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Response time of radon monitors under controlled conditions

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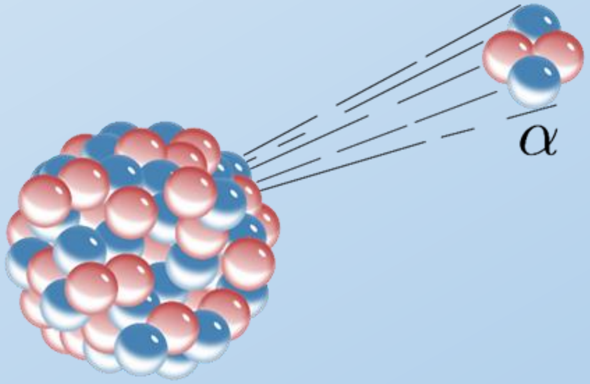
Introduction

- Most studies include radon measurements to classify the radon risk areas, to evaluate dwellings, etc.
- Passive detectors are commonly used to carry out long-term measurements:
  - Time-integrated concentration
- Active detectors are frequently used in Rn diagnostic measurement:
  - Continuous monitoring
- It is important to ensure radon measurements quality and maintain traceability to calibration standards.



Objectives

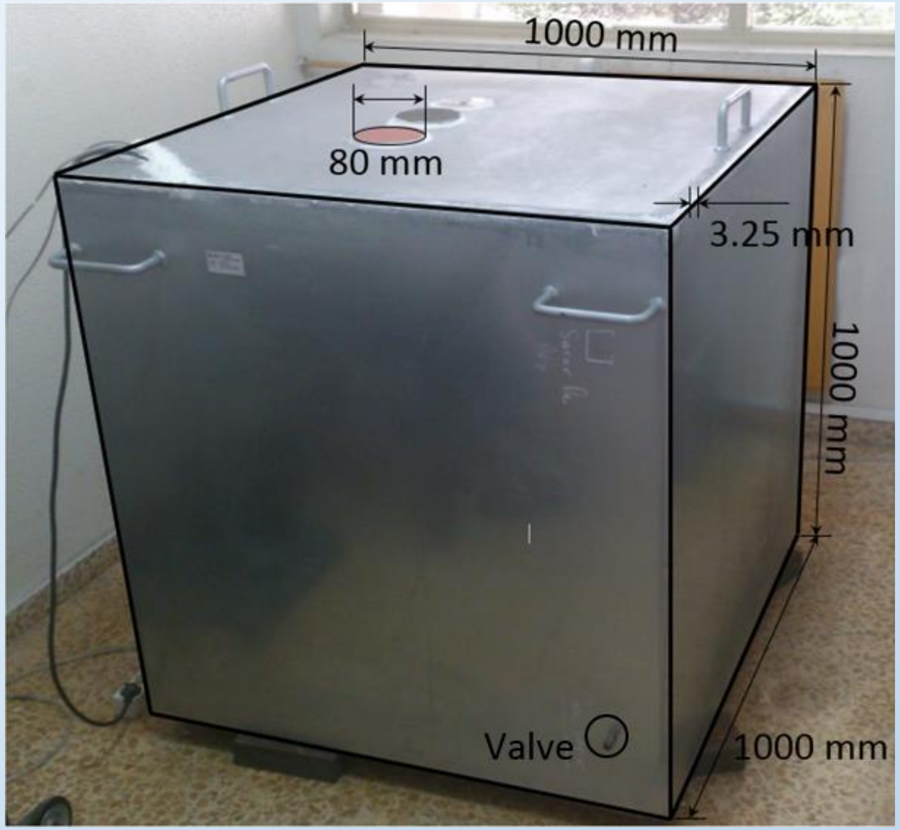
To benchmark several different radon monitors:

(1) To quantify accuracy during a period of stable radon concentration

(2) To study response time during increase and decrease periods

Material and Methods

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



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

- Radon sources: from 30 to 1100 Bq h^{-1}
- Air exchange with exterior controlled with a pump

Material and Methods

Experimental design:

- Radon source inside the chamber
- Sealed with acrylic putty
- Air exchange with exterior/ leakages: controlled with the pump
- Radon concentration in the chamber is monitored with a reference monitor traceable to international standards

Material and Methods

Radon detectors:

- **AlphaGUARD** [Saphymo - Bertin Technologies SAS] (Reference)
- **Atmos12** [Gammadata instruments AB]
- **Radon Scout** [Sarad GmbH]
- **Tera** [Tesla]
- **Radon Scout Home** [Sarad GmbH]
- **Wave** [Airthings]
- **Canary** [Airthings]
- **Etched track detector (CR-39)** [Radosys]

Material and Methods

Experimental design:

