Desintegraties in weefsels/organen

Uitgezonden stralingsdeeltjes

$$\int_0^{\tau} A_T(t)\,\mathrm{d}t$$

Geabsorbeerde orgaandosis D_T (Gy)

w_R

Equivalente orgaandosis H_T (Sv)

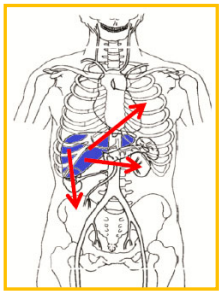
w_T

Effectieve dosis E (Sv)

$$e(\tau) = \sum_T w_T \left[\frac{h_T^M(\tau) + h_T^F(\tau)}{2}\right]$$

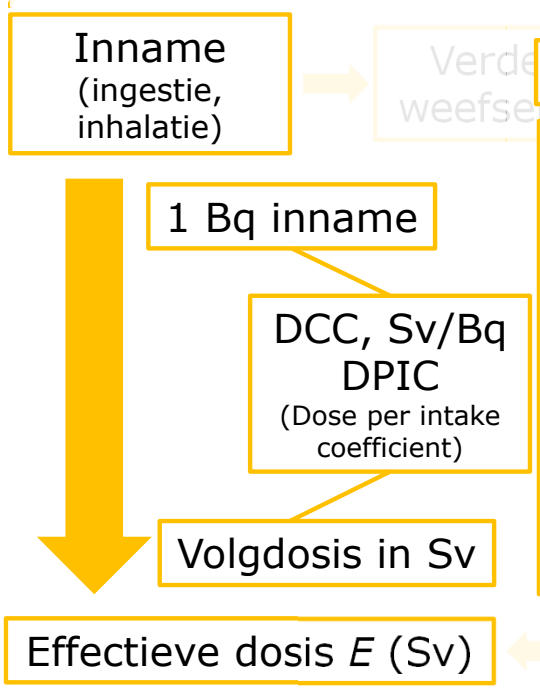
Uit ICRP 116





Dosimetrie
Fantomen
Transport

Route naar DCC's (2)



Effectieve volgdosis = Inname x DCC

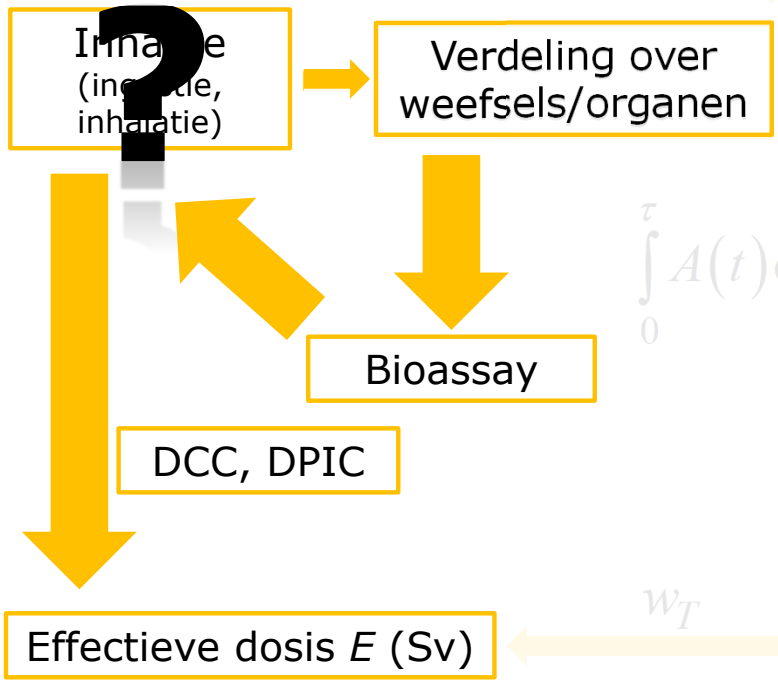
Table 12.5. Committed effective dose coefficients (Sv Bq^{-1}) for the inhalation or ingestion of ^{95}Zr compounds.

