Exposure of the German Population to Outdoor Radon

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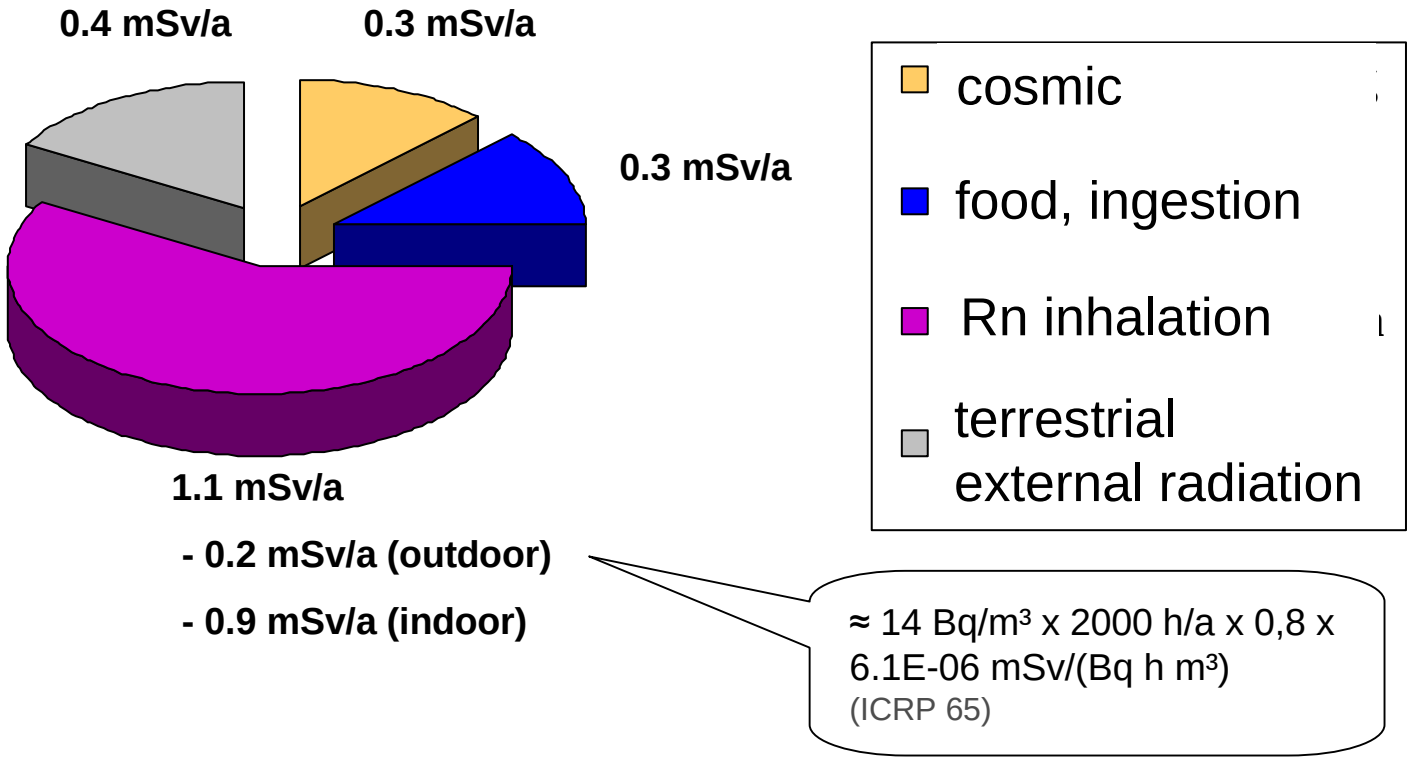
Overview

- Motivation
- Methods
- Experimental design
- Results (Radon, Radon progenies)
- Exposure estimate

Why investigating outdoor Rn ?

- Epidemiology (dose - response)
- Assessment radon indoor
- Separation from natural background (estimation of anthropogenic influence)
- So far no data on outdoor Rn concentrations over the whole German territory



Reference: BfS annual report 2008

Mean exposure to natural radiation, Germany

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outdoor Rn concentration controlled by

Rn exhalation	atmospheric dispersion
• ^{226}Ra conent	• Advection
• Porosity	• Turbulence
• Diffusion	• Precipitation (Rn progenies)
• Convection	
→ spatial density of sampling points ?	→ long term measurements

Measuring method of the BfS for assessing outdoor Rn concentrations

- Diffusion chamber, solid state detector (MAKROFOL)

  (Preparation, evaluation, calibration, statistics by BfS)

- On each sampling point: 2 diffusion chambers, 1.5 m above ground

- Exposure: 1 year; decision threshold: 3 Bq/m³

- Measurement uncertainty: up to 20 % for Rn exposure > 80 kBq·h/m³

(80 kBq.h/m³ … Rn concentration ca. 10 Bq/m³ for 1 a exposure)

estimate of total process uncertainty

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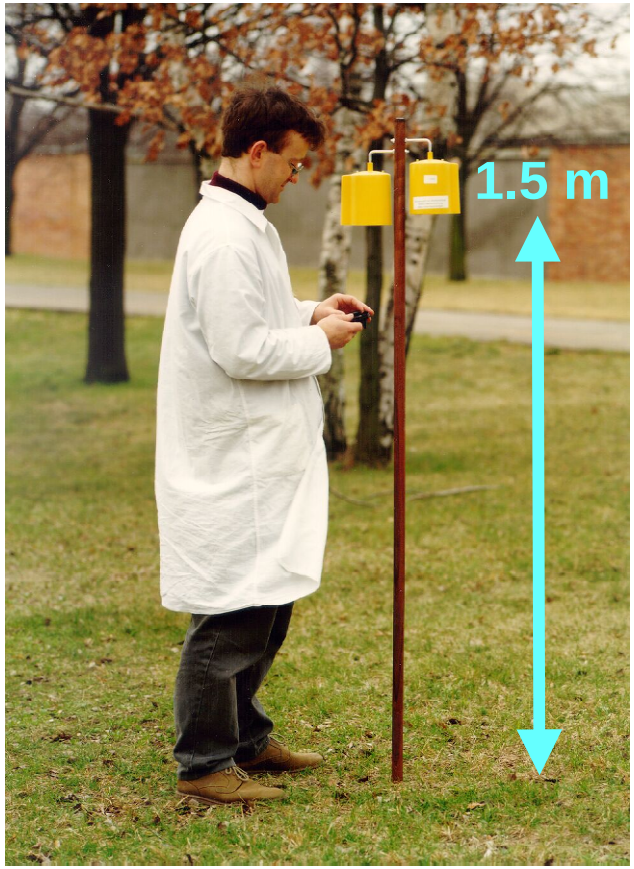
Measurement of long term outdoor Rn concentration at the Bfs (FKSD) at BfS



