Uncertainty in Whole body counting

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From measurement value to dose

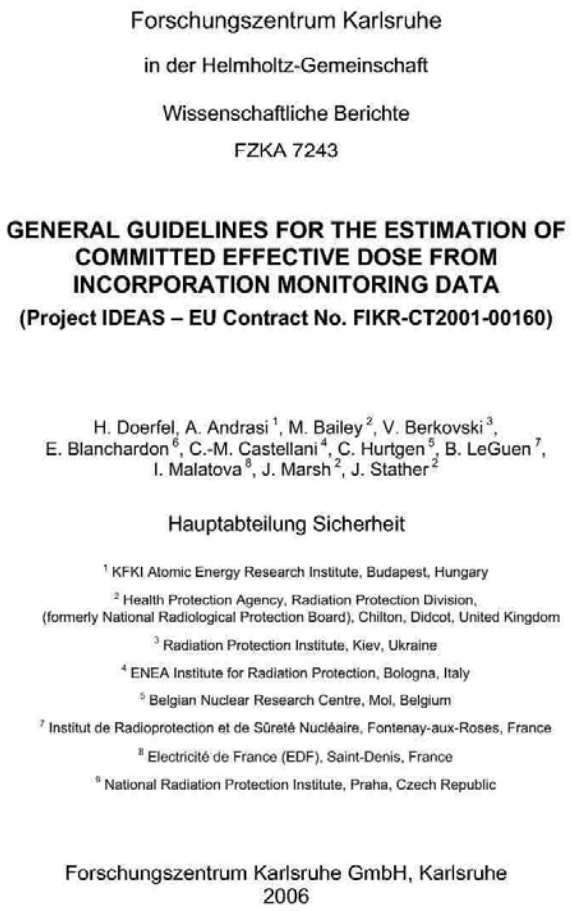
Critical parameters:

- time of intake → often not so well known
- particle size, AMAD → can be ”measured”
- molecule/atom? → ^{60}Co = atom/oxide, ^{3}H = who knows
- inhalation/ingestion/wound?

Not so critical

- Size of the person
- how exact is the measurement geometry

IDEAS Guidelines



Forschungszentrum Karlsruhe

in der Helmholtz-Gemeinschaft

Wissenschaftliche Berichte

FZKA 7243

GENERAL GUIDELINES FOR THE ESTIMATION OF COMMITTED EFFECTIVE DOSE FROM INCORPORATION MONITORING DATA

(Project IDEAS – EU Contract No. FIKR-CT2001-00160)

H. Doerfel, A. Andrasi [1], M. Bailey [2], V. Berkovski [3], E. Blanchardon [6], C.-M. Castellani [4], C. Hurtgen [5], B. LeGuen [7], I. Malatova [8], J. Marsh [2], J. Stather [2]

Hauptabteilung Sicherheit

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[2] Health Protection Agency, Radiation Protection Division, (formerly National Radiological Protection Board), Chilton, Didcot, United Kingdom

[3] Radiation Protection Institute, Kiev, Ukraine

[4] ENEA Institute for Radiation Protection, Bologna, Italy

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[7] Institut de Radioprotection et de Sûreté Nucléaire, Fontenay-aux-Roses, France

[8] Electricité de France (EDF), Saint-Denis, France

[9] National Radiation Protection Institute, Praha, Czech Republic

Forschungszentrum Karlsruhe GmbH, Karlsruhe
2006

Trigger:
Intercomparison excercise where results deviated that much that committee came to conclusion that general guidelines are desperately needed

Forschungszentrum Karlsruhe

Technik und Umwelt

Wissenschaftliche Berichte

FZKA 6457

Third European Intercomparison Exercise on Internal Dose Assessment

Results of a Research Programme in the Framework of the EULEP/EURADOS Action Group "Derivation of Parameter Values for Application to the New Model of the Human Respiratory Tract for Occupational Exposure"

1997-1999

H. Doerfel, A. Andrasi [1)], M. R. Bailey [2)], A. Birchall [2)], C.-M. Castellani [3)], C. Hurtgen [4)], N. Jarvis [2)], L. Johansson [5)], B. LeGuen [6)], G. Tarroni [3)]