- 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

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

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

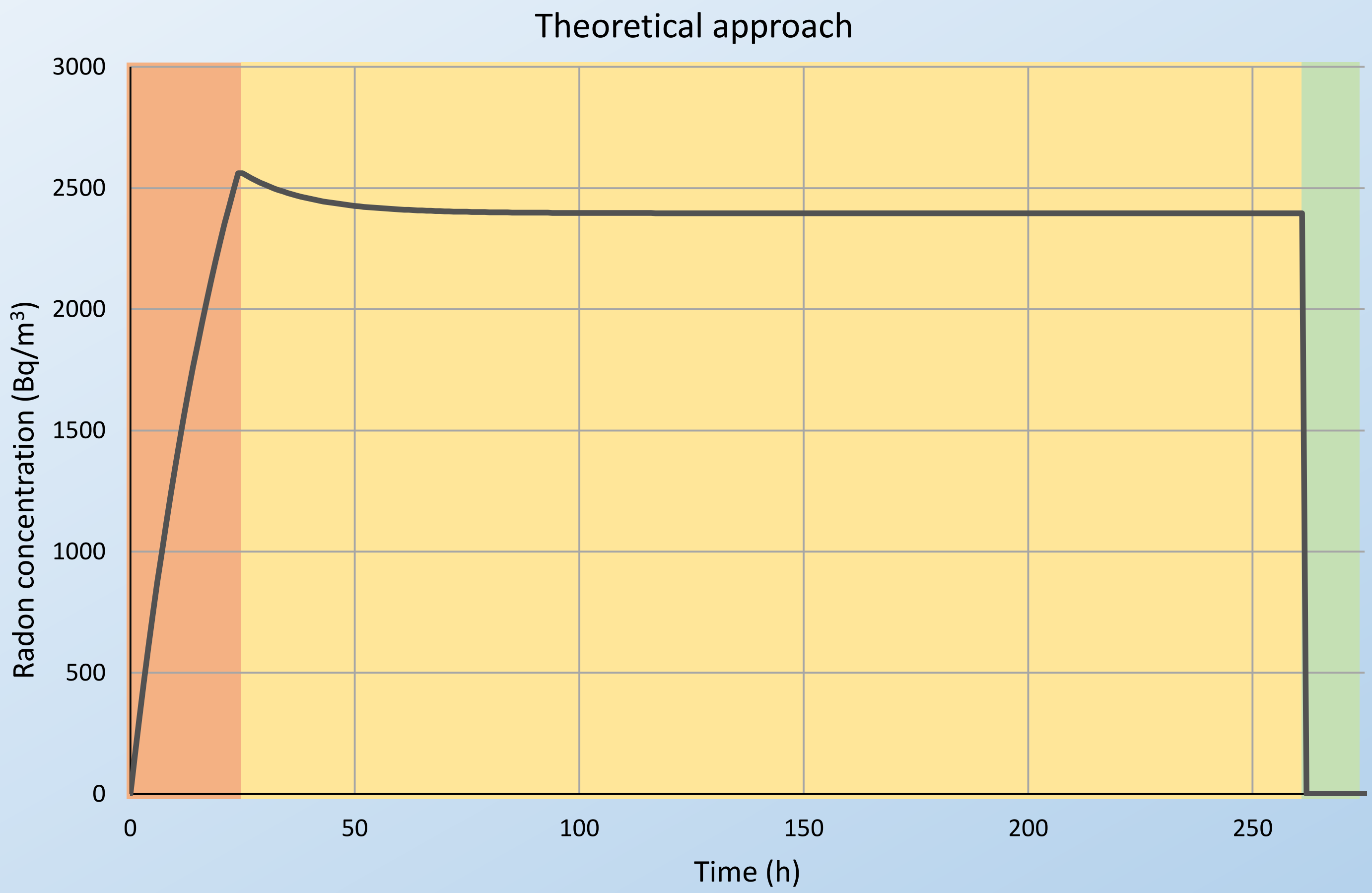
λ_e : Reflects air exchange rate per hour → $\boxed{\lambda_e = \frac{F}{V}}$

F : pump flow rate

V : Rn chamber volume

Material and Methods

Experimental design:



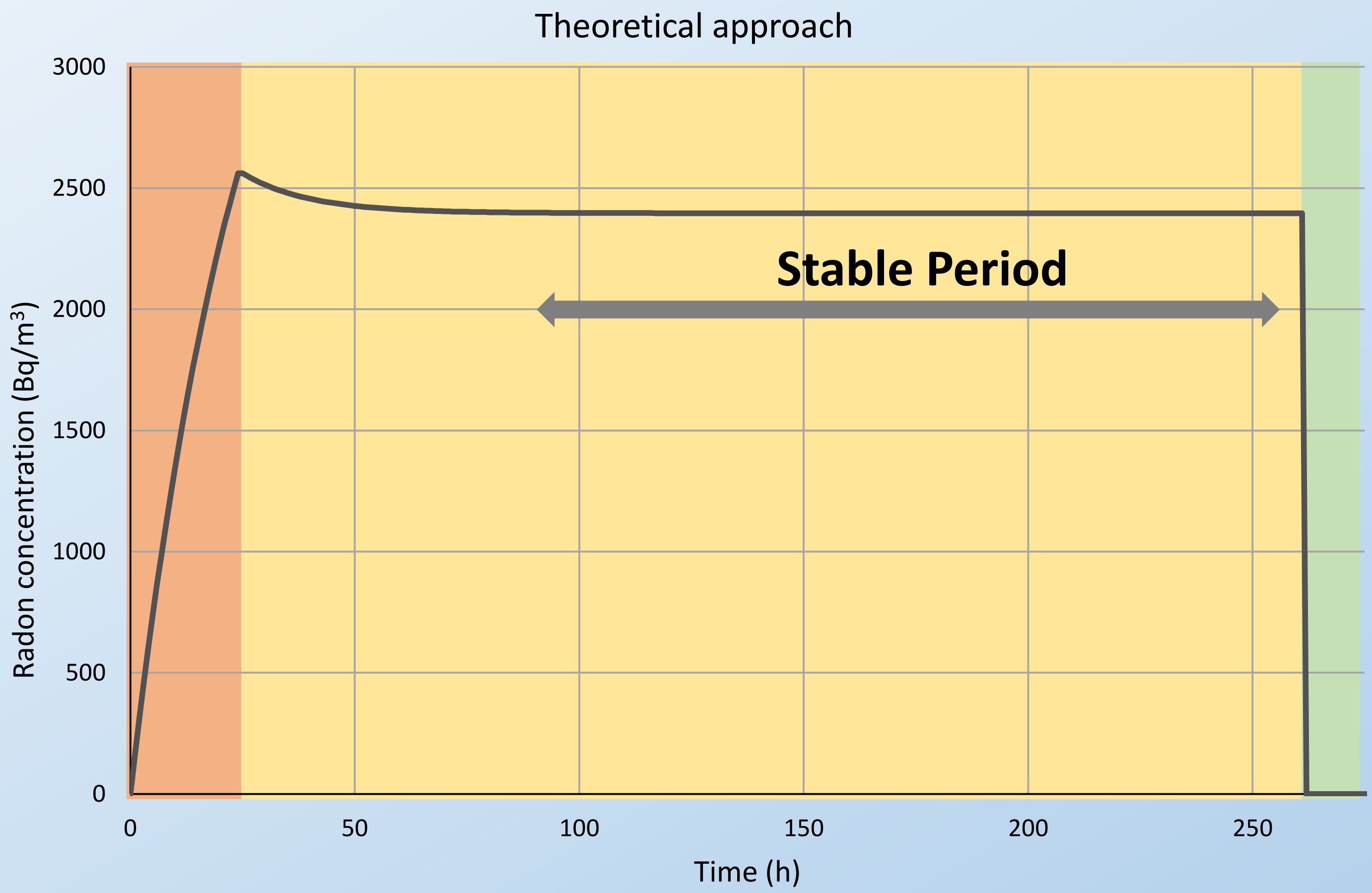
Radon Source : ϕ = (162 ± 5) Bq/h
Pump flow: F = 0.5 L/min
$\lambda = \lambda_{Rn} + \lambda_e = 0.0367\ h^{-1}$