	Effective dose coefficients (Sv Bq^{-1})
Inhaled particulate materials (5 μm AMAD aerosols)	^{95}Zr
Type F	2.9E-09
Type M, oxalate, all unspecified forms	1.9E-09
Type S, carbonate, oxide, tritide	2.6E-09
Ingested materials	
f_A=0.002, all chemical forms	3.2E-10

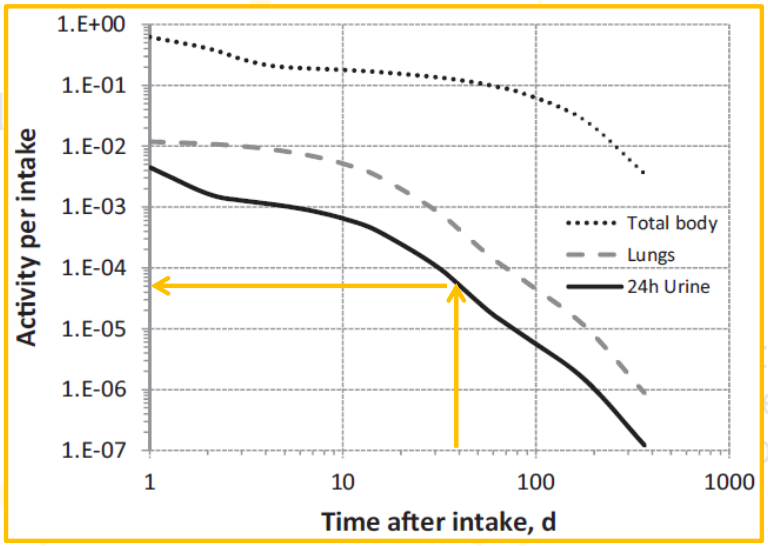
AMAD, activity median aerodynamic diameter.

Bron: ICRP-134, p. 276 (Tabel 12.5)

Bioassays (1)
Retentie en excretie

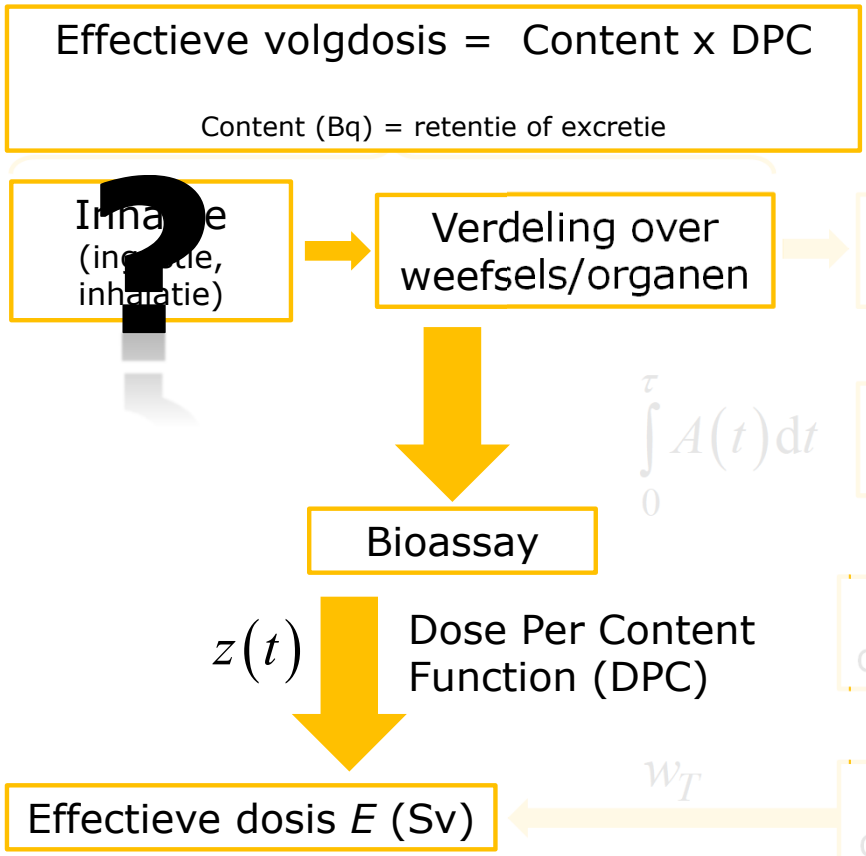


Referentie Bioassay Functie
(Retentie en excretie)



