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Estimation of Correction Factors for RadonEye Continuous Monitors

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INTRODUCTION

Low-cost electronic radon monitors are becoming more widely used. Metrological assurance of such devices is necessary, especially when used for testing the non-exceedance of the recommended threshold (300 Bq·m⁻³ in Europe). Even the same type of devices show large differences [1, 2] and therefore, individual calibration is recommended.

MATERIALS

RadonEye Plus 2 (in short RadonEye, by RadonFTLab, South Korea) is an electronic radon monitor based on a pulsed-ionization chamber. An hour average is recorded in the memory every hour (a 60-min moving average can be reported over the WiFi every 10 min). The following specifications are given by the producer: Sensitivity: 0.0135 cpm/(Bq·m⁻³); Range: 7 to 9,435 Bq·m⁻³; Reproducibility: < ± 10% at 370 Bq·m⁻³ and Accuracy: < ± 10%.

Previous studies indicate that the reproducibility of measurements with different RadonEyes is within 10%, but their individual accuracy can differ by more than 10% [2]. A non-linearity of the signal is observed [2, 3], but it is significant above 3500 Bq·m⁻³. The background of new detectors is of the order of a few Bq·m⁻³ [4]. Different devices saturate at different levels, but in some, the **saturation leads to zero signal even below 6000 Bq·m⁻³** [4]. The response time of RadonEyes is about 90 min for reaching 90% of their plateau [3]. They also have sensitivity to thoron [5].

UKHSA radon chamber is a walk-in chamber with a volume of 43 m³. Two primary instruments are used for control of the activity concentration in the chamber: Atmos 12 DPX and Alphaguard P2000. The instruments are regularly calibrated by radon sources traceable to primary standards supplied by LNHB. The measurement of the volume used during the instrument calibration is traceable to UK National Measurement Regulation Office.

The correction factor of a RadonEye monitor is defined as:

$$R_i = \frac{C_{A,ref}}{C_{A,i}}$$

RESULTS

The background signal of the RadonEye monitors was estimated by a 10-day exposure at nitrogen atmosphere at UKHSA. All 20 devices showed similar background of 2 – 3 Bq·m⁻³ with comparable standard deviation.

Two exposure modes were tried – at constant (Fig.1) and at slowly increasing activity concentration (Fig.2). For all 20 detectors the estimates of R (the slopes of the fits, e.g. Fig. 3-4) coincided for the two modes within the statistical uncertainty – see Fig. 5. An uncertainty budget is shown in Table 1.