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Determination of sample size

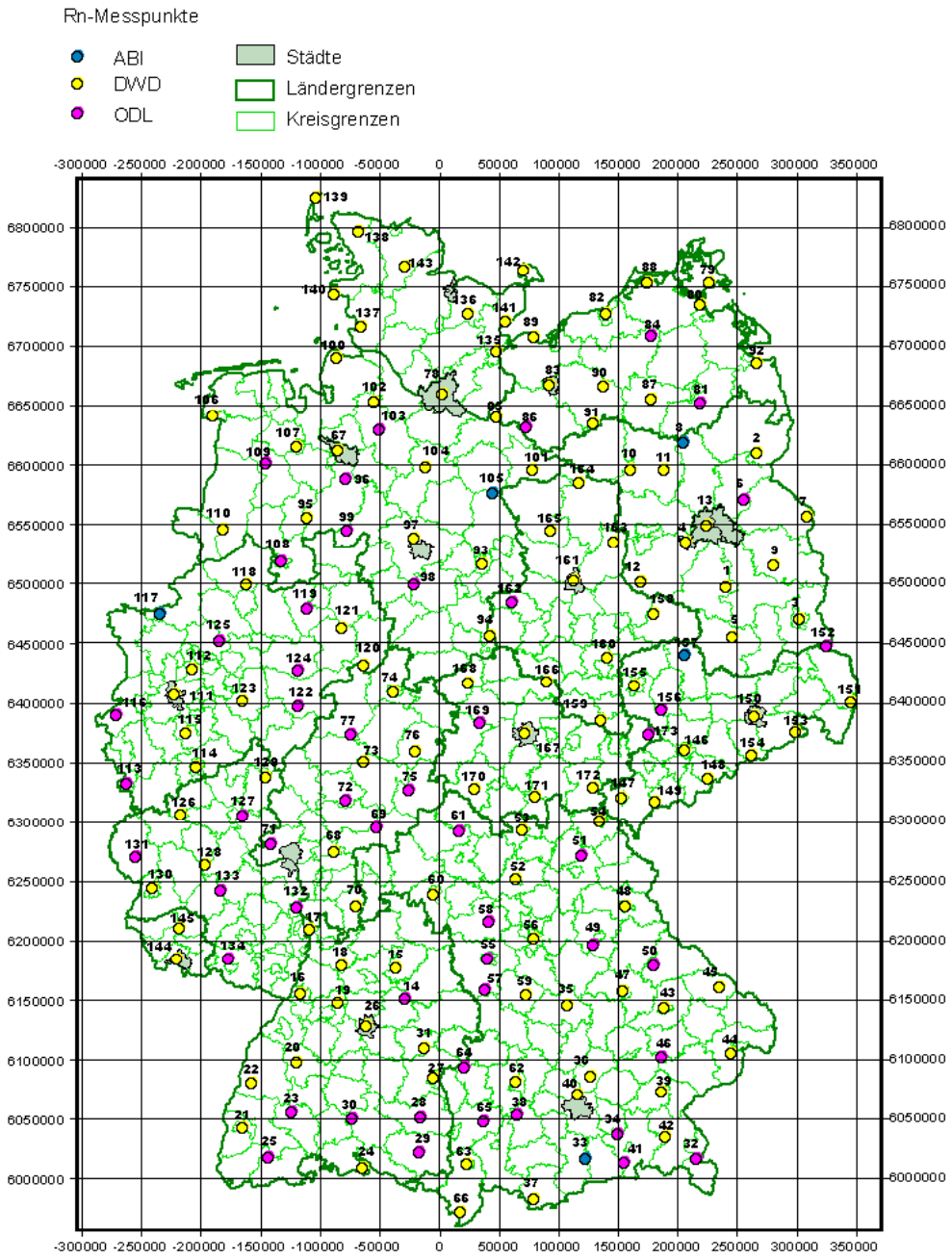
- spatial design: regular grid over territory of Germany
- Estimate upper bound of st. dev. for spatial variability of outdoor Rn, from existing data (KfK, BfS)
- Condition: 95%-confidence interval of mean ≤ 5 Bq/m³
- → Sample size ca. n = 150
- → grid mesh ca. 50 km (quadratic grid)

Choosing sampling locations

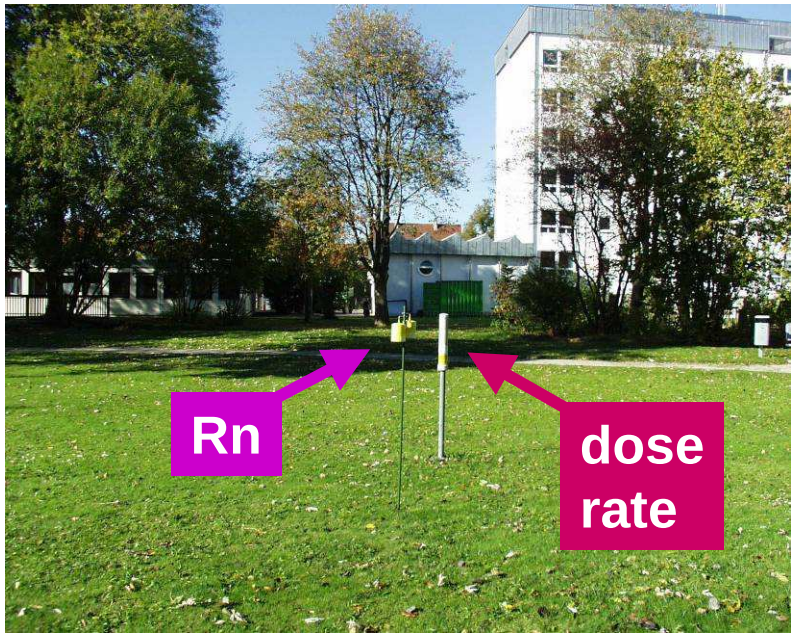
- Each grid cell should contain 1 sampling location
- Sampling locations should be in inhabited areas (i.e. not on mountain tops, small uninhabited islands, deserts, glaciers etc.)
- on fenced property (no schoolyards, sport grounds, public parks etc.)
- Logistic effort as small as possible

