HelmholtzZentrum münchen
German Research Center for Environmental Health

Department of Radiation Sciences

Institute of Radiation Protection

Application of age-dependent phantoms for environmental exposures

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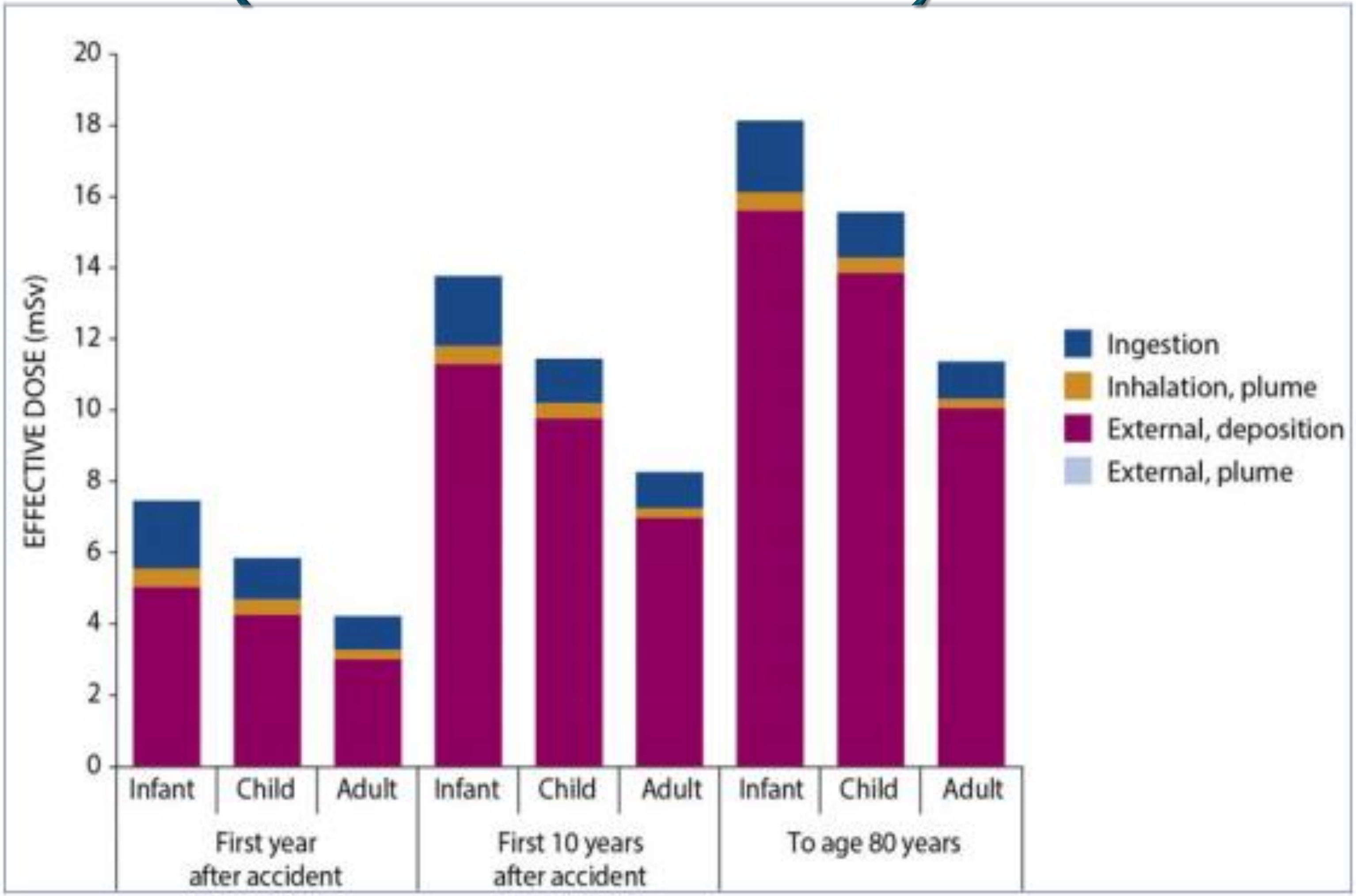
EURADOS Winter School 2018

Effective dose to adults, children and infants, living in the Fukushima city
(from UNSCEAR 2013)



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Some recent work

With the release of the ICRP reference adult computational phantoms and after the occurrence of the accident at the NPP in Fukushima in 2011:

- Petoussi-Henss *et al* (2012)
- Saito *et al* (2012, 2014)
- Yoo *et al* (2013)
- Satoh *et al* (2014, 2015, 2017)
- Bellamy *et al* (2016), Veinot *et al* (2017)

Ongoing:

- ➢ **ICRP Committee 2: External environmental exposures**
- ➢ Federal Guidance Report FRG 15 (in press)

ICRP task group: to establish reference dose coefficients

What is a Dose Coefficient? (external exposures)

A dose (conversion) coefficient in the context of external exposures is defined as either the organ equivalent dose h_T or the effective dose e per unit physical quantity.

The normalizing physical quantities may be:

- Incident particle fluence
- Incident air kerma
- Environmental activity concentration

ICRP task group: establishment of reference dose coefficients

- **Conversion coefficients**:
  measured activity or ambient dose equivalent rates
  → organ and effective dose rate
- **Three different scenarios**
  - Ground contamination
  - Air submersion
  - Water immersion
- **For gamma and beta rasdiations**
- **ICRP reference computational phantoms**
  - Reference adults (ICRP 110)
  - Reference paediatric models

Steps to evaluate organ dose (rate) coefficients

Step 1. Computation of environmental radiation field

- Radiation transport through many mean free paths of air and/or soil

Step 2. Calculation of organ doses and effective doses from the environmental radiation field

- ICRP Phantoms are exposed to the environmental field obtained in Step 1. Radiation transport in human phantoms
- Effective doses are determined based on ICRP 2007 definition