Bron:
ICRP-134, p. 278
Figuur 12.3
(nuclide: Zr-95)

Bioassays (2)
Dose Per Content



DPC function $z(t)$
Sv/Bq$_{content}$

Type F

Time after intake (d)	Total body	Lungs	Urine
1	4.6E-09	2.4E-07	6.4E-07
2	7.1E-09	2.6E-07	1.7E-06
3	1.1E-08	2.9E-07	2.2E-06
4	1.3E-08	3.2E-07	2.5E-06
5	1.4E-08	3.5E-07	2.8E-06
6	1.5E-08	3.8E-07	3.1E-06
7	1.5E-08	4.2E-07	3.4E-06
8	1.6E-08	4.6E-07	3.7E-06
9	1.6E-08	5.1E-07	4.0E-06
10	1.6E-08	5.6E-07	4.4E-06
15	1.7E-08	8.8E-07	7.0E-06
30	2.1E-08	3.2E-06	2.6E-05
45	2.5E-08	9.5E-06	7.8E-05
60	3.0E-08	2.1E-05	1.7E-04
90	4.1E-08	5.1E-05	4.1E-04
180	1.1E-07	2.7E-04	2.0E-03
365	8.2E-07	3.3E-03	2.4E-02

Bron:
ICRP-134, p. 277
Tabel 12.6
(nuclide: Zr-95)

Nieuwe DCC's werkers: wat is aangepast?

Implementatie van ICRP-103 (w_R, w_T)

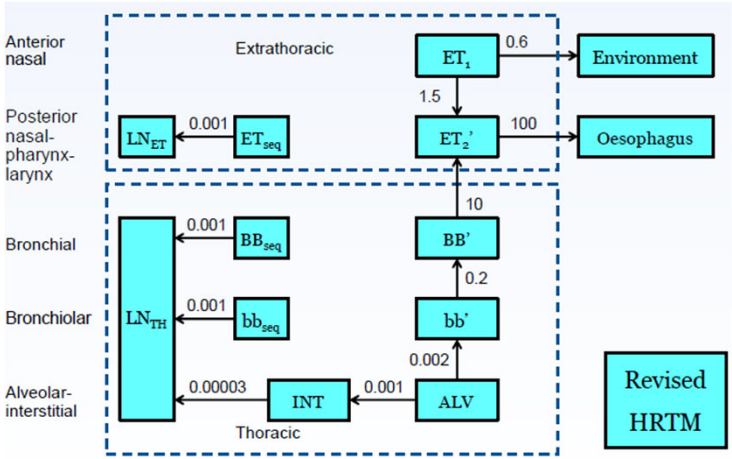
Update biokinetische modellen (# desintegraties/50 jaar)

Nieuwe regels voor radioactieve dochters (biokinetiek)

Aangepast longmodel HRTM (ICRP-130, 2017)

Nieuw model maag-darmkanaal HATM (ICRP-100, 2006)

Nieuwe vervaldata (ICRP-107, 2008)