173 sampling locations chosen

- 117 locations: stations of the DWD (German meteorological service)
- 56 locations: dose rate monitoring sites of the BfS



spatial distribution of sampling locations



Example: hospital Mindelheim (Bavaria)

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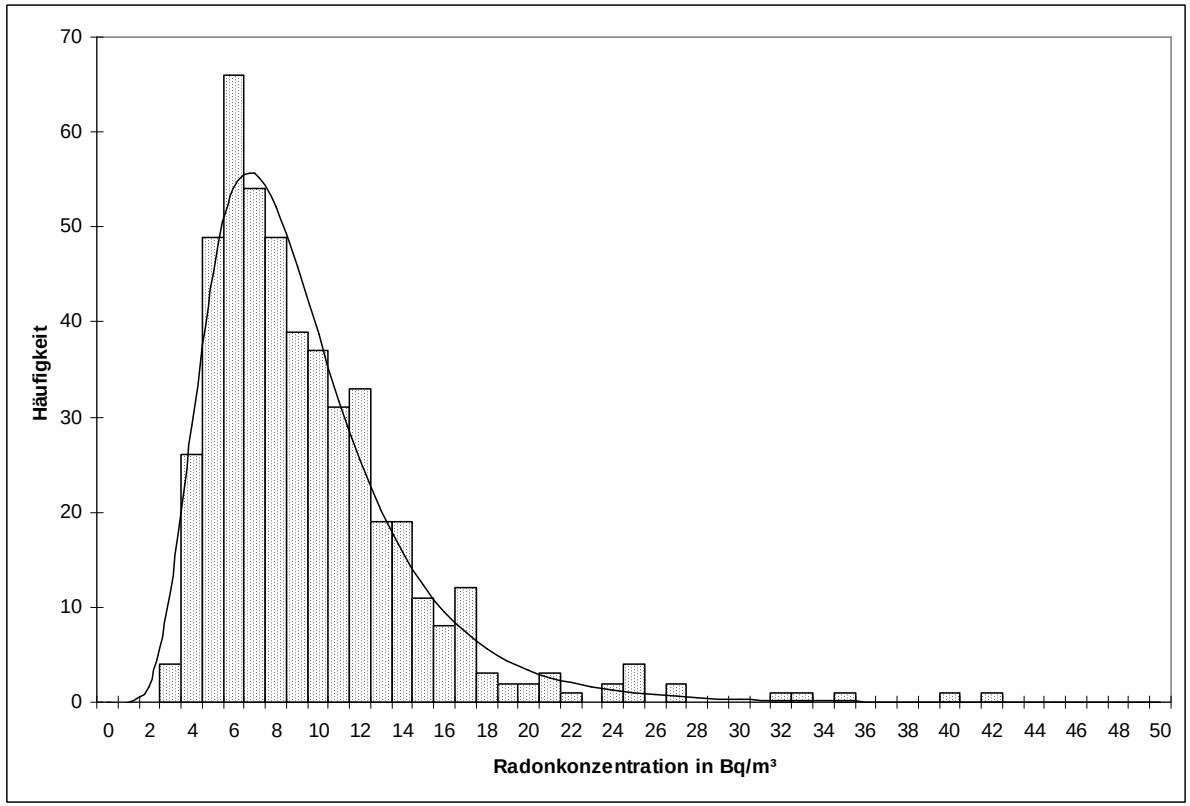
Results, outdoor ^{222}Rn concentrations



Histogram, outdoor ^{222}Rn, all measurements 2003 bis 2006/07

Statistical parameters;
log-normal distribution
assumed :

ar. mean: 9.3 Bq/m³

St. dev: 4.5 Bq/m³

geo. mean: 8.3 Bq/m³

geom. st. dev: 1.6

quantiles:

25%:	6 Bq/m³
75%:	12 Bq/m³
90%:	15 Bq/m³
95%:	17 Bq/m³
99%:	28 Bq/m³

estimation:
AML:=AM{ln x}, SDL:=SD{ln x}
GM=e^{AML}, GSD=e^{SDL},
AM=GM*$e^{SDL^2/2}$, SD=AM*$\sqrt{(e^{SDL^2}-1)}$,
quantiles from data.

