Study of the influence of CO_2 concentration on the sensitivity of the SARAD radon measurement chamber

Veikko Oeser
SARAD GmbH, Wiesbadener Straße 10, 01159 Dresden
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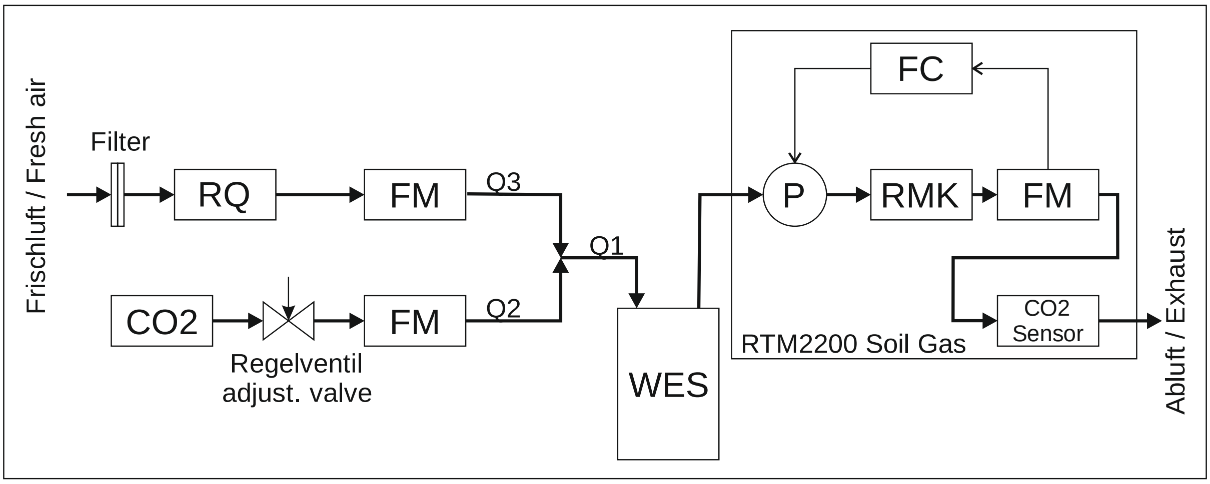
Motivation

Soil air is the continuation of the earth's atmosphere in the soil layers near the surface. Thus, the compositions of soil air and the atmosphere near the ground are similar. However, due to geology and vegetation, significantly higher concentrations of carbon dioxide (CO2) can occur in the soil air. These are usually in the low percentage range, but can reach higher concentrations when geogenic gases escape [1]. For the measurement of radon in soil gas, spectroscopic instruments such as the SARAD RTM2200 Soil Gas or the RTM 1688-2 are usually used to avoid interference from thoron (Rn-220). All RTM 2200, RTM 1688-2 and EQF 32xx devices use the same measurement chamber to determine radon concentration. This raises the question of whether an increased concentration of CO_2 has an effect on the sensitivity of these measuring devices.

The experiment carried out shows that the variation of the CO_2 concentration in the range of 400 ppm (free atmosphere) and 20% does not influence the result of the radon measurement.

Test setup



RQ Radon source
CO2 CO_2 gas cylinder
FM Flow meter
WES Water inlet protection
P Pump
FC Flow controller
RMK Radon measurement chamber

By using a certified radon flow source, a constant radon concentration can be generated in this airflow by a constant flow rate:

$$C_{Rn} = \frac{E}{Q}$$

C_{Rn} Radon activity concentration in the volume flow [Bq/m³].

E Emanation rate [Bq/s]

Q Flow rate [l/min]

This arrangement allows to carry out the test without a reference measurement. This is an advantage because the device used for the reference measurement could also be influenced by the variation of the CO_2 concentration. For the test, an RTM 2200 Soil Gas device was used, as it has both a flow control and an internal CO_2 sensor. A value of 0.5 l/min was chosen as the setpoint for the flow rate. A measurement using an external flow meter applied to the RTM air inlet resulted in an actual volume flow (Q1) of 0.53 l/min. The emanation rate of the source is 0.20 Bq/s, resulting in an expected radon activity concentration of 22.6 kBq/m³.

CO_2 is added via a control valve from a commercially available pressurised gas cylinder with pressure reducer. For control purposes, the partial volume flows (Q2, Q3) were monitored with flow meters. Sufficient mixing is ensured by an appropriately long tube connection and the water inlet protection upstream of the RTM 2200 Soil Gas. Due to the regulation of Q1, the flow rate Q3 decreases with an increased flow rate Q2. This has no influence on the radon concentration, as the emanated radon is diluted in Q1.

After a measurement with normal room air, the CO_2 concentration was increased in steps of about 5%. The measurement time for each CO_2 level was four hours, only overnight there was no readjustment.

Used materials

A calorimetric mass flow sensor from Kobold was used to determine Q2 (MAS1004, measuring range 0...0.1 l/min air). The calibration must be adapted for the volume flow measurement of CO_2. The correction factor is 0.74, i.e. with a display of 0.1 l/min, the actual CO_2 flow rate is 0.74 l/min.

