

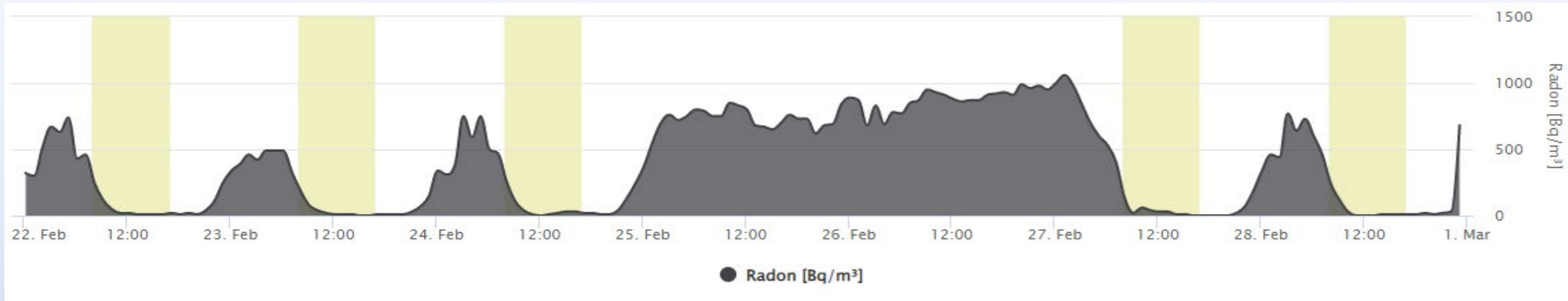
RADON LEVELS DURING WORKING HOURS AND NON-WORKING HOURS IN WORKPLACES AND SCHOOLS

- Follow-up measurement data from about 200 CRM measurements in Swedish schools and workplaces.
- Follow-up measurement protocol in Canada and in the Nordic countries
- Occupied/unoccupied evaluation in ANSI/AARST MA-MFLB-2023
- Different examples on time variations in radon levels

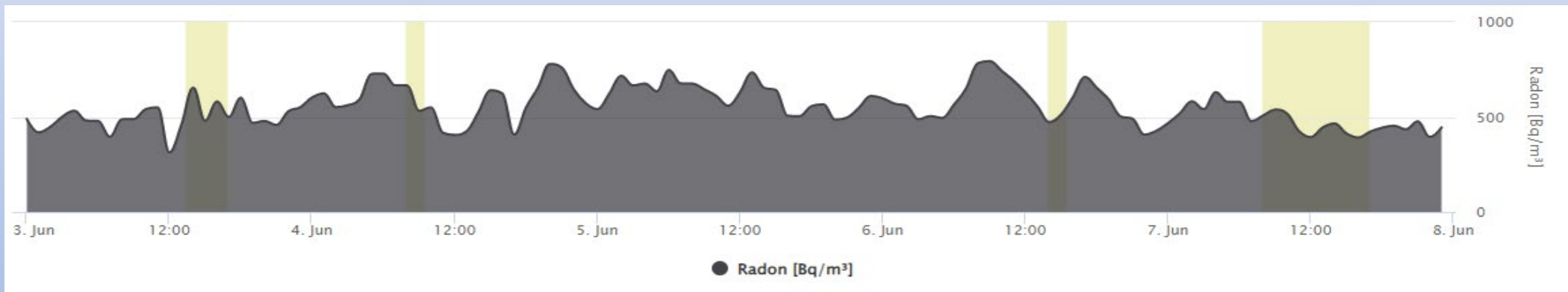
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EXAMPLES FROM WORKPLACE MEASUREMENTS