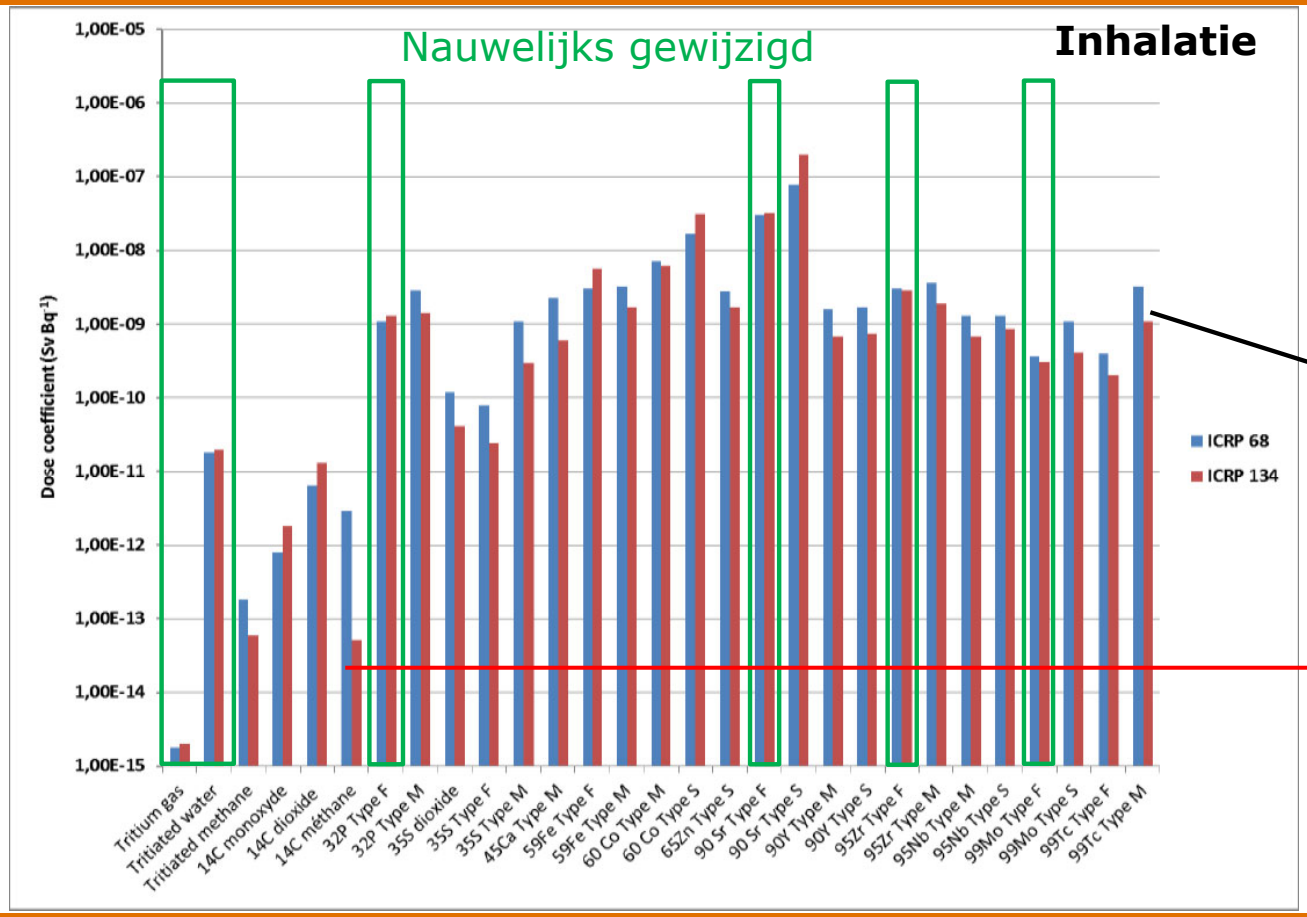
Nieuwe voxelfantomen (ICRP-110, 2009) → aangepaste dosimetrie

Nieuwe skeletdosimetrie (Dosis-Respons-Functies, ICRP-116, 2010)

Interpretatie bioassay data, DPC functie

Source image from presentation by F. Paquet, ICRP symposium 2017, Paris, France
https://www.icrp.org/docs/icrp2017/5%20Paquet%20Presentation.pdf

Resultaten DCC's: maakt het wat uit?