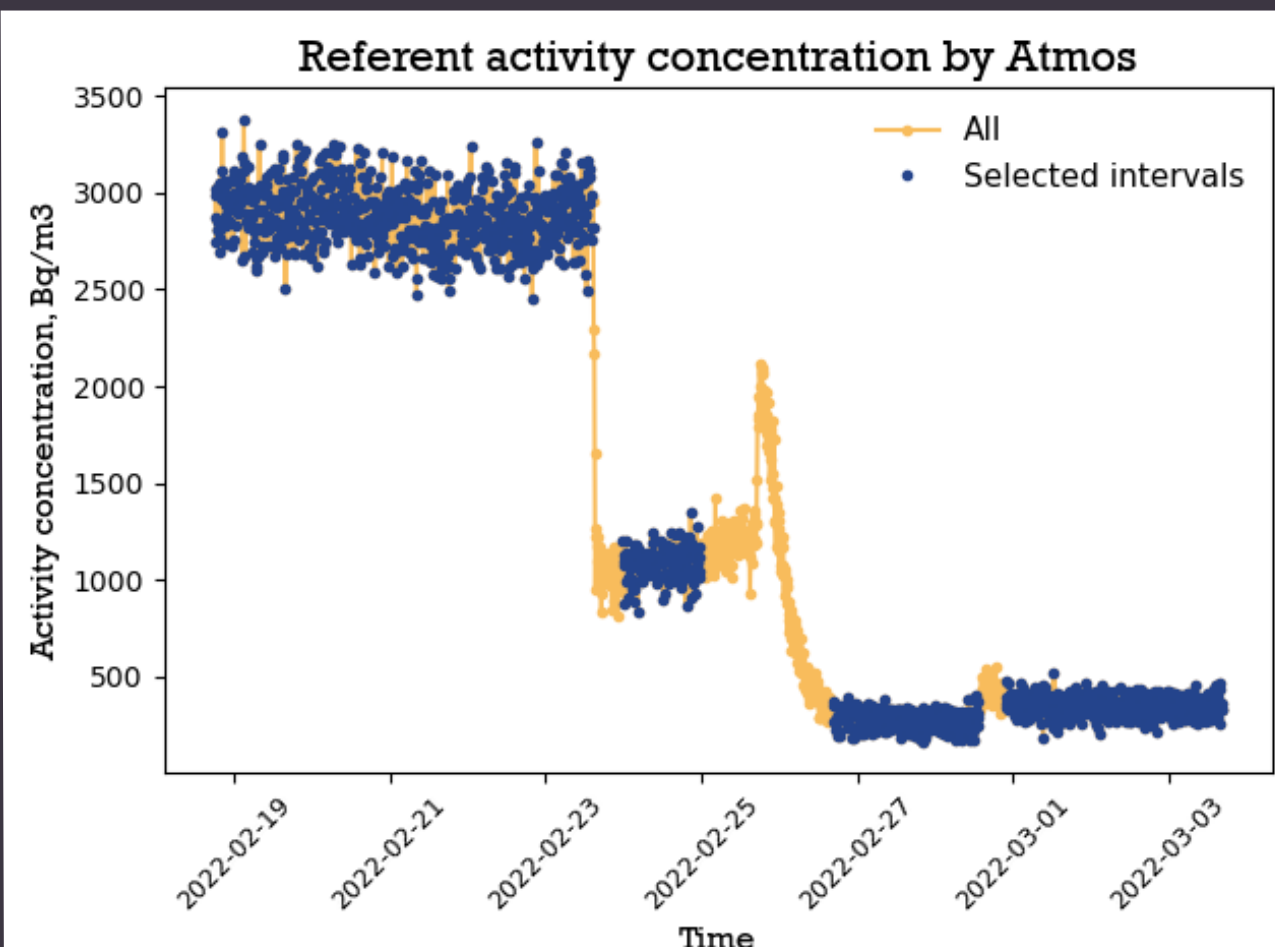


Fig. 1. Selected 4 intervals with constant activity concentration - shortest is 24 hours.