The volume flow Q2 was measured with a calorimetric flow meter from Tylan (FM3901, measuring range 0...5 l/min air).

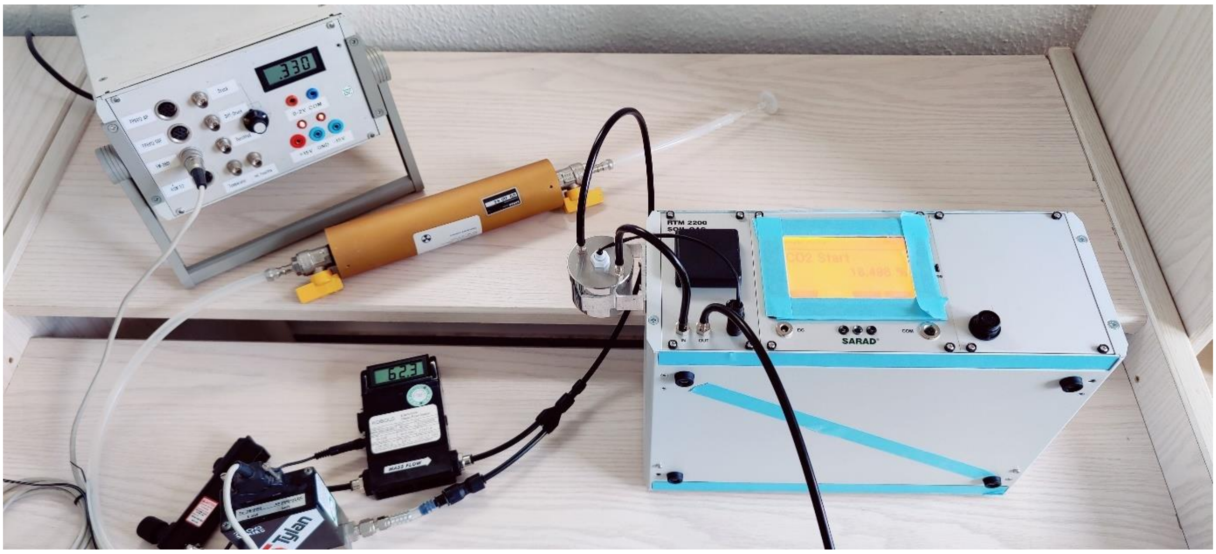
The flow measurement in the controller of the RTM 2200 is also calorimetric (First Sensor FMA, measuring range 0...6 l/min). With an admixture of max. 20% CO_2 and a correction factor of 0.74 with respect to air, the change in the controlled flow rate due to the CO_2 content appears negligible.

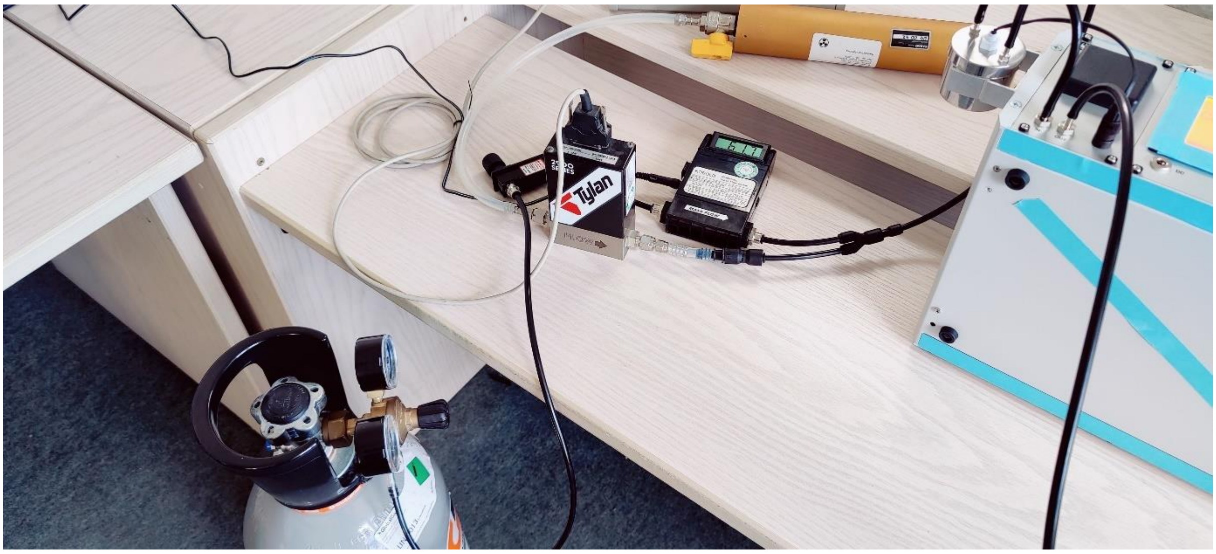
The radon source is an emanation source from CMI (Czech Meteorologic Institute) with a nominal Ra-226 activity of 100 kBq/m³ and an emanation rate of 0.2 Bq/s.