Radon Source : ϕ = (162 ± 5) Bq/h
Pump flow: F = 1 L/min
$\lambda = \lambda_{Rn} + \lambda_e = 0.0676\ h^{-1}$

- Chamber lid opened
- Source removed
- High ventilation rate

Material and Methods

Experimental design:



Objectives

(2) To study **response time** (increase period)

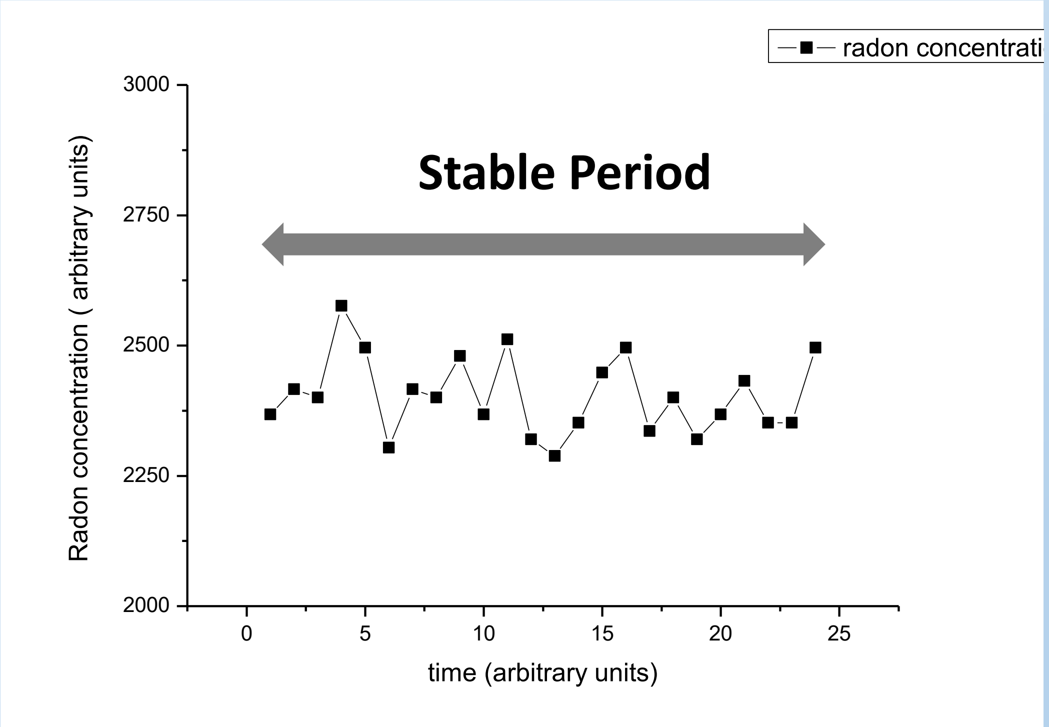
(1) To study **accuracy** in a radon concentration **stable period ( )**

(2) To study **response time** (decrease period)

Material and Methods

Accuracy analysis:

- To examine the radon concentration stable period
- To compare mean values obtained for each device with the reference monitor
- To obtain the deviation from the reference
- Mean value and Standard deviation