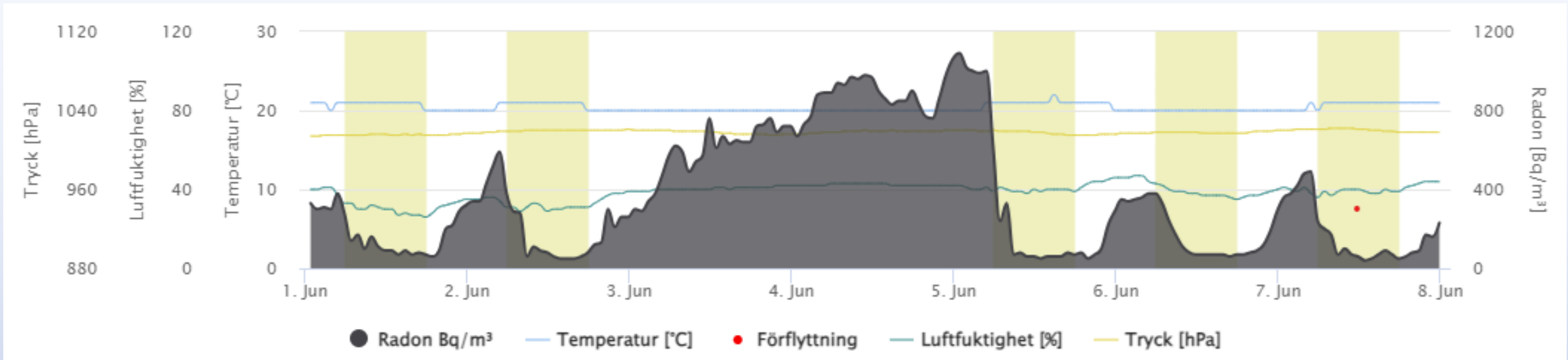


Example – preschool with time-controlled mechanical ventilation



Example church with natural ventilation

EXAMPLES FROM WORKPLACE MEASUREMENTS



Example – school with time-controlled mechanical ventilation

The radon levels during weekends are often higher than during nights in the working week since the ventilation has been OFF for a longer time.

MEASUREMENT PROTOCOLS - FOLLOW-UP MEASUREMENT

$$[\text{RADON}]_{\text{ELTARCDOH}} = [\text{RADON}]_{\text{LTARC}} \times \left(\frac{[\text{RADON}]_{\text{STARCDOH}}}{[\text{RADON}]_{\text{STARC}}} \right)$$

where:

ELTARCDOH = estimated long-term average radon concentration during occupied hours;

LTARC = long-term average radon concentration;

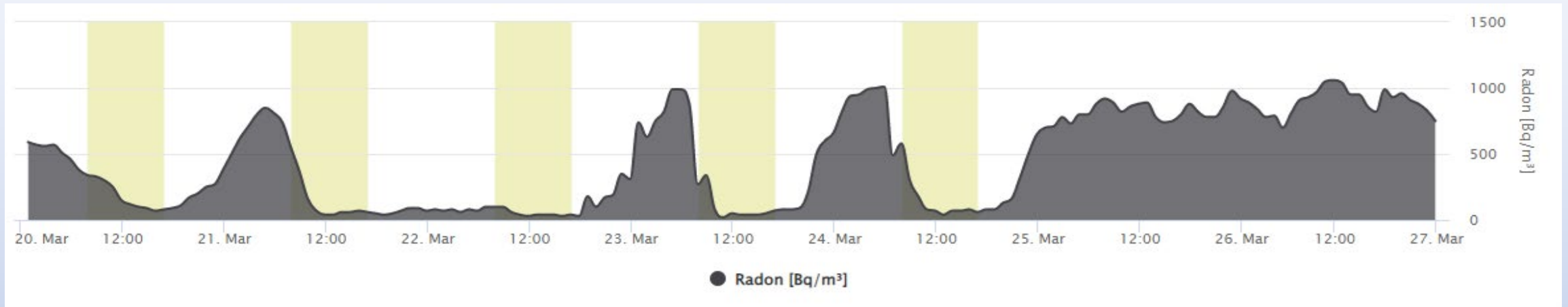
STARCDOH = short-term average radon concentration during occupied hours; and

STARC = short-term average radon concentration.

An estimated long-term average during occupied hours in a building with time-controlled ventilation could be obtained by multiplying a previous long-term value with a factor between radon levels during occupied hours and the entire measurement period in a follow-up CRM-measurement of **7 days**. This factor has been found to be more stable than the average radon level variations from week to week.