Step 3. Calculation of nuclide-specific dose conversion coefficients

- Nuclear decay data of ICRP107 are utilized

Simulation of the environmental field: soil contamination

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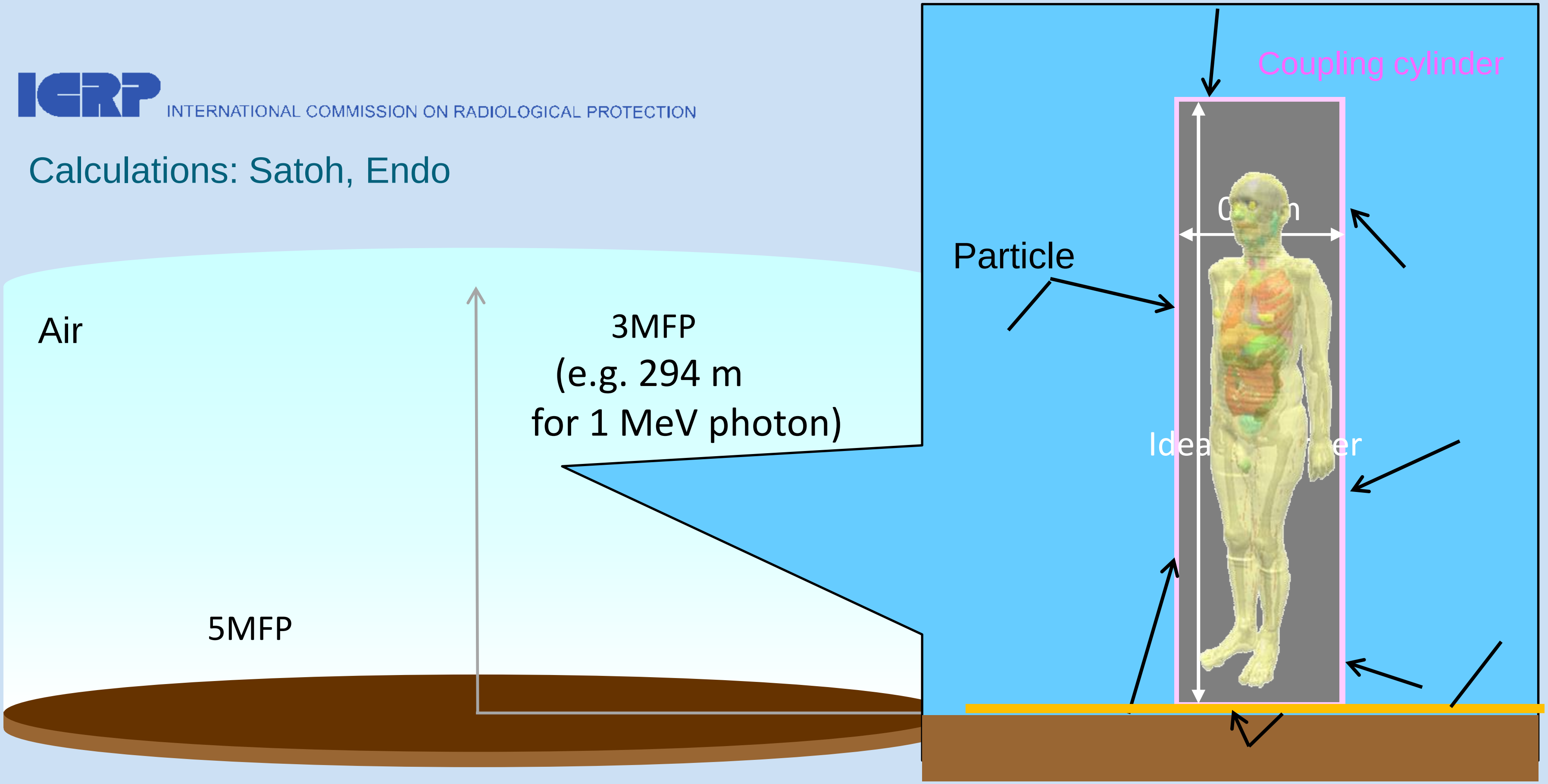
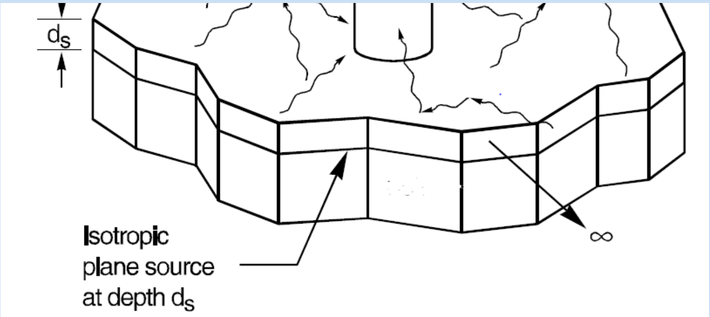
Calculations: Satoh, Endo



Isotropic infinite planar sources
25 energies from 0.01 to 8 MeV



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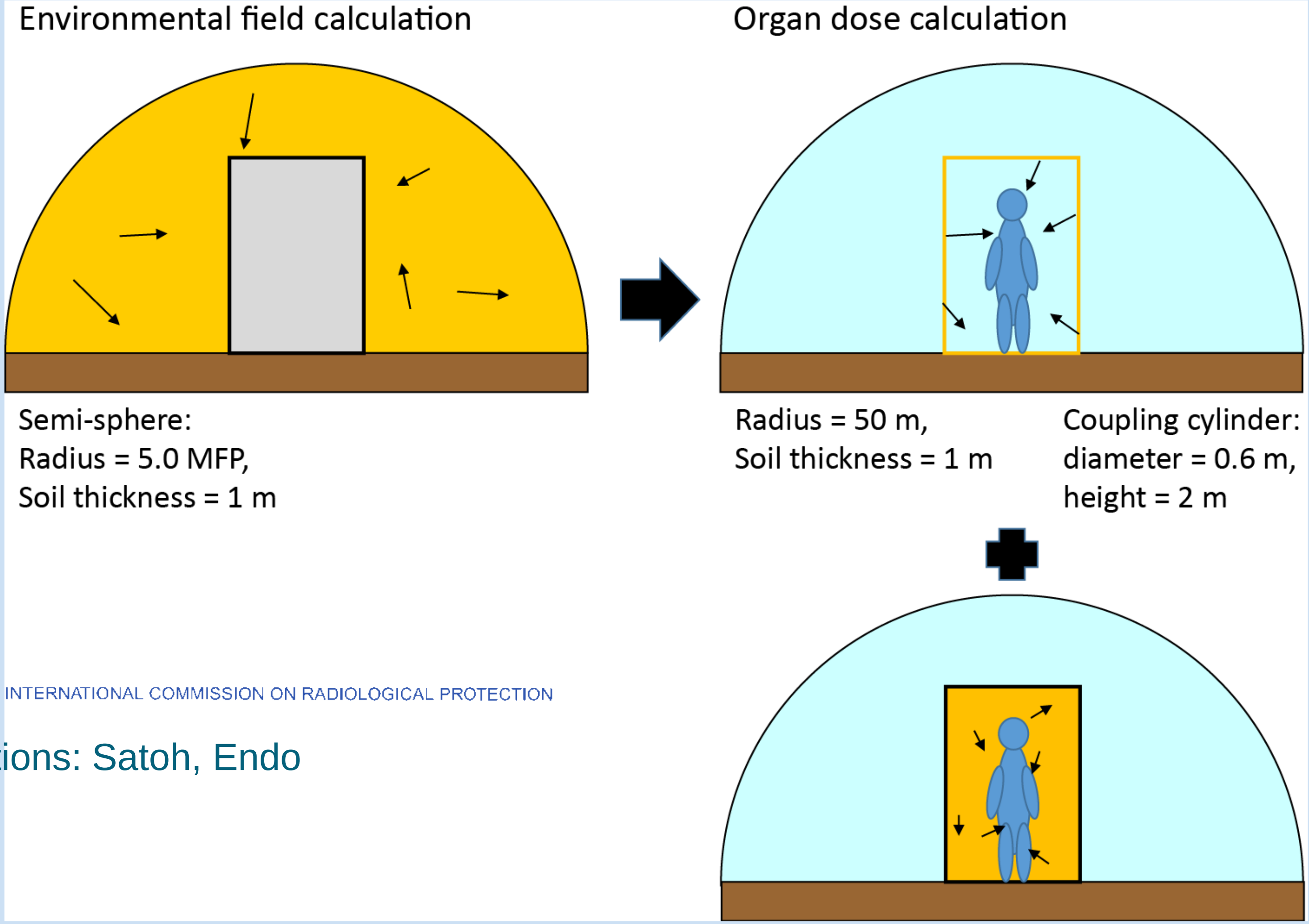
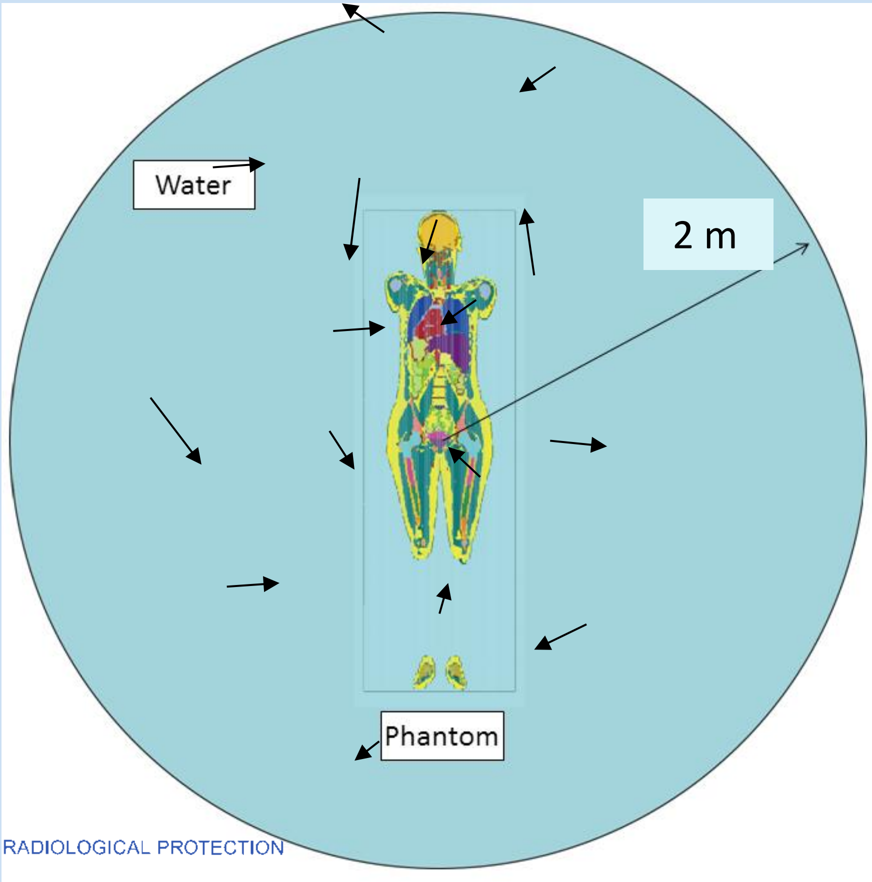
Geometry simulating the environmental field due to submersion to contaminated air



ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Calculations: Satoh, Endo

Geometry simulating the environmental field due to water immersion



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Calculations: Satoh, Endo, Hunt, Jansen, Yeom, Yoo

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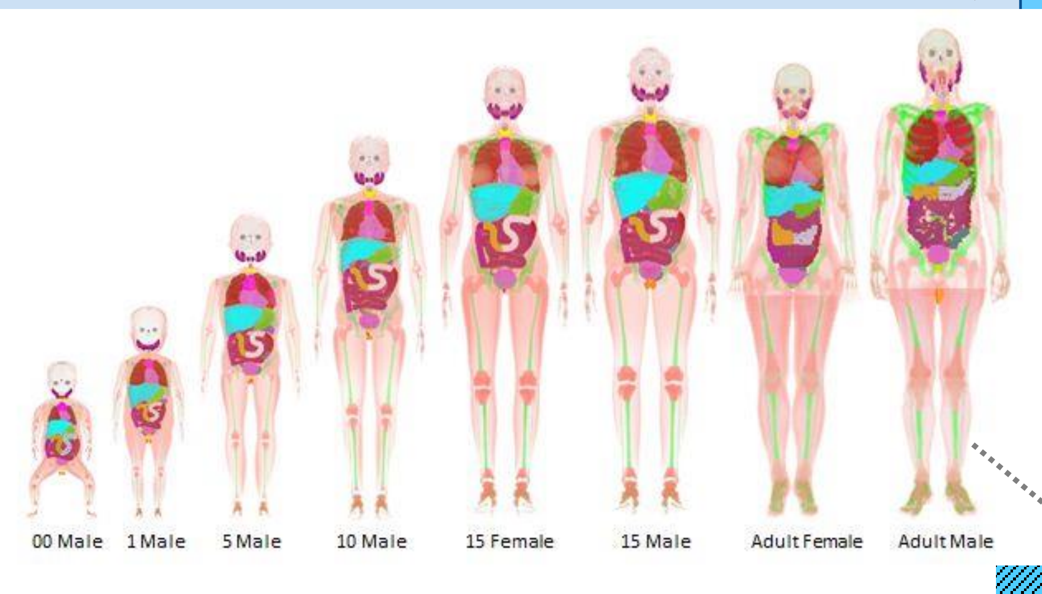
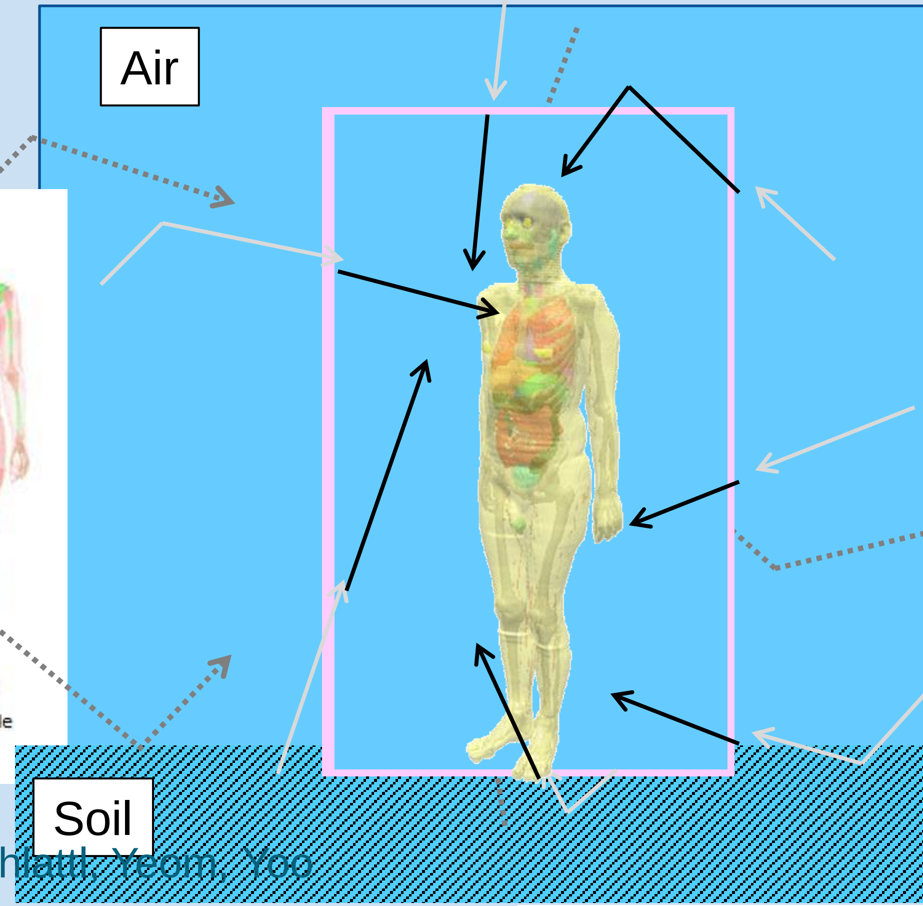
Computation organ and effective doses in the environmental radiation field

