Proceedings of ICGG7 (2003): 62–64

ICGG7 2003

Development of the method for measurement of radon exhalation from the ground

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Abstract. During our investigations in Upper Silesian Coal Basin (USCB), we found that in some parts of the basin radon concentrations in dwellings were enhanced. Coal mining in this area leads to specific geodynamic phenomena, as quakes and tremors. On the other hand, underground exploitation induces the presence of emptiness, cracks and fissures in the strata. All mentioned above factors lead very often to subsidence of the surface and damages of buildings, located in affected zones. Radon migration in fractured rocks and ground is much easier.

1 Introduction

One of possible indicators of radon risk is radon concentration in soil gas, commonly used in many countries. Very important factor, affecting radon levels in dwellings, is permeability of the soil. Measurement of soil permeability is difficult, therefore in our opinion a better indicator of radon risk is exhalation rate from the ground. The radon exhalation coefficient from ground is very useful in prediction of radon risk of investigated areas. The theoretical calculation of the coefficient is possible, but requires a lot of parameters of the ground. Especially in regions, where the top layers of rocks and ground are affected by mining, the theoretical approach may lead to significant errors due to non- homogenous soil structure and disturbed underneath layers. Therefore we decided to develop our method for measurements of exhalation rate.

The measurement of the exhalation rate in this method is based on the assumption, that the accumulation time t is much shorter as the half life of radon $T_{1/2\mathrm{Rn}}$ and the correction for the decay of radon during accumulation time can be omitted ($t \ll T_{1/2\mathrm{Rn}}$). We use following formula:

$$\varphi\mathrm{Rn} = A_{\mathrm{Rn}}/(S^{*}t)$$

where: A_{Rn} – radon activity in accumulation chamber $[Bq]$, a product of radon concentration C_{Rn} and chamber volume V;
S – exhalation surface [m^2]
t – accumulation period [s]

Firstly, an accumulation chamber has been constructed. It is a metal cylinder with diameter phi350 mm and height 200 mm. Two Swagelock connectors have been mounted to enable air sampling from the chamber. The lower edge of the cylinder is sharp and during measurements the wall is buried into ground at the depth of few centimetres to seal the accumulation chamber and prevent ventilation by atmospheric air. After a certain time of accumulation of radon, but not shorter as 2,5 h, air from the chamber has been sampled. Air was sucked through a dryer into a Lucas cell in a close loop to avoid radon loss. We applied this method in preliminary investigations. But the detection limit for Lucas cells is of about 50–100 Bq/m^3. For the accumulation time 3 h and counting time 10 min is corresponds to the lower limit of detection of exhalation coefficient equal 1–2 mBqm^{-2} s^{-1}. This detection limit is too high in some cases, therefore we started to look for another method to improve results of measurements.

Charcoal detectors have been applied for investigations of radon exhalation and the detection of radon is done by liquid scintillation counting (LSC). LSC offers low detection limit of the exhalation coefficient, as low as 0.1 mBqm^{-2} s^{-1}. For measurement of radon our own detectors have been used, consisting of 5 g of activated charcoal, placed in the scintillator vial. After the exposure of detectors, radon was washed out into liquid scintillator and LSC has been applied. The detection limit of this method is much lower, but the calibration of the method causes some problems.

Standard procedure of the calibration has been performed in radon chamber with a volume 7.25 m^3 and stable radon concentration (≈10–15 kBq/m^3). The exposure time of charcoal detectors in the chamber was short and varied from 2 to 4.5 h. Simultaneously, continuous measurements of radon concentration in the chamber have been done by AB-5 Pylon monitor with passive Lucas cell, type PRD. Results of LS counting and continuous radon monitoring were used for

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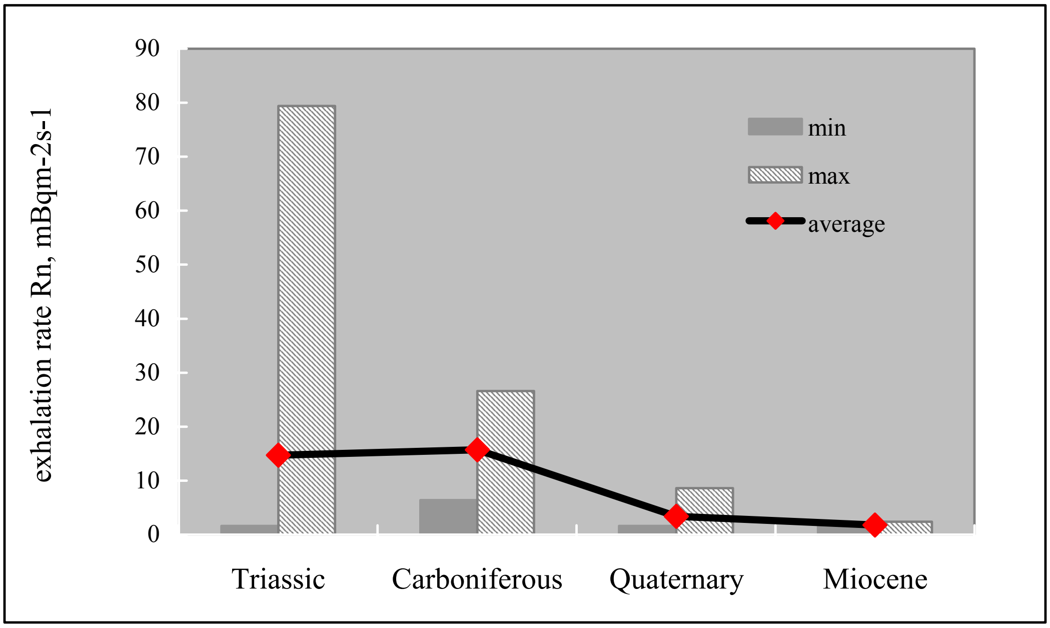

