THE PERFORMANCE OF EUROPEAN CALIBRATION SERVICES REGARDING RADON IN AIR

- EMPIR Project *Metrology for Radon* –

Preliminary Results

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EMPIR EURAMET
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Metro RADON

EMPIR Project *Metrology for Radon*

Work Package 5.2 (extract): Radon Intercomparison

- Selection of a suitable reference instrument for the use as transfer standard and its preparation for the intercomparison (good linearity and repeatability of the measurements, a high measurement range, mechanical robustness, ease of use).
- Developing of a protocol for the comparison, including a form for the participants to document their calibration procedures and measures for quality assurance.
- Excecution of the comparison.

EMPIR Project *Metrology for Radon*

Work Package 5.2 (extract): Radon Intercomparison

- Assessment of the results of the intercomparison regarding their closeness of agreement (precision). Conclusions shall be drawn for the realization of radon activity concentration in air at the European radon calibration facilities in the range from 300 Bq/m^3 to 10 000 Bq/m^3.

EMPIR Radon Intercomparison

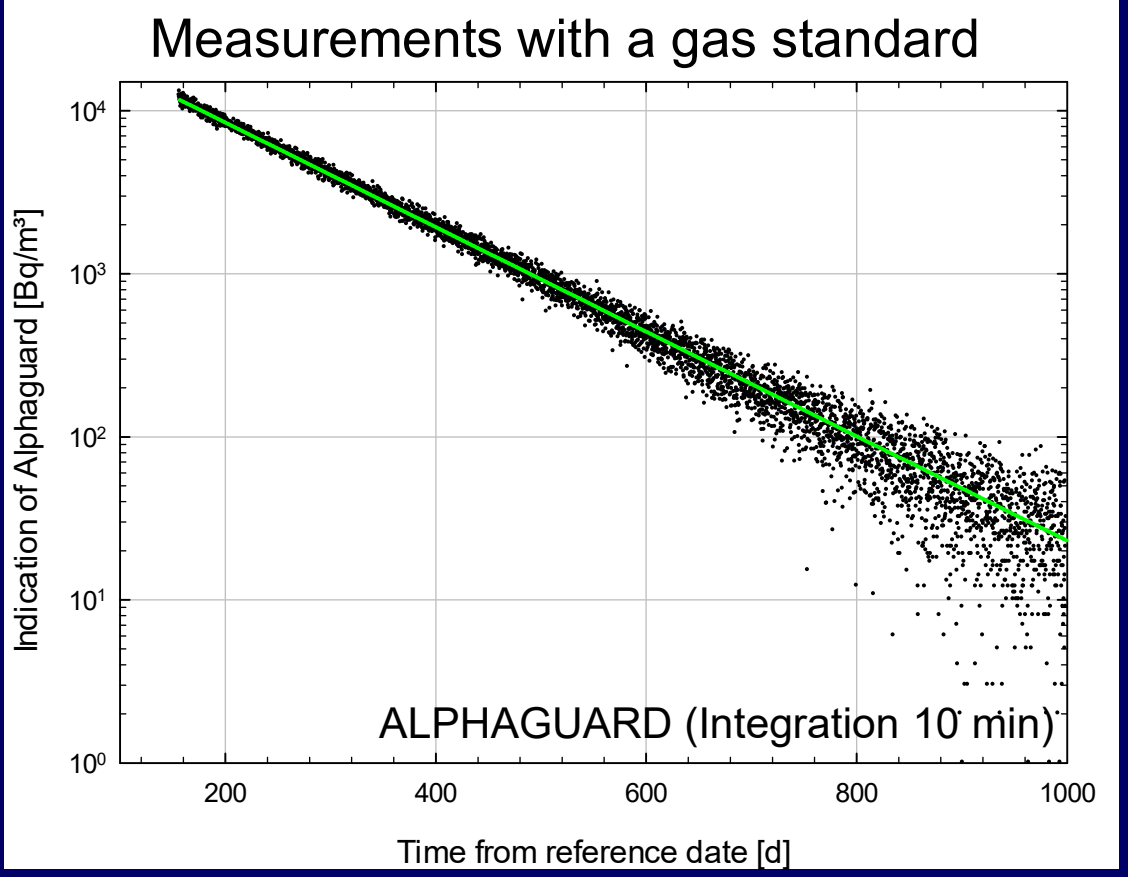
Transfer comparison device: AlphaGUARD PQ 2000 PRO TTL