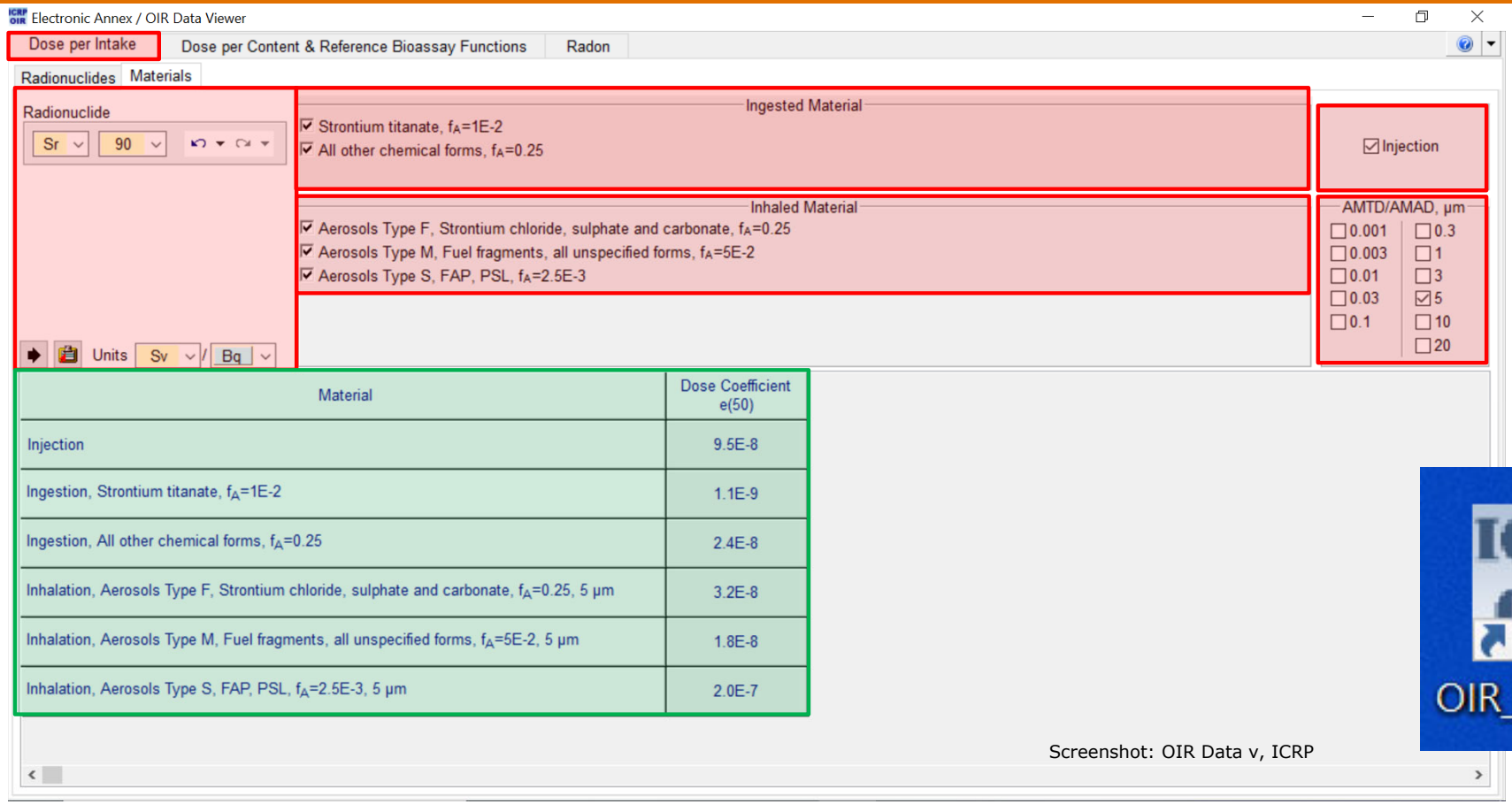


Verandering met factor 2-5 niet ongebruikelijk

Soms ook >10

Source image from presentation by F. Paquet, ICRP symposium 2017, Paris, France
https://www.icrp.org/docs/icrp2017/5%20Paquet%20Presentation.pdf

