Verification and time response of Continous Radon Monitors at UC Radon Chamber

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MetroRADON

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- Introduction
- Practical Arrangements
- Radon Monitors Calibration – Verification
- Response time analysis
- Conclusions

Introduction

- Quality assurance is essential in the internal management of laboratories to perform tests and measurements

- Many commercial radon monitors should be tested

- Transfer devices to calibration Institutes/Laboratories are used as reference

- Maintain the traceability to national or international Metrological institutes

Introduction

INTERNATIONAL STANDARD

IEC 61577

- Radon field there is a standard of the IEC (International Electrotechnical Commission): 61577 series (1 to 4)

- Covers the general features concerning test and calibration of radon and radon decay products measuring instruments.

- It is also intended to help define type tests, which have to be conducted in order to qualify these instruments

Introduction

- IEC 61577-4 concerns the System for Test Atmospheres with Radon (STAR) needed for testing, in a reference atmosphere, the instruments measuring radon and RnDP

Radiation protection instrumentation – Radon and radon decay product measuring instruments –
Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR)

- Instrumentation to verify or calibrate radon monitors: Radon chamber

Introduction

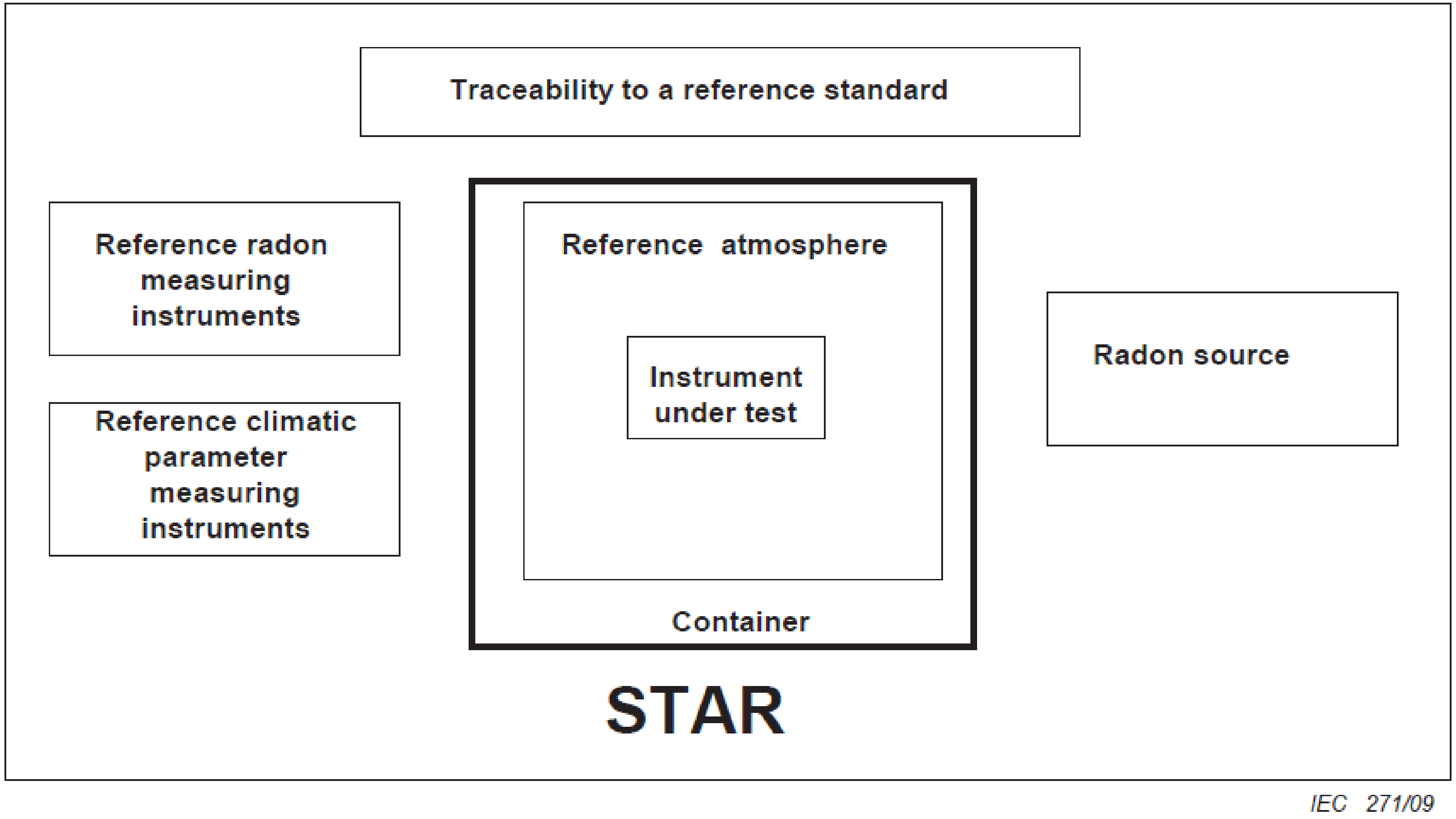


Figure 2 – Minimum requirements for a STAR

Theoretical approach

$$\frac{dC}{dt} = \frac{\phi}{V} - \lambda \cdot C$$

C_0 (Bq/m^3): initial radon concentration

ϕ (Bq/h): radon emission rate from source

$\lambda = \lambda_{Rn} + \lambda_L + \lambda_e$

λ_{Rn} : Rn decay constant (0,0076 h^{-1})

λ_L : Chamber leakages

λ_e : Reflects air exchange rate per hour → *f* : pump flow rate; *V* : Rn chamber volume

Theoretical approach

$$C(t) = C_0 e^{-\lambda t} + \frac{\phi}{V\lambda}(1 - e^{-\lambda t})$$

C_0 (Bq/m^3): initial radon concentration

ϕ (Bq/h): radon emission rate from source

$\lambda = \lambda_{Rn} + \lambda_L + \lambda_e$

λ_{Rn} : Rn decay constant (0,0076 h^{-1})