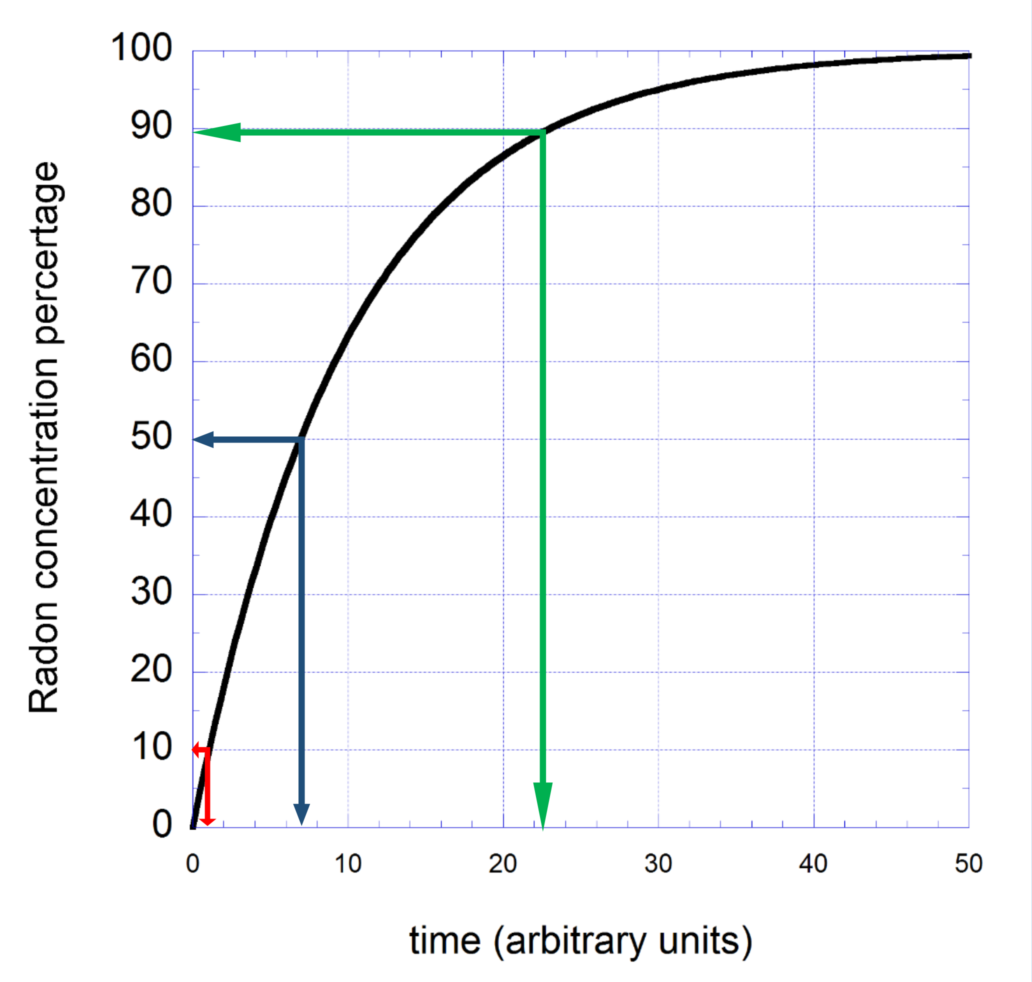


Material and Methods

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%.



Material and Methods

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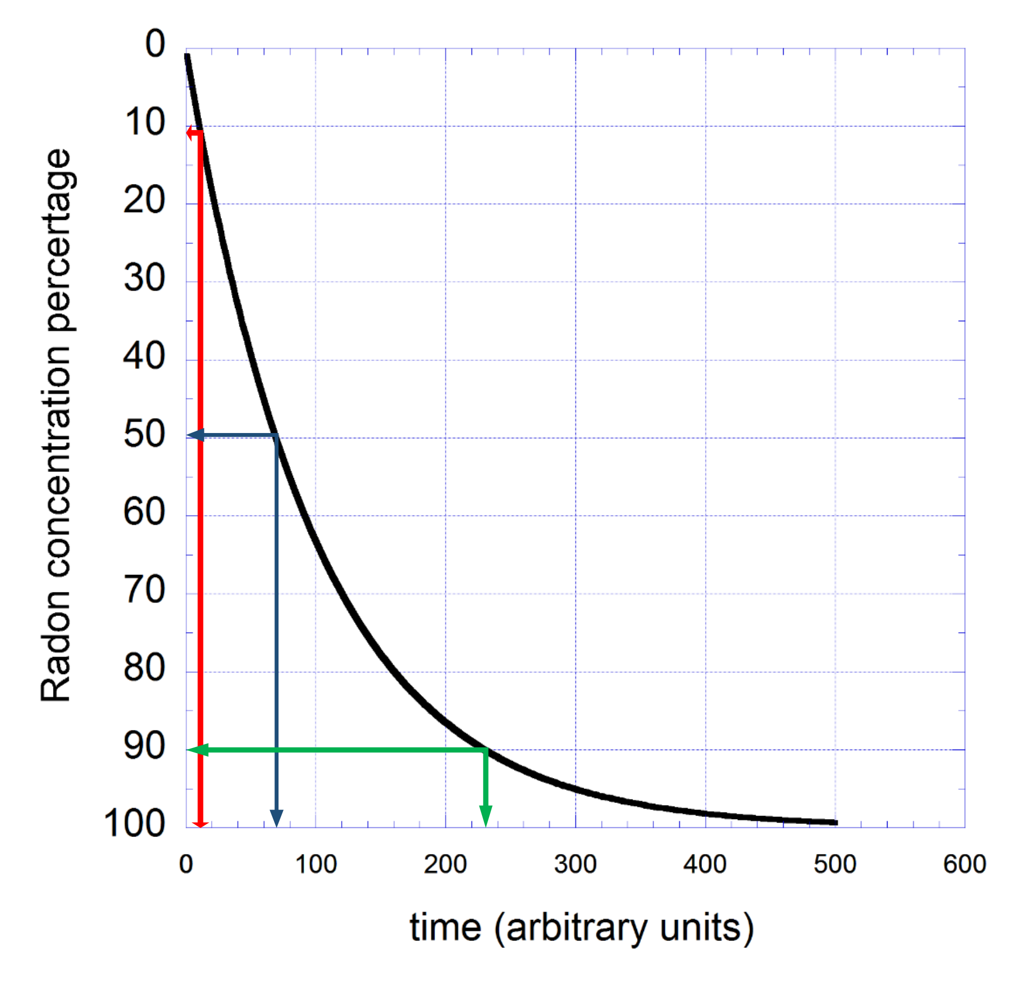


Material and Methods

Response time analysis:

Method 2:

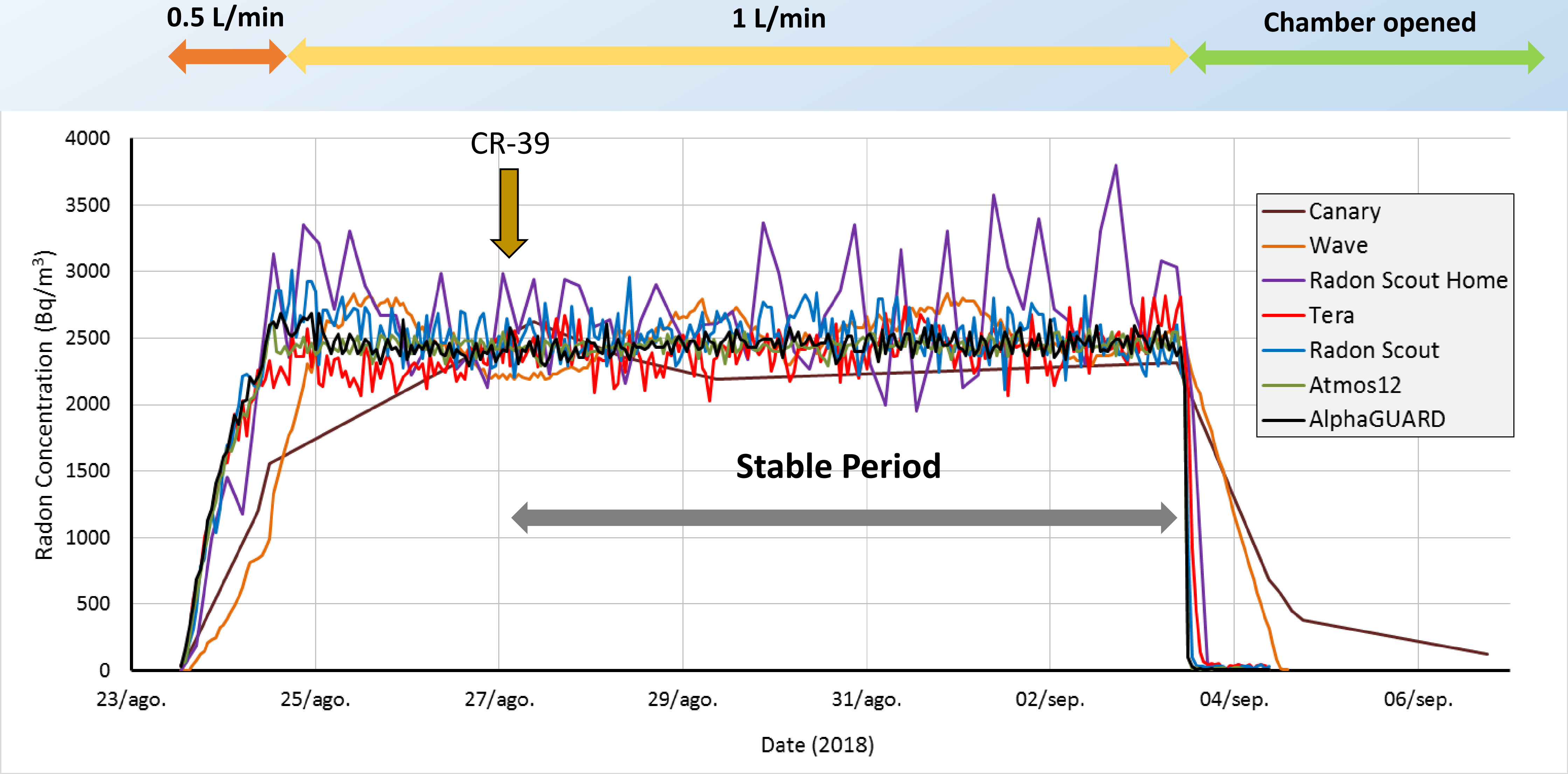
Analysis of the radon concentration relative error (RE) from the AlphaGUARD reference, obtained for each monitor as:

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

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%

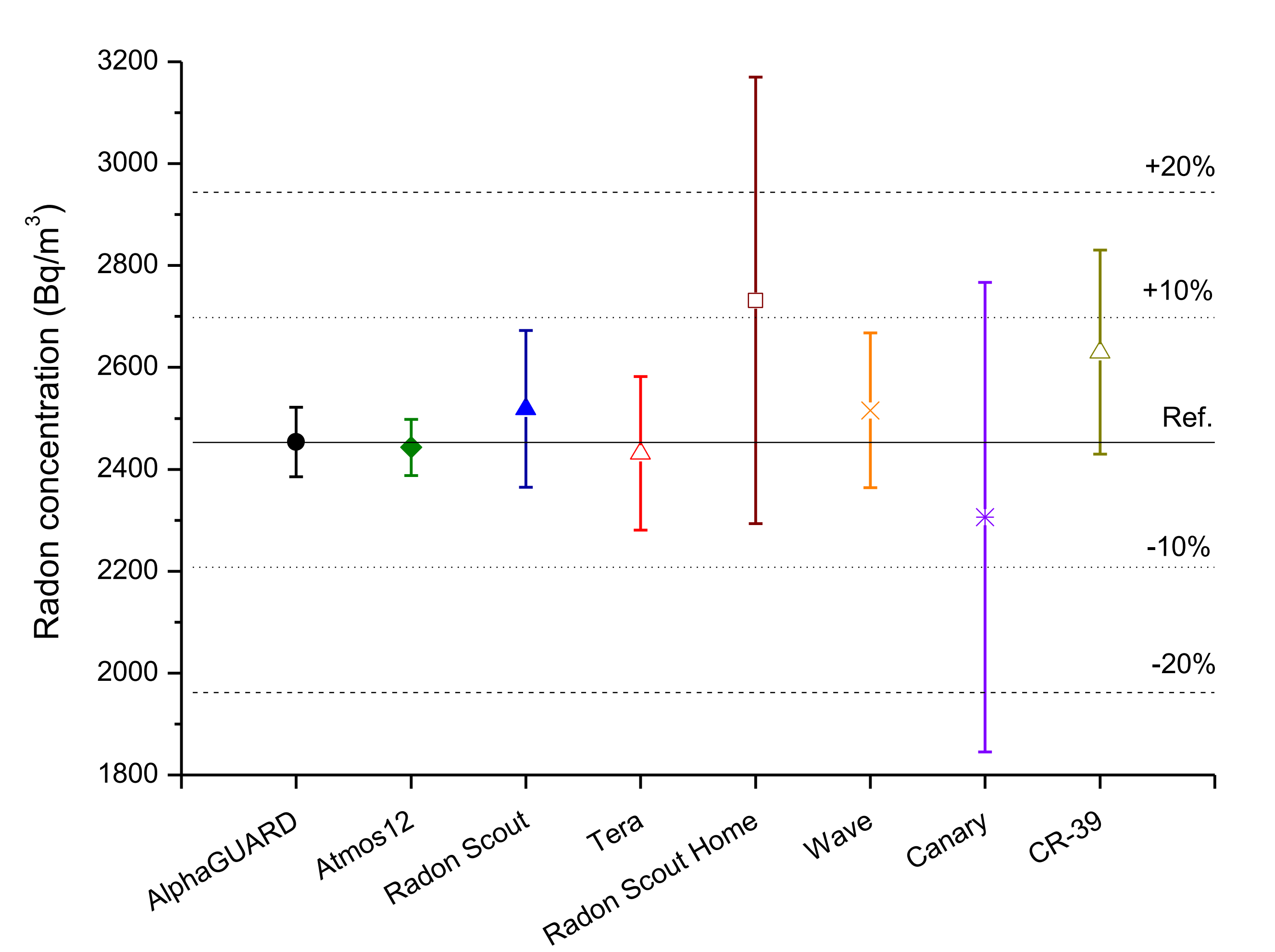
Results



0.5 L/min
1 L/min
Chamber opened
CR-39
Stable Period
Radon Concentration (Bq/m³)
4000
3500
3000
2500
2000
1500
1000
500
0
23/ago.
25/ago.
27/ago.
29/ago.
31/ago.
02/sep.
04/sep.
06/sep.
Date (2018)
Canary
Wave
Radon Scout Home
Tera
Radon Scout
Atmos12
AlphaGUARD