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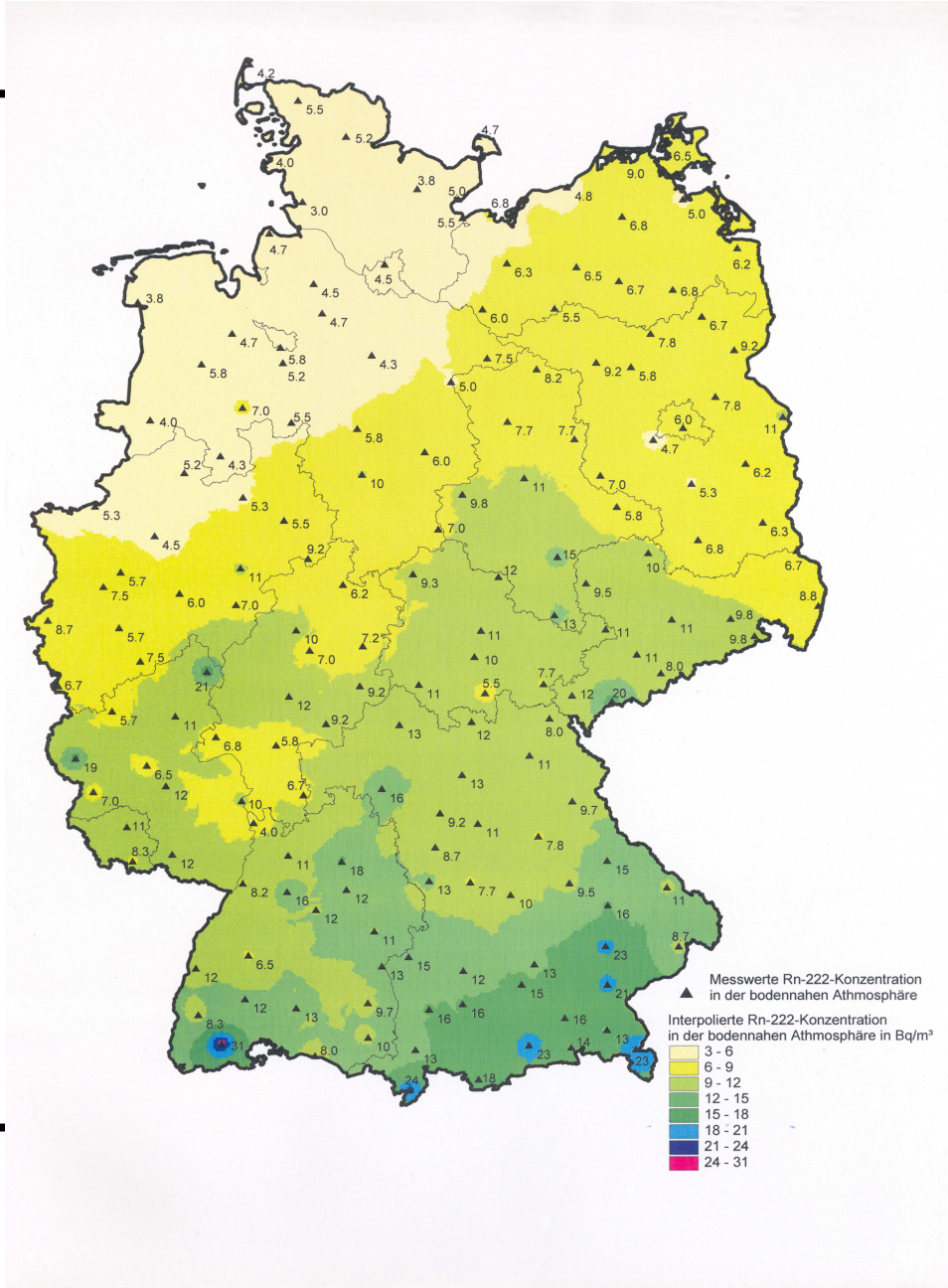

^{222}Rn concentration in near-ground atmosphere

(mean over 3 years, Bq/m³)

Estimated spatial mean ^{222}Rn concentration in Germany:

(9 ± 1) Bq/m³

95% C.I., from samples

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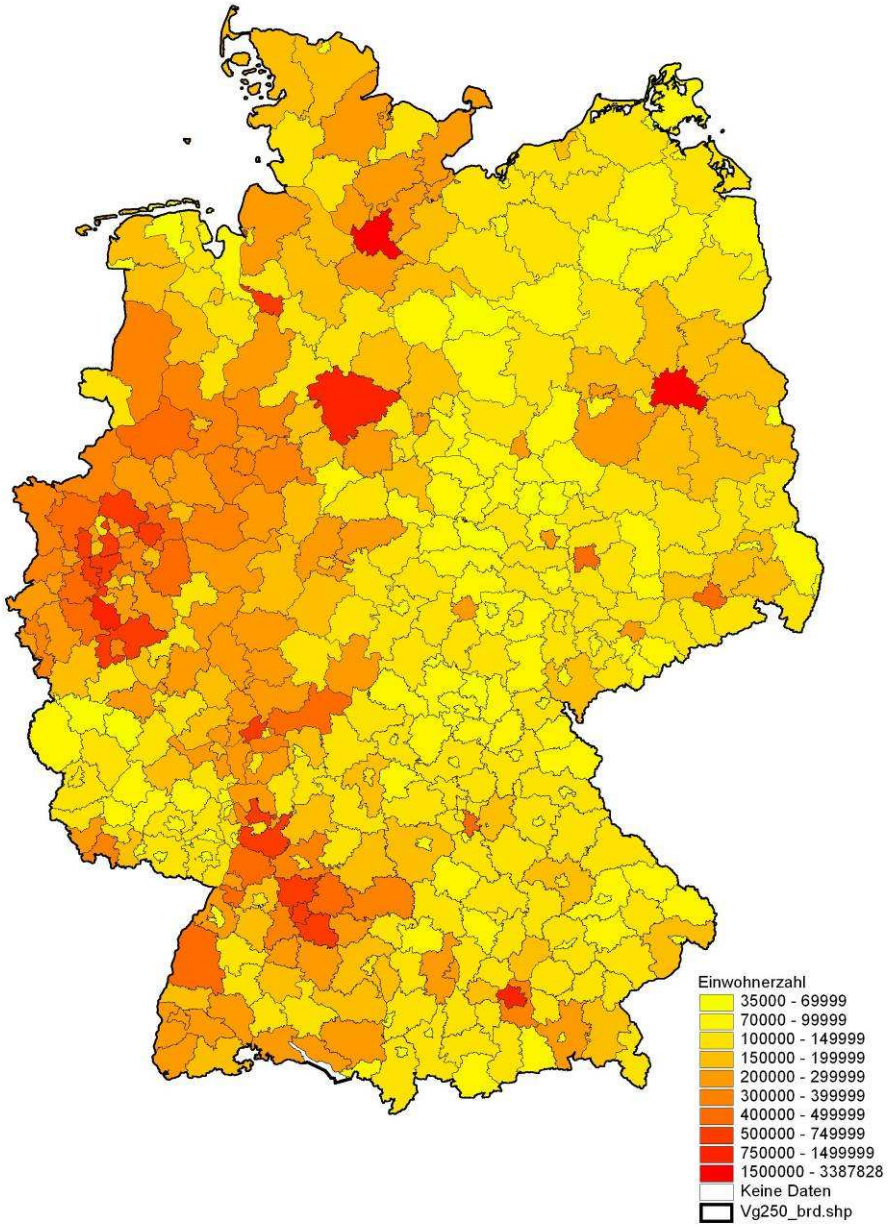

Population distribution of Germany

Population weighted mean ^{222}Rn concentration in Germany:

8,9 Bq/m³

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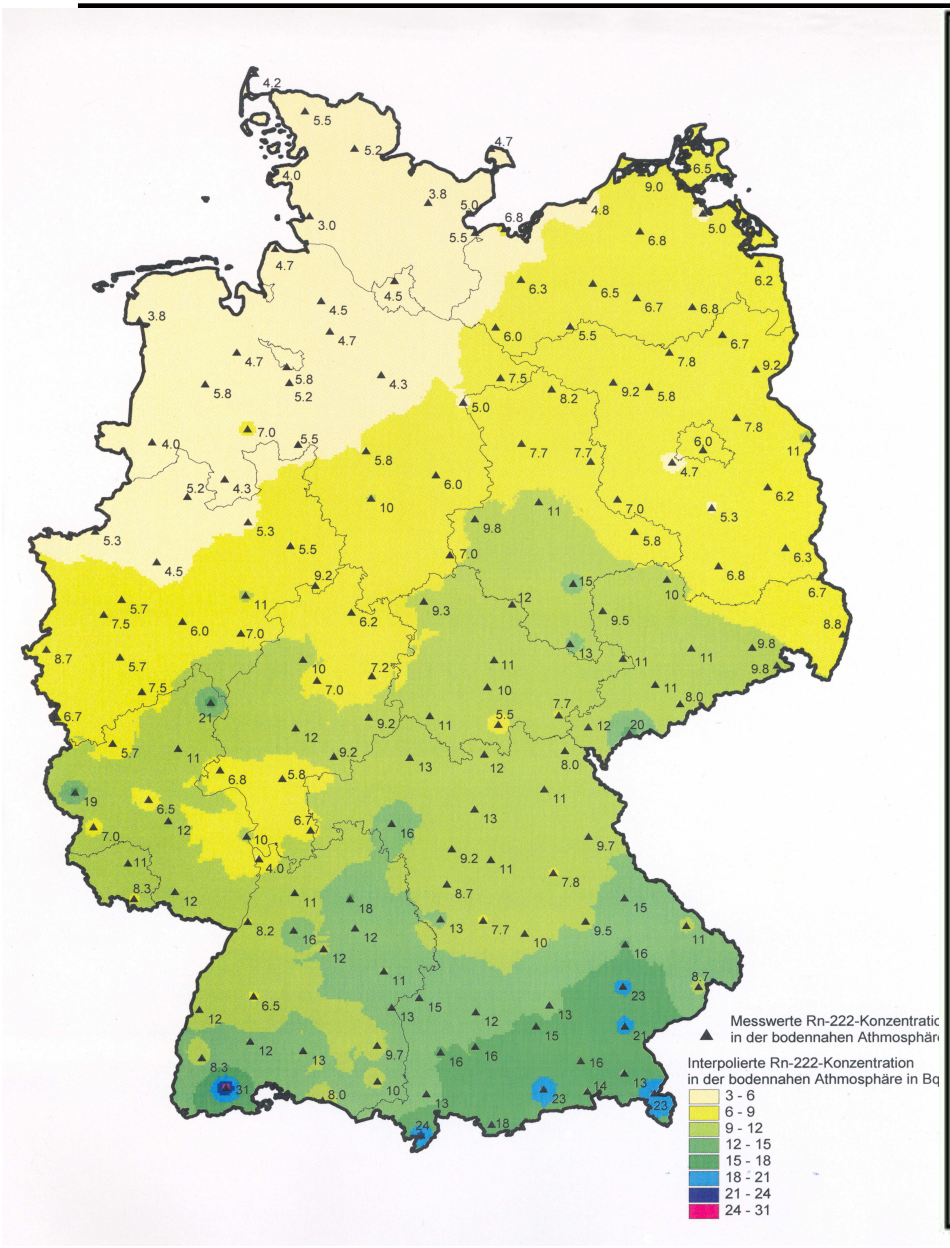
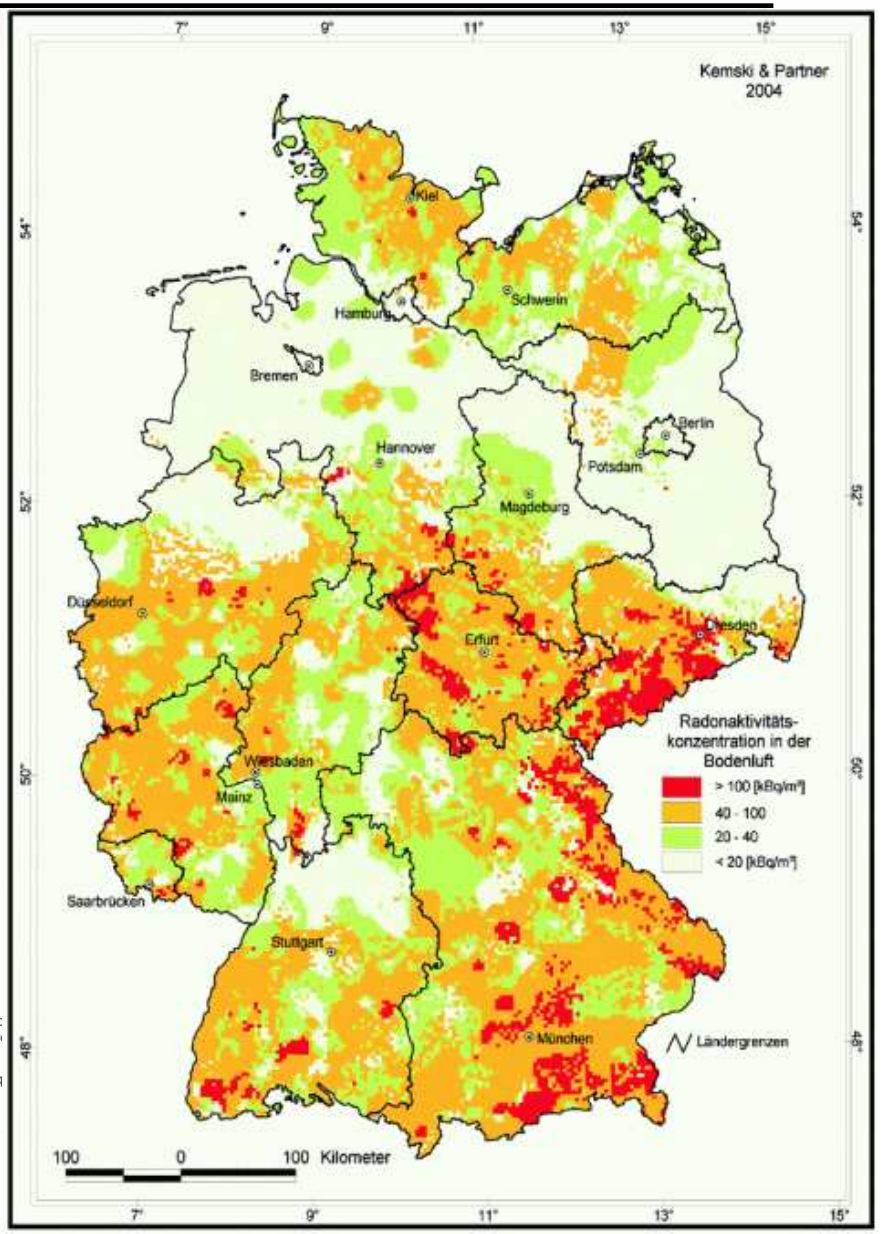
left: outdoor Rn, right: Rn in soil air