λ_L : Chamber leakages

λ_e : Reflects air exchange rate per hour

$$\lambda_e\,(h^{-1}) = \frac{60 \cdot f\,(L/min)}{1000 \cdot V\,(m^3)}$$

f : pump flow rate

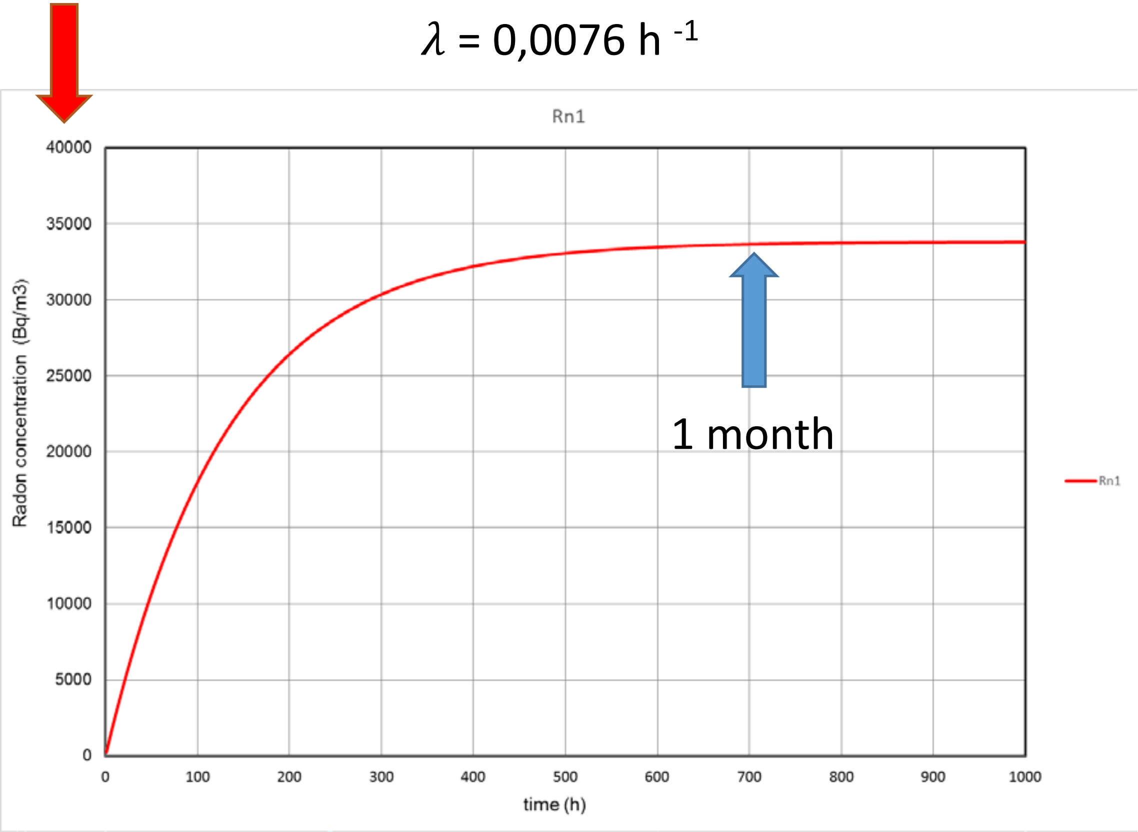
V : Rn chamber volume

Theoretical approach

Radon source ϕ= 255 Bq/h

Chamber Closed

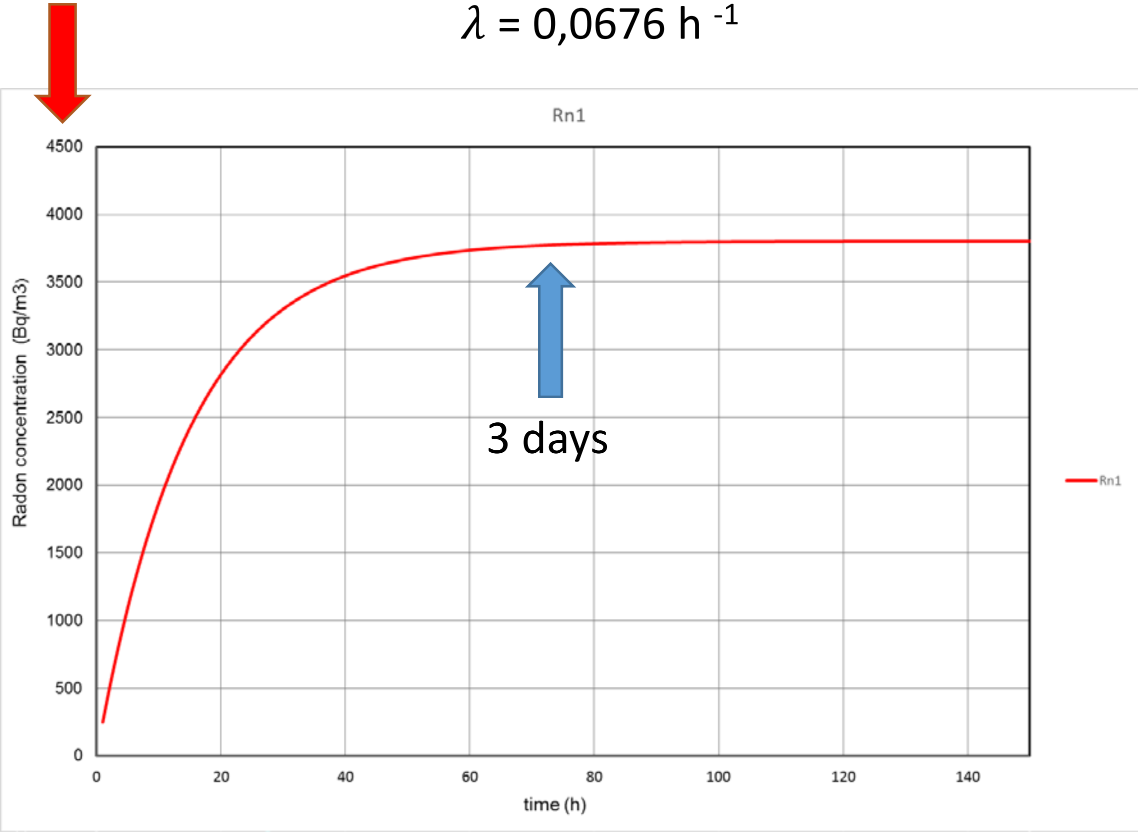
λ = 0,0076 h^{-1}



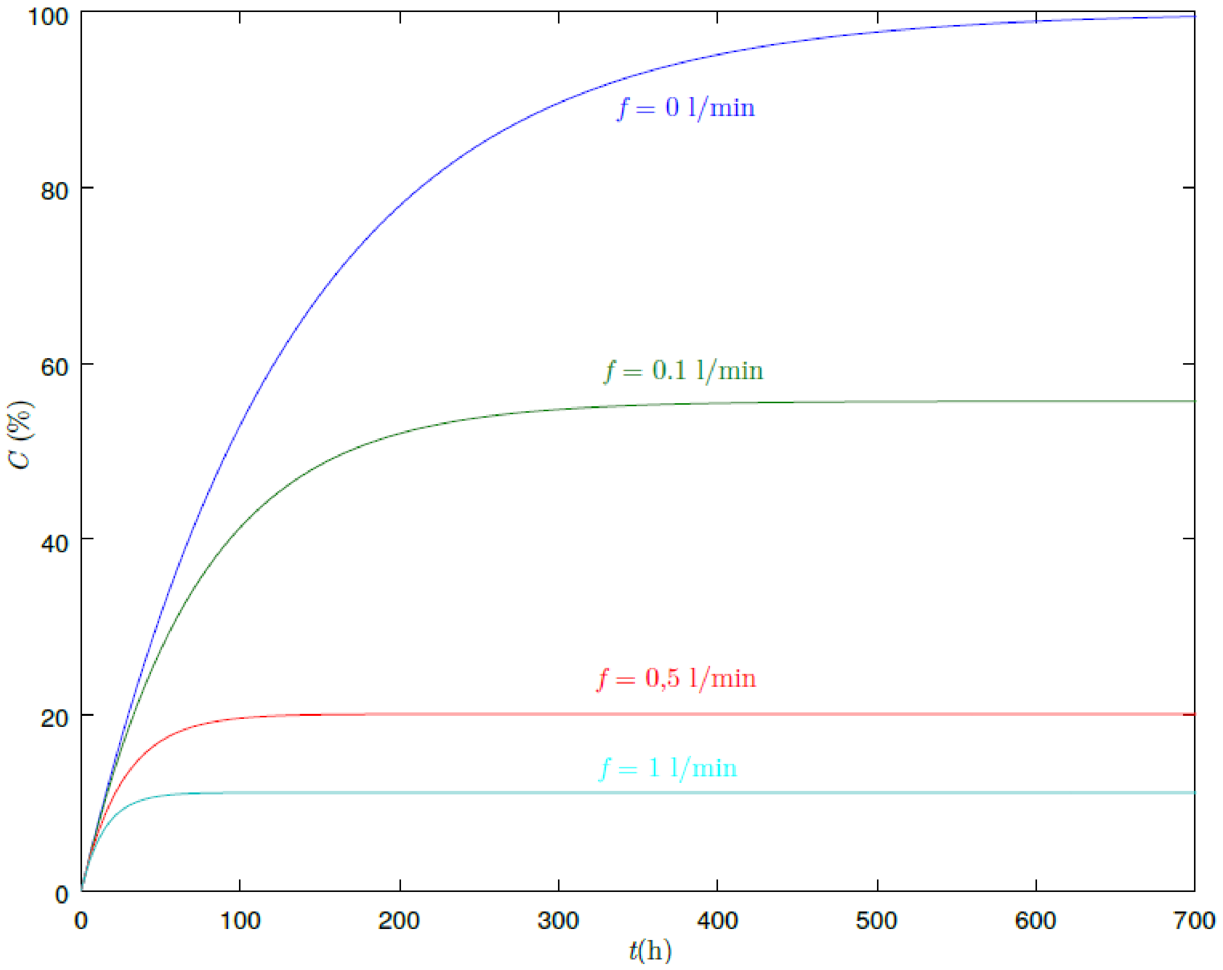
Chamber with Pump

$F = 1\text{L/min}$

λ = 0,0676 h^{-1}



Theoretical approach



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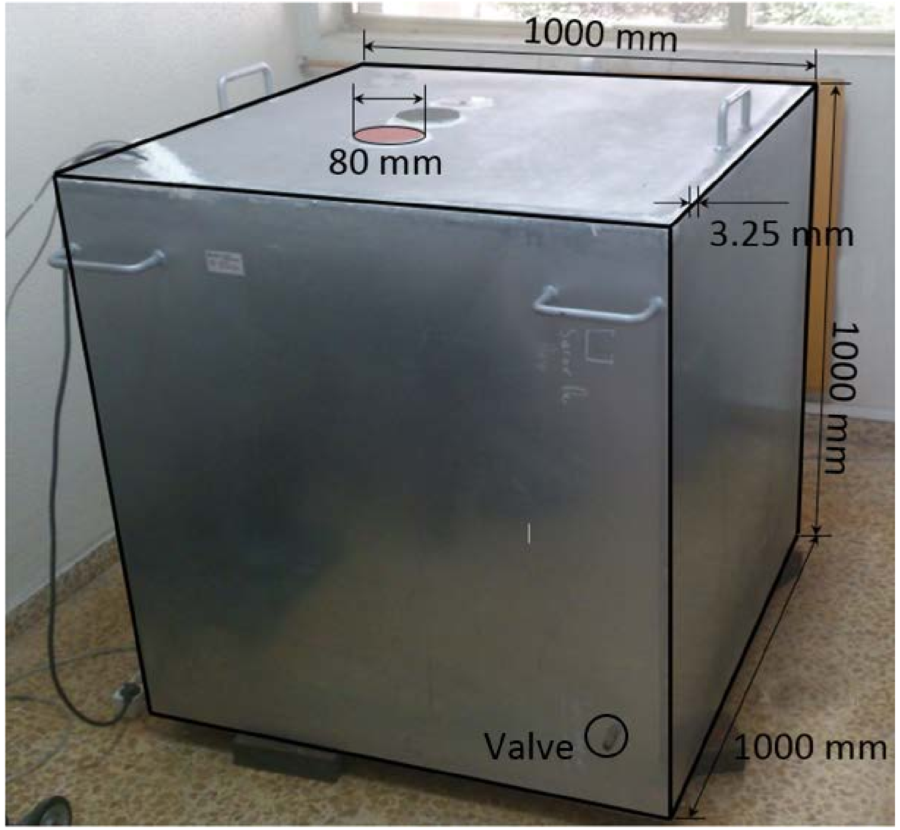
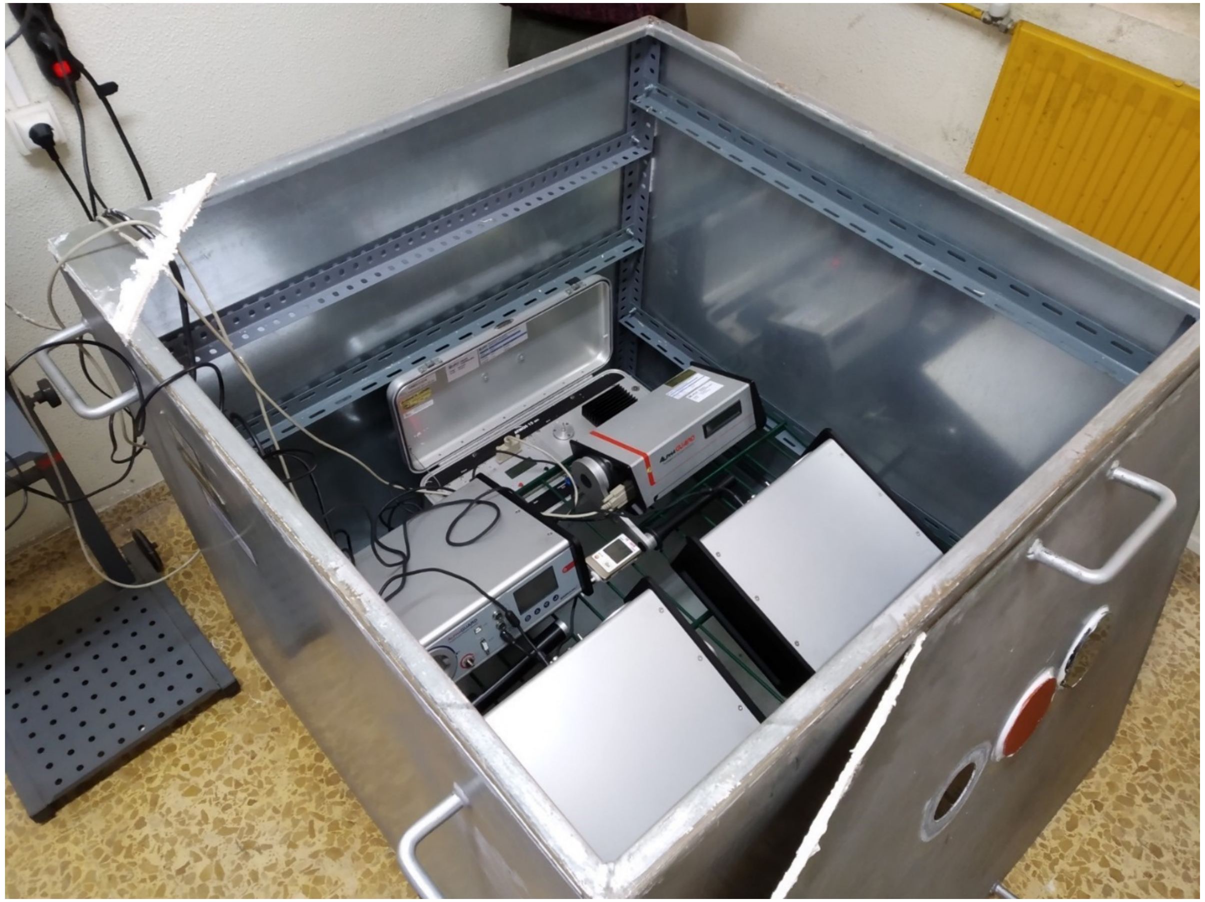
Practical Arrangements

Radon Chamber: Laboratory of Environmental Radioactivity, University of Cantabria (Spain)



- Stainless steel
- Thickness of 3.25 mm
- Carefully welded
- Internal volume 1 m^3
- Top face is a lid that can be removed
- 3 circular holes to insert etched track detectors