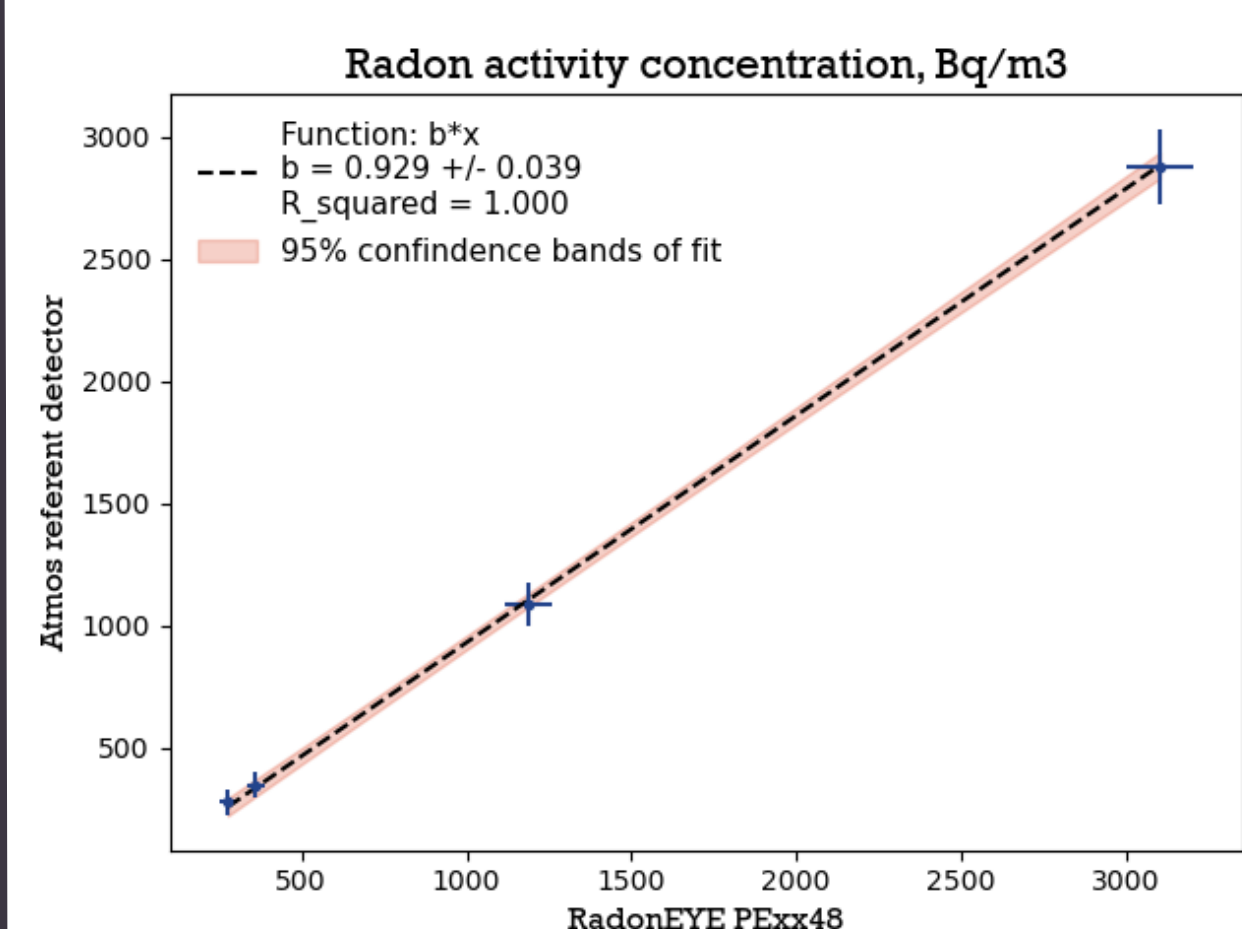


Fig. 3. Atmos vs RadonEye average activity concentration for the interval in Fig.2. The error bars are the 1-sigma stat. uncertainty estimated as a st.dev.

