LSC-BASED APPROACH FOR RADON IN SOIL GAS MEASUREMENTS

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ABSTRACT. Estimation of radon risk in soil gas is a preventive practice when building safe dwellings. We propose a method for measuring of ^{222}Rn in soil gas based on liquid scintillation counting (LSC). A small-diameter hollow steel probe with a sharpened lower-end tip combined with a large-volume syringe (RADON v.o.s., Czech Republic) is used as a soil gas sampling system. One measurement approach includes direct soil gas counting in a special LS vial coated inside with plastic scintillation material, Meltilex™. Another approach is about 10 times more sensitive. It includes a radon trap-glass bubbler filled with a 20-mL portion of a toluene-based LS cocktail. After sampling, the LS solution is transferred into conventional vials for LS counting. The air inside the 150-mL syringe in both cases is blown through a vial or a bubbler. In the bubbler method, 3 portions of the air syringe volume are blown through the bubbler to make the method more reproducible. Rn sorption in the trap depends on the toluene and bubbler volumes, temperature, and humidity. In both measurement approaches, modern LSC measurement equipment with alpha/beta separation is used. The method was tested on Quantulus 1220™ and Triathler LS spectrometers. The described measurement approaches yielded count rates in the alpha window of 2.4 cpm for direct counting in Meltilex-coated vials and ~24 cpm when Rn is trapped in toluene, both corresponding to a concentration of 1 kBq m^{-3} for Rn in soil gas.

INTRODUCTION

Surface soil and underlying rock are the main sources of indoor radon in most buildings. Potential Rn risk estimation is a preventive practice when building safe dwellings using appropriate construction materials. Estimation of Rn risk includes determination of Rn flow flux (exhalation) measured on the soil surface (Gulabianz et al. 2000) or Rn concentration in soil gas measured at an optimized depth of 0.8–1.0 m below the soil surface (Akerblom 1994; Barnet 1994; Neznal et al. 2004). Both approaches can take into account the regional knowledge and measurement practices used on local equipment.

Different measurement techniques can be used for Rn in soil gas measurement: scintillation chamber, ionization chamber, and charcoal sampling systems. Two commercially available equipment setups are often used: single chamber (Markus 10, Gammadata Inc., or RAD 7, Durridge Inc.) and multiple chambers (ionization chamber or Lucas cell, Radon v.o.s.). We are concerned about Rn in soil gas measurement for building sites, where multiple measurements (15 and more) are required (Neznal et al. 2004). The latter method was selected here. It allows for carrying out separate air probe sampling and its later measurement (Barnet 1994; Neznal et al. 2004). In addition, attention was paid to possible variation of weather conditions and their influence on the measurement results.

METHODS

Air Sampling

A soil gas sampling system produced by Radon v.o.s., Czech Republic (Neznal et al. 2004) was selected. A small-diameter hollow steel probe with a sharpened lower-end tip combined with a large-volume (150 mL) syringe (Radon v.o.s., Czech Republic) is used as a soil gas sampling system. The entire system must be perfectly sealed during sampling. Two different approaches were applied in this study for measuring Rn in soil gas.

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One measurement approach includes direct soil gas counting in special LS vials coated inside with the plastic scintillation material Meltilex™. Such a vial was developed by Kaihola et al. (1992). It looks like a Lucas chamber and the sample of soil gas is blown into a vial via a syringe. The sample is then measured after ingrowth of the ^{222}Rn proxies in the vial using LS spectrometers equipped with electronics for α/β discrimination.

The second approach is about 10 times more sensitive. A glass bubbler filled with 20-mL of a toluene-based LS cocktail serves as a trap. After Rn sampling, this LS cocktail is moved into a conventional vial for counting. The entire 150-mL syringe air sample is blown through a vial or a bubbler trap. Volume ratios between the sample and the measurement volume are 150:22 and 150:100, respectively. Only a 2-second interval for the vial and 3–5 second interval for the bubbler is required for a complete air transfer. In the bubbler method, 3 portions of the air syringe volume are blown through the bubbler to make the method more reproducible.