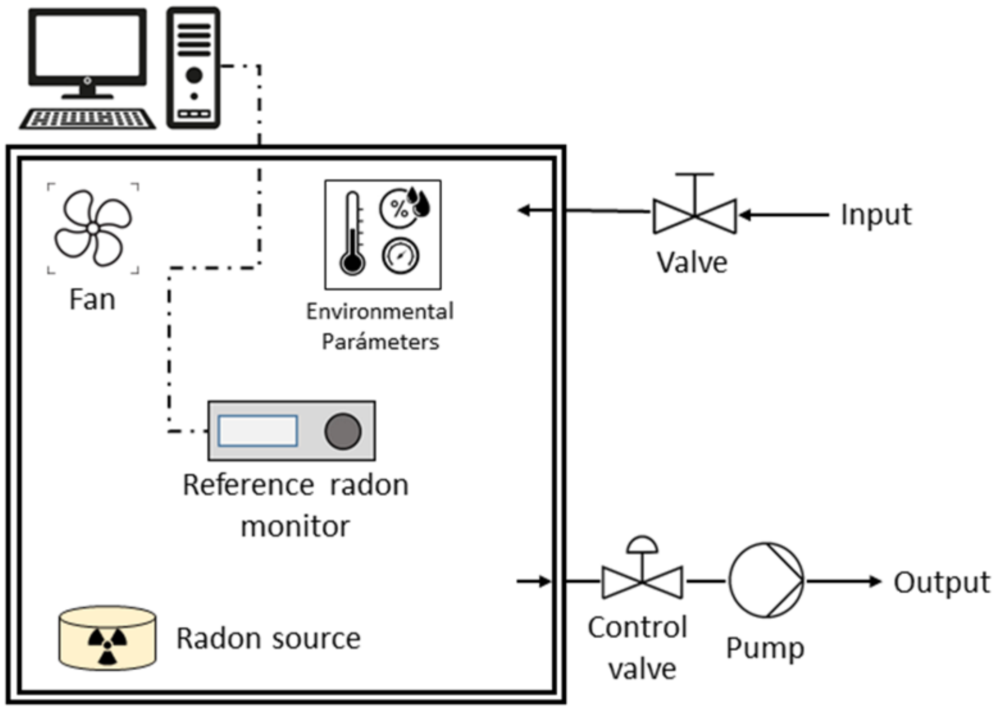
Practical Arrangements



- Internal volume 1 m^3
- Top face is a lid that can be removed
- Some internal levels

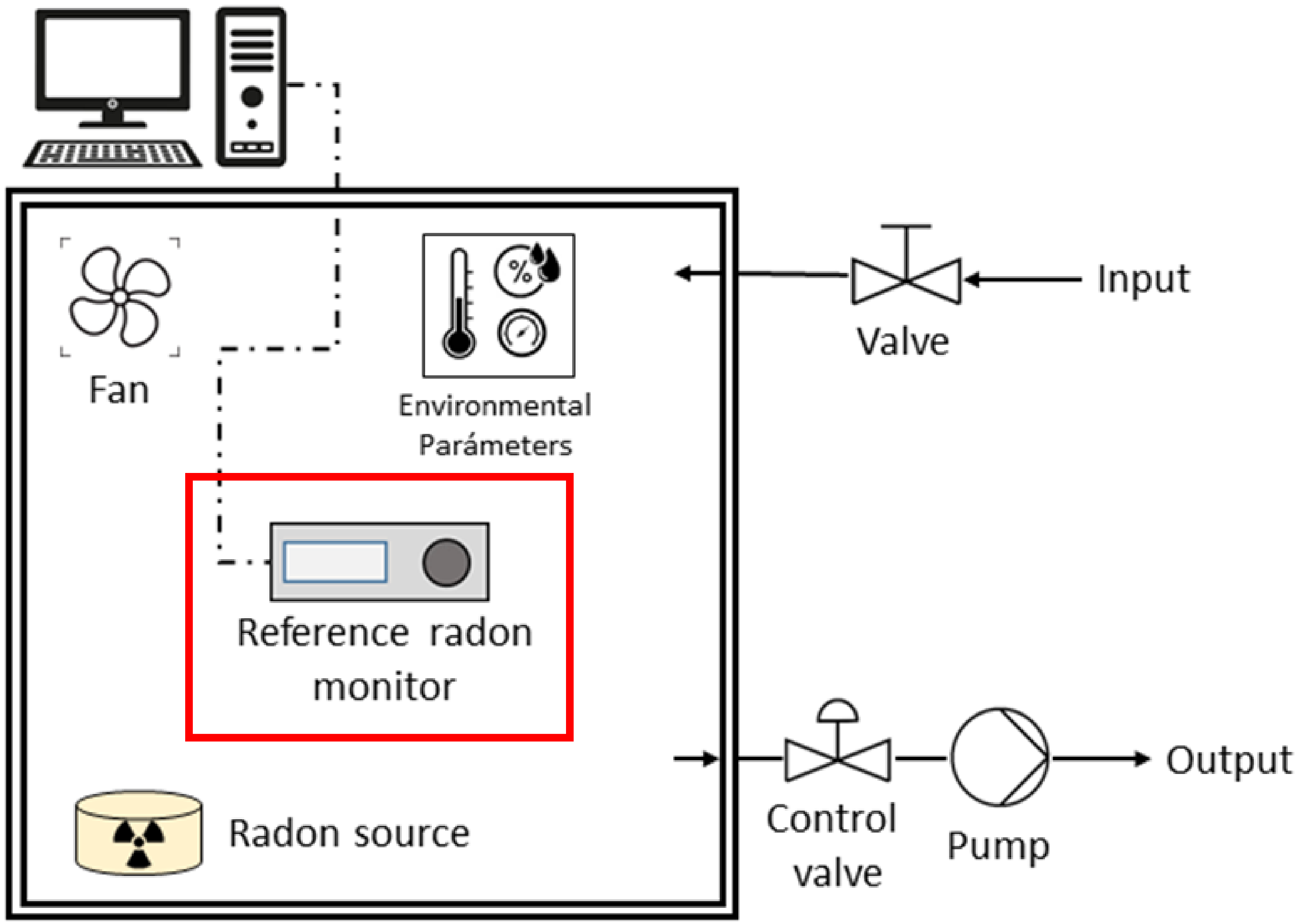
Practical Arrangements

Radon Chamber: Laboratory of Environmental Radioactivity, University of Cantabria (Spain)



- Reference monitor traceable to international standards
- Radon sources (Bq/h)
- Air exchange with exterior controlled with a pump
- Environmental parameters monitored (*P*, *rH*, *T*)
- Keep the Rn concentration between:
  - 300 and 20000 Bq/m^3

Reference Radon Monitors



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Reference Radon Monitors

- Calibrated in BfS

Bundesamt für Strahlenschutz

AlphaGUARD

Atmos12

Monitor	Detection technology	Sensitivity (cpm at 1 kBq m^{-3})
AlphaGUARD	Ionisation chamber	50
ATMOS12 DPX	Ionisation chamber	20

Reference Radon Monitors

- Calibrated in BfS

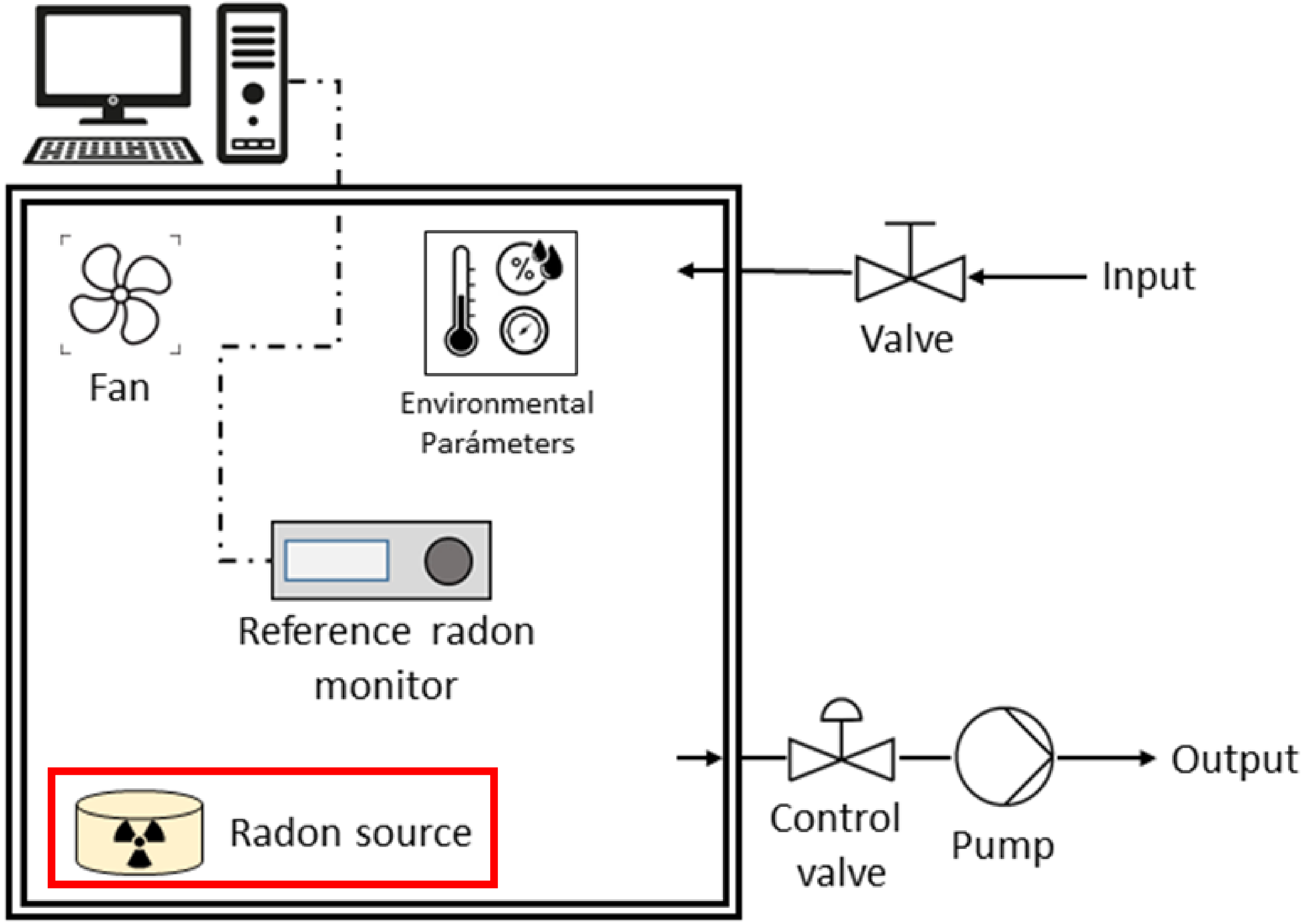
Bundesamt für Strahlenschutz

	(1)	(2)	(3)
Levels (kBq/m^3)	0.3 – 0.5	1 - 2	10 - 12

- Calibration factor as: $$F = \frac{C_{ref}}{C_M}$$ $$\boxed{F \pm u(F)}$$

- Aplication in measurements in order to keep the traceability

Radon Sources



Radon Sources

- Dry soil power with high Radium content (Closed by diffusion)