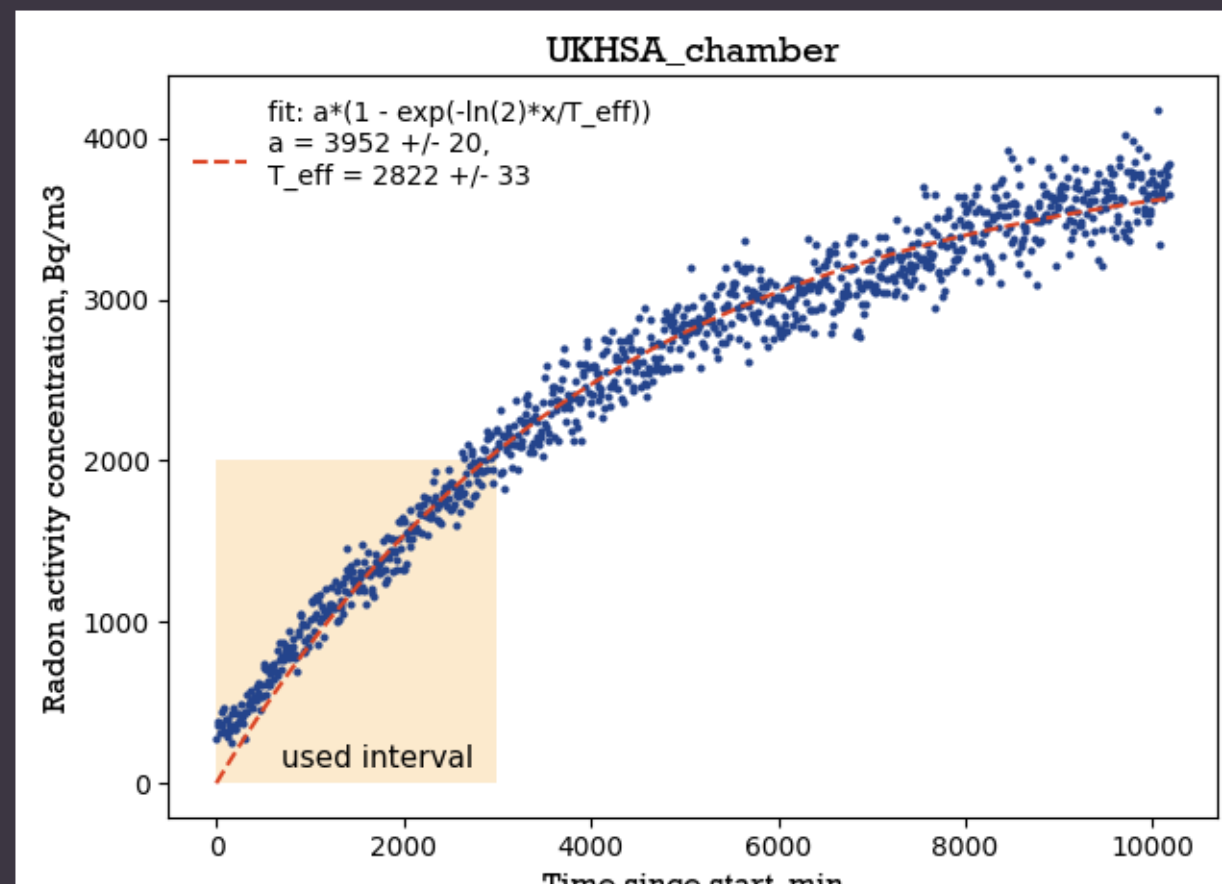


Fig. 2. Activity concentration increasing with an effective half-time of about 47 hours. The region below 2000 Bq·m⁻³ is used, in which RadonEyes are shown to be linear and the points are well spread.

