Testing and calibration of CDs as radon detectors at highly variable radon concentrations and temperature

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1. Introduction

The CD-method for radon measurements was proposed in 2001 [1]. It is based on analysis of alpha tracks at certain depth (that should be at least 76 µm) beneath the disk surface as described elsewhere [1, 2]. Since 2001 it has been thoroughly studied in the laboratory and in indoor radon surveys [2]. The temperature is the only identified environmental factor to have an effect on the results, which can be corrected for a posteriori. Past comparisons made indoors showed good correspondence between the CD/DVD method and conventional measurements [2]. However, new applications of this method, e. g. for measurements in mines [3], require tests of the method under much more extreme conditions than those typically found indoors. In particular comparison under extremely high variations in radon levels and variable temperature can enlighten the potential of the method for applications at peculiar working places or environmental conditions. Here we describe the results of a blind comparison of radon measurements by CDs and continuous radon monitors, which was carried-out In the Laboratory of Natural Radiation (LNR) Saelices el chico, Spain (Fig. 1). This is a unique laboratory facility where radon concentration can vary by orders of magnitude and in which continuous follow-up of radon concentrations and environmental parameters (temperature, humidity, pressure) is made by reference instruments (Fig. 2).

2. Exposure and calibration

The disks were exposed from 29.09.2017 to 19.03.2018. CDs (Verbatim, recordable) in jewel cases were placed for exposure at a shell in the laboratory (Fig. 2). The concentrations and major environmental parameters were followed continuously (every 10 min) by a reference instrument AlphaGUARD, Saphymo [4]. The radon concentrations during the exposure varied by orders of magnitude: from < 10 to 147000 Bq m^{-3} (Fig. 3). The average temperature was 12.6^{0}C (range 6.5 - 24.9^{0}C, Fig. 4), the pressure 944 hPa (903.6 - 960.2 hPa) and the humidity 64.4% (27.5 - 97.4%). The variations in radon levels were irregular, while those in the temperature showed irregular as well as systematic seasonal pattern.

The calibration of CDs was carried out at Sofia University "St Kliment Ohridski", Bulgaria by exposure of identical disk at reference radon concentration at the average temperature (12.6^{0}C). The calibration exposure was done using the calibration facility described in Ref. [5]. The reference concentrations were followed by the reference monitor AlphaGUARD PQ2000 Pro, Saphymo. The calibration factor (*CF*) was determined for two depths beneath the disk surface: 80 µm and 120 µm. The *CF* values are as follows:

- *CF*(80 µm) = 0.00946 ± 0.00054 cm^{-2}/kBq h m^{-3}
- *CF*(120 µm) = 0.00286 ± 0.00024 cm^{-2}/kBq h m^{-3}

The potential bias in the calibration factor due to the unstable temperature conditions during exposure was studied by theoretical modelling, using the model [6]. The analysis revealed that the bias depends both on temperature and radon concentrations profile. Under the "constant concentration conditions" it was 4.2% at depth 80 µm and 7.7% at depth 120 µm beneath the disk surface. This bias was included in the uncertainty budget of the results.

3. Results

The results are illustrated in Figs. 5 and 6. The laboratory processing of the disks after exposure included chemical pre-etching, electrochemical etching and automatic track counting [2]. The integrated radon concentration was determined by the net track-density at two depths beneath the CD surface: 80 µm and 120 µm. The integrated radon concentration determined by the reference continuous monitors in this experiment was 122500±6100 kBq h m^{-3}. The integrated concentration determined by CDs was (Fig.5):

- at 80 µm: 118000 ±12000 kBq h m^{-3} (difference 3.7% from the reference value)
- at 120 µm: 106000 ± 12000 kBq h m^{-3} (difference of 13.5%).

The variation between individual disks was within 12% and in only one CD it was 20% (Fig. 6). The individual results were statistically coherent within the set of analyzed disks, none difference being significant at 95% level.

