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APPLICATION NOTE AN-006_EN

Quantifying of Radon Exhalation on Surfaces

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This application paper describes how to simply and quickly quantify Radon exhalation on surfaces using a Radon-monitor and an exhalation bonnet.

Physical Basics

The quantifying of Radon exhalation on surfaces is based on observing the increase of Radon activity concentration related to a well-defined gas volume until a steady concentration level is obtained in a certain time.

The Radon flux (or exhalation rate) E [Bq / (m²s)] on a surface is defined as ratio of (Radon-) activity A [Bq] to a Radon exhalating surface area (area F [m²]) and a durance t [s]:

$$E = A / (F * t) \quad [Bq / (m^2 s)] \qquad (1)$$

Consider an exhalation bonnet with the shape of a rectangular solid or a cylinder and with covered area F [m²] and height h [m], also with volume V :

$$V = F * h \quad [m^3] \qquad (2)$$

Let a concentration increase C_{Diff} [Bq/m³] be obtained in this volume during a time interval of length t [s]. The (activity-) concentration C [Bq / m³] of Radon in aerosols denotes the ratio (Radon-) activity A [Bq] to the (gas-) volume V:

$$C = A / V \quad [Bq / m^3] \qquad (3)$$

Using the parameters accessible by measurements C_{Diff} , h, t, the exhalation rate can be expressed as

$$E = C_{Diff} * h / t \qquad (4)$$

by the calculation:

$$\begin{aligned} E &= A / (F\, t) && [Bq / (m^2 s)] \\ &= (V / V) * A / (F\, t) && [(m^3/m^3)\ (Bq / (m^2 s))] \\ &= (A / V) * (V / (F * t)) && [(Bq/m^3)\ (m^3 / (m^2 s))] \\ &= C * (F * h) / (F * t) && [(Bq/m^3)\ (m^2 m / (m^2 s))] \\ &= C * h / t && [(Bq/m^3)\ (m/s)] \qquad (5) \end{aligned}$$

Example: In an exhalation bonnet of 12 cm height over a certain area covered, a maximal concentration of 1.540 Bq/m³ is measured after a measuring time of 1 hour. Beforehand, the Radon concentration of 100 Bq/m³ was measured outside the bonnet. For the Radon flux E, it holds:

$E = (120 \text{ mm} * 1440 \text{ Bq/m}^3) / 3600 \text{ s} = 48 \text{ mBq} / (\text{m}^2\text{s})$

Procedure of Measurement

At first, a Radon monitor with an internal or with a connected external pump is switched on for measuring the Radon activity concentration C_1 in the ambient air. Then, the exhalation bonnet of height h is placed upon the surface to be investigated. Its position should be suitably fixed in order to press on the elastic rabbet on the surface (for instance, put weights on a bonnet in horizontal position). Furthermore, an additional sealing is recommended (for instance, silicone paste, adhesive strip or also soil material in case of field measurements). After this, inlet and outlet port of the still running monitor are connected with two ports of the exhalation bonnet via PVC-tubes. In this way, it is obtained a closed circuit through which the contained air is circulating. The length t of time from starting with the short-circuit to achieving the level of maximal Radon activity concentration (quantum C_2) are minuted. From $C_{Diff} = C_2 - C_1$ and by using h and t, the exhalation rate E can be calculated according to (4).

Appropriate Radon Monitors

The mesurement method described
There are some requirements concerning the used Radon monitor which have to be taken in account. The monitor has to provide an internal pressure tight air loop (sealed chamber and tube connectors for inlet and outlet). An internal pump is an advantage. Membrane pumps are more suitable than rotary pumps because membrane pumps offer a much lower leakage rate.

To get a short sample period, a spectroscopic (Alpha spectroscopy) monitor is required. The internal volume of the monitor should be as small as possible since this volume and the sensitivity of the instrument are the parameters which are defining the detection limits of the sampling method.

For Radon exhalation measurements, the RTM1688-2 is the most recommended solution. The unit offers a high sensitivity of more than 3 cpm/(kBq/m³) (fast mode) obtained from a very small internal volume of only 130 ml. Although the sensitivity of the RTM2200 is lower (1.5 cpm/(kBq/m³) at possibly occuring high humidity levels) and its internal volume is nearly three times higher (370 ml), also this instrument is suitable for Radon exhalation measurements.
Both units are working with Alpha spectroscopy and both are equipped with membrane pumps.

Detection Limits

The detection limit depends on the used sampling configuration (volumes) and on the sensitivity of the Radon monitor on the one hand and on the sampling period used for the Radon measurement in the air loop, ont the other hand. Since the detection limit as well as the statistical error of the measurement corresponds only with the number of detected decays within the sampling period, the configuration can be optimised by the following rules:

- use a Radon monitor with a high sensitivity
- choose a sampling interval as long as possible

Standard Operating Procedure

- Flush the Radon monitor and the air loop with fresh air for at least 15 Minutes.
- Measure Radon concentration in the ambient air.
- Place and carefully seal the exhalation bonnet.
- Connect the exhalation bonnet with the Radon monitor.
- Determine the maximal Radon concentration of the gas inside the circuit and the time since short-circuit.
- Calculate the Radon exhalation according to formula (4).

IMPORTANT HINT: The stated procedure should be performed only under visual control. No water must enter the Radon monitor. This can cause the damage of the pump and the detectors/sensors. Work, if possible, with a protection flask.

Final Remarks

Because of the various objective factors affecting the results - and - taking into account that placing the exhalation equipment is always a subjective procedure, a reliable measurement is only possible if the conditions are repeatable. This should be less or not a problem inside a laboratory but keep in mind that “in situ” measurements with varying conditions will definitely result in a higher uncertainty.
To evaluate the sampling procedure, a calibration measurement should be carried out by the use of an exhalating surface with well-known rate and under keeping strictly the standard operating procedure as used later on for the measurements.