Results

Accuracy analysis: Comparison of mean values during the stable period with the reference monitor

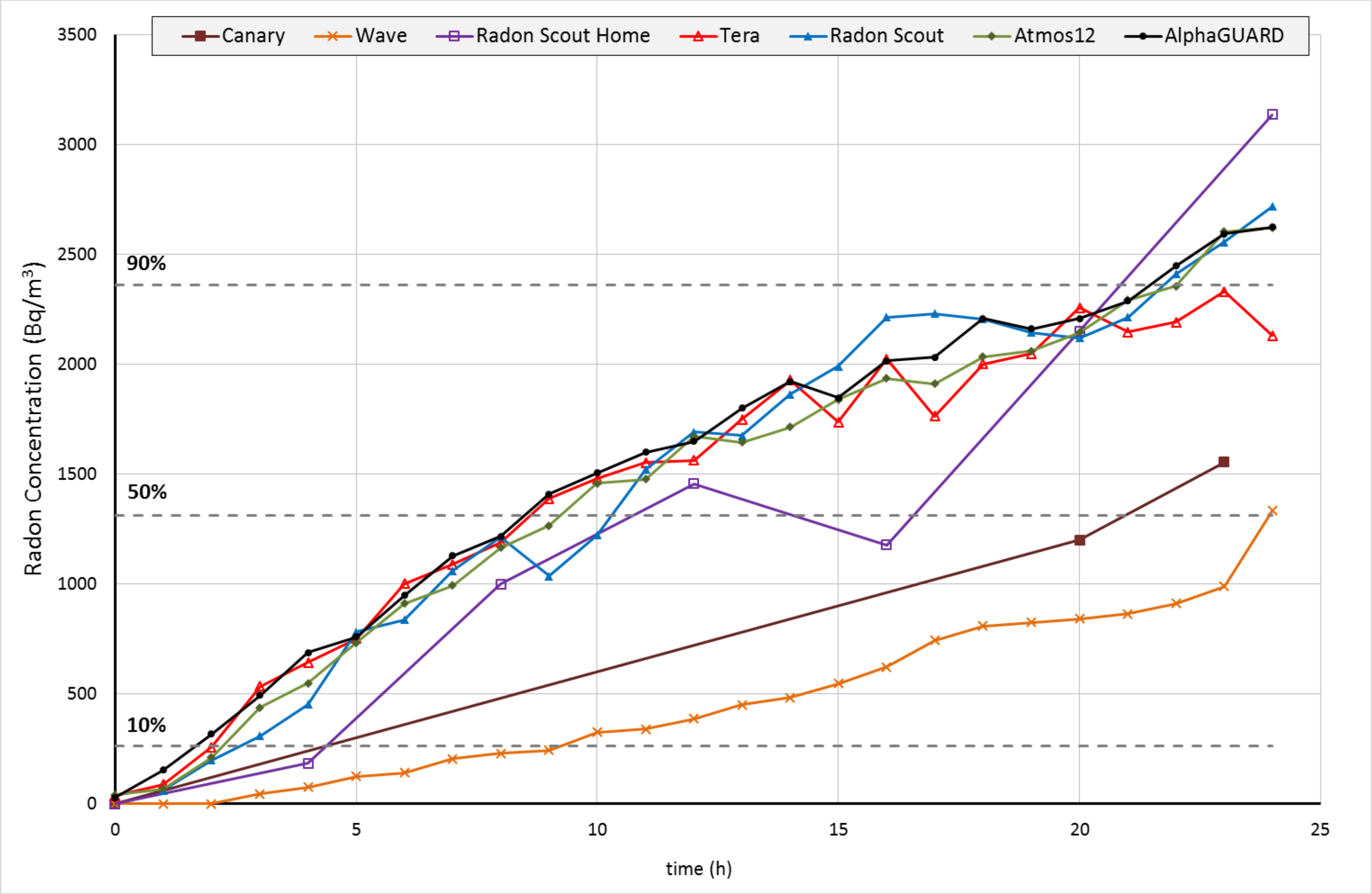


	Mean (Bq/m3)	SD (Bq/m3)	δ (%)
AlphaGUARD	2453	68	-
Atmos12	2443	55	-0,4
Radon Scout	2519	154	2,7
Tera	2431	151	-0,9
Radon Scout Home	2732	439	11,3
Wave	2516	152	2,5
Canary	2306	461	-6,0
CR-39	2630	200	7,2

- δ : relative percentage difference (%)
- Error bars: Standard deviation
- Most devices mean value within 10%
- Dependence with slope