Such follow-up measurement protocols can be used in Canada and the Nordic countries when radon levels, from long-term measurements in buildings with time-controlled ventilation, are above the reference levels.

EXAMPLE OF 7-DAYS FOLLOW-UP MEASUREMENT



Average in selection $100 \pm 20 \text{ Bq/m}^3$	}	Factor 0.22	X	Previous long term measurement 550 Bq/m^3	=	Corrected result from previous long term measurement 130 Bq/m^3
Average level for all points $450 \pm 60 \text{ Bq/m}^3$						

ANSI/AARST STANDARD MA-MFLB-2023

5.2 Evaluation of Occupied Versus Unoccupied Concentrations

For non-residential buildings or portions of a building that are not significantly occupied day and night most the year, an evaluation of occupied versus unoccupied radon concentrations is recommended and shall be permitted as an additional line of evidence relative to mitigation decisions. When conducting such evaluation, the test devices, procedures and reporting shall comply with Normative Appendix B.

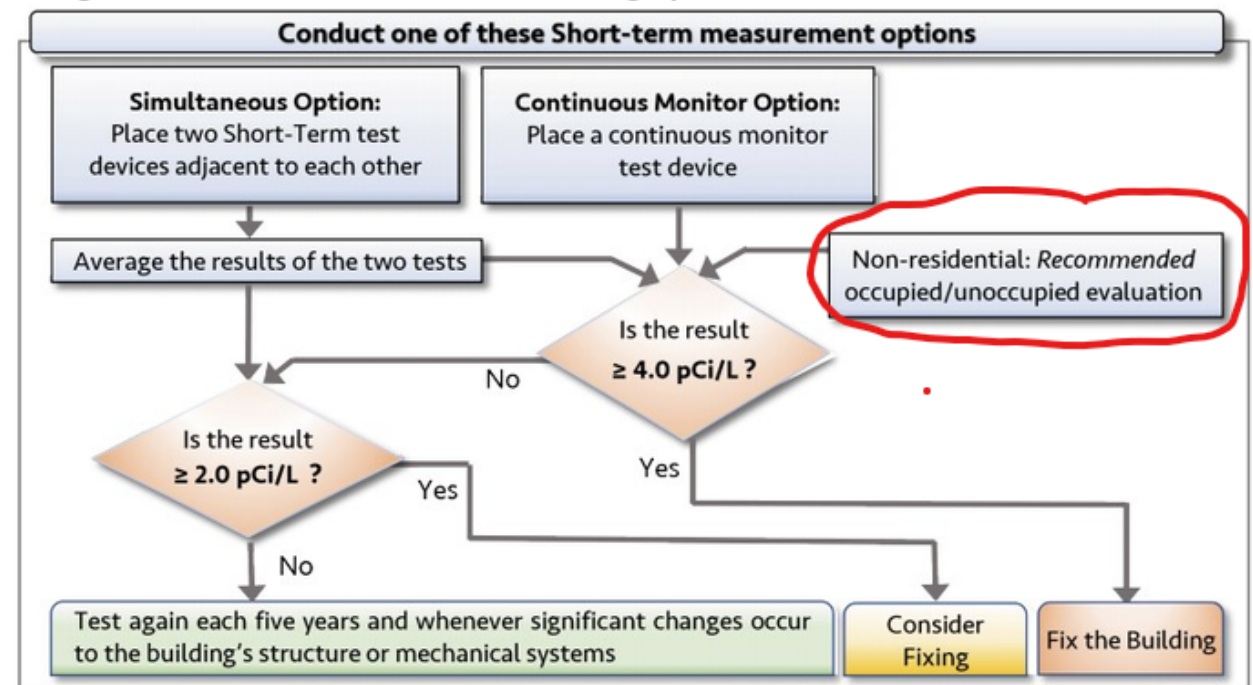
5.2.1 When to conduct the evaluation

An evaluation of occupied versus unoccupied radon concentrations is permitted during initial testing, follow-up testing, post-mitigation testing, or in a series of sequential tests. An evaluation that simulates various building operating conditions is also permitted in accordance with