Effective dose, *E*, (Sv)

$$E = \sum_{T} w_{T} \sum_{R} w_{R} D_{T,R}$$



Coupling cylinder



Calculations: Satoh, Endo, Jansen, Hunt, Lee, Schlattl, Yeom, Yoo

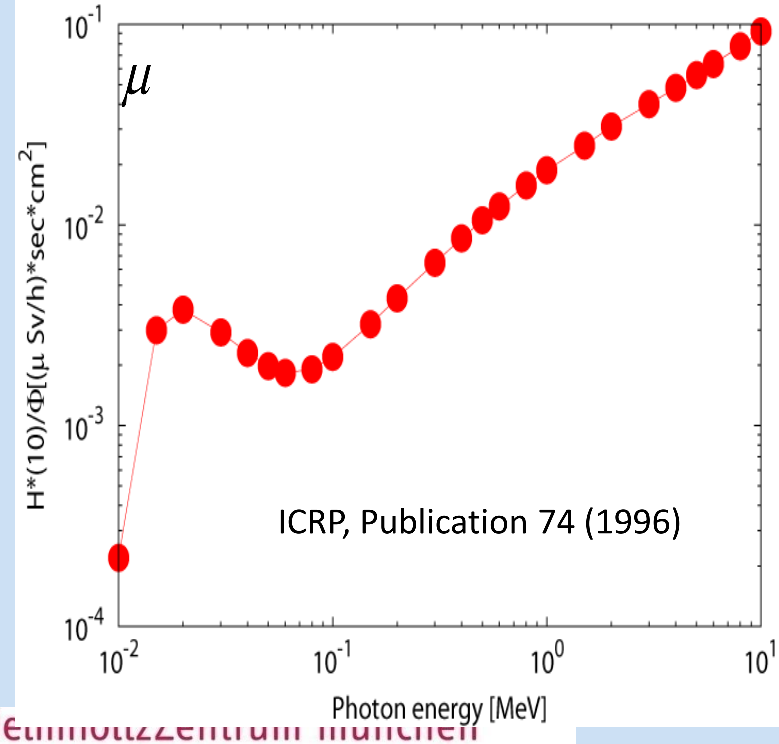
Ambient dose equivalent, H*(10), at a height of 1 m above ground

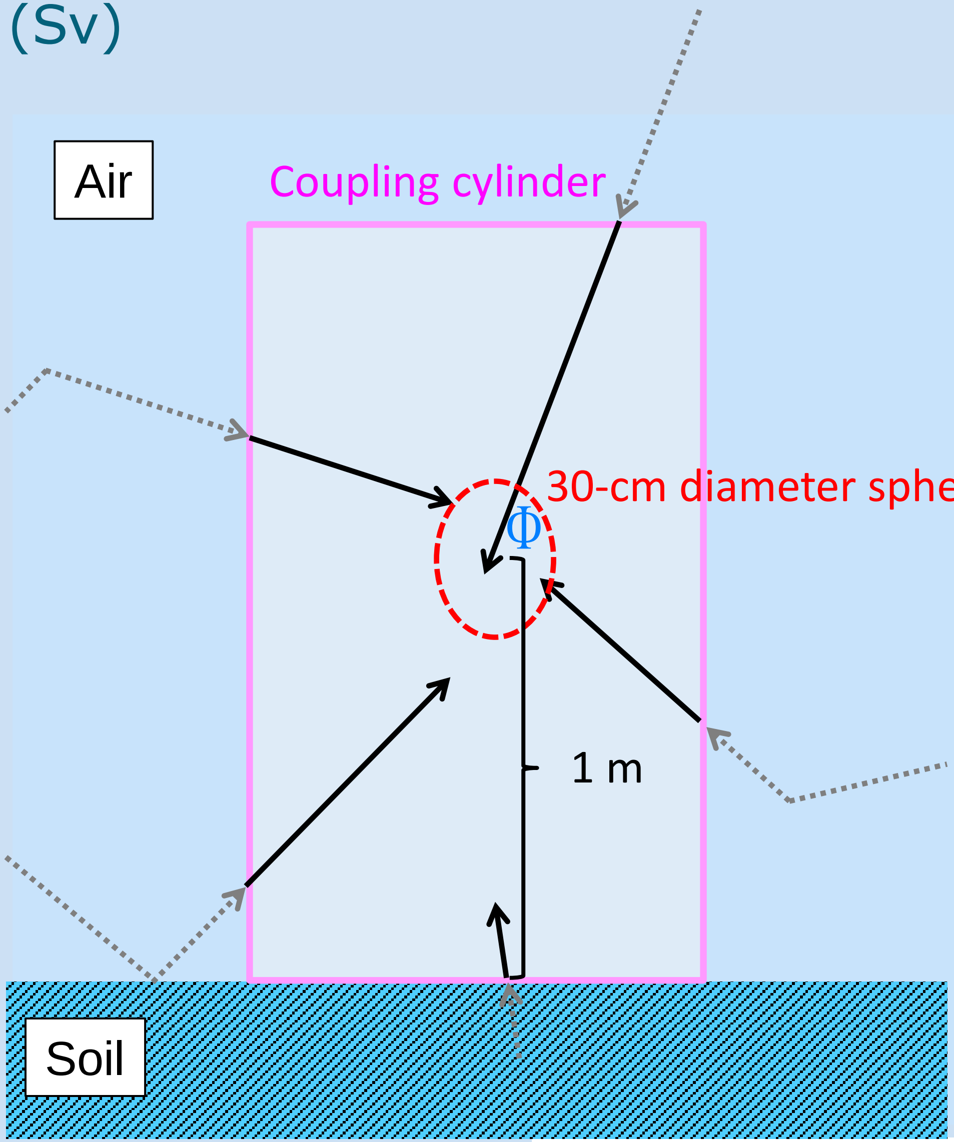
Ambient dose equivalent, *H**(10), (Sv)

$$H^*(10) = \sum \Phi(E) \cdot \mu(E)$$

Φ : photon fluence (1/cm²)

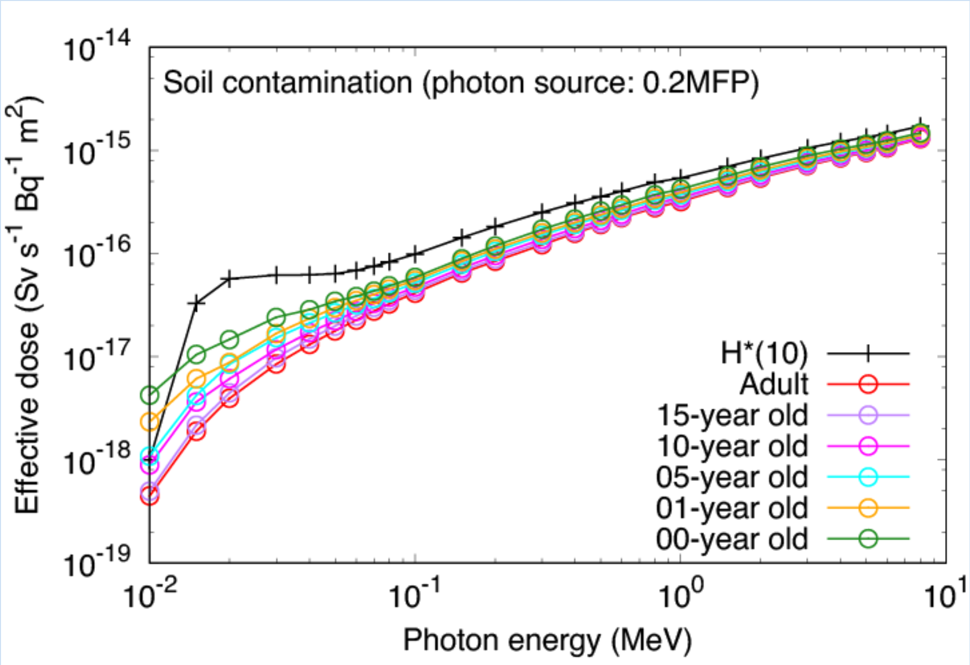
μ : conversion coefficient* for ambient dose equivalent from photon fluence (pSv cm²)