Fig. 1. Results of measurements of the radon exhalation coefficient in USCB.

the calculation of calibration coefficient. In this case the calibration coefficient was time-dependent as a linear function of the exposure time. The reason is that the saturation of charcoal detectors can be reached after several hours from the beginning of the exposure.

The next step of the survey was the comparison of two methods – the use of Lucas cells and charcoal detectors during field measurements. Accumulation chamber were coupled at chosen sites. In one of chambers the activated charcoal detector was placed and in another one the radon concentration was measured with application of Lucas cells. Preliminary results showed big discrepancies between both methods, up to 50%. Repeated measurements confirmed such big bias. After careful analysis we found, that these differences were due to the calibration procedure of charcoal detectors. Results of the analysis have been used as guidelines to change the calibration procedure.

In the calibration chamber we simulated similar conditions as during field measurements. Firstly radon level in the chamber was similar as the outdoor concentration. Then charcoal detector had been placed inside the chamber. The radon source from PYLON has been used to produce the steady increase of radon concentration in the chamber. Independently, radon concentration in the calibration chamber has been monitored, a grab radon sampling has been done by Lucas cells. After the calibration, we compared results of grab sampling and LS reading. We found out that new calibration factor was not time-dependent. Possible reason of such behaviour would be quick sorption of radon on charcoal, as the adsorbed activity might be proportional to the total activity of radon in the chamber and the calibration factor is more or less stable in time.

After the correction of the calibration procedure field experiments have been started. to investigate relationship between radon exhalation rates and local geological structure in different regions of USCB. Additionally, some areas after ground reclamation have been tested, because we predicted enhanced radon exhalation rates in some specific sites like abandoned settling ponds or waste piles.

Major number of exhalation rate results are within the range from 2 $\mathrm{mBqm^{-2}\,s^{-1}}$ up to 50 $\mathrm{mBqm^{-2}\,s^{-1}}$, known from the literature as typical values for different soils. Extreme values of exhalation coefficient were measured at Triassic outcrops – 0.4 and 79.4 $\mathrm{mBqm^{-2}\,s^{-1}}$. In both areas with Triassic outcrops we observed very wide range of measured values, while the average exhalation rate is 15 $\mathrm{mBqm^{-2}\,s^{-1}}$. Similar value of the average exhalation rate was calculated for area with outcrops of Carboniferous rocks: 15.6 $\mathrm{Bqm^{-2}\,s^{-1}}$, although the range of measured values is not so wide, as for Triassic rocks (see Fig. 1).

In areas, where Carboniferous rocks are covered by thick Quaternary sediment (more than 10 m) we measured low values of exhalation rate, with average 3.4 $\mathrm{mBqm^{-2}\,s^{-1}}$. The lowest coefficients of exhalation have been found in area with Tertiary sediments – from 0.7 up to 2.4 $\mathrm{mBqm^{-2}\,s^{-1}}$. Usually these Miocene clays are covered by Quaternary sediments, mainly clayey sands. Due to this fact radon concentrations in soil gas in this zone varied in a limited, narrow range – from 500 to 7500 $\mathrm{Bq/m^3}$, additionally exhalation coefficients were always low.

Preliminary results of our investigations confirm the thesis, that the most important factor, controlling migration and exhalation of radon from soil is geological structure of top layer of the ground. The most important are rocks, underlying the soil to the depth of about 10 m, because radon cannot migrate from deeper levels due to its relatively short half life.

2 Summary

- The application of the charcoal detectors for measurements of radon exhalation rate from the ground enables a significant decrease of the detection limit but enforced changes in the calibration procedure. The calibration cannot be done under stable radon concentration but must be performed in similar condition as in the field.
- Results of preliminary investigations show, that a strong correlation between radon exhalation and geological structure of surface layer exists. Also mining activity may cause the increase of exhalation due to its influence on the surface layers of the ground.