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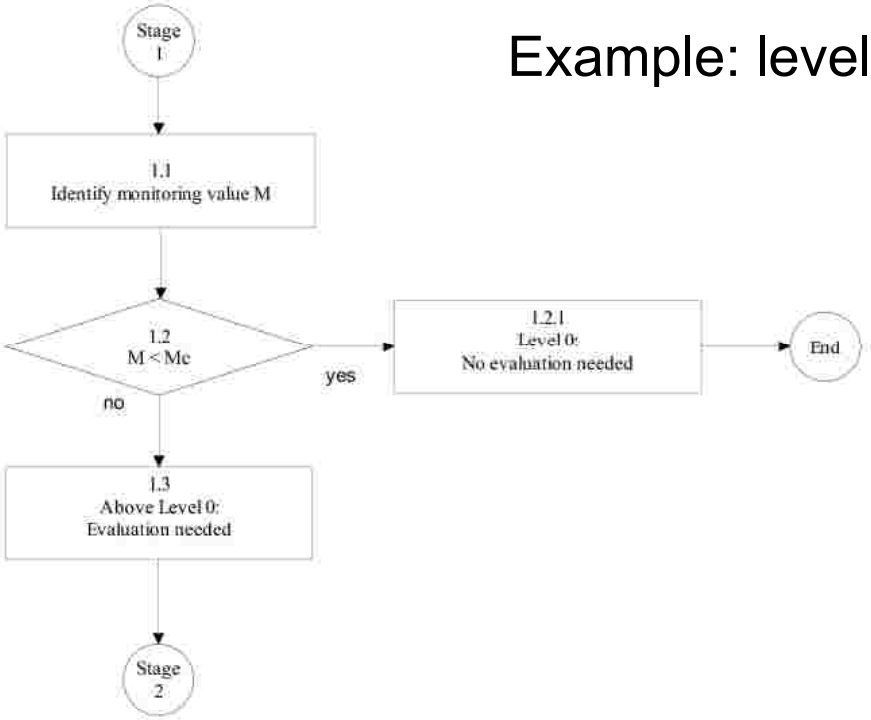
[6)] EDF-GDF, Saint Denis Cedex, France

Forschungszentrum Karlsruhe GmbH, Karlsruhe

2000

Seven case scenarios where particpants were asked to estimate intake and internal dose:
^{3}H, ^{90}Sr, ^{125}I, ^{137}Cs, ^{210}Po, ^{238}U, ^{239}Pu

IDEAS Guidelines



Example: level 0

Figure 6.1: Stage 1. Check of need for evaluation.

Critical monitoring value

$$M_c = \frac{0.1 mSv\ m(T/2)\ T}{e(50)\ 365}$$

If measured value is smaller than critical monitoring value, it is safe to note that dose is less than 0.1 mSv.

IDEAS General Guidelines – June 2006

Table 5.1: Critical monitoring value M_C for some selected radionuclides and the corresponding monitoring procedures.

Radionuclide	Absorption type (chemical form)	Type of monitoring	Monitoring interval (d)	Critical monitoring value M_C
H-3	HTO	Urine	14 30 60	4400 Bq/d 5500 Bq/d 3900 Bq/d
Co-60	M	Whole body	90 180 360	160 Bq 230 Bq 290 Bq
Co-60	S or Unknown	Whole body	90-360	70 Bq
Sr-90	F	Urine	90 180 360	0.4 Bq/d 0.2 Bq/d 0.2 Bq/d
Sr-90	S	Urine	90-360	3 mBq/d <LLD
I-131	F	Thyroid	7 14 30	18 Bq 26 Bq 26 Bq
Cs-137	F	Whole body	90 180 360	1200 Bq 1800 Bq 2000 Bq
U-235	S	Lungs	90 180 360	0.2 Bq < LLD 0.3 Bq < LLD 0.5 Bq < LLD
Pu-239	M	Urine	90 180 360	0.007 mBq/d < LLD 0.011 mBq/d < LLD 0.017 mBq/d < LLD