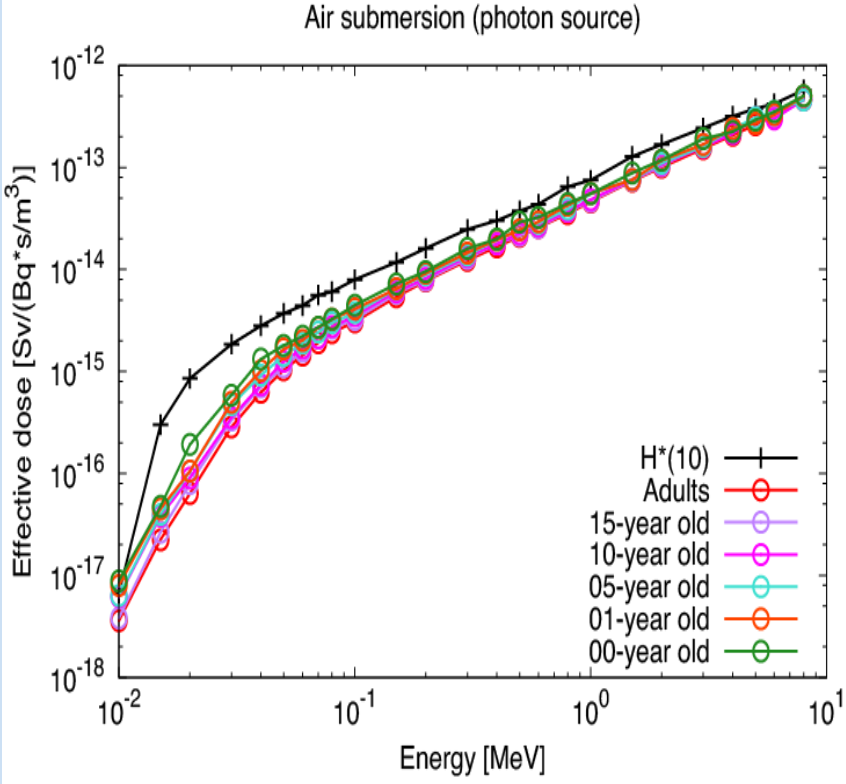




Calculations: Satoh, Endo

Age dependency of effective dose coefficients





*H**(10) vs *E*:
Conservative approach mostly retained

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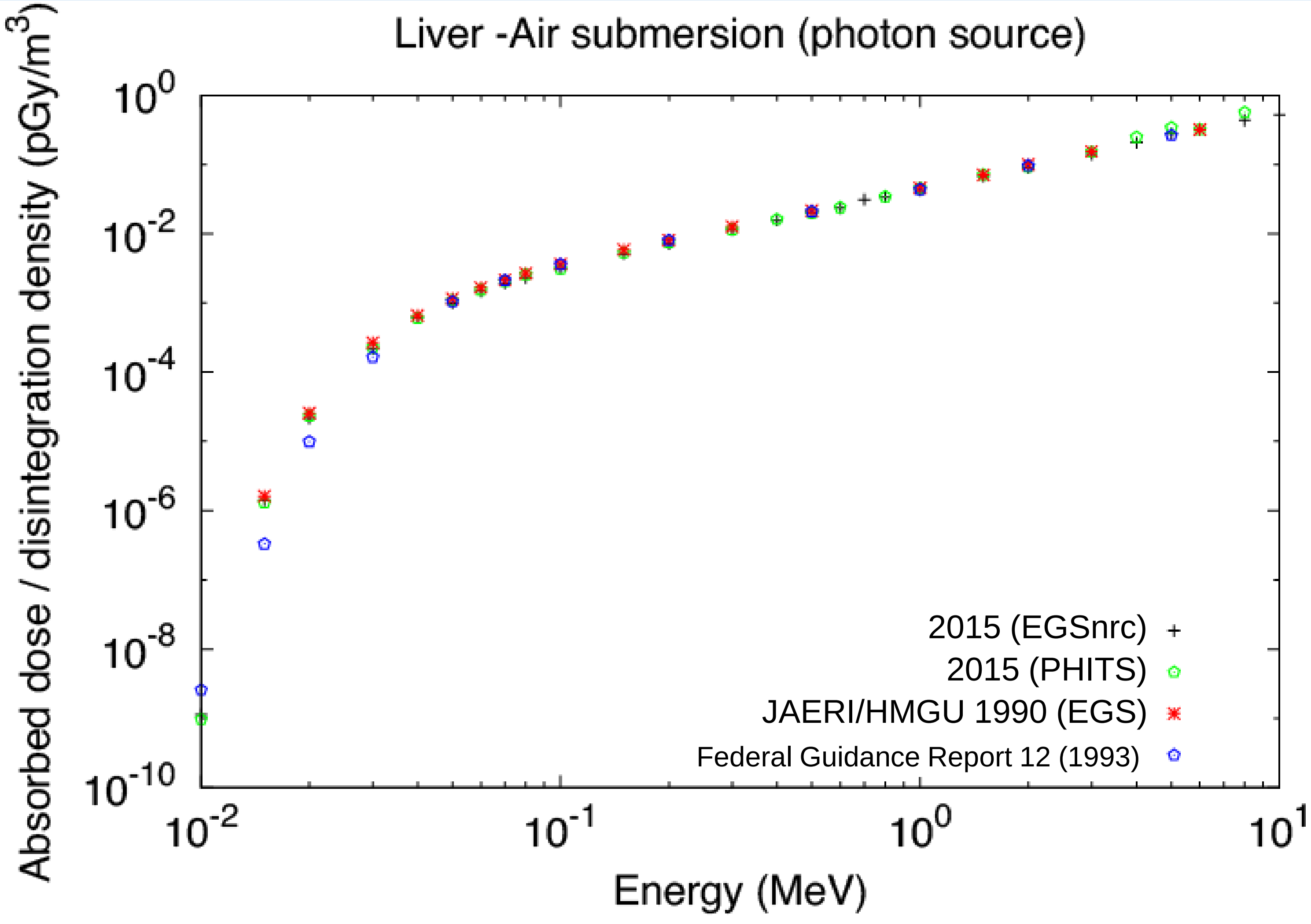
Comparison for different types of phantoms voxel vs. mathematical