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Correlation between outdoor Rn concentration, Rn exhalation from and atmospheric dilution (P. Bossew)

1. Dilution by Rn depleted air from the North Sea

   → rough proxy: mean distance (d) of a sampling point from the coast line between NL and DK

2. Radon exhalation

   → rough proxy: external terrestrial dose rate, nearest dose rate station; variable „**bg“**

correlation matrix (c = Rn concentration; all values significant > 0 ($p < 0,05$)

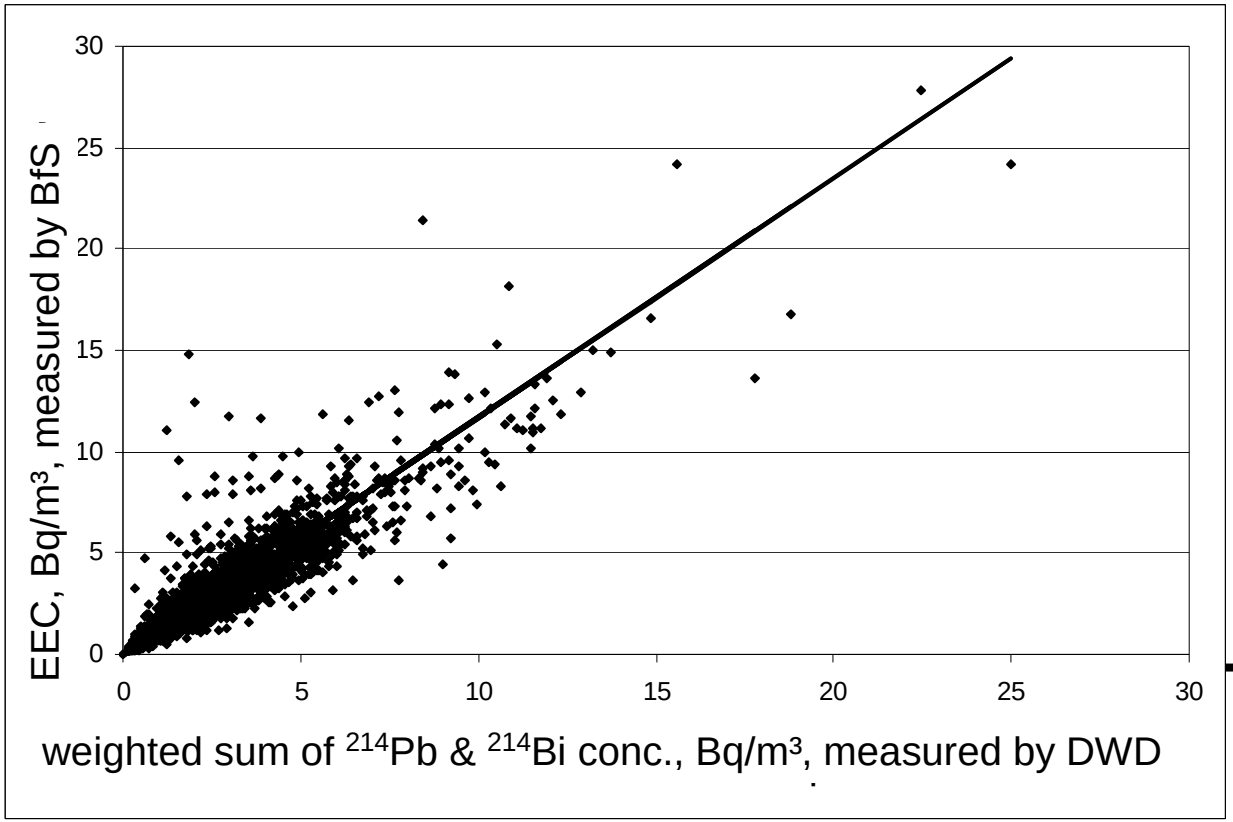
	distance, d	dose rate, bg	concentration, c
distance, d	1	0.46	0.69
dose rate, bg	0.46	1	0.50
conc., c	0.69	0.50	1

→ correlation c ~ d stronger than c ~ bg

Concentrations of short-lived Rn progenies in the near-ground atmosphere

Monitoring network of the German meteo. service (DWD): 40 stations, quasi continuous measurement of atmospherical radioactivity (stepwise moving band filter; ^{214}Bi, ^{214}Pb, ^{212}Bi; measuring period 2h)

Parallel measurements by BfS at two DWD stations (Berlin-Tempelhof, Seehausen): AMZ 200, Tracerlab; one year measurements, 1.5 above ground



$y = 1.18 * x - 0.115$

by orthogonal regression,
95%-C.I. of slope: (1.16 … 1.19)