Uncertainty on internal dose assessment

Dose delivered by the internal contamination:

$$E(50) = \sum_T w_T \; See(T \leftarrow WB) \int_{t_1}^{t_1+50\,y} (F_{re})dt$$

Where:

w_T=tissue weighting factor

See(T←WB)= equivalent dose in T per disintegration in the whole body source organ

the integral gives number of disintegrations in 50 y in the whole body

Model A Parameters

50 parameters

Transfer coefficients (d^{-1}) for a reference adult male

Plasma to heart	14.128
Plasma to liver	19.515
Plasma to kidneys	67.108
Plasma to muscle	30.022
Plasma to GI tract tissue	52.98
Plasma to stomach contents	4.516
Plasma to small intestine contents	1.0480
Plasma to large intestine contents	0.02
Plasma to spleen	5.298
Plasma to pancreas	1.766
Plasma to brain	0.424
Plasma to red marrow	5.298
Plasma to other skeleton	3.532
Plasma to skin	4.415
Plasma to lungs	4.415
Plasma to adipose tissue	8.83
Plasma to Other 1	8.826
Plasma to Other 2	0.00353
Plasma to RBC	1.8
Heart to plasma	8.073
Liver to plasma	2.204
Liver to small intestine contents	0.116
Kidneys to urinary bladder contents	1.678
Kidneys to plasma	31.876
Muscle to plasma	0.0751
GI tract tissue to plasma	8.191
GI tract tissue to liver	0.431
GI tract tissue to stomach contents	0.0333
GI tract tissue to small intestine contents	0.108
GI tract tissue to large intestine contents	0.0667
Spleen to plasma	5.033
Spleen to liver	0.265
Pancreas to plasma	1.678
Pancreas to liver	0.0883
Skin to plasma	0.867
Skin to excreta	0.0159
Brain to plasma	0.0848
Red marrow to plasma	0.706
Other skeleton to plasma	0.128
Lungs to plasma	1.472
Adipose tissue to plasma	1.766
Other 1 to plasma	0.692
Other 2 to plasma	0.00141
RBC to plasma	0.257
Urinary bladder contents to urine	12.0
Stomach to small intestine (contents)	40.0
Small intestine contents to plasma	28.215
Small intestine to large intestine (contents)	0.3
Small intestine contents to liver	1.485
Large intestine contents to feces	0.5

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HELMHOLTZ ASSOCIATION

Propagation of Uncertainties for Model Parameters

$$x = f(u, v, \ldots)$$

$$\sigma_x^2 \cong \sigma_u^2 \left(\frac{\partial x}{\partial u}\right)^2 + \sigma_v^2 \left(\frac{\partial x}{\partial v}\right)^2 + \cdots + 2\sigma_{uv}^2 \left(\frac{\partial x}{\partial u}\right)\left(\frac{\partial x}{\partial v}\right) + \cdots$$

$$\sigma_{uv}^2 = r_{uv}\sigma_u\sigma_v$$

ISO GUM 1995

About metabolic models

Generally, metabolism is well known
- most of the uncertainty comes from complicated behaviour of an element in the body
  - this can be either several routes and end locations or
  - chemical reactions (study ^{14}C or ^{3}H!)