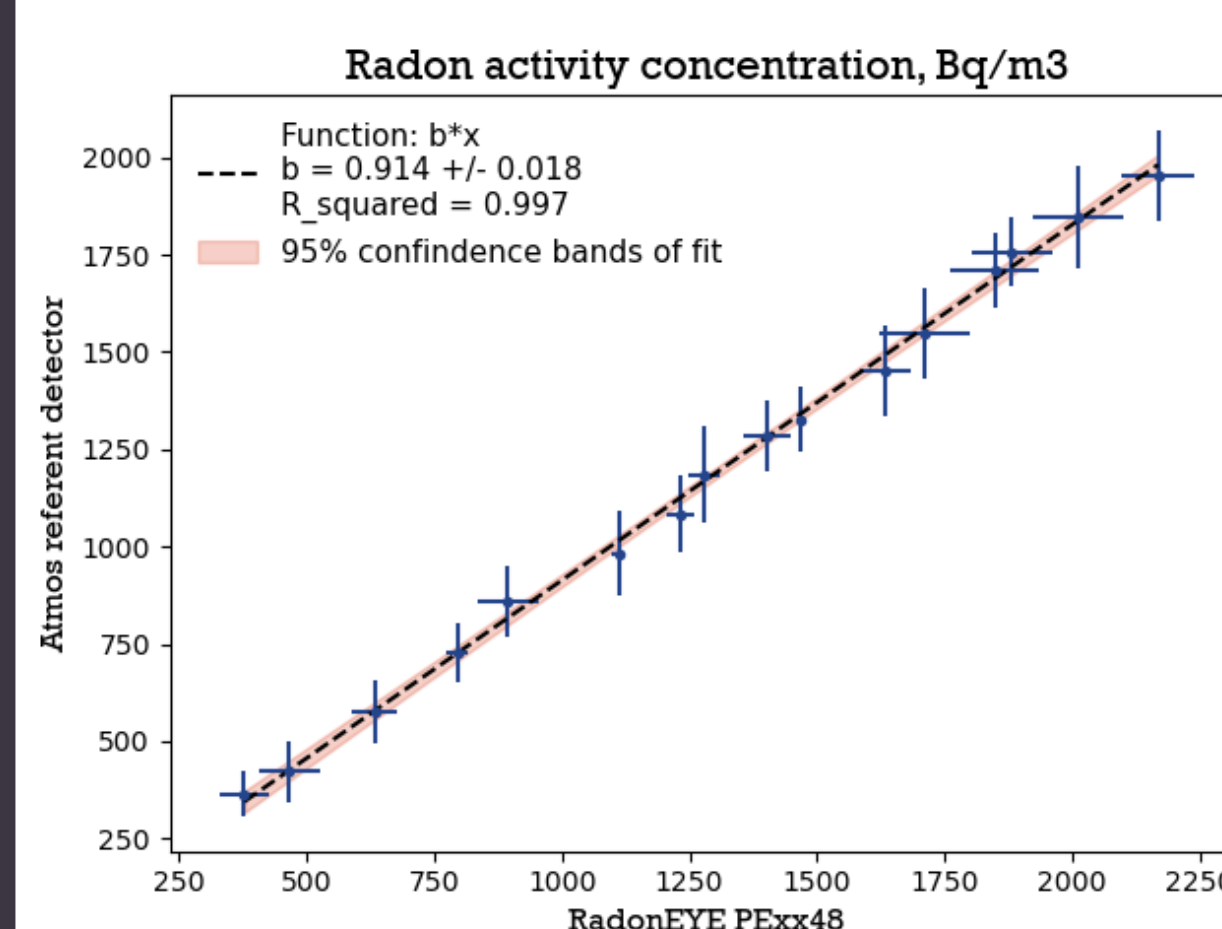


Fig. 4. Atmos vs RadonEye activity concentration. The datapoints are 3-hour averages for the exposure in Fig.3. The error bars are the 1-sigma stat. uncertainty estimated as a st.dev.