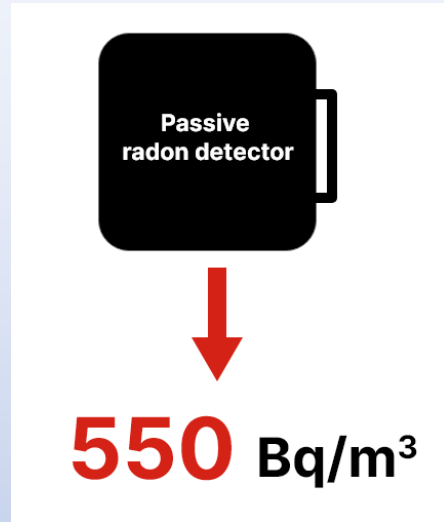
For non-residential buildings, occupied/unoccupied evaluation is recommended in the ANSI/AARST standard MA-MFLB-2023 if results are above 4.0 pCi/L.

A full 7-days measurement is not motivated since no factor-multiplication with a previous long-term result is made.

Figure 5.3 Time-Sensitive Testing Option Flowchart



FOLLOW-UP MEASUREMENT – DATA COLLECTION



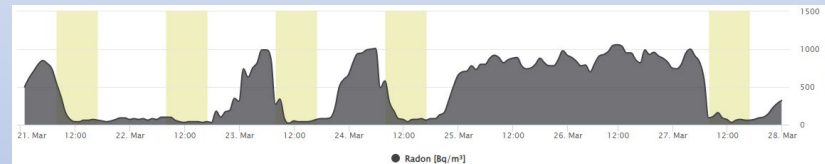
Long-term measurement



Follow up measurement



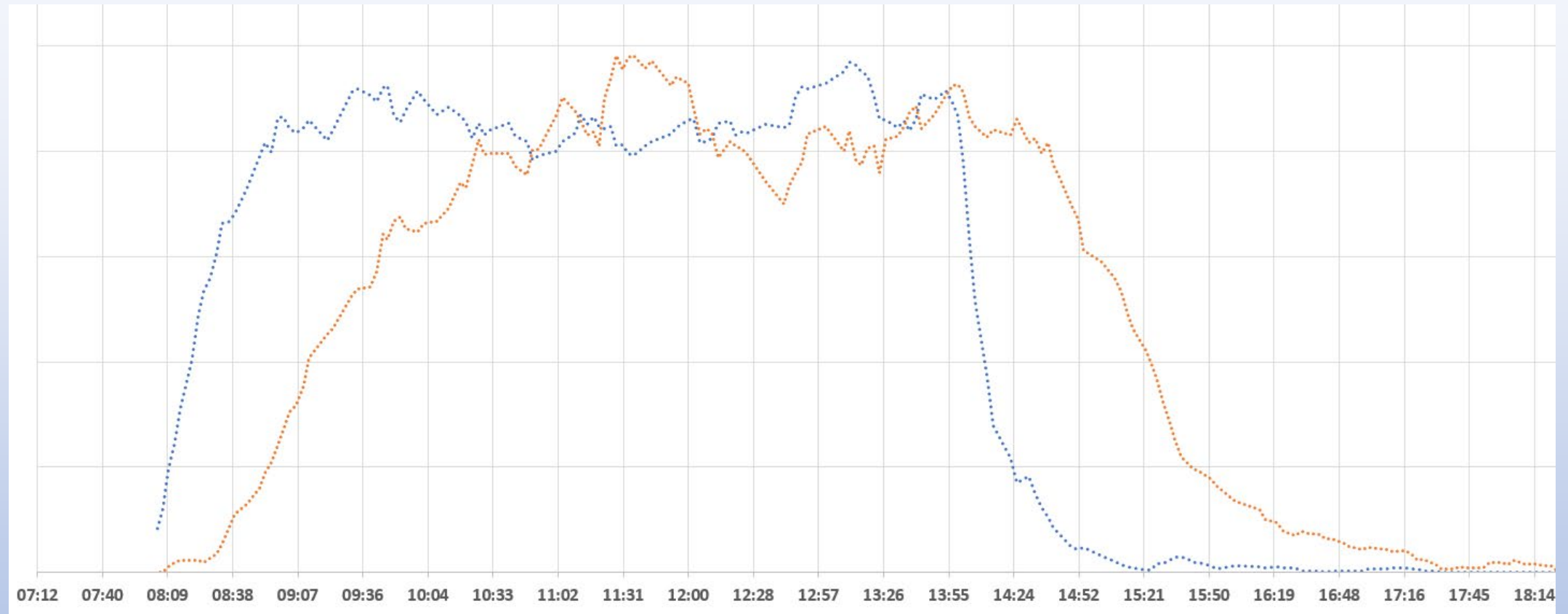
CRM device transfer raw measurement data to application server in which calculation and reporting is done