Results

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

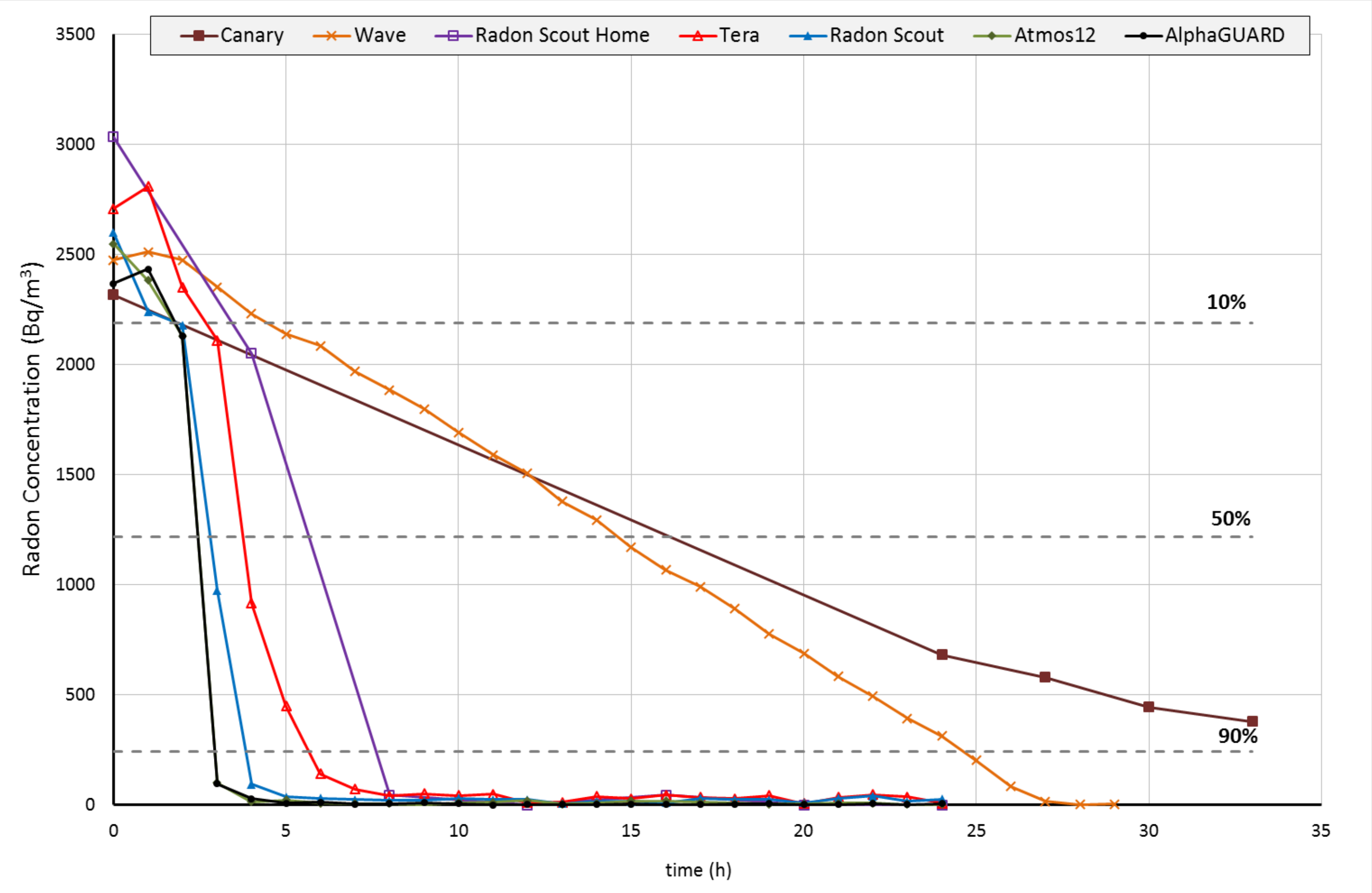


	time (hours) Increasing Period					
	10%	Ratio	50%	Ratio	90%	Ratio
AlphaGUARD	1,7	1,0	8,5	1,0	21,5	1,0
Atmos12	2,2	0,8	9,2	0,9	22	1,0
Radon Scout	2,7	0,6	10,3	0,8	22	1,0
Tera	2	0,9	8,5	1,0	23	0,9
Radon Scout Home	4,4	0,4	10,8	0,8	21	1,0
Wave	9,3	0,2	24	0,4	>24	-
Canary	4,4	0,4	21	0,4	>24	-