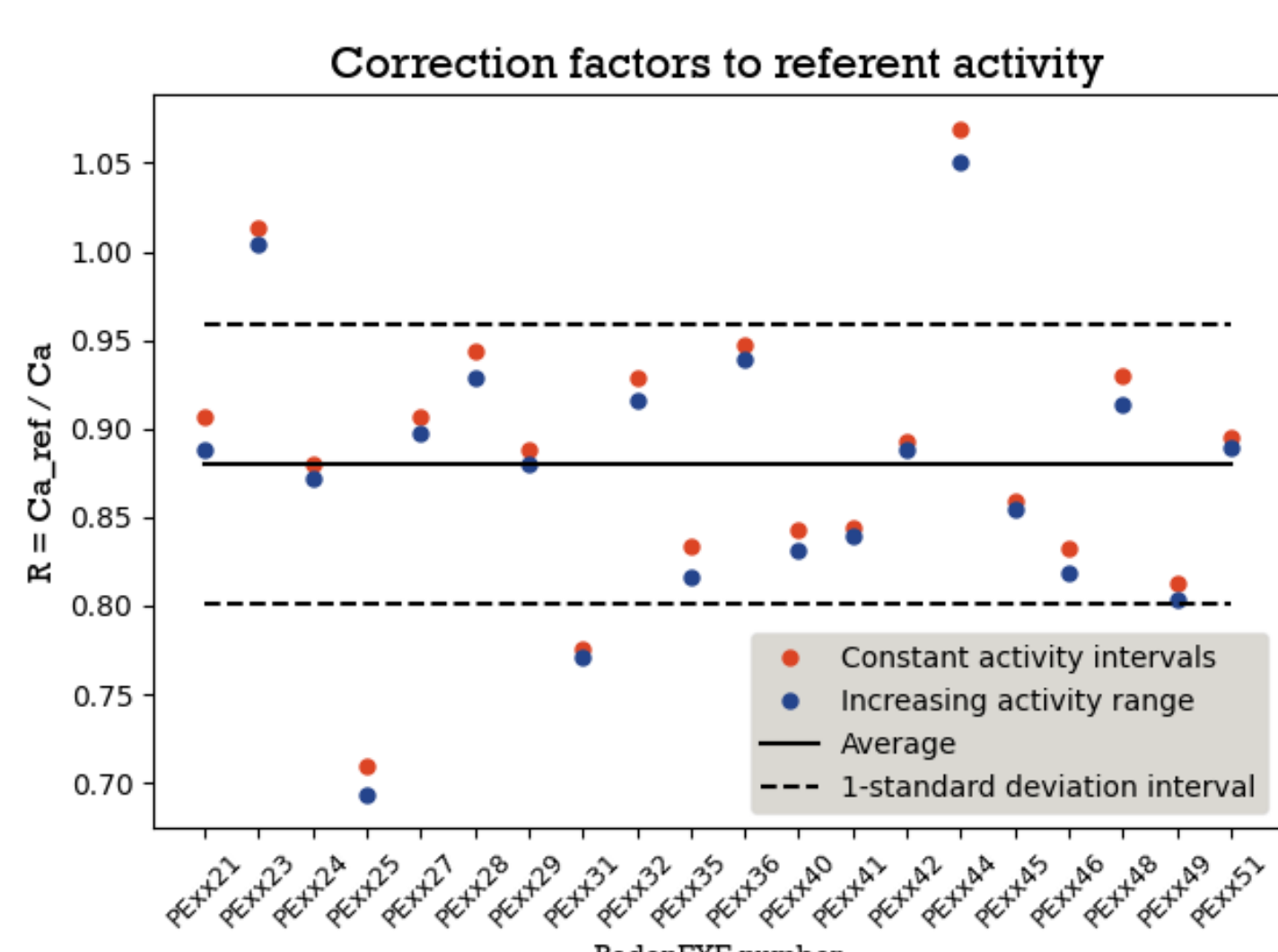


Fig. 5. Comparison of the correction factors obtained by exposure at intervals with constant C_A (Fig.1) and at one interval with slowly increasing C_A (Fig. 2). The values coincide within the uncertainty of the slope of the fits (e.g. Figs 3-4), which for all RadonEyes is higher than 2% at the level of 1-sigma.

Table 1. Uncertainty budget of the estimated correction factors for the RadonEye monitors.

Quantity	Components	Method	Relative standard uncertainty, %	
Referent C_A by Atmos	Efficiency of referent monitor, including unc. of radon gas standard, calibration volume and statistical counting unc.	By standard calibration certificate, calculation of the volume unc. and statistics of measurements	2.7	
			RadonEye response	Statistical counting unc.
Combined standard uncertainty of $R = C_{A,ref} / C_A$				
			(k=1)	3.5
			(k=2)	7.0

STATISTICAL VARIATION OF RADONEYE READINGS

The producer of RadonEYES does not provide values for the measurement uncertainty or number of counts. A rough estimate could be made by using the declared sensitivity of $k = 0.0135$ cpm/(Bq·m³). Neglecting the background uncertainty and assuming Poisson distribution of the counts one gets:

$$\sigma_{stat}(C_A) = C_A \cdot \delta_{stat} = \frac{C_A}{\sqrt{N}} = \frac{C_A}{\sqrt{k \cdot C_A \cdot \Delta t}} = \sqrt{\frac{C_A}{k \cdot \Delta t}}$$

where δ_{stat} is the relative uncertainty of the counts N and Δt is the duration of the measurement interval (60 minutes).

A comparison with the standard deviation during exposures at constant activity concentration in the UKHSA and SU chambers is shown in Table 2.

Radon activity concentration, Bq·m ⁻³	Relative statistical uncertainty of readings, %	
	Using producer sensitivity and Poisson statistics	By statistics of a series of measurements in lab exposures (range for 20 devices)
300	6.4	8 - 10
350	5.9	7 - 10
450	5.2	6 - 10
900	3.7	5 - 6
1800	2.6	2.5 - 4
3000	2.0	3

Table 2. Estimates of the relative statistical uncertainty of the RadonEye readings (60-minute measurement duration) made by the Eq. (2) and observed standard deviation in laboratory exposures.

For all detectors the standard deviation during the laboratory exposures is slightly higher than the above estimate (see Table 2). This could be attributed to smaller sensitivity of the detectors, to non-stable activity in the chambers (less probably) or to the oversimplification of the estimate. Variations in homes are much higher even when intervals with relatively constant daily average are selected – see Figs 6-7. The laboratory exposures can help to estimate the statistical variation and study the variations due to external factors.