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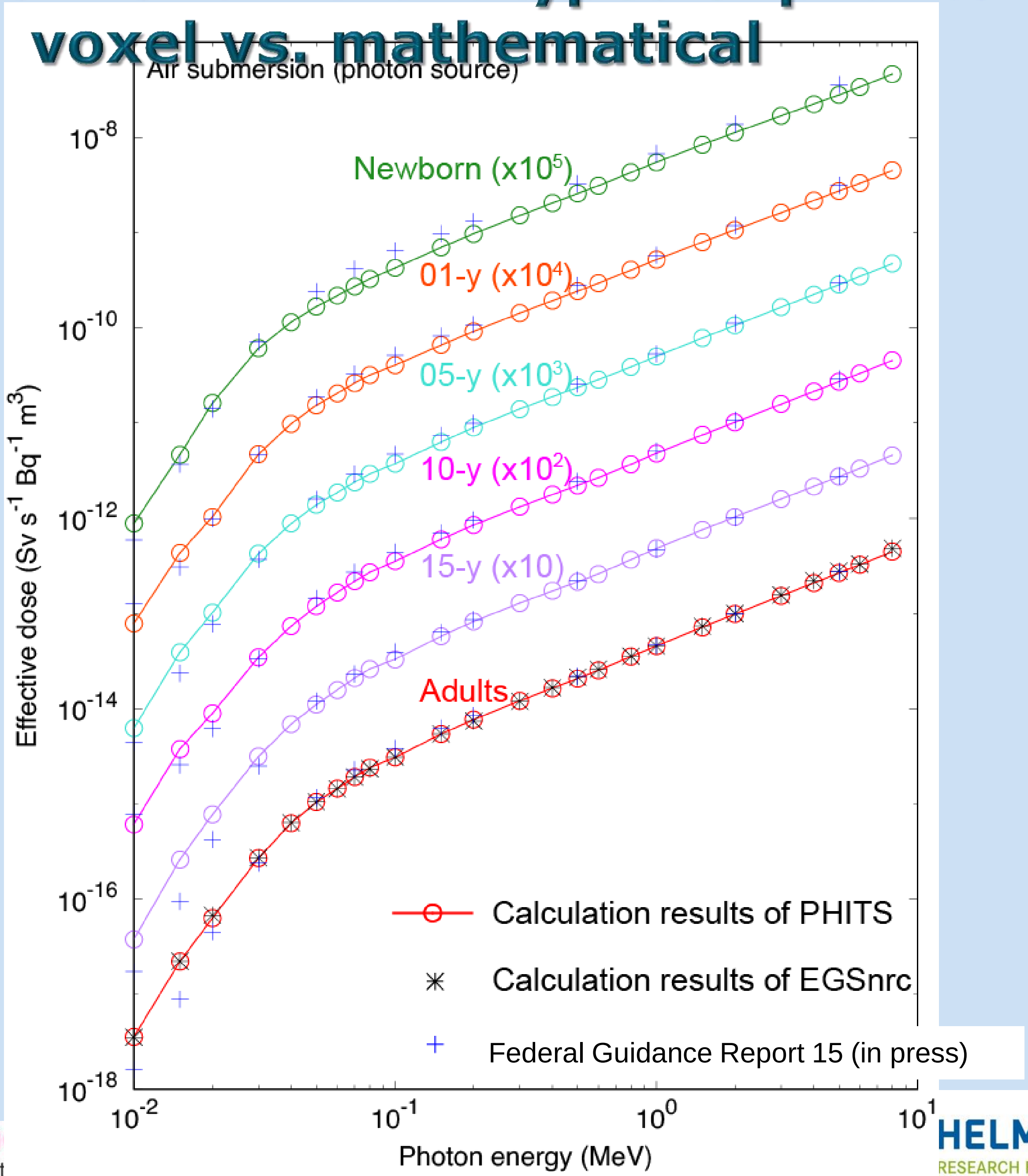
Comparison for different types of phantoms voxel vs. mathematical



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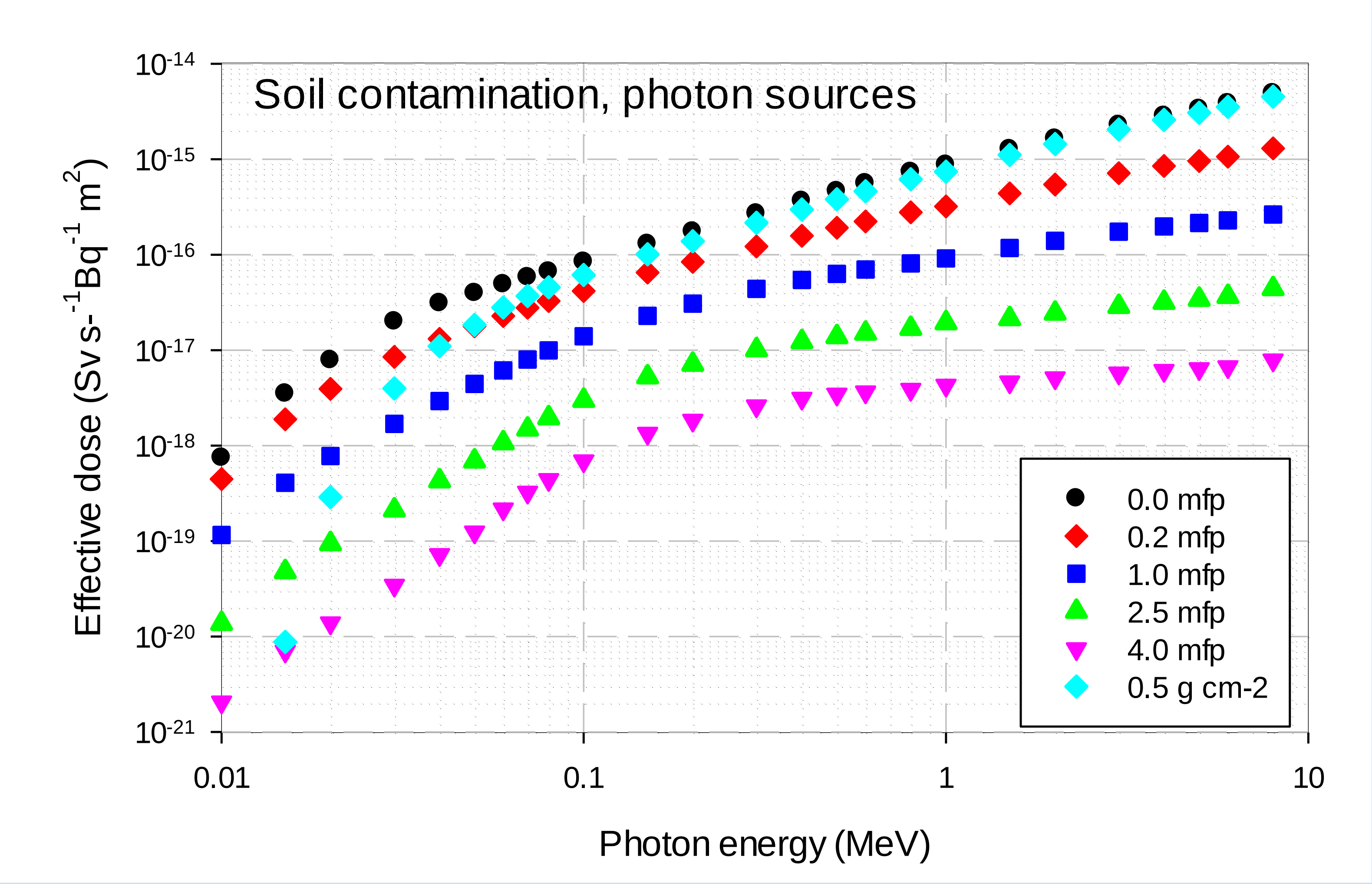
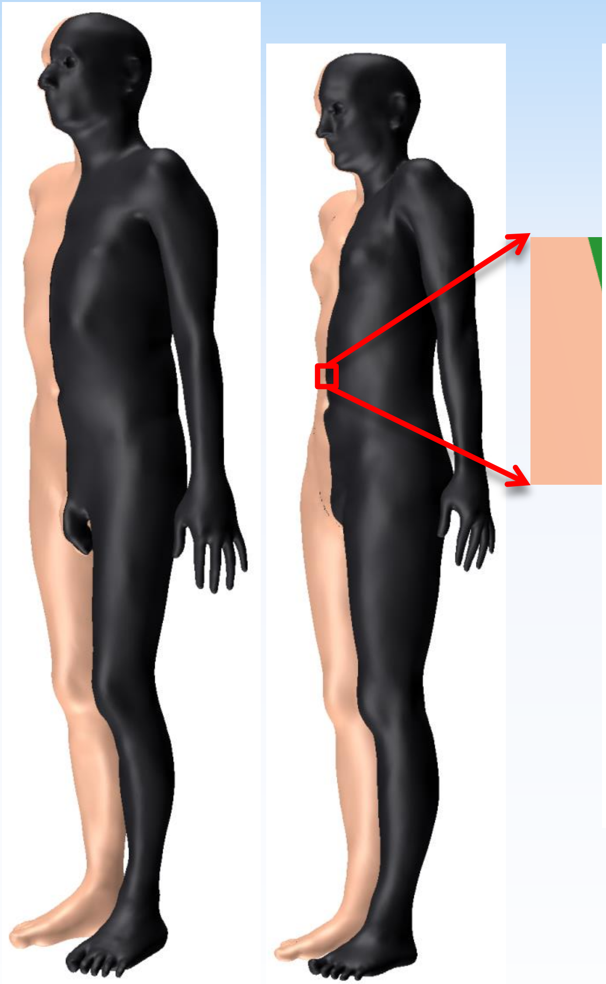
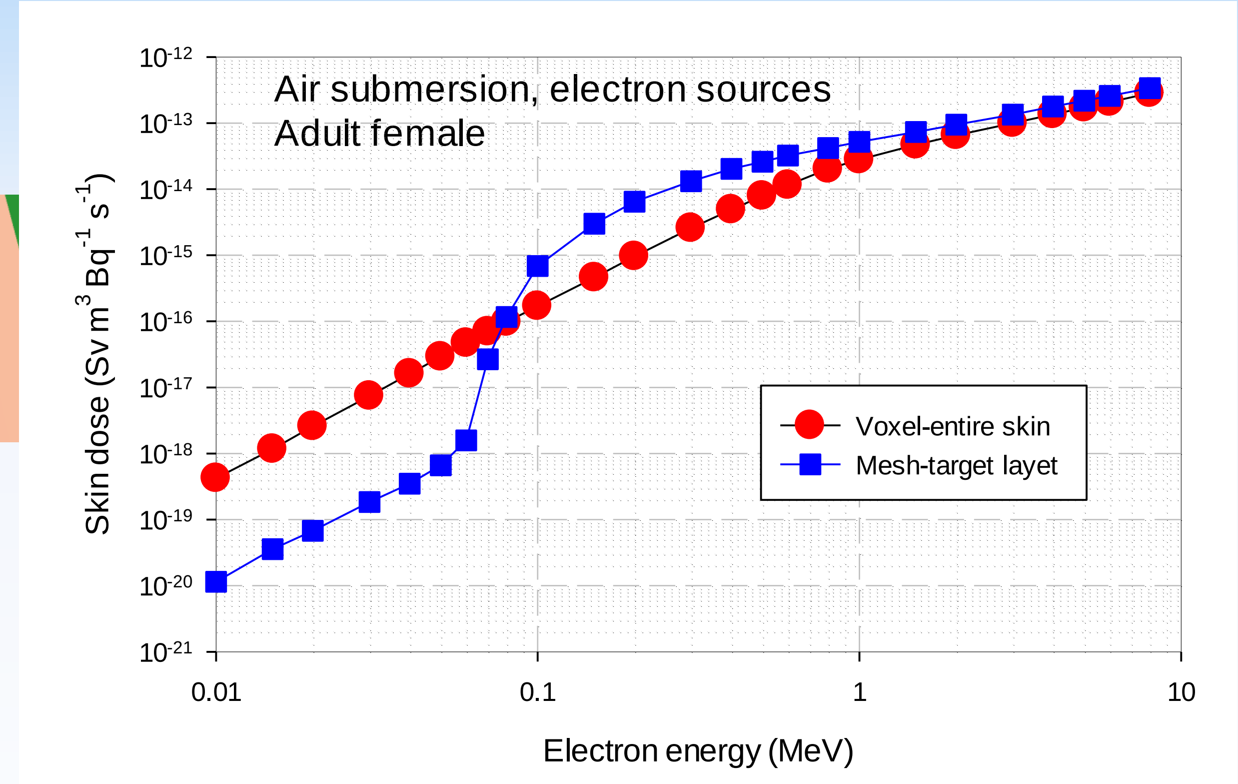
Source-depth dependence of dose coefficients