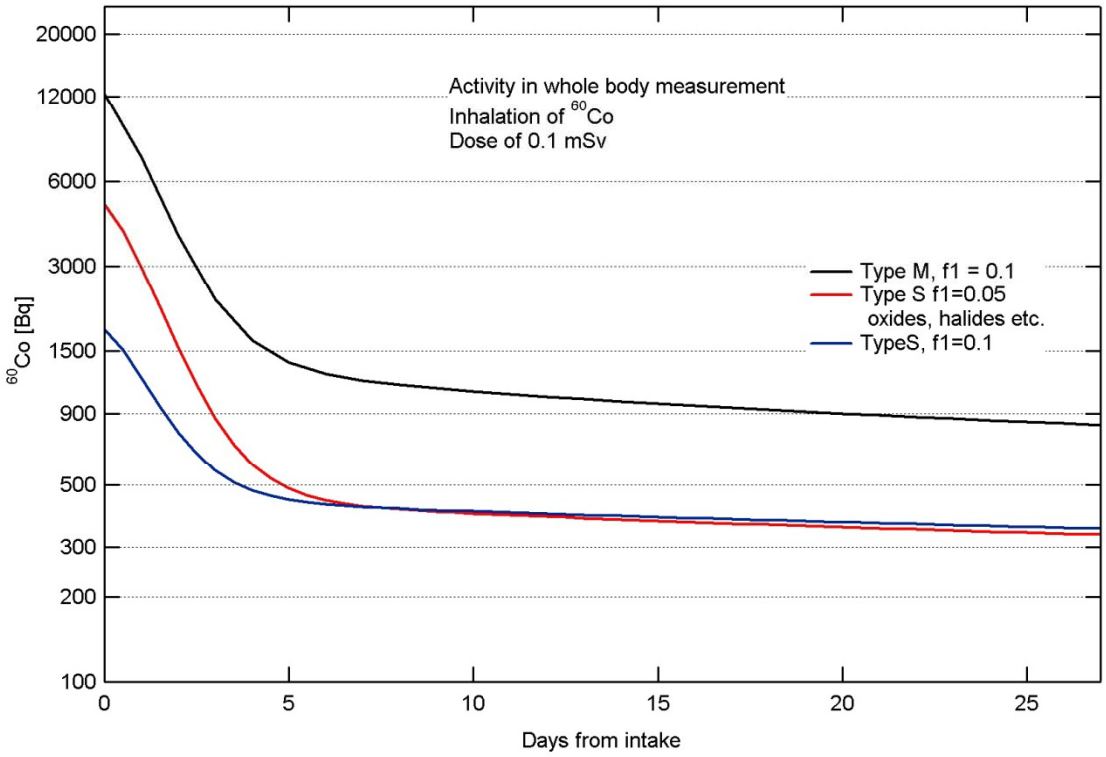
Individual differences usually not significant

Uncertainties

Time of intake can determined by repeated measurements

Other parameters to take into account:

- Absobtion class
- Compound
- Particle size: can be determined by faeces and lung data



Uncertainty budget of STUK mobile unit

Uncertainty	Value [%]	Cumulative unc. [%]
Calibration source	5	5
Efficiency calibration	10	11
Peak area	10	15
Size of the person	10	18

Uncertainty on peak area is $\sqrt{A}$, so value above is hypotethical.

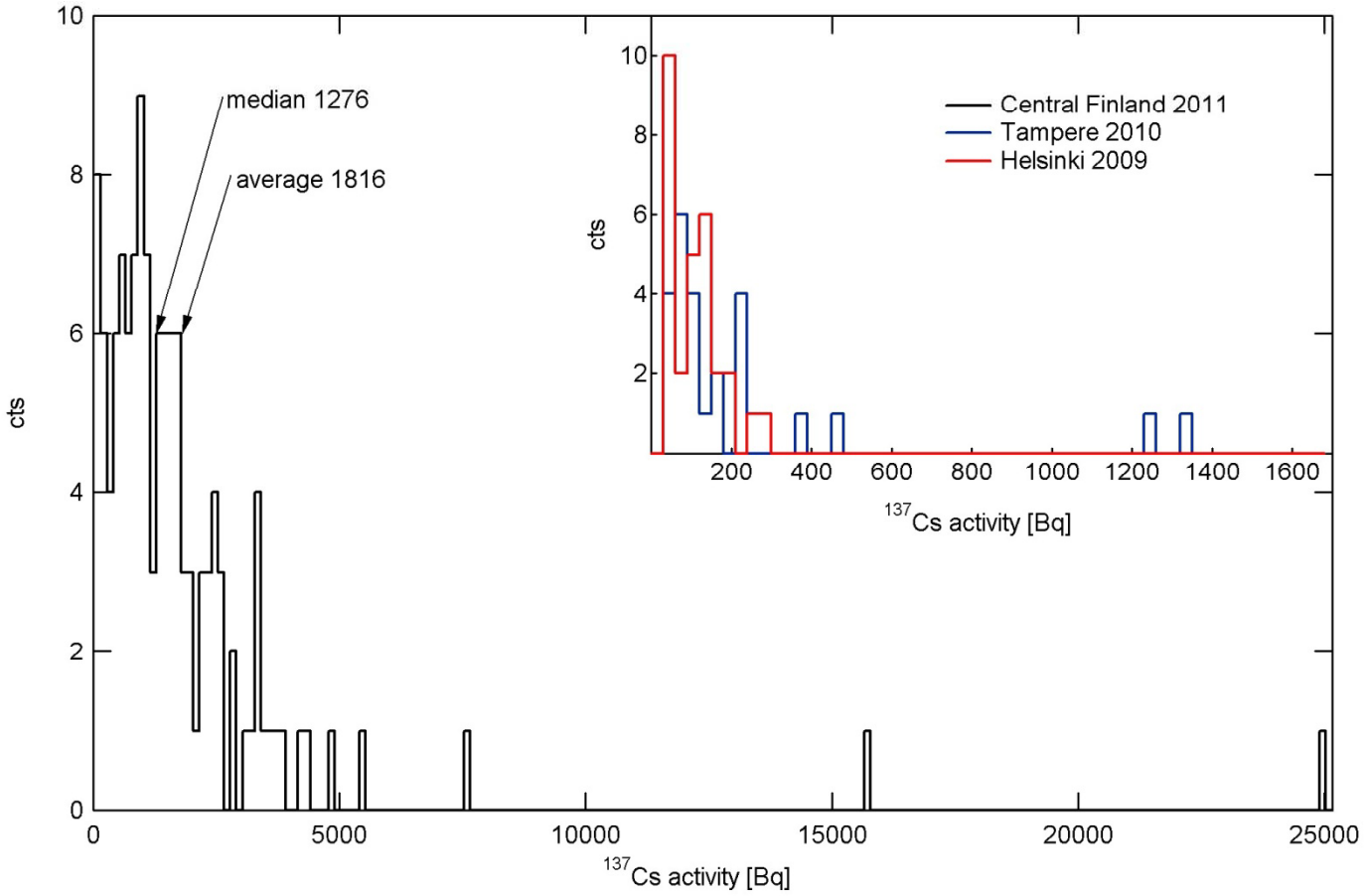
NOTE: this uncertainty does not include metabolic model!