- **Diffusion mode**
- **Integration time 10 min**

Transfer Comparison Device

Procedure for checking linearity and precision

Slope
(estimated from regression)
$\lambda = 0{,}007502 \pm 0{,}000025\ h^{-1}$



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Transfer Comparison Device

Procedure for checking linearity and precision

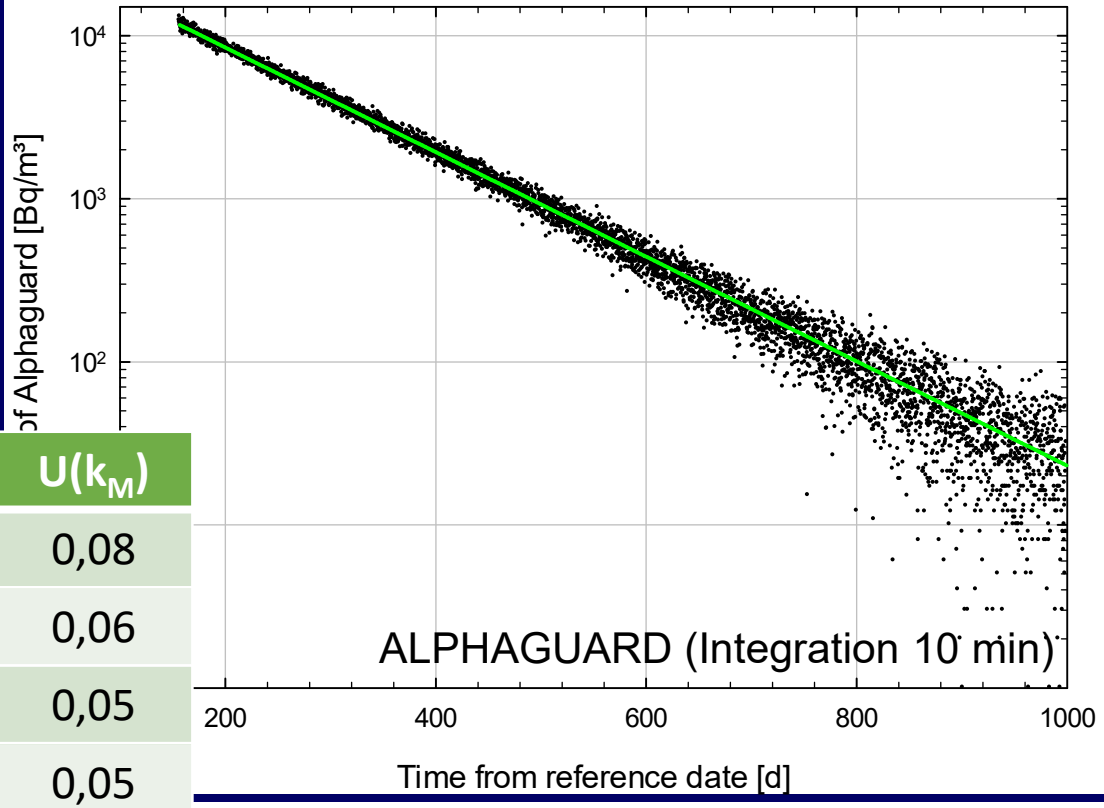
Slope
(estimated from regression)
$\lambda = 0{,}007502 \pm 0{,}000025\ h^{-1}$