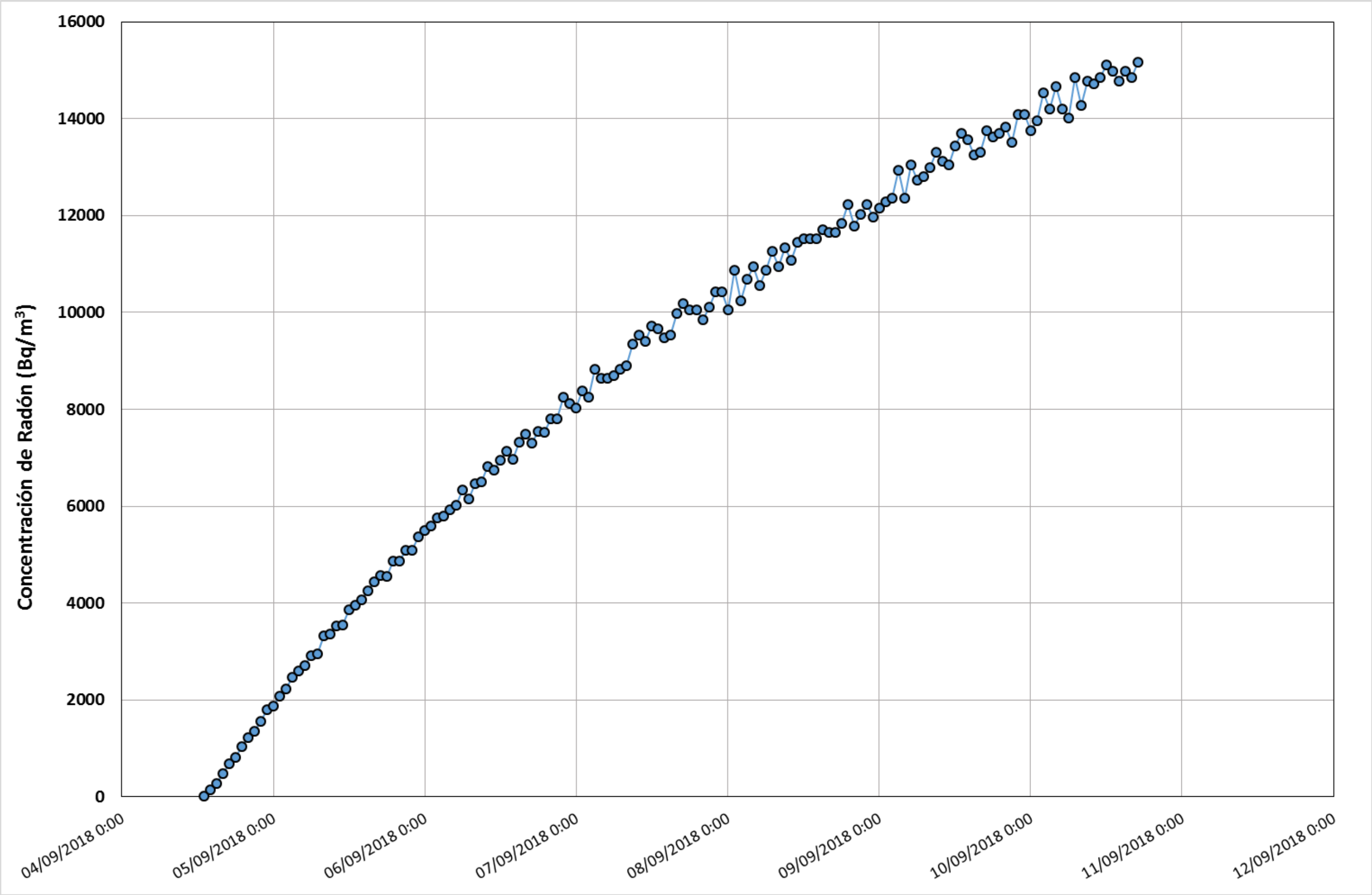
- Commercial radon sources Pylon

- Characterization in the chamber
- ϕ (Bq/h):

  Emission rate from source

- Checked and adjusted periodically

Radon Sources

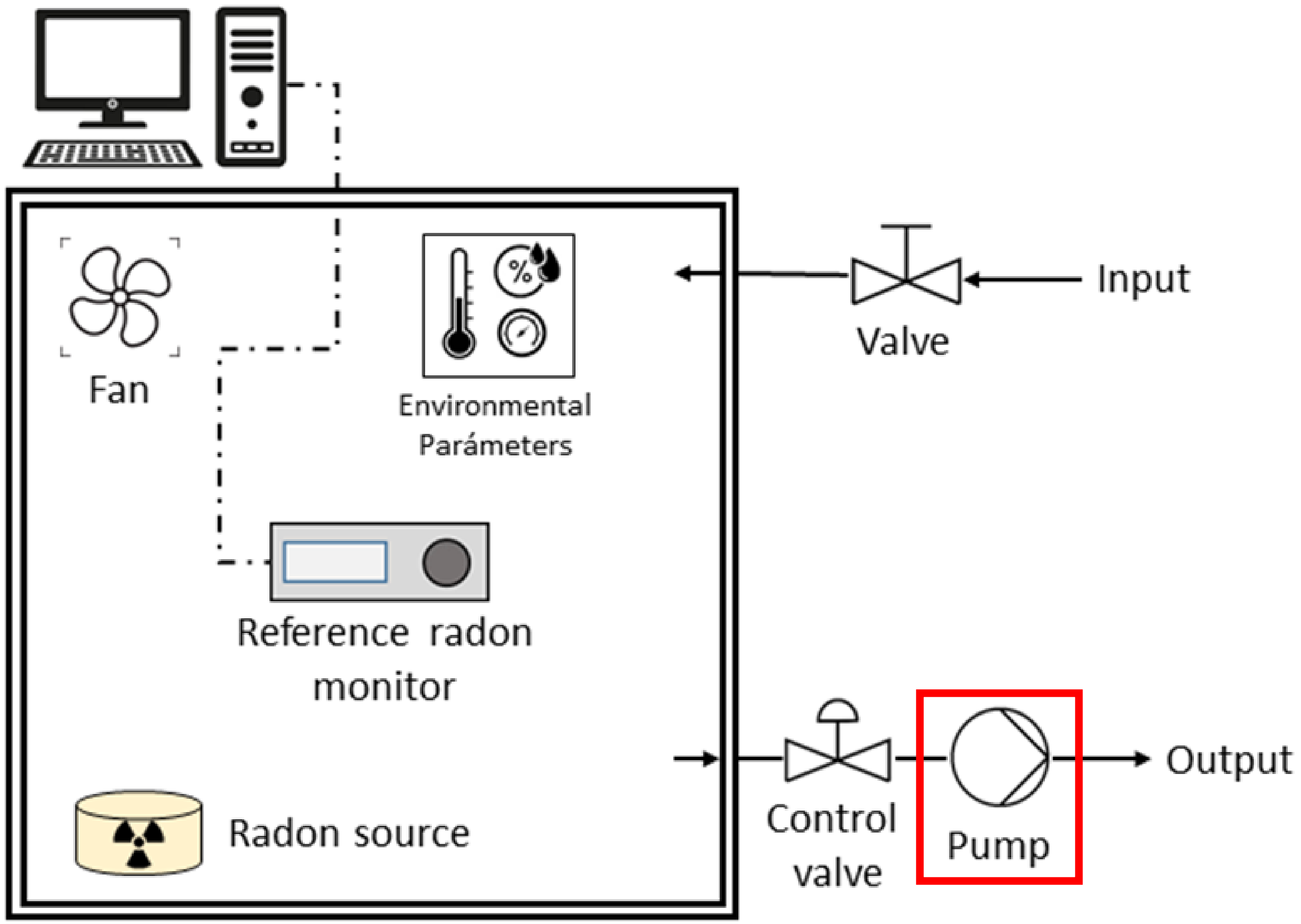


$$C(t) = C_0 e^{-\lambda t} + \frac{\phi}{V\lambda}(1 - e^{-\lambda t})$$

0

ϕ = 162 ± 5 Bq/h

Pump


Fan
Environmental Parámeters
Reference radon monitor
Radon source
Valve
Input
Control valve
Pump
Output

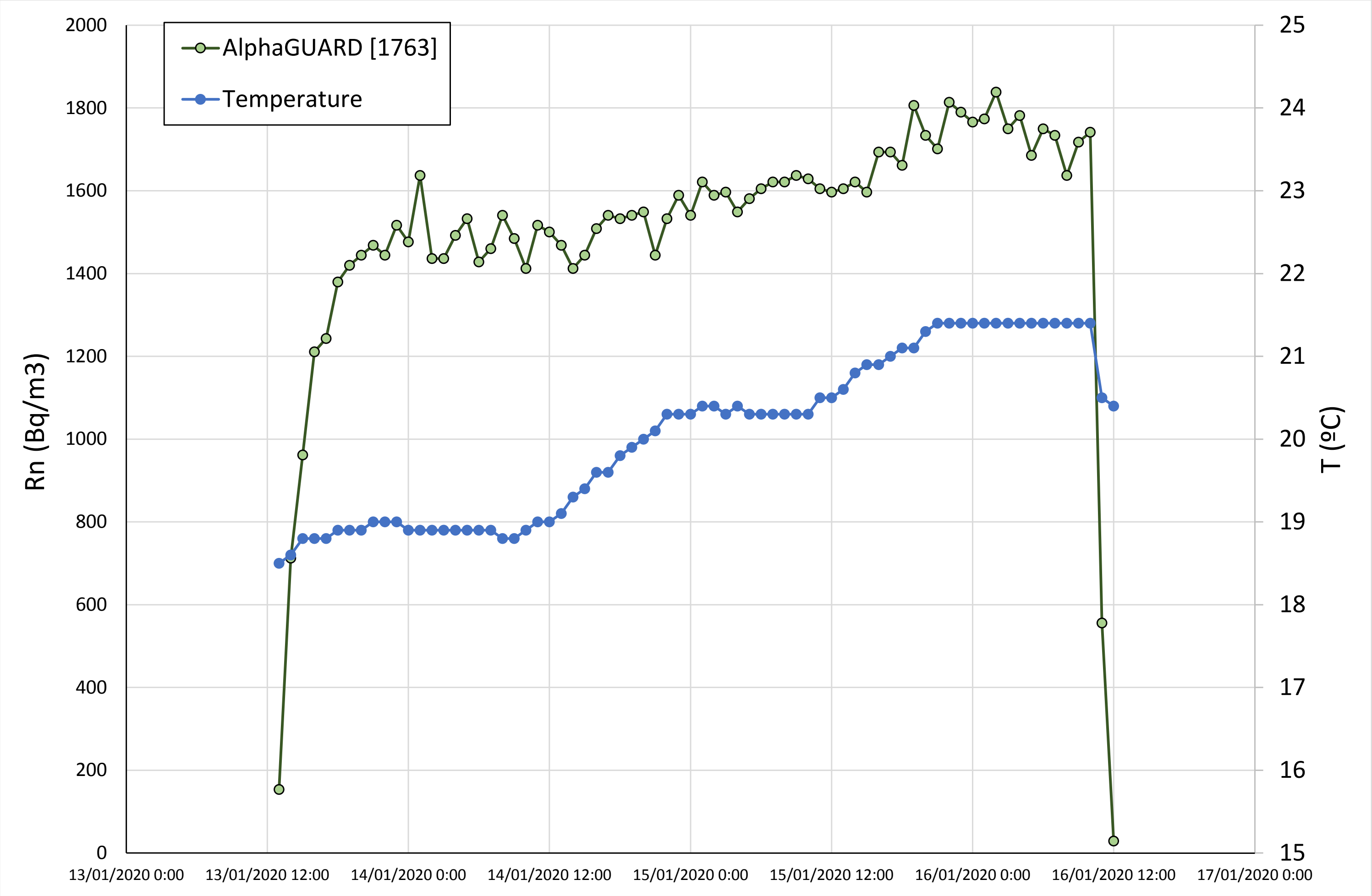
Pump

- Air exchange with outside atmosphere
- Extraction
- From 0.5 to 30 L/min
- Stabilize the Rn concentration inside