As CO_2 source a pressurised gas cylinder with a net filling quantity of 10 kg pure CO_2 was used.

The radon monitor is a SARAD RTM2200 Soil Gas with water inlet protection, CO_2 and CH_4 sensor. The CO_2 sensor used in the device, type Vaisala GMP 251, has a measuring range of 0...20%. The RTM 2200 Soil Gas was previously calibrated in the DAkkS-accredited radon calibration laboratory of SARAD GmbH.

The following illustrations show the test setup.





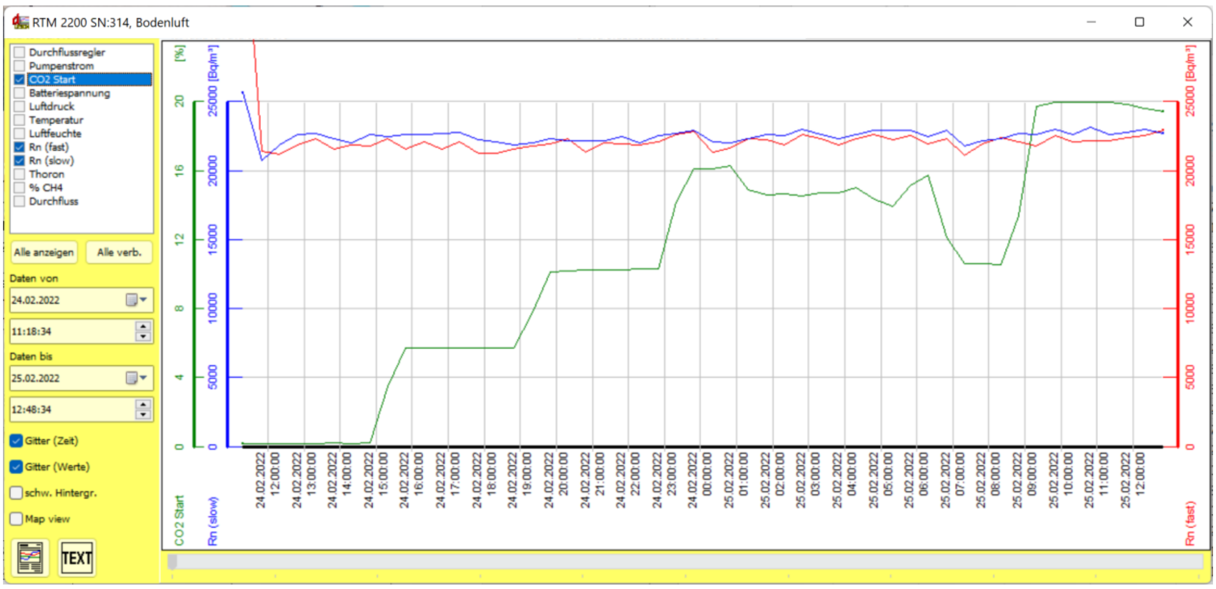
Results

The values given in the table refer to the mean value of seven measured values (measuring interval 30 min) for any adjusted CO_2 level. The first value after adjustment was discarded. The stated expanded standard uncertainty refers to the counting statistics of the RTM 2200 Soil Gas. According to GUM [2], for a number of individual values smaller than 20, the coverage factor k = 2 is to be expanded for the confidence interval of 95% to be specified. For seven values, the expansion factor is 2.43.

CO_2 Concentration	Measured Radon concentration in Bq/m³	Deviation from 400 ppm result in %	Expanded standard deviation in %
400 ppm	22466	-	±2,7
5,7 %	22412	-0,25	±3,4
10,3 %	22255	-0,94	±1,9
14,8%	22664	+0,88	±2,2
19,9%	22852	+1,72	±1,9

All measured values are within the expected uncertainty budget. There is a tendency for a slight increase in the radon measured value with increasing CO_2 concentration. However, this is not due to a real CO_2 influence, but to the reduction of the actual flow Q1 with respect to the display value of the flow meter in the flow control circuit. Due to the rising CO_2 content, the density of the measured air increases so that the calorimetric sensor outputs an actual value that is too high. As result, the flow controller reduces the pump speed. The changes in barometric pressure (approx. 12 mbar) that occur during the measurement also lead to slight changes in the actual value measurement (note: calorimetric flow meters always determine the mass flow in SLPM).

The following figure shows a screenshot with the measurement data of the CO_2 test (green = CO_2; red = C_{Rn}(fast); blue = C_{Rn}(slow)).



Literature

[1] Handbuch der Bodenkunde – Gasphase im Boden (Prozesse und Konzentrationen); Prof. Dr. Jürgen Böttcher; Wiley Online Library

[2] EA-4/02 M: 2013 Ermittlung der Messunsicherheit bei Kalibrierungen (Deutsche Übersetzung)