Skin dosimetry: Use of Polygon Mesh Phantoms

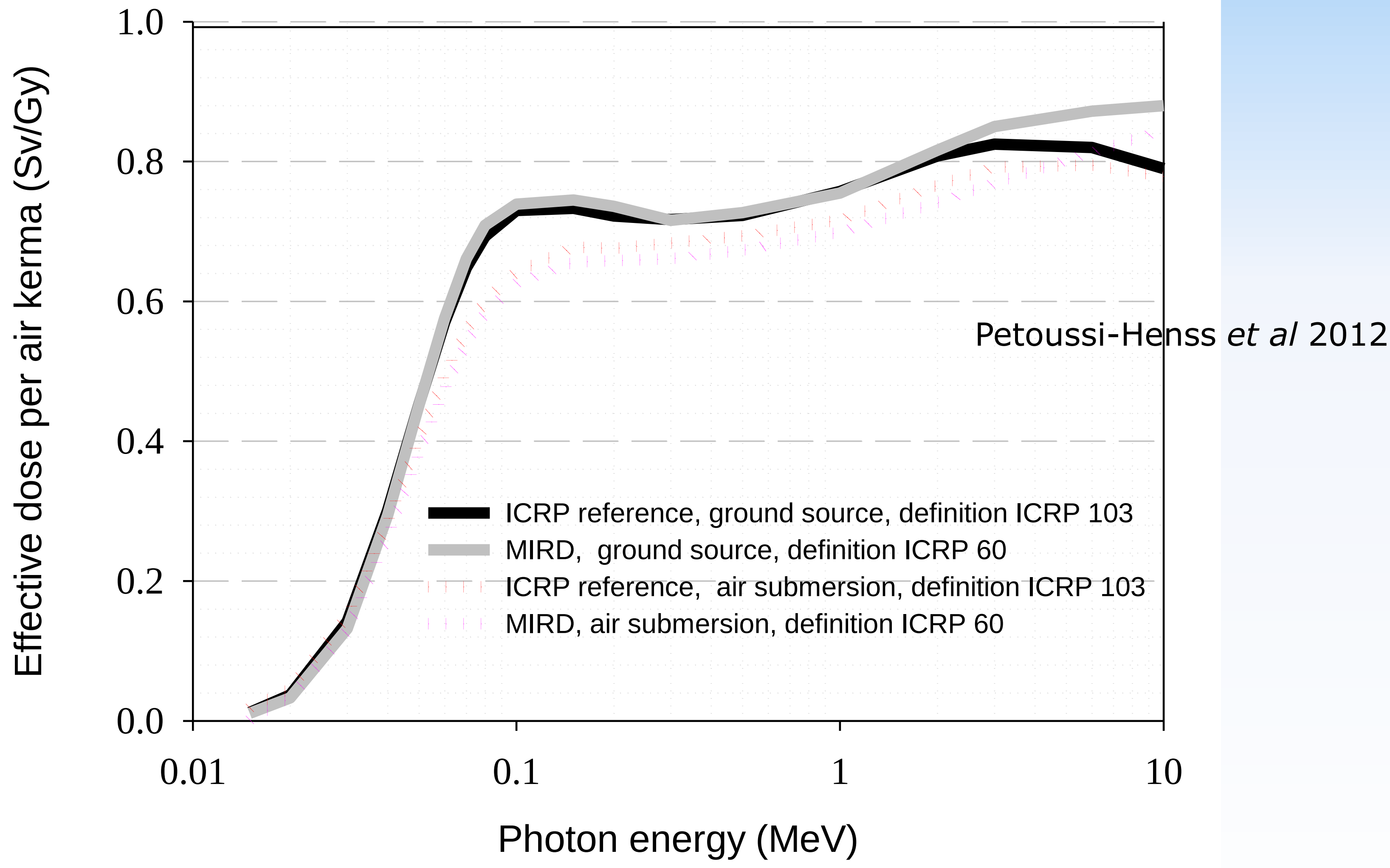




Calculations: Satoh, Yeom

Polygon Mesh phantoms from Hanyang University (Kim, Yeom *et al*)