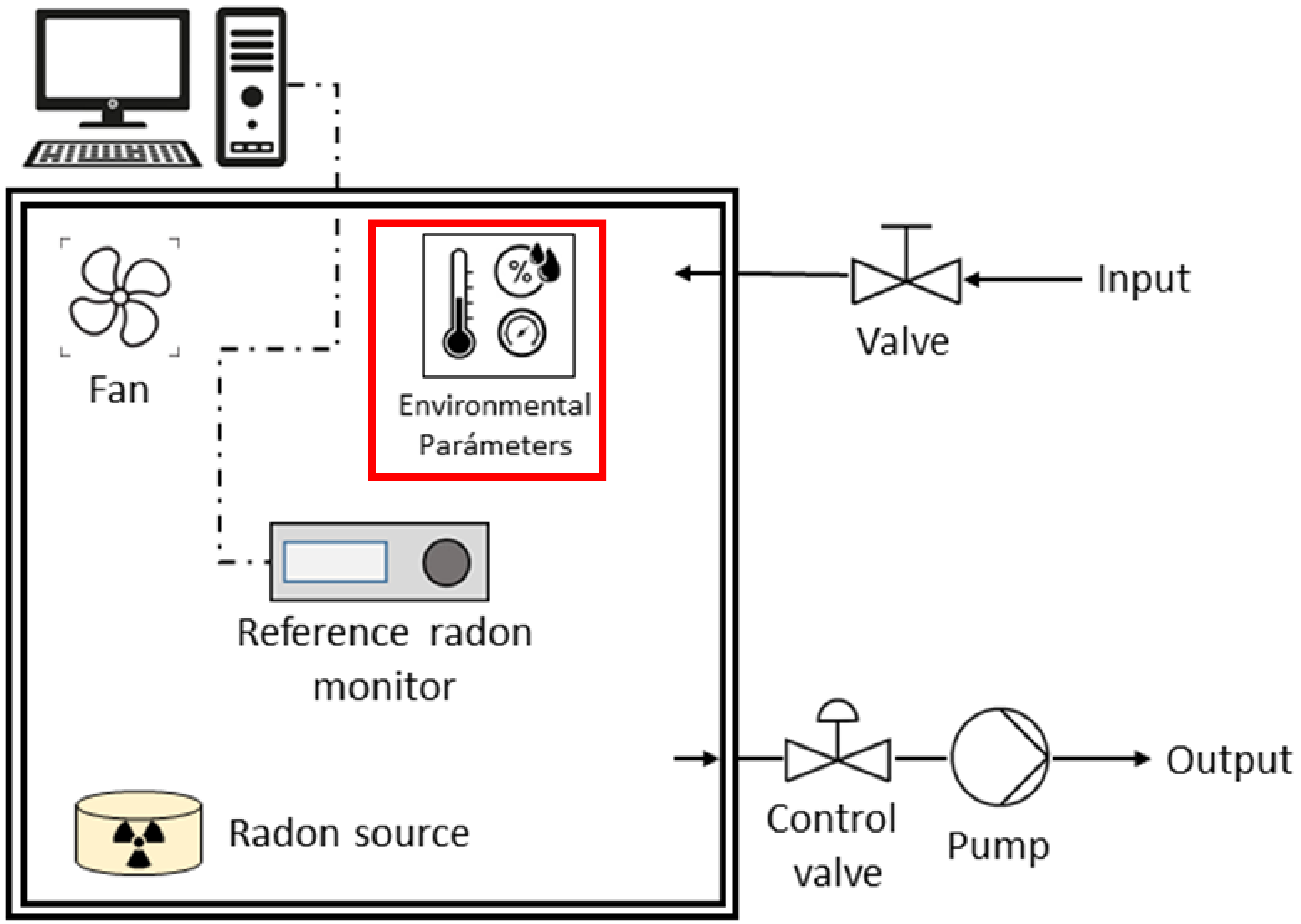
PUMP

Pump

- Pump flow correlated with chamber temperature



Environmental conditions



Environmental conditions

- **Inside:**
  - Pressure: 600 to 1100 hPa (± 3 hPa)
  - Temperature: -20 to 70 °C (± 3 °C)
  - Relative Humidity: 0 to 100% (2% at 25 °C)
- Every sensor is calibrated in accredited laboratories
- Traceable measurements

- **Outside:**
  - Temperature control to maintain the room and chamber
  - Humidity control

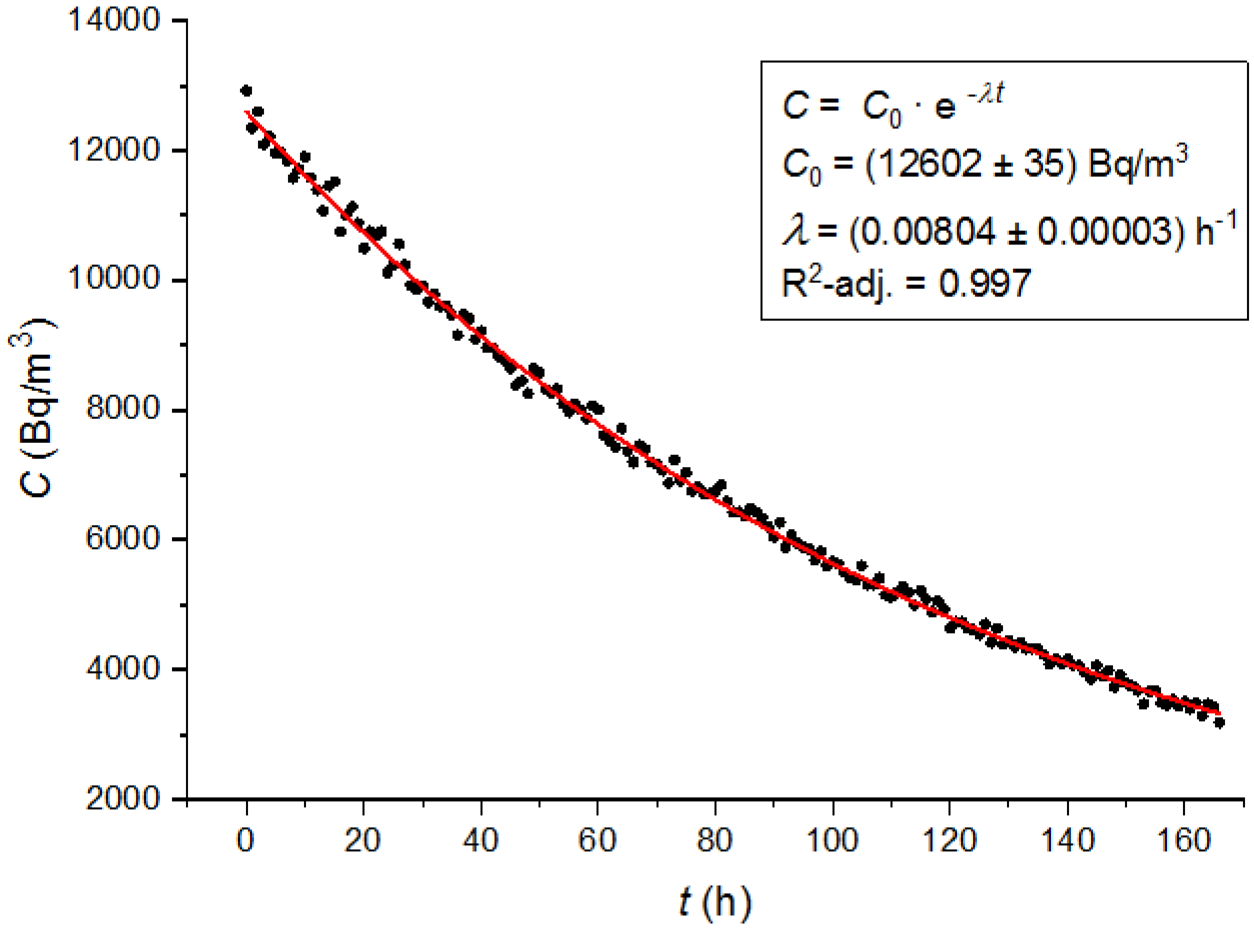
Sealing material

- Acrylic putty
- Many profs with different materials (aluminium tape)
- Radon coeficient diffusion < 10^{-13} m^2/s (ISO/DTS 11665-13)
- Easy aplication and removal
- Other colleagues: rubber joints plus parafin

Sealing material

- Radon introducted
- Chamber totally sealed
- Rn Decay

- Analysis of radón decay constant versus the obtained experimental



$$\lambda = (8.04 \pm 0.03)\ 10^{-3}\ h^{-1}$$

$$\lambda_{Rn} = (7.5575 \pm 0.0004)\ 10^{-3}\ h^{-1}$$

$$\Rightarrow \lambda_L = (0.48 \pm 0.03) \cdot 10^{-3}\ h^{-1}$$

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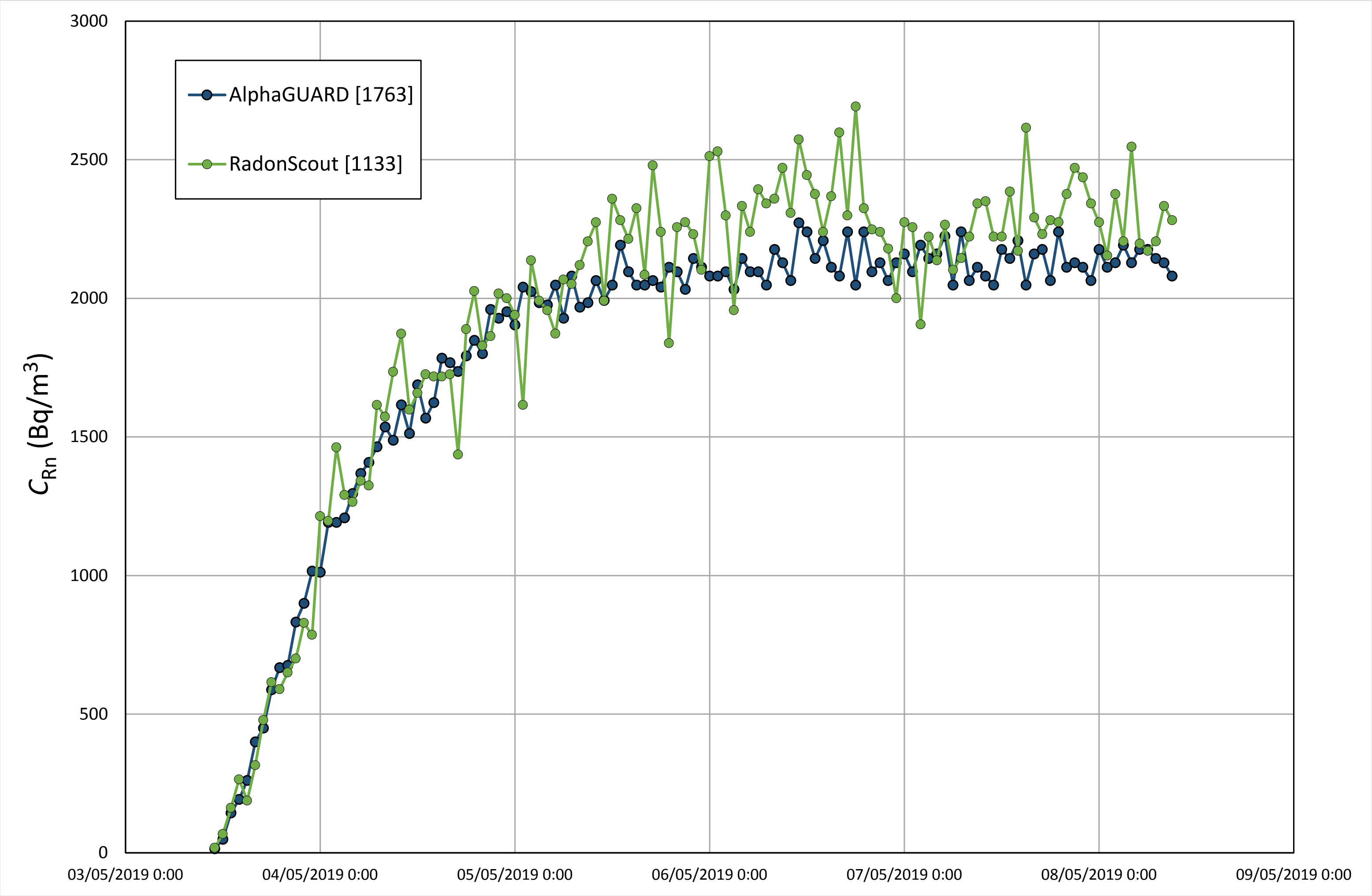
Radon monitors calibration - Verification

Background control:

- Close the chamber with monitor during 2 Rn periods previously “clean” with outside air
- Clean the chamber with aged air and determine the background