Calibration factor k_M at fixed levels

No.	C_{ref} [Bq/m³]	k_M	$U(k_M)$
1	330	0,98	0,08
2	1480	0,97	0,06
3	5750	0,97	0,05
4	11800	0,98	0,05

U includes a coverage factor of 2

Measurements with a gas standard



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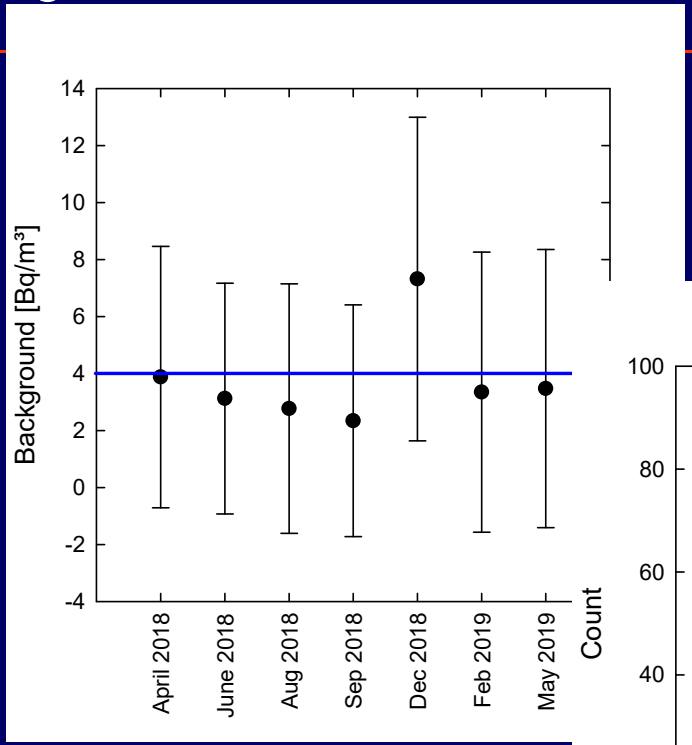
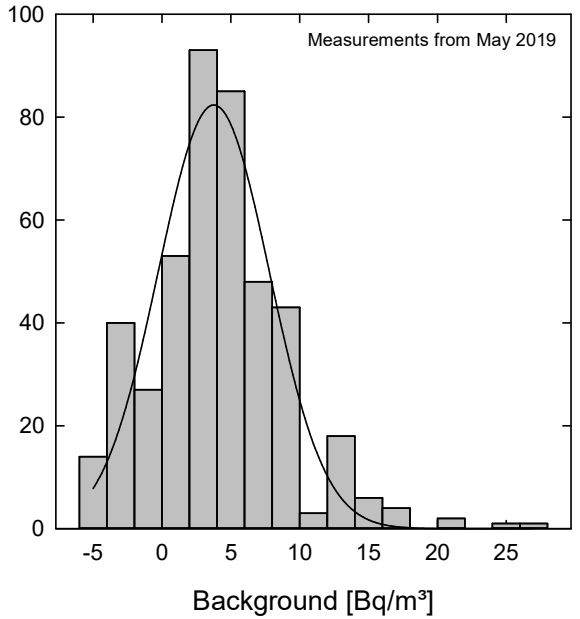
Transfer Comparison Device

Regular checks of background and instrument settings

Nominal correction for background: 4 Bq/m³





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EMPIR Radon Intercomparison

Protocols, Information and Documentation

Information about

- Instrument used as transfer comparison device
- Course of the comparison
- Shipment and transport
- Concentration levels