For 30 DWD stations: estimate of EEC from regression

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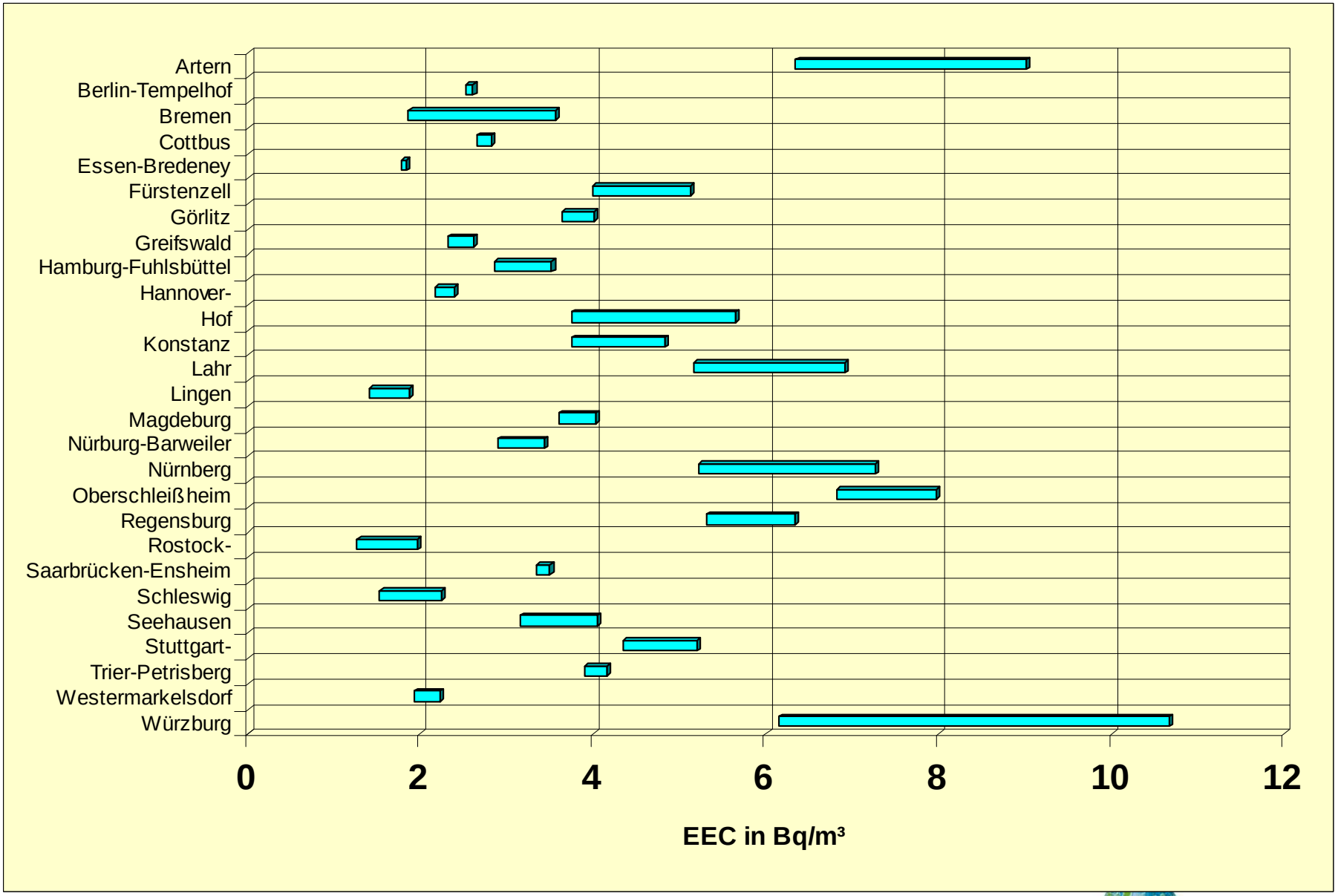

Estimated (from regression) EEC for 27 DWD stations
(ranges; period 2003 – 2006/7)

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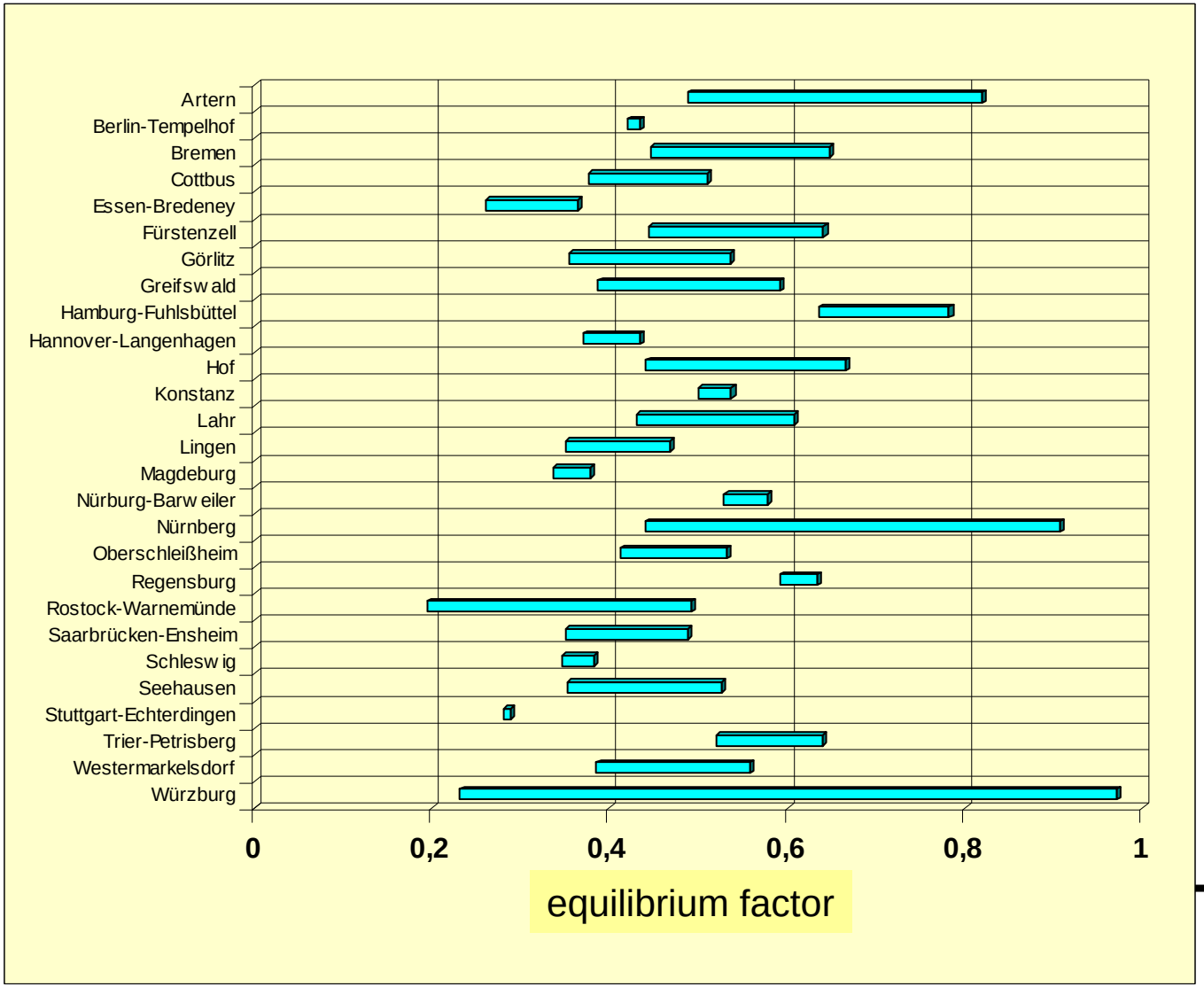
Equilibrium factor



systematic errors are possible!
Reason: slightly different locations of samplers → different air volumes sampled