Effective dose: Comparison with ICRP 60 definition

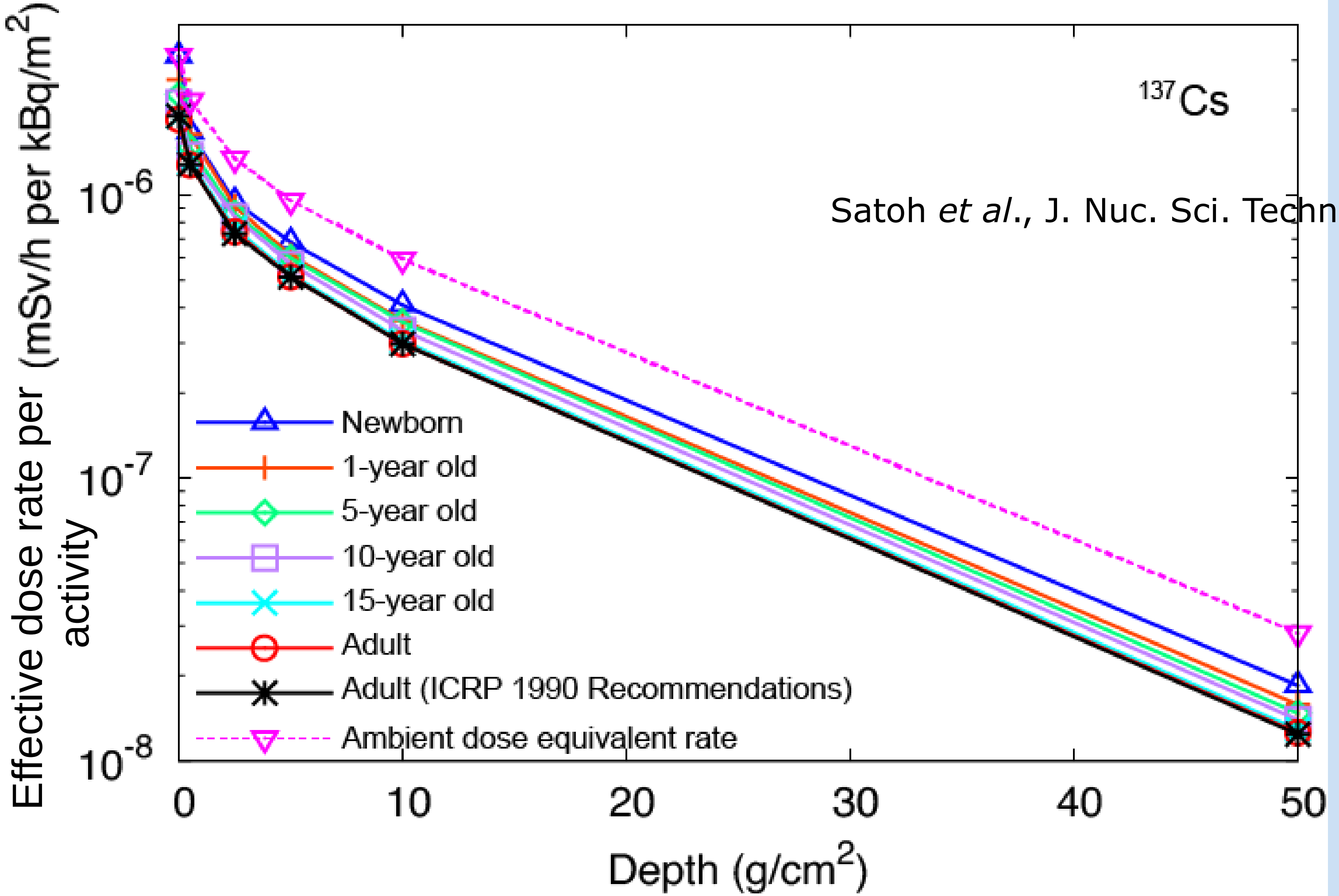


Age dependency of effective dose coefficients for radionuclides detected as ground contamination in Japan after the Fukushima accident

	Contamination of the ground: Effective dose rate in nSv/h per kBq/m^2			
	≤ 1 y	4 – 7 y	7 – 12 y	Adult
^{95}Zr (+ ^{95m}Nb, ^{95}Nb)	4.45	3.84	3.56	3.33
^{110m}Ag (+ ^{110}Ag)	8.04	6.96	6.48	6.07
^{129m}Te (+ ^{129}Te)	0.21	0.18	0.16	0.15
^{131}I	1.17	1.00	0.92	0.85
^{132}I	6.67	5.76	5.35	5.00
^{134}Cs	4.63	3.99	3.70	3.46
^{136}Cs	6.20	5.36	4.99	4.67
^{137}Cs (+ ^{137m}Ba)	1.69	1.45	1.34	1.25
^{140}Ba (+ ^{140}La)	6.97	6.06	5.67	5.33

Petoussi-Henss *et al,* Phys Med Biol 57,2012

Radiation control based on the ambient dose equivalent rate gives a conservative adherence of the dose limits for all ages defined by the effective dose



Satoh *et al*., J. Nuc. Sci. Technol. 2015

Update of the dosimetry system would not cause an undesirable confusion for estimating the doses

Dose reduction factor

Table A3.8 Dose reduction factor for external dose from radioactive material in air (from http://radioactivity.mext.go.jp/en/1750/2011/04/1305904_0424e.pdf)

Cloud gamma location factor (indoors)	0.4
Occupancy factor	66%
Cloud gamma dose reduction factor	0.60 [0.66 x 0.4 + (1 - 0.66) x 1]

Table A3.9 Dose reduction factor for external dose from ground deposits (from http://radioactivity.mext.go.jp/en/1750/2011/04/1305904_0424e.pdf)

Deposited gamma location factor (indoors)	0.4
Occupancy factor	66%
Deposited gamma dose reduction factor	0.60 [0.66 x 0.4 + (1 - 0.66) x 1]

Summary

- ICRP nuclide-specific reference dose rate coefficients for ground contamination, air submersion, and water immersion calculated with state of the art tools
- Photons and electrons for all organs
- Coefficient rates given per radioactivity concentration; can be easily correlated to ambient dose equivalent
- Age dependency of coefficients by using the ICRP adult and paediatric reference phantoms
- Ambient dose rate is a conservative effective-dose rate estimator for all ages
- Change of effective dose due to Publ. 103 definition is moderate

Expected applications of the ICRP coefficients

- Pre-accident

  To predict impacts on the public by postulated accidents
- Post-accident

  To estimate doses to make a radiological protection strategy for the public

- The pre/post-accident analyses are performed by dedicated emergency programs which predict dispersion, migration and distribution of radionuclides in the environment. **These coefficients are indispensable to estimate doses from predicted radionuclide distribution**
- When radiation monitoring is available, the effective dose can be directly estimated by survey instruments by correlating the measured quantity with the dose coefficient (rates)

Report will be published ca. end 2018
Public consultation summer 2018

This presentation is based on input of the ICRP Task Group 90 of Committee 2

D Satoh	A Endo	
M Bellamy	W Bolch	K Eckerman
N Hertel	J Hunt	JTM Jansen
C Lee	K Saito	H Schlattl
Y S Yeom	S J Yoo	

Chair: N Petoussi-Henss