Rn sorption into the toluene trap depends on the bubbler volume and geometry, the duration of air contact with the cocktail, and the soil gas conditions on site (e.g. temperature and humidity). Application of this measurement approach requires calibration. Thus, a set of bubbler samples (15 or more) requires 1–3 air samples to be measured in a vial coated with Meltilex™ inside. Air samples for calibration purposes are taken from the same sampling tube into the scintillation vial and into the bubbler containing the toluene trap.

Sample Measurement

Two different LS spectrometers were tested for measuring Rn in soil gas: a Quantulus 1220™ (PerkinElmer) and a Triathler (Hidex Oy), both equipped with α/β separation circuits. Both modern liquid scintillation counters are sensitive enough for routine Rn soil gas measurements at a level of 1.0 kBq m^{-3} and higher. Both sampling approaches are applicable with modern LS measurement systems equipped with α/β discrimination circuits. Each scintillator requires corresponding individual settings of α/β separation parameters for each device.

Calculation

According to the estimation of Kaihola (Kaihola et al. 1992; Kaihola 1996), the efficiency is ~178% for alpha counting of ^{222}Rn equilibrated with daughters in Teflon® vials (22 mL) coated with Meltilex™. The escribed measurement approaches yield count rates of 2.4 cpm for direct counting in the Meltilex-coated vial, and ~24 cpm for a Rn sample initially trapped in bubbler with toluene and then counted in conventional vial while measuring a standard with 1 kBq m^{-3} of Rn.

Measurement Data Explanations

Figure 1 shows the distribution of Rn in soil gas concentration measured in 3 building sites. Table 1 summarizes the corresponding statistical data sets for these 3 building sites. A comparison of count rate sets obtained by the application of 2 different approaches for simultaneous measurements of Rn in soil gas is given in Figure 2. The most contrasting distribution of Rn in soil gas concentration was observed in a tailing site from a uranium mine. As shown in Figure 3, the Rn concentration data varies by over 4 orders of magnitude.

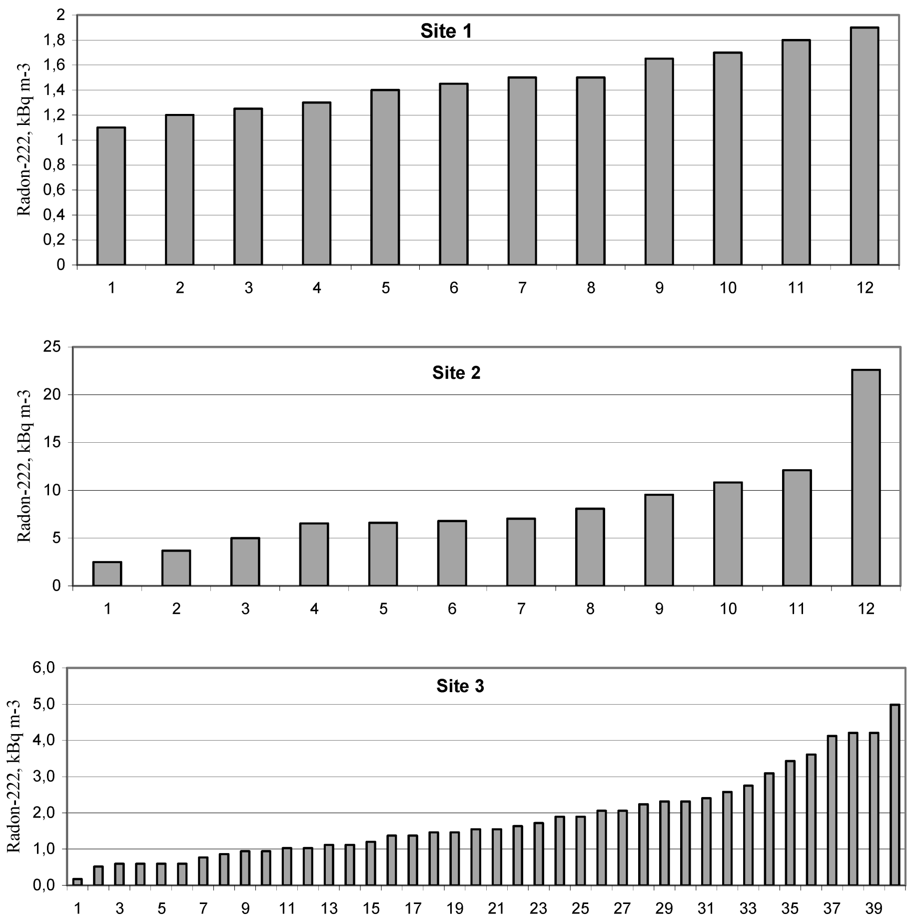

Figure 1 Distribution of radon in soil gas concentration (kBq m^{-3}) for 3 building sites

Table 1 Statistical data of Rn in soil gas measurement for 3 building sites (in kBq m^{-3}).