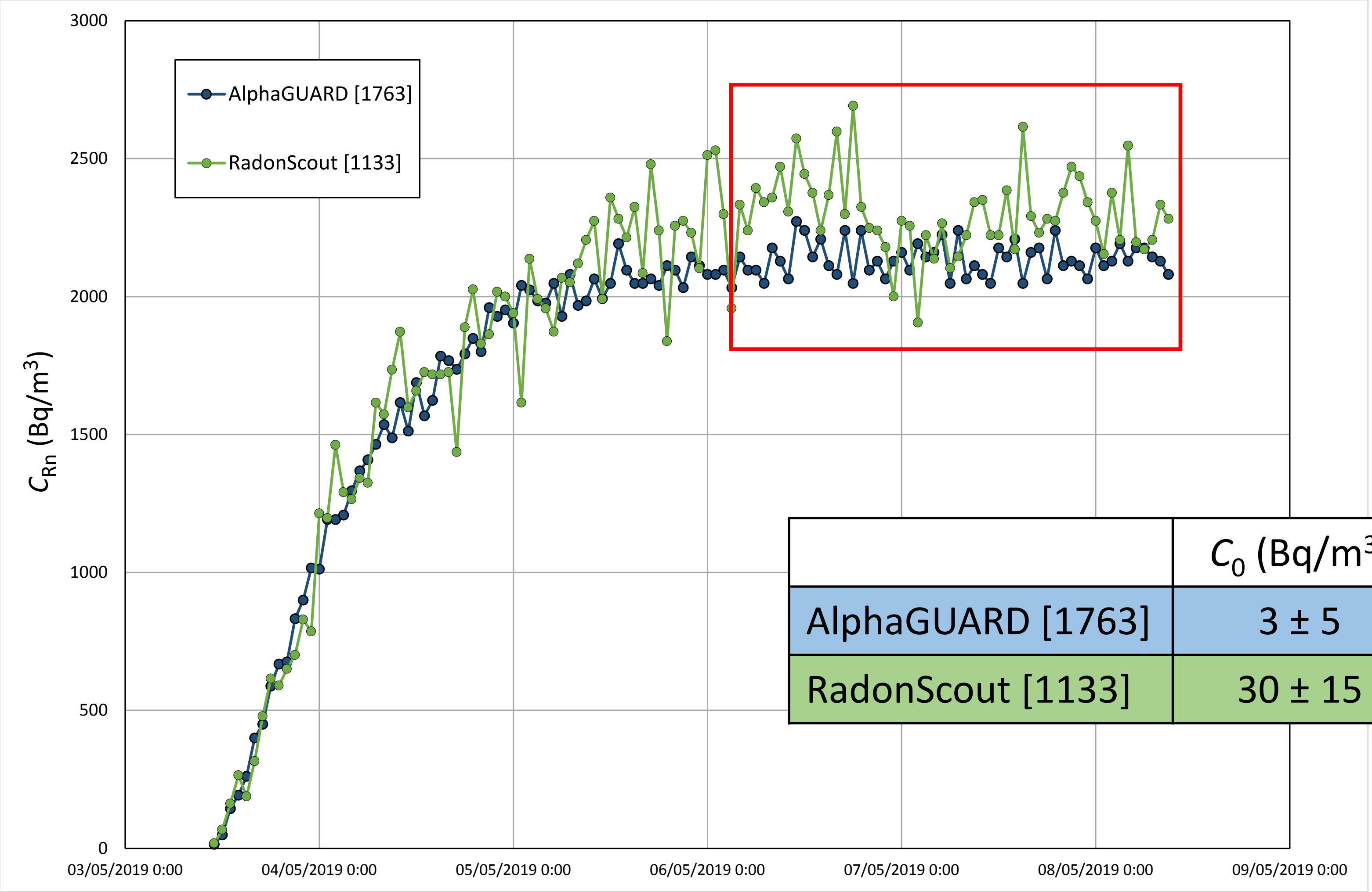
- **Experimental design**
  - Keep the Rn concentration according to previous equation
  - Compare the measurements with the reference monitor
  - **Calibration:** Obtain the calibration factor plus uncertainty to correct the measurements
  - **Verification**: Monitor should be in a defined interval (10%, 20%, etc)

Radon monitors calibration



- Reference Monitor:
  - AlphaGUARD [1763]
- Source:
  - PylonRN-1025: (140 ± 4) Bq/h
- Pump: (1.0 ± 0.1) L/min
- *T*= (19.9 ± 0.5) ºC
- *P*= (1011 ± 6) mbar
- *rH* = (52 ± 3)%

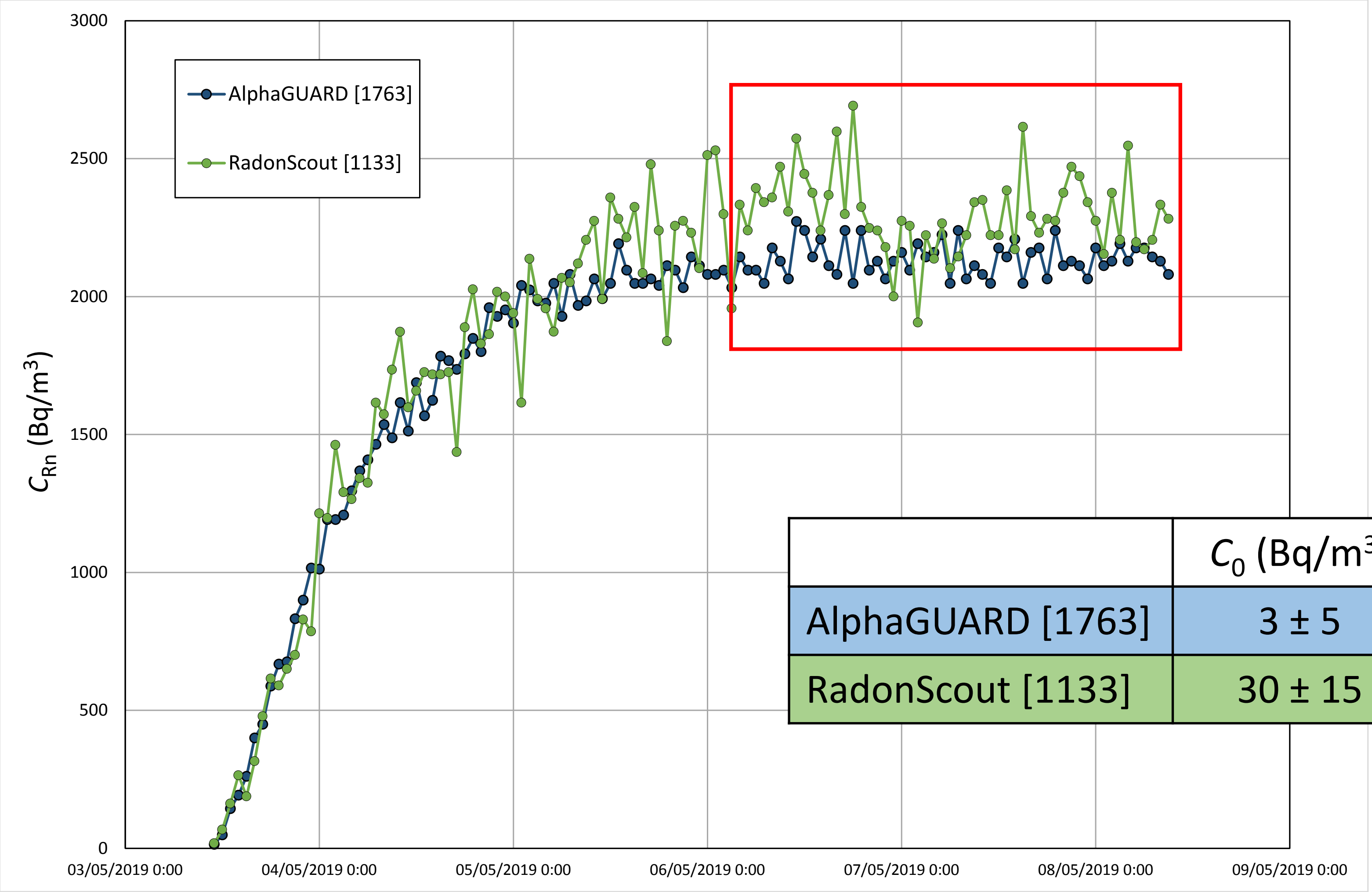
Radon monitors calibration



$$F = \frac{\left(C_{ref} - C_{0\,ref}\right) F_{ref}}{C_M - C_0}$$

	C_0 (Bq/m^3)	C (Bq/m^3)	F
AlphaGUARD [1763]	3 ± 5	2140 ± 9	1.005 ± 0.024
RadonScout [1133]	30 ± 15	2290 ± 20	0.950 ± 0.027

Radon monitors calibration



$$F = \frac{\left(C_{ref} - C_{0ref}\right) F_{ref}}{C_M - C_0}$$

	C_0 (Bq/m³)	C (Bq/m³)	F
AlphaGUARD [1763]	3 ± 5	2140 ± 9	1.005 ± 0.024
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Calibration

$$F = \frac{\left(C^*_{ref} - C_{0,ref}\right)F_{ref}}{C^*_M - C_{0,M}} = \frac{C_{ref}}{C_M}$$

$u(C^*_{ref})$ uncertainty of mean radon concentration measured by reference monitor.

$u\left(C_{0,ref}\right)$: uncertainty of background of reference monitor

$u\left(F_{ref}\right)$: uncertainty of calibration factor given in the calibration certificate (keep traceability)

$u(C^*_M)$: uncertainty of mean radon concentration measured by monitor under calibration.

$u\left(C_{0,M}\right)$: uncertainty of background of monitor under calibration

Verification

- Accuracy

$$D(\%) = 100 \cdot \frac{C_M - C_{ref}}{C_{ref}}$$

- Precision

$$RSD\ (\%) = 100 \cdot \frac{SD}{C_M}$$

C_{ref}: mean radon concentration measured by reference monitor
C_M: mean radon concentration measured by monitor under verification
SD: Standard deviation of radon concentration measured by monitor under verification

- Background and Calibration factors applied
- Criteria of every lab. To these parameters

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Response time of Radon Monitors

IOP Publishing | Society for Radiological Protection Journal of Radiological Protection
J. Radiol. Prot. 38 (2018) 1111–1127 (17pp) https://doi.org/10.1088/1361-6498/aad969

Performance of radon monitors in a purpose-built radon chamber

Marta Fuente[1], Daniel Rabago[2,4], Sixto Herrera[3], Luis Quindos[2], Ismael Fuente[2], Mark Foley[1] and Carlos Sainz[2]