Uncertainty on a dose caused by distribution

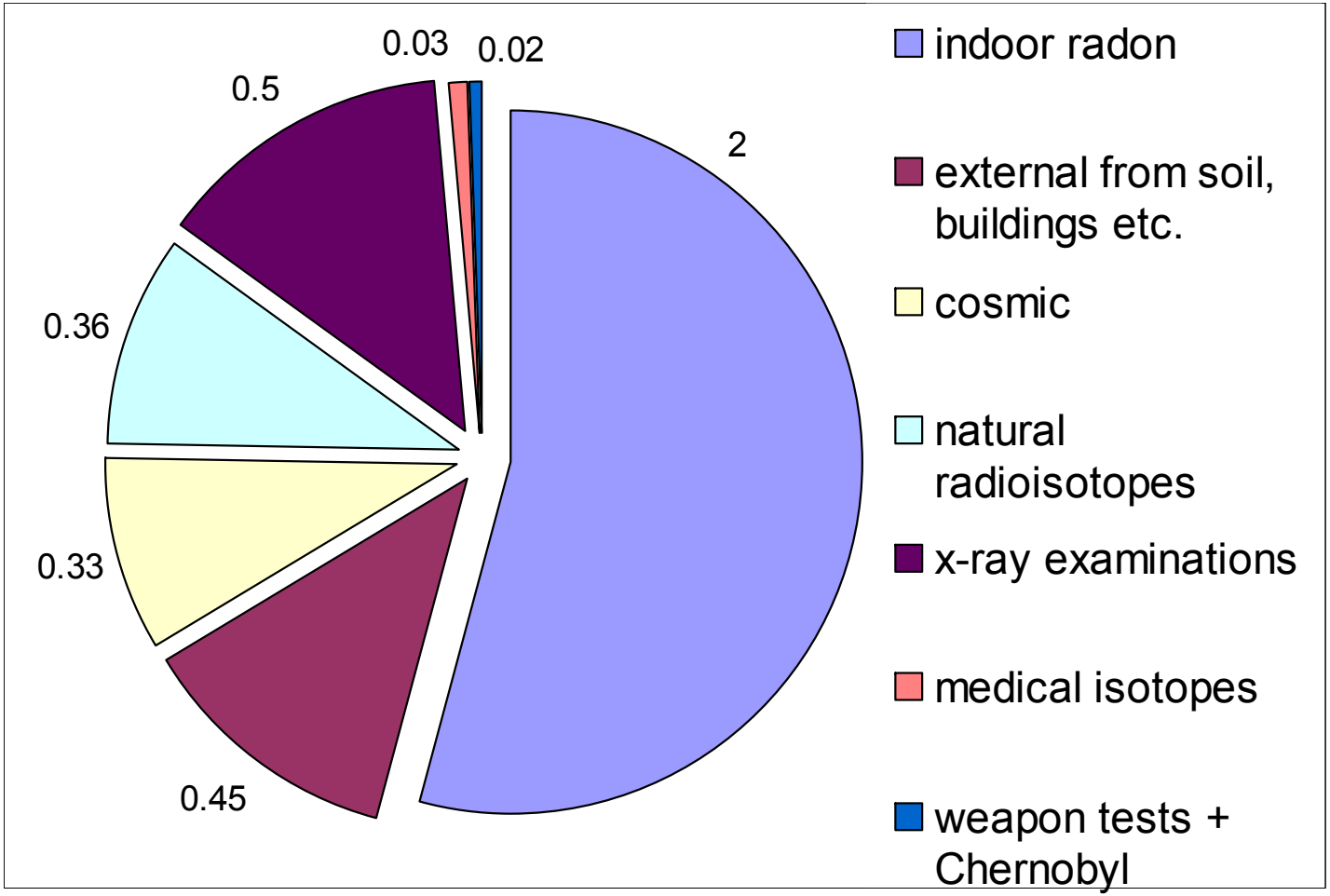
Dose for the population:
- individuals are easy, you have the number
- is the group you measured representive?