Characteristics	Site 1	Site 2	Site 3
Average	1.48	8.4	1.9
Standard deviation	0.25	5.2	1.2
Relative standard deviation	17%	62%	63%
Median	1.50	9.8	2.2
Number of samples	12	12	40

CONCLUSIONS

- Two LSC-based approaches for measuring Rn in soil gas, where sampling and counting are performed separately, yielded reproducible results. These methods are of advantage especially when a large number of measurements is required.
- Direct scintillation vial measurement is an appropriate tool for measuring Rn in soil gas.
- The Rn bubbling approach is about ~10 times more sensitive for measuring Rn in soil gas as compared to direct measurement using scintillation vial. This enables less counting time.

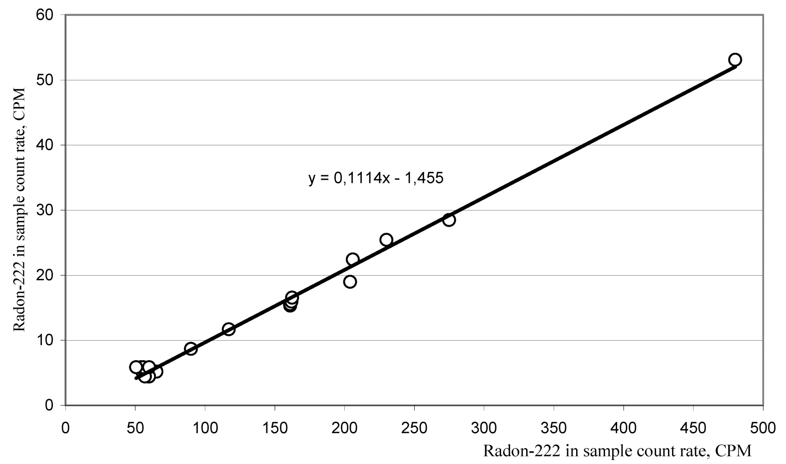

Figure 2 Comparison of simultaneous measurements of Rn in soil gas using 2 different approaches: direct counting (vertical axis); Rn trapped in toluene (horizontal axis).

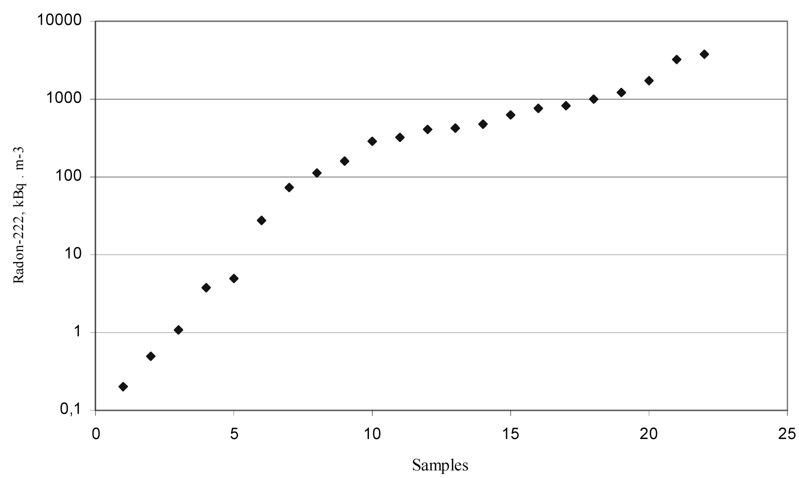

Figure 3 Distribution (ordered by amplitude) of Rn in soil gas concentration (kBq m^{-3}) measured in uranium tailings site

- Application of the scintillation vial method for measurement of Rn in soil gas is suitable for the observation of contrasting sites where cross-contamination is possible during sampling, especially when compared to 1-chamber measurement methods, which have a "memory effect" due to their sample by sample measurement approach.

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