Data set 1: 88 measurements until 04/05/2023 – comparison between 7-days, 5-days and 2-days measurements

Data set 2: 108 measurements 04/20/2023 – 07/21/2023 (mostly outside heating season)

THE RESPONSE TIME OF THE INSTRUMENT MATTERS



Response from Po-218 (blue curve) and Po-214 (orange curve).

RESULTS FROM DATA SET 1

	Full week	5 days (Without weekend)	2 days (Mo & Tu)	2 days (Th & Fr)
Average factor	0.33 ± 0.23	0.44 ± 0.23	0.42 ± 0.25	0.46 ± 0.22

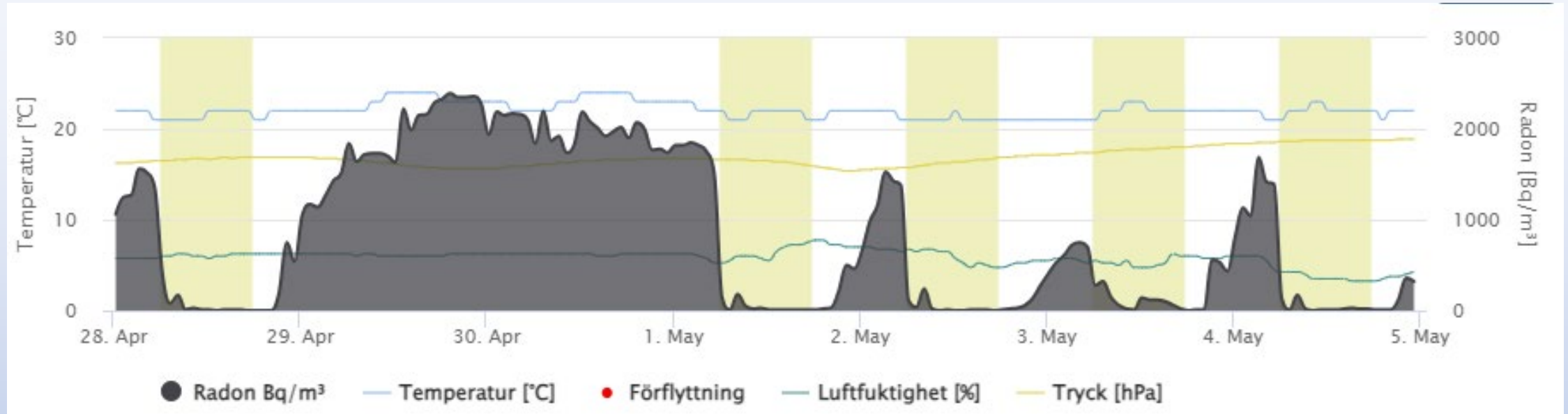
	5 days (Without weekend)	2 days (Mo & Tu)	2 days (Th & Fr)
Average difference between factors in percent from 'Full week'	+70% ± 40%	+37% ± 30%	+72% ± 79%

Follow-up measurement periods not in whole weeks might lead to an overestimation of the estimated long-term radon concentration during occupied hours.