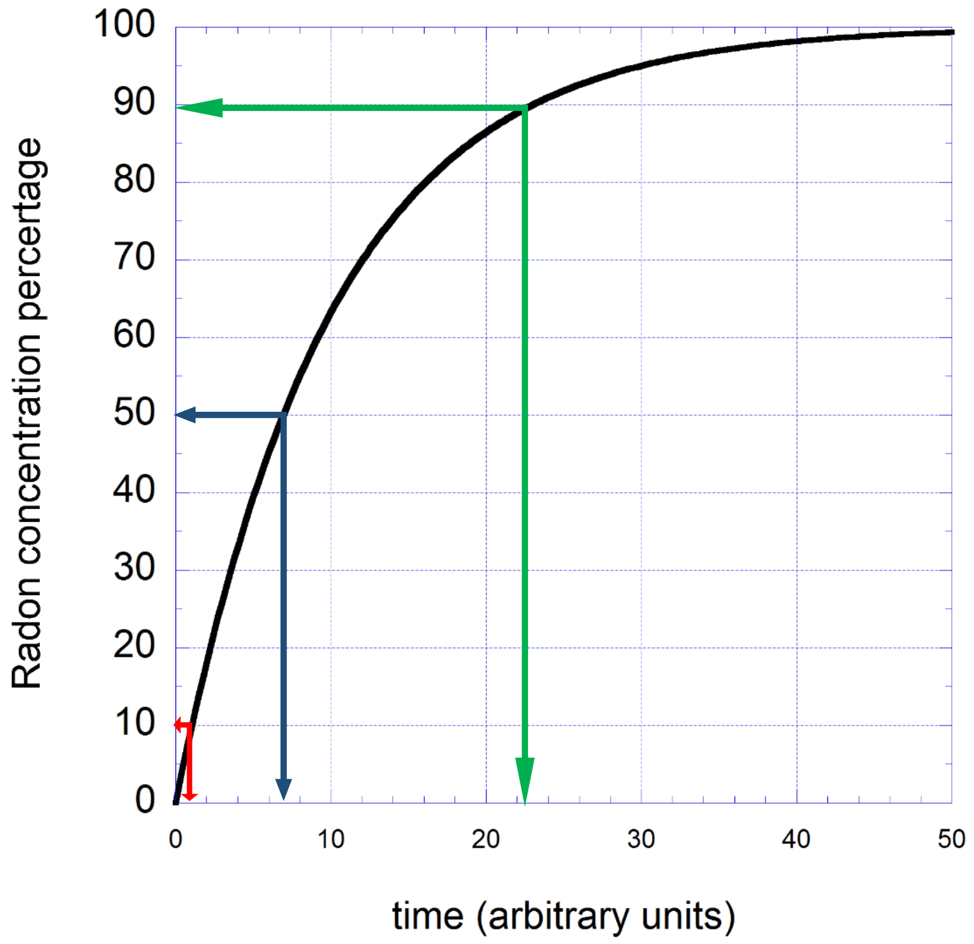
[1] School of Physics, National University of Ireland Galway, Ireland
[2] Radon Group, University of Cantabria, Spain
[3] Meteorology Group, Department of Applied Mathematics and Computer Sciences, University of Cantabria, Spain

Response time of Radon Monitors

Response time analysis:

Method 1:

- Analysis of the time that it takes for each monitor to reach a percentage of the final reference radon concentration in a given time interval.
- Key percentages proposed are 10%, 50% and 90%.



Response time of Radon Monitors

Response time analysis:

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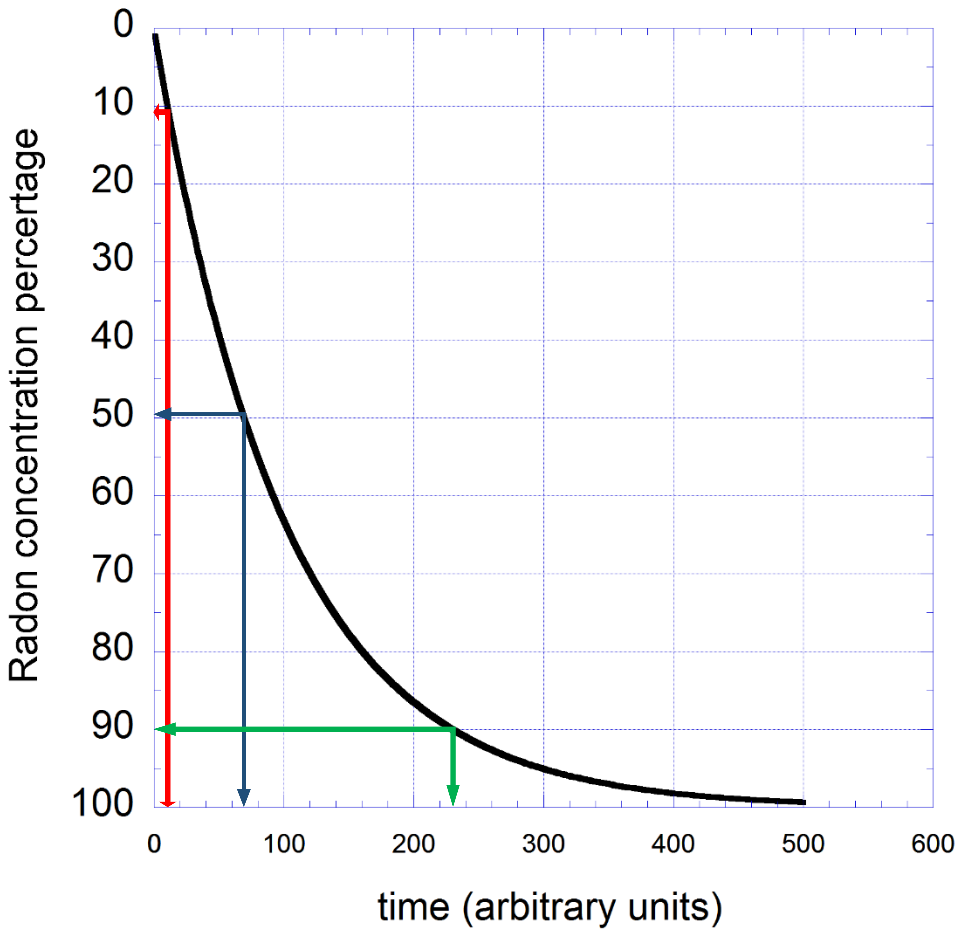


Response time of Radon Monitors

Response time analysis:

Method 2:

Analysis of the radon concentration relative error (RE) from the AlphaGUARD reference, obtained for each monitor as:

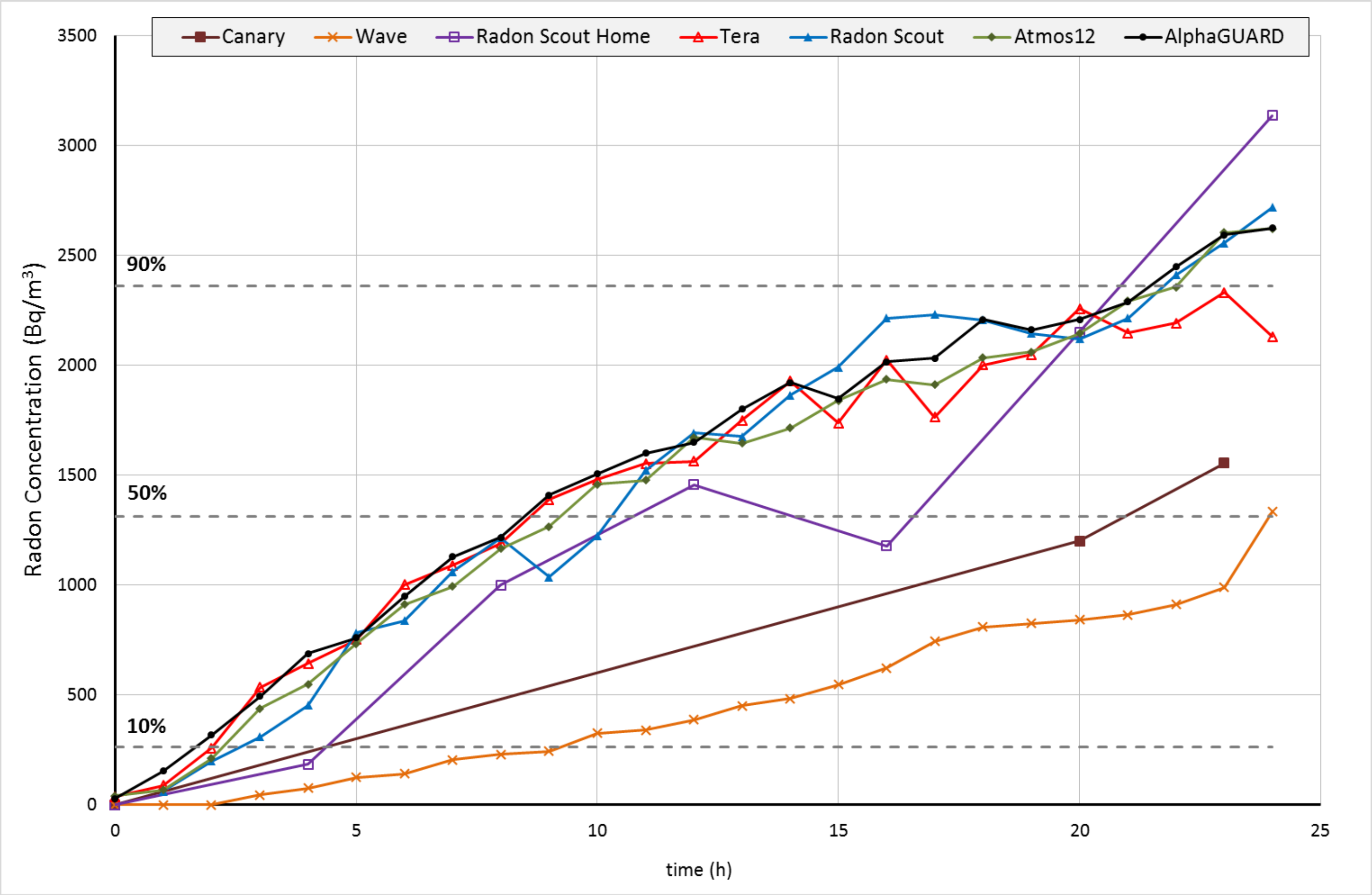
$$\mathrm{RE} = \frac{(C_i[\mathrm{monitor}] - C_i[\mathrm{reference}])}{C_i[\mathrm{reference}]}$$

C_i is the radon concentration measured by each device at time *i*.

Response time is defined as the time that it takes for each detector to reach a relative error within ±10%

Response time of Radon Monitors

Response time analysis (Method 1): Time to reach the percentage of the final reference concentration