Provision of forms

- for recording calibration procedures and
- for reporting results

Basis for compiling the data and calculating the results

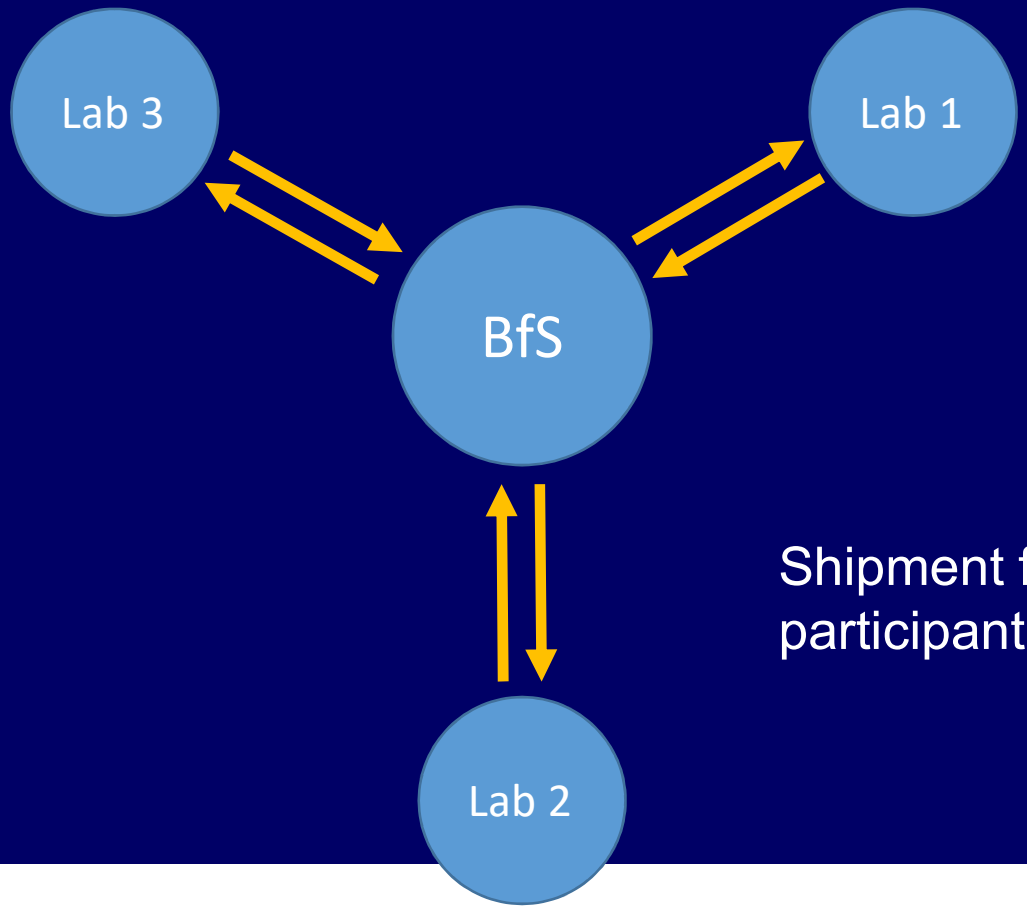
Protocol, Information and Documentation

Radon activity concentrations

	Nominal value	Accepted deviation
1	400 $Bq \cdot m^{-3}$	350 $Bq \cdot m^{-3}$ – 450 $Bq \cdot m^{-3}$
2	1000 $Bq \cdot m^{-3}$	900 $Bq \cdot m^{-3}$ – 1100 $Bq \cdot m^{-3}$
3	6000 $Bq \cdot m^{-3}$	5500 $Bq \cdot m^{-3}$ – 6500 $Bq \cdot m^{-3}$

EMPIR Radon Intercomparison

Execution



Shipment from BfS to the participant and return to BfS

EMPIR Radon Intercomparison

Participants

15 Laboratories
(12 EU countries + Montenegro)

NMI	Montenegro	Goran Vukoslavovic
BEV-PTP	Austria	Franz Josef Maringer
IRSN	France	Sylvain Bondiguel
STUK	Finland	Tuukka Turtiainen
SUJCHBO	Czech Rep.	Josef Vošahlik
BFKH	Hungary	Norbert Szabó
CLOR	Poland	Katarzyna Wołoszczuk
SSI	Sweden	Jens Jensen
UNICAN	Spain	Carlos F. Sainz
SMU	Slovakia	Matej Krivošík
UBB	Romania	Kinga Szacsvai
IFIN-HH	Romania	
UPC	Spain	
BfS	Germany	
ENEA	Italy	