→ further studies necessary

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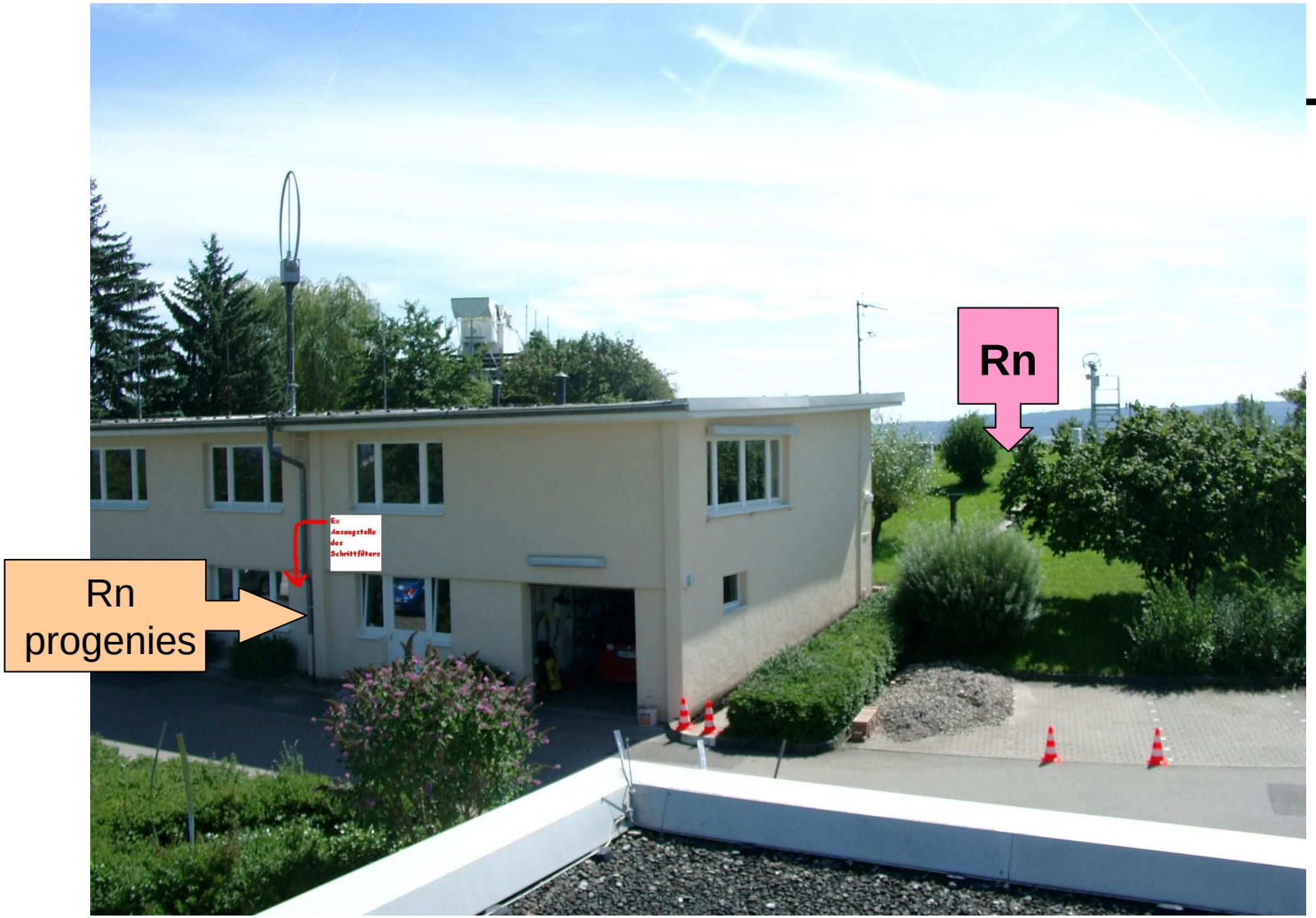

Quelle: DWD

Example of different locations of Rn and Rn progeny sampling; DWD station Stuttgart

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Individual exposure by outdoor Rn to German residents

Effective dose = 9 Bq/m³ x 0.6 x 2000 h/a x 9E-06 mSv / (Bq h m³)

Effective dose = 0.097 mSv/a ≈ 0.1 mSv/a

Dose conversion factor used: from UNSCEAR 2000, better than ICRP 65 value;
according new ICRP: 25% higher dose = 0.12 mSv/a

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Annex: How to ?

Cooking recipe

1) from
   - area of country or region,
   - estimated std. dev.,
   - required accuracy:
   estimate number of locations.

Germany: 173 stations per 357,112 km² = 1 per 2064 km² = 1 per 45 * 45 km² cell;
⇒ Europe: 10.2 Mill. km² : 4940 stations

2) Locations ca. uniformly distributed, best acc. to grid; locations in inhabited area, easily accessible, protected, logistically convenient.
   (Try using existing networks: meteo, dose rate,..)
3) at each location: 1 year measurement period, 2 detectors.
4) at least 2 years, better 3 years ! ⇒ 4 or 6 detectors per location.
5) Costs:
   - 2 detectors: less than 200 € incl. evaluation. ⇒ 400-600 per location.
   - Logistic costs (deploying & collecting the detectors: 4 visits for 3-year measurement) extra.
   - Σ quite cheap !

weather-proof, robust detectors: several manufacturers

cost per station certainly decreases with number

The BfS is happy to help with consulting !

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Thank you for your attention !

We would like to thank the colleagues
of the DWD for their kind support.

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