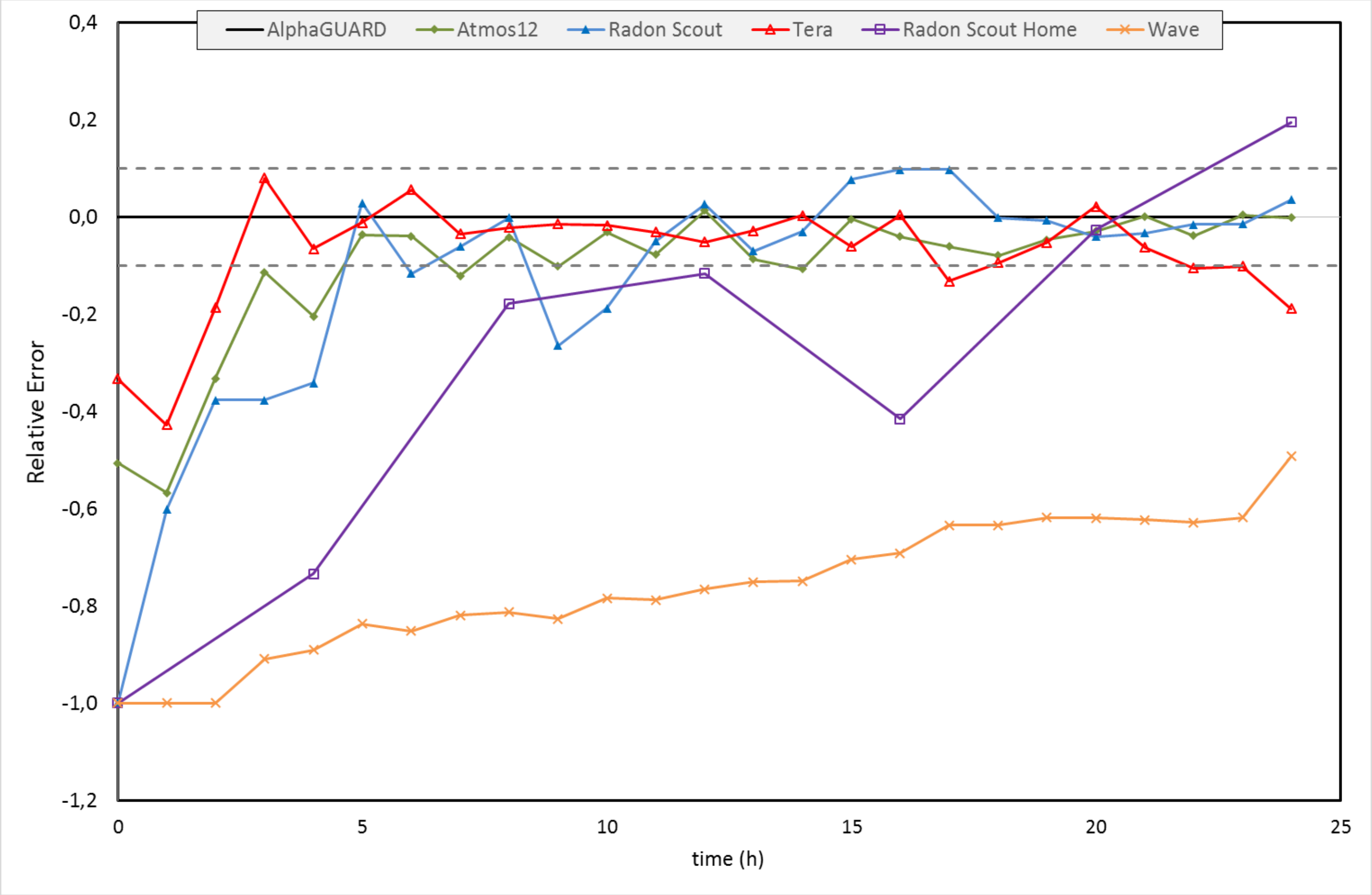


	time (hours) Increasing Period					
	10%	Ratio	50%	Ratio	90%	Ratio
AlphaGUARD	1,7	1,0	8,5	1,0	21,5	1,0
Atmos12	2,2	0,8	9,2	0,9	22	1,0
Radon Scout	2,7	0,6	10,3	0,8	22	1,0
Tera	2	0,9	8,5	1,0	23	0,9
Radon Scout Home	4,4	0,4	10,8	0,8	21	1,0
Wave	9,3	0,2	24	0,4	>24	-
Canary	4,4	0,4	21	0,4	>24	-

- As Rn concentration is increasing, monitors try to reach the reference evolution
- Ratio (Ref/Monitor) increases with time
- Dependence with slope

Response time of Radon Monitors

Response time analysis (Method 2): Relative Error analysis from reference monitor

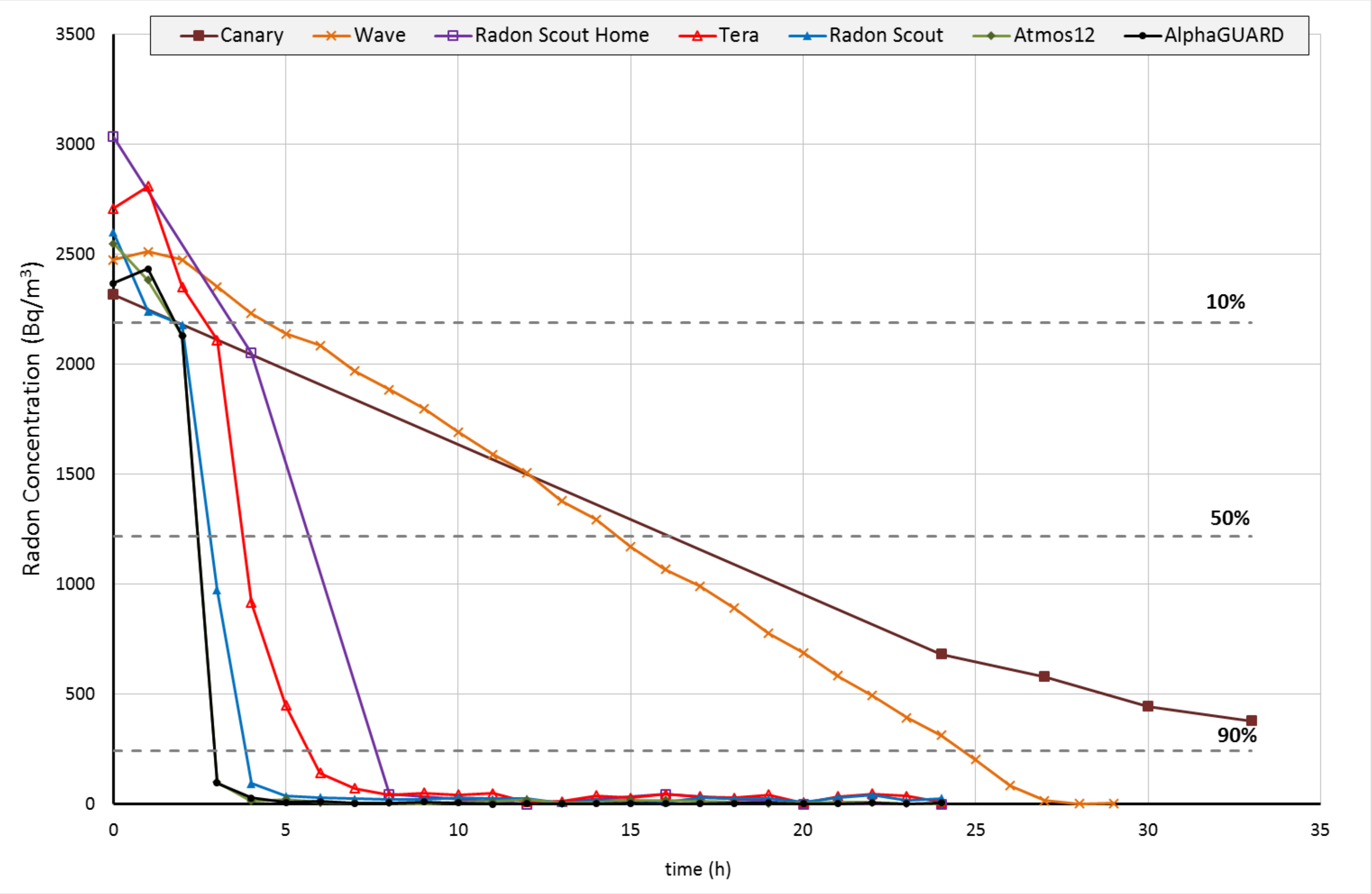


	time (hours) Increasing Period
Atmos12	4,5
Radon Scout	4,5
Tera	3,5
Radon Scout Home	19
Wave	>24

- Relative error within ±10%
- Within 10% RE we assume that response/behaviour is the same for all devices
- Fluctuations outside the ±10% are due do intrinsic dispersion of the monitors

Response time of Radon Monitors

Response time analysis (Method 1): Time to reach the percentage of the final reference concentration

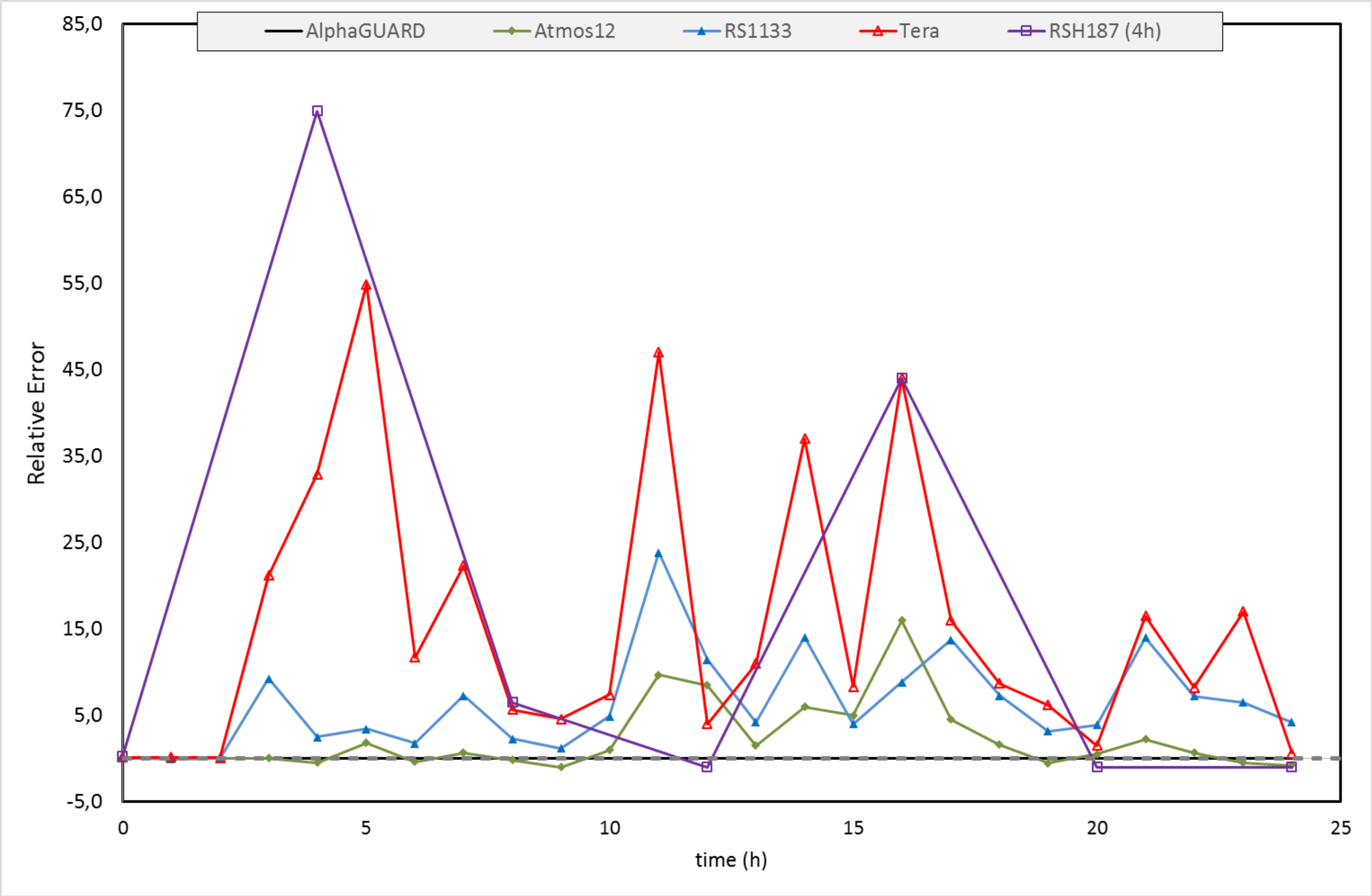


	time (hours) Decreasing Period					
	10%	Ratio	50%	Ratio	90%	Ratio
AlphaGUARD	2	1,0	2,5	1,0	3	1,0
Atmos12	2	1,0	2,5	1,0	3	1,0
Radon Scout	2	1,0	2,8	0,9	3,9	0,8
Tera	2,7	0,7	3,8	0,7	5,7	0,5
Radon Scout Home	3,4	0,6	5,7	0,4	7,6	0,4
Wave	4,4	0,5	14,6	0,2	25	0,1
Canary	2	1,0	16,2	0,2	>33	-

- Chamber opened: High ventilation rate
- Instant degassing: High Rn concentration variability
- AlphaGUARD: From 2400 Bq/m^3 to 100 Bq/m^3 in 2 hours
- Ratio (Ref/Monitor) decreasing with time
- Easy classification from slow to quick Response time

Response time of Radon Monitors

Response time analysis (Method 2): Relative Error analysis from reference monitor



- Relative error within ±10%
- Response time > interval period (24 h)
- Background values dominate
- Not possible to evaluate ER

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Summary

- The stable period seems to be a good approach to evaluate accuracy and precision of the monitors, as concentration fluctuations are minimised and intrinsic dispersion of the devices is shown.
- Two methods were proposed to evaluate the response time
- Analysis of the final concentration percentage during concentration increase or decrease periods seems to be a reasonable method to evaluate response time.
- Response time for the different monitors is shown clearly from the radon concentration decrease period.
- Relative Errors analysis has problems with values close to background

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Thank you very much for your attention

Any Question?