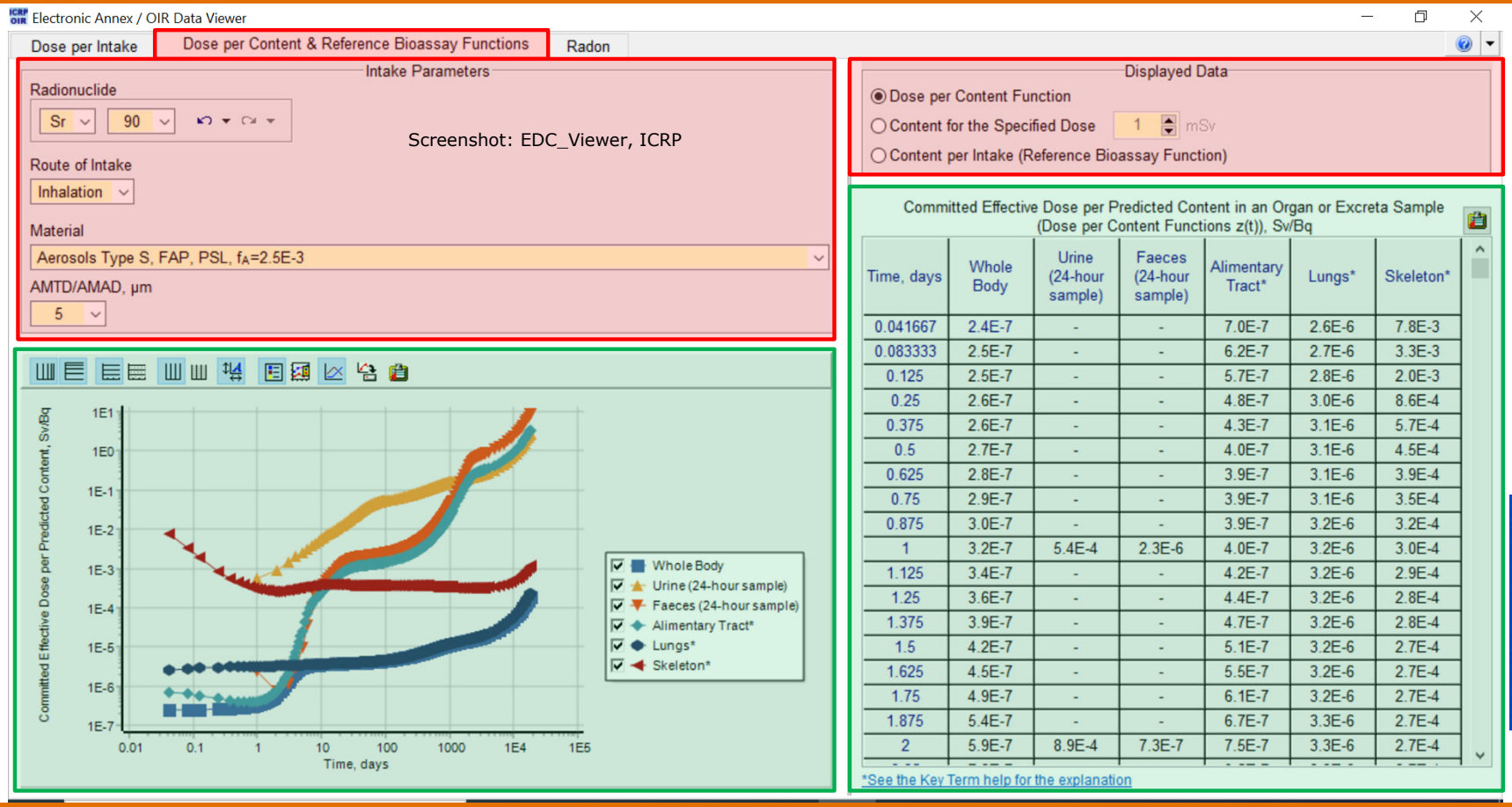
Resultaten DCC's: OIR Data Viewer (1)



Screenshot: OIR Data v, ICRP



Resultaten DCC's: OIR Data Viewer (2)