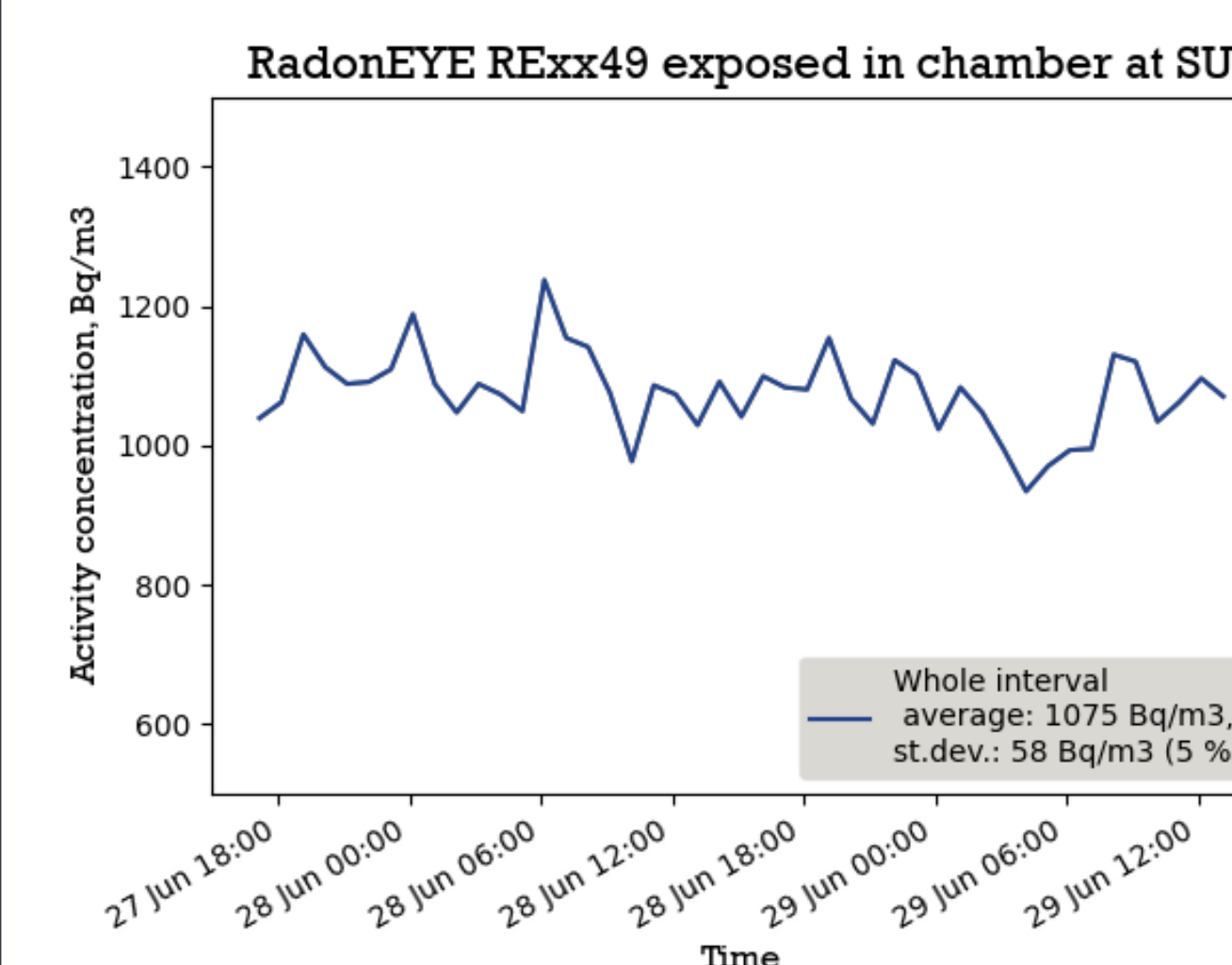


Fig. 6. Time dependence of the readings of a RadonEye (RExx49) during laboratory exposure. The relative standard deviation at 1075 Bq·m⁻³ is 5%.