Data Assessment

Quantity of Comparison, R_i

Ratio of radon activity concentrations determined by participant and by transfer device:

$$R_i = \frac{\bar{C}_{Participant,i}}{\bar{C}_{transfer,i}}$$

Relative standard deviation of R_i:

$$u_{rel,i}^2 = \left(\frac{\Delta R_i}{R_i}\right)^2 = \left(\frac{\Delta \bar{C}_{Participant,i}}{\bar{C}_{participant,i}}\right)^2 + \left(\frac{\Delta \bar{C}_{transfer,i}}{\bar{C}_{transfer,i}}\right)^2$$

Only statistical uncertainties, no calibration uncertainties

Data Assessment

Uncertainty-weighted mean $\bar{R}$ of all participants

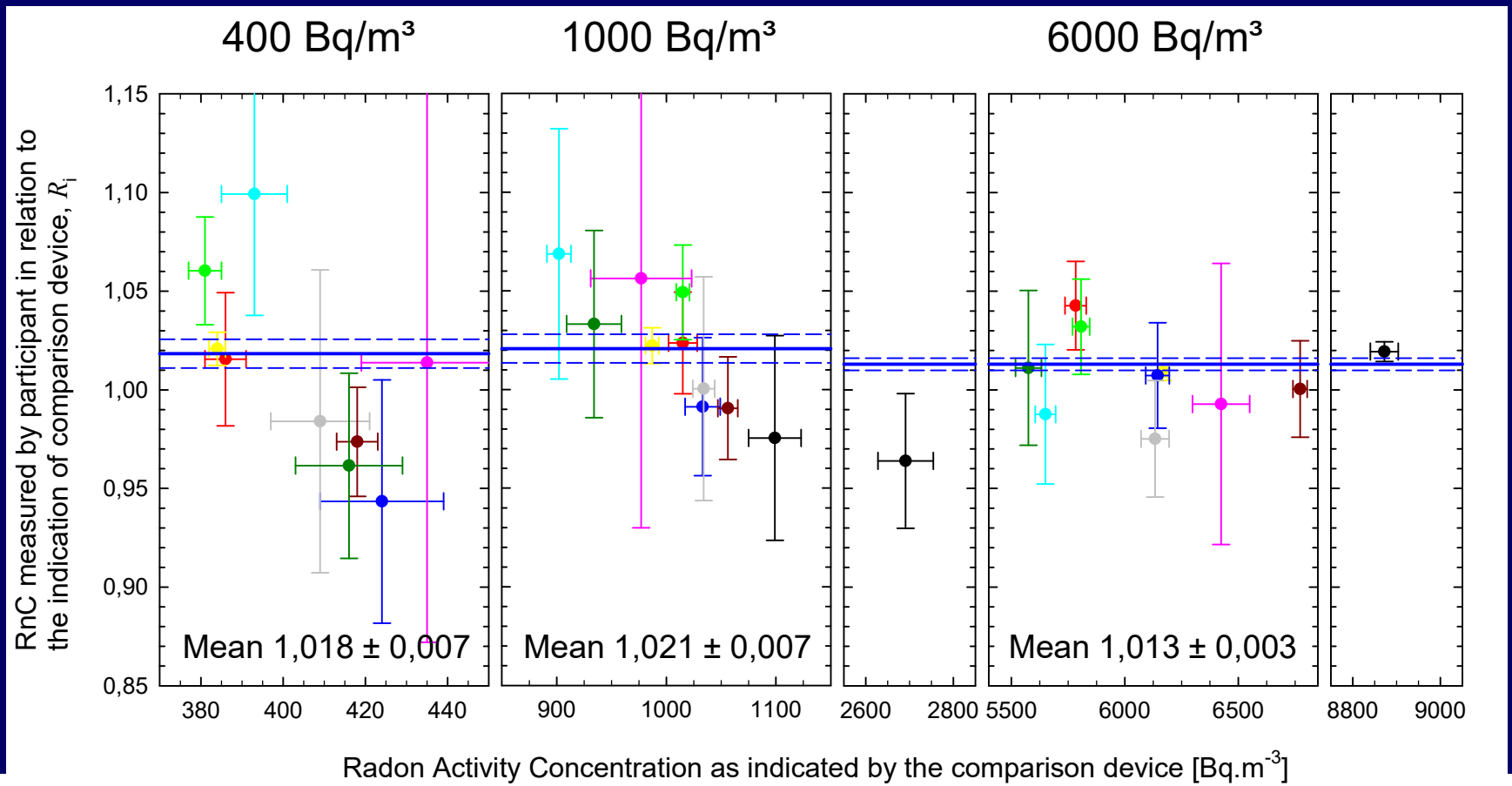
$$\bar{R} = \frac{R_1/u_1^2 + \cdots + R_n/u_n^2}{1/u_1^2 + \cdots + 1/u_n^2} = \sum_{i=1}^{n} w_i R_i$$