There is no reason that distribution of radioactive material in the group of people is Gaussian
- average alone is not a good number
- STUK publishes median
- take a look on distribution!

Some distributions

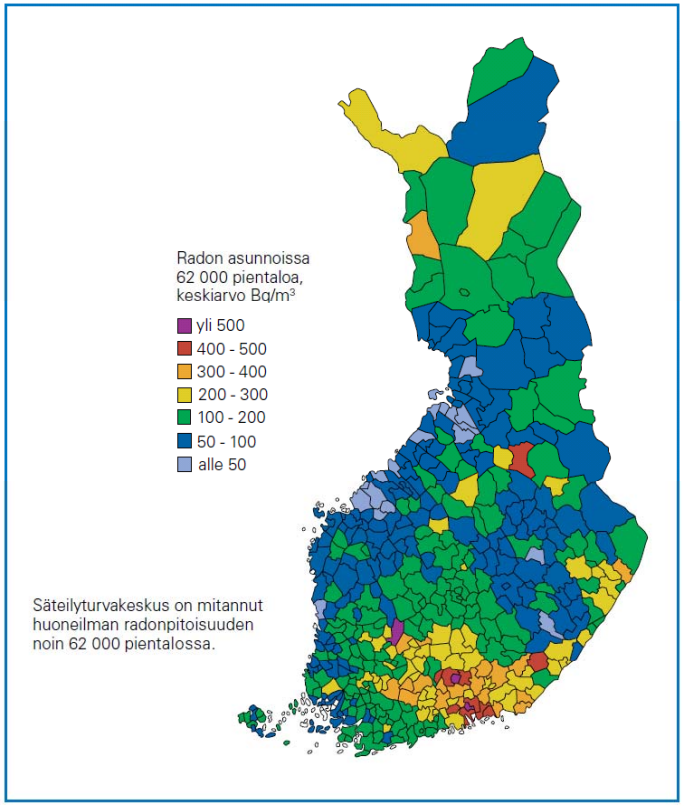


Average dose for an average Finn (1)



Average dose for an average Finn (2)

- An average Finn is non-existent in reality
- Averages are tricky when assessing dose
  - Especially radon:
  - Certain areas, e.g. Ostrobothnia, indoor radon is negligible
  - Also, medical doses are not evenly distributed



Conclusions

With these contamination levels it is no use to spent too much time on analysing the results (Level 0)

Useful only for academic/educational purposes.

Taking into account all uncertainty sources listed above, we can conclude that order of magnitude is absolutely correct.

For a higher dose, more measurements results better estimate, obviously

Comments above DOES NOT mean that you should not measure, how would you know without measuring?