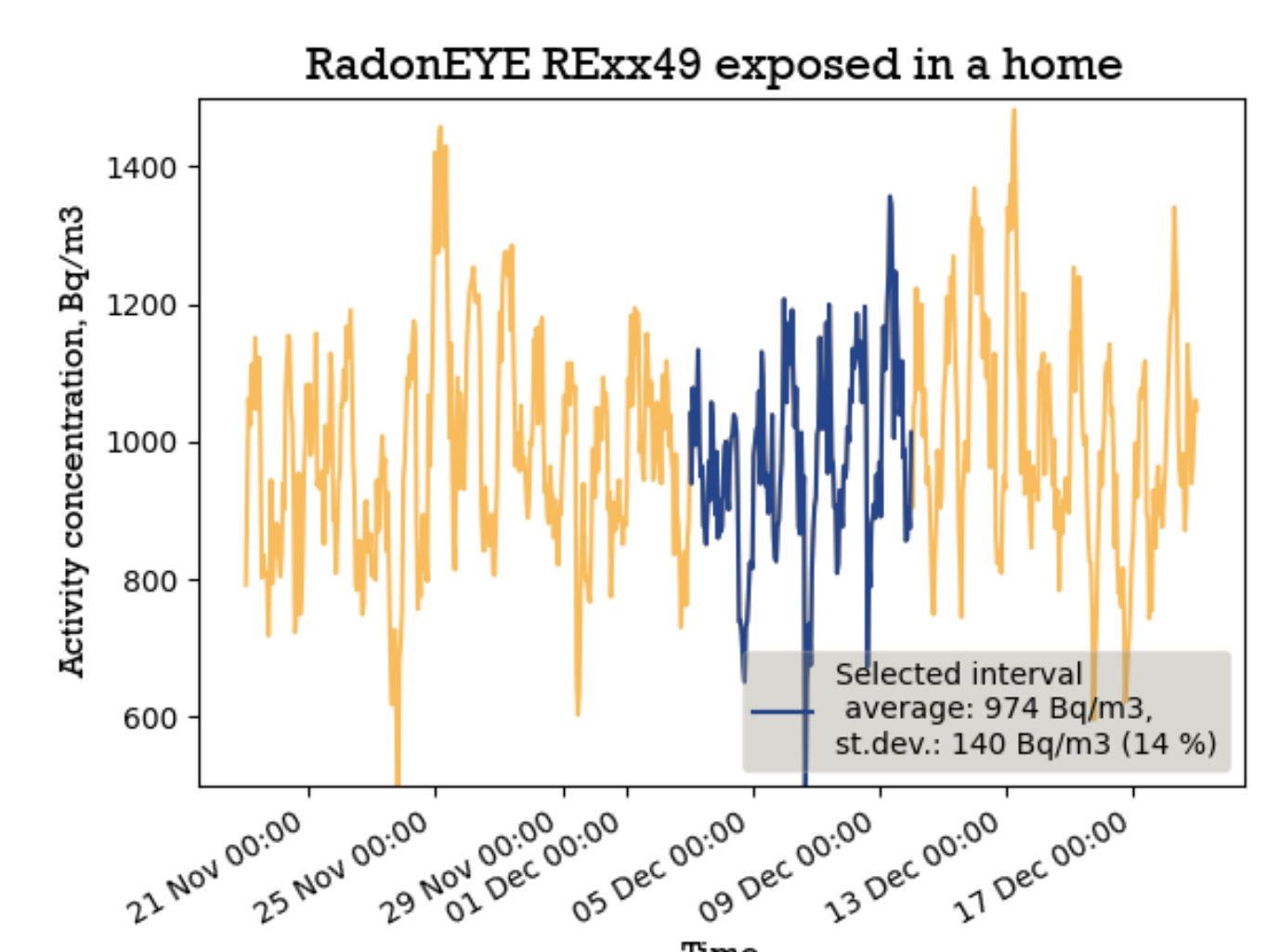


Fig. 7. Time dependence of the readings of a RadonEye (RExx49 – same as in Fig.6) during exposure in a private home. A region with constant daily average is selected. The relative standard deviation at 974 Bq·m⁻³ is 14%.

CONCLUSIONS

- For the 20 studied RadonEye Plus2 monitors the correction factors ranged from 0.70 to 1.06 with an average of 0.88 and a rel. st. dev. of 9.0%.
- Exposures were at slowly increasing activity concentration as well as at constant. The results show that continuous monitors can be exposed under activity concentration that is changing very little for the duration of a single measurement and for the time of monitors' response.
- The statistical variations of the RadonEye readings when exposed at constant activity concentration in the laboratory are slightly higher than it could be estimated from the producer specifications, e.g. 8 – 10% at 300 Bq·m³.

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