RESULTS FROM DATA SET 2

- Factor between occupied hours and entire period 0.35 ± 0.30
- Large spreading in factor values
- 45 % of the follow-up measurements have a factor < 0.2
- Most follow-up measurement are made in schools or preschools/kindergarten
- About 10-15 % of the follow-up measurements gave an estimated long-term concentration during occupied working hours above the Swedish reference level of 200 Bq/m^3

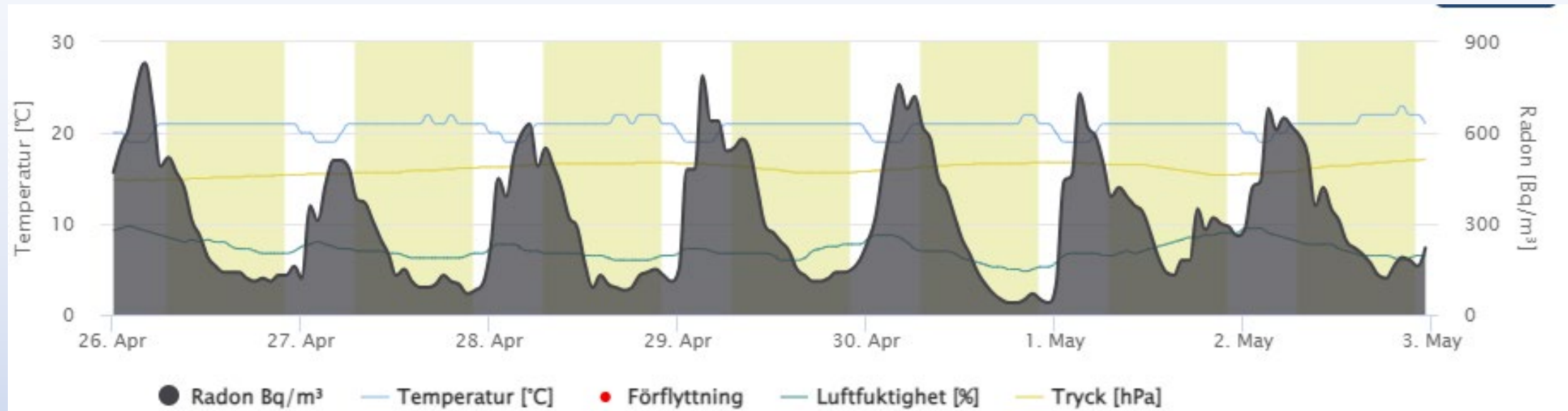
FOLLOW-UP MEASUREMENT EXAMPLE – LARGE VARIATIONS



Example – Kindergarten/preschool with time-controlled mechanical ventilation

- Average radon levels during entire measurement period > 20 pCi/L
- Average radon levels during occupied hours 1.0 pCi/L
- Factor between occupied hours and entire period as low as 0.04

FOLLOW-UP MEASUREMENT EXAMPLE – TOO LATE VENTILATION START



Example – Office with time-controlled mechanical ventilation

- Average radon levels during entire measurement period 8.4 pCi/L
- Average radon levels during occupied hours 5.4 pCi/L
- Factor between occupied hours and entire period 0.64
- Working hours 07:00 – 22:00

CONCLUSIONS AND THOUGHTS

- In buildings with time-controlled ventilation, the radon levels during occupied hours are in average about one third of the levels during the entire measurement period but with large variations in this factor.
- If this factor should be used together with a previous long-term value, the follow-up measurement should be performed during a whole week.
- The time when ventilation is started after weekends and night could have a large influence on the radon exposure to the people in the building.

CONCLUSIONS AND **THOUGHTS**

- Consider mitigation if estimated occupied levels are close to the reference level?
- Are people using the building also outside normal occupied hours?
- How close in time to a previous long-term measurement should a follow-up measurements be done?
- How much can the radon level during the entire period in a follow-up measurement differ from a previous long-term measurement and still be used in an estimation of a long-term value during occupied hours?

THANK YOU !!

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