Time, days	Whole Body	Urine (24-hour sample)	Faeces (24-hour sample)	Alimentary Tract*	Lungs*	Skeleton*
0.041667	2.4E-7	-	-	7.0E-7	2.6E-6	7.8E-3
0.083333	2.5E-7	-	-	6.2E-7	2.7E-6	3.3E-3
0.125	2.5E-7	-	-	5.7E-7	2.8E-6	2.0E-3
0.25	2.6E-7	-	-	4.8E-7	3.0E-6	8.6E-4
0.375	2.6E-7	-	-	4.3E-7	3.1E-6	5.7E-4
0.5	2.7E-7	-	-	4.0E-7	3.1E-6	4.5E-4
0.625	2.8E-7	-	-	3.9E-7	3.1E-6	3.9E-4
0.75	2.9E-7	-	-	3.9E-7	3.1E-6	3.5E-4
0.875	3.0E-7	-	-	3.9E-7	3.2E-6	3.2E-4
1	3.2E-7	5.4E-4	2.3E-6	4.0E-7	3.2E-6	3.0E-4
1.125	3.4E-7	-	-	4.2E-7	3.2E-6	2.9E-4
1.25	3.6E-7	-	-	4.4E-7	3.2E-6	2.8E-4
1.375	3.9E-7	-	-	4.7E-7	3.2E-6	2.8E-4
1.5	4.2E-7	-	-	5.1E-7	3.2E-6	2.7E-4
1.625	4.5E-7	-	-	5.5E-7	3.2E-6	2.7E-4
1.75	4.9E-7	-	-	6.1E-7	3.2E-6	2.7E-4
1.875	5.4E-7	-	-	6.7E-7	3.3E-6	2.7E-4
2	5.9E-7	8.9E-4	7.3E-7	7.5E-7	3.3E-6	2.7E-4



Het nieuwe Handboek Radionucliden

data voor 116 radionucliden

Taal: Engels

Nieuwe DCC's in het handboek opgenomen

Pas op: bronconstanten voor nieuwe operationele grootheid H^*
(foutief benoemd als $H^*(10)$)

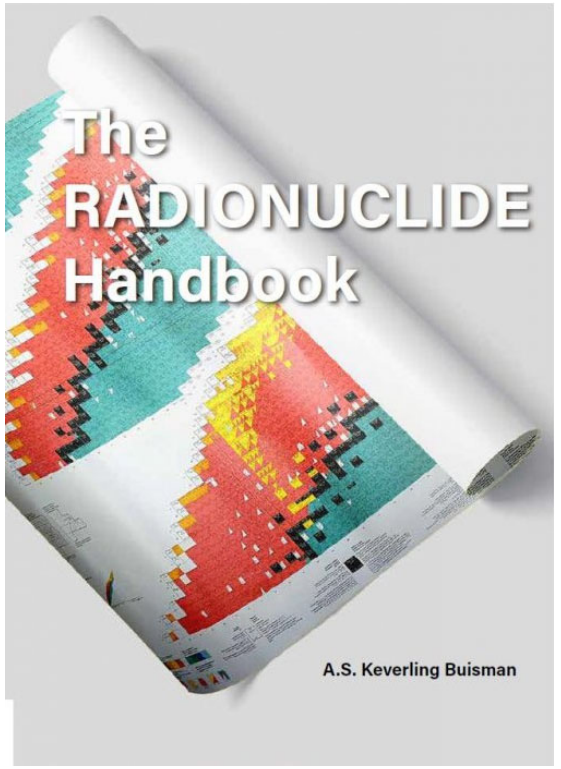
Nieuwe DCC's voor inhalatie, ingestie en injectie uit:
ICRP-134, 137 en 141

Missende nucliden: DCC's uit ICRP-119 (oude waarden)

Waar mogelijk e(50) voor radiofarmaca uit ICRP-128

Ook DCC's huidbesmetting (β, ICRP-107), submersie (ICRP-119)

Nieuwe gegevens bioassay (maar geen DPC!)



Leerdoelen

Na afloop van de scholing is de deelnemer op de hoogte van de **recente ontwikkelingen betreffende dosisconversiecoëfficiënten** voor:

- externe straling (ICRP 116 en ICRP 144);
- inwendige besmetting (inhalatie en ingestie, ICRP 130+).

Met aandacht voor de belangrijkste:

- ingrediënten van
- wijzigingen in
- gevolgen van

de nieuwe rekenmethodiek.