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

Results

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

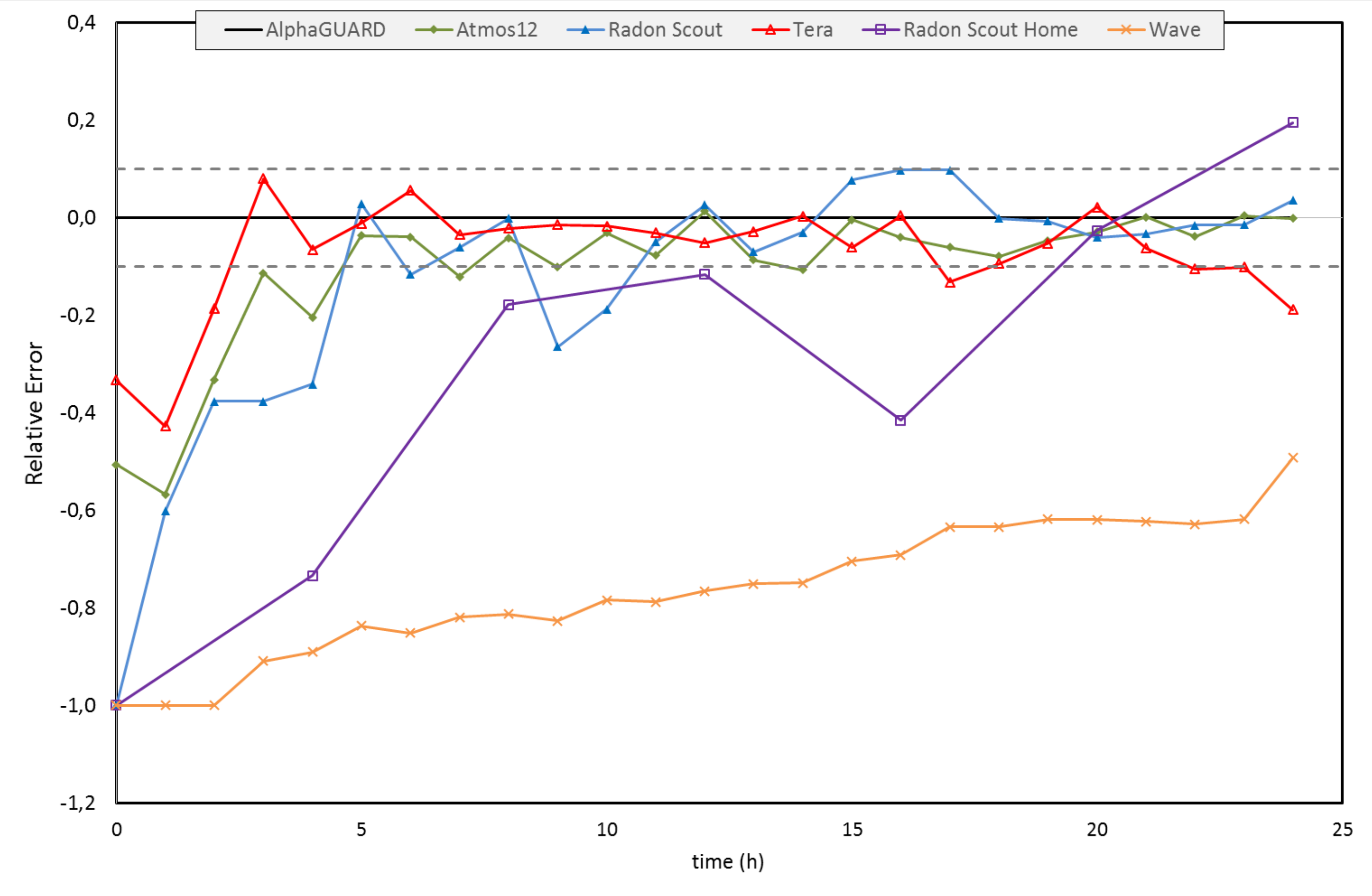


	time (hours) Decreasing Period					
	10%	Ratio	50%	Ratio	90%	Ratio
AlphaGUARD	2	1,0	2,5	1,0	3	1,0
Atmos12	2	1,0	2,5	1,0	3	1,0
Radon Scout	2	1,0	2,8	0,9	3,9	0,8
Tera	2,7	0,7	3,8	0,7	5,7	0,5
Radon Scout Home	3,4	0,6	5,7	0,4	7,6	0,4
Wave	4,4	0,5	14,6	0,2	25	0,1
Canary	2	1,0	16,2	0,2	>33	-

- 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

Results

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

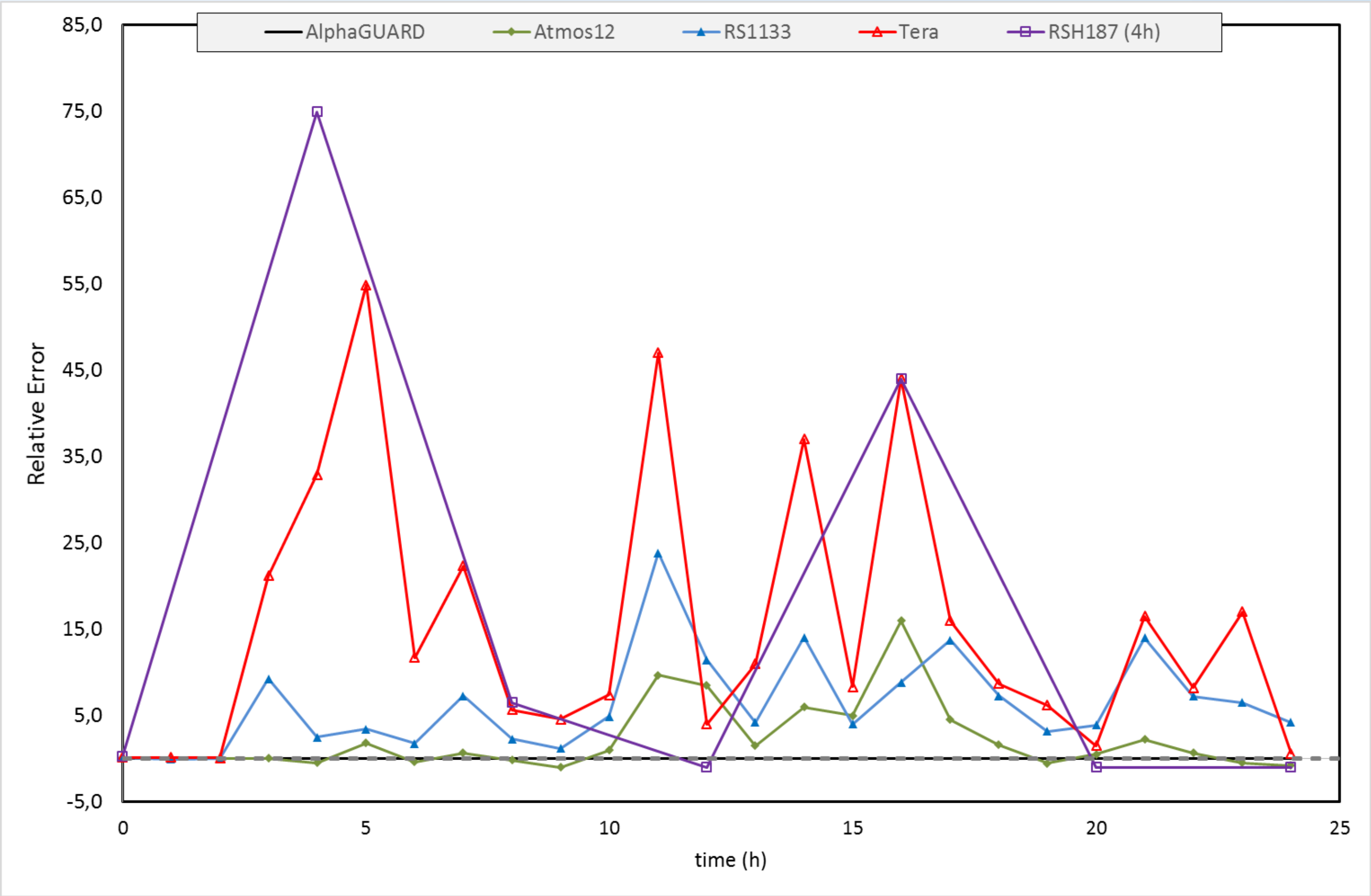


	time (hours) Increasing Period
Atmos12	4,5
Radon Scout	4,5
Tera	3,5
Radon Scout Home	19
Wave	>24

- 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

Results

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

Conclusions

- The stable period seems to be a good approach to evaluate accuracy 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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Thanks for your attention

Fuente et al. (2018).

Performance of radon monitors in a purpose-built radon chamber

10.1088/1361-6498/aad969