Normalized weights: $$w_i = \frac{1/u_i^2}{\sum_{i=1}^{n} 1/u_i^2}$$

Variance associated with $\bar{R}$: $$\frac{1}{u^2(\bar{R})} = \frac{1}{u_1^2} + \ \ldots + \frac{1}{u_n^2}$$

Radon Intercomparison

Provisional results



All uncertainties are given with the extension k=1.

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Radon Intercomparison

Problems with the common variance (and accordingly standard derivation)

Variance associated with $\bar{R}$: $$\frac{1}{u^2(\bar{R})} = \frac{1}{u_1^2} + \ldots + \frac{1}{u_n^2}$$

Literature:
… the reciprocal square-root … becomes too small as the number of participants increases and many labs fall outside the uncertainty interval. [Rukhin, Metrologica 46 (2009)]

The widely used traditional variance estimator … underestimates the variance … and the intervals formed by this estimator have poor coverage probability .... [Zhang, Metrologica 43 (2006)]

The variance estimator seems to be not suitable for quantifying the closeness of agreement (precision) between the participants.

Radon Intercomparison

Consistency check of results

Hypothesis H_0: Results belong to the same basic population
Hypothesis H_1: Results do not belong to the same basic population

Test statistic $$\chi^2 = \sum_{i=1}^{n} \frac{(R_i - \bar{R}_i)^2}{u_i^2}$$

n: Number of participants

Hypothesis H_0 has to be rejected, if $\chi^2 \geq \chi^2_{n-1;1-\alpha}$

$\chi^2_{n-1;1-\alpha}$: Quantile of the χ^2 distribution for the significance level $1 - \alpha$

Radon Intercomparison

Consistency check of results, Error probability 5% (α=0,05)

Radon Level	n	χ^2		$\chi^2_{n-1;1-\alpha}$
400 Bq/m³	9	9,94	<	15,5
1000 Bq/m³	10	5,12	<	16,9
6000 Bq/m³	11	9,44	<	18,3
All	30	24,40	<	42,6

Hypothesis H_0 cannot be rejected: The results are samples of the same population.

The results are mutually consistent. Participants share a common mean value. Deviations from the mean value are normally distributed.

Radon Intercomparison

Preliminary Summary

- The comparison is carried out according to relevant guidelines: EURAMET Guide on Comparison; BIPM/CCQM Guidance note on the estimation of a consensus reference value.
- The results are mutually consistent. Not outlier was observed.
- The majority of the calibration facilities shows a closeness of agreement within an interval of ±5% around the common mean values.
- A statistically meaningful quantification of the closeness of agreement is still in progress.

Thank you for your attention!