References

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Figure 1. Laboratory of Natural Radiation (LNR) Saelices el chico, Salamanca, Spain

Figure 2. Disposal of set of disks at the shell and the reference instrument.

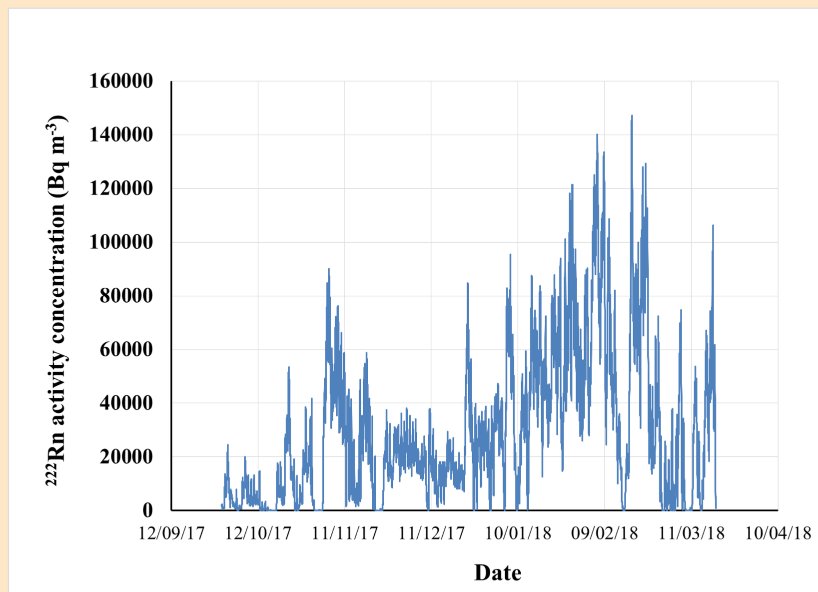

Figure 3. Radon-222 concentrations during exposure. The concentrations varied from < 10 to 147 000 Bq m^{-3} .

Figure.4. Temperature during exposure. The average temperature was 12.6^{0} C.

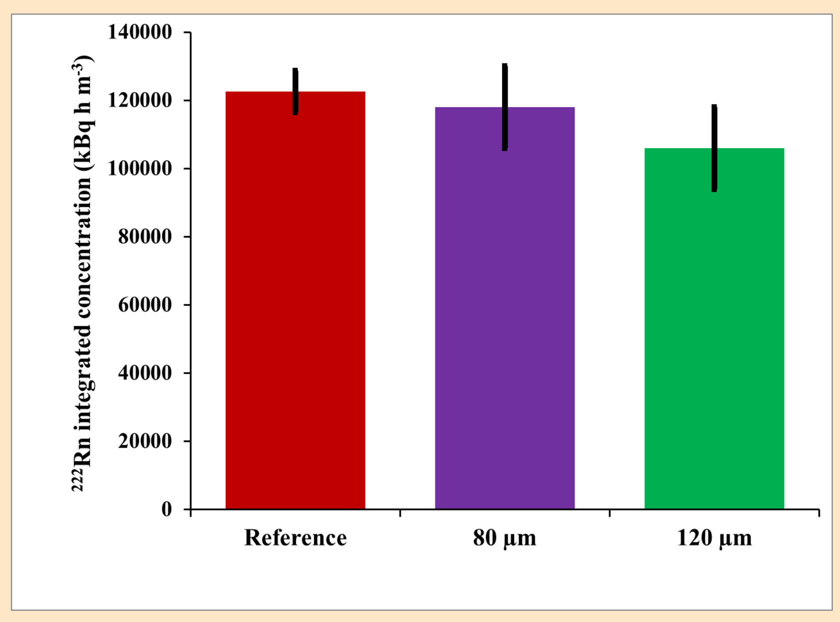

Figure 5. Integrated ^{222}Rn concentration assessed by reference measurements and by CDs analyzed at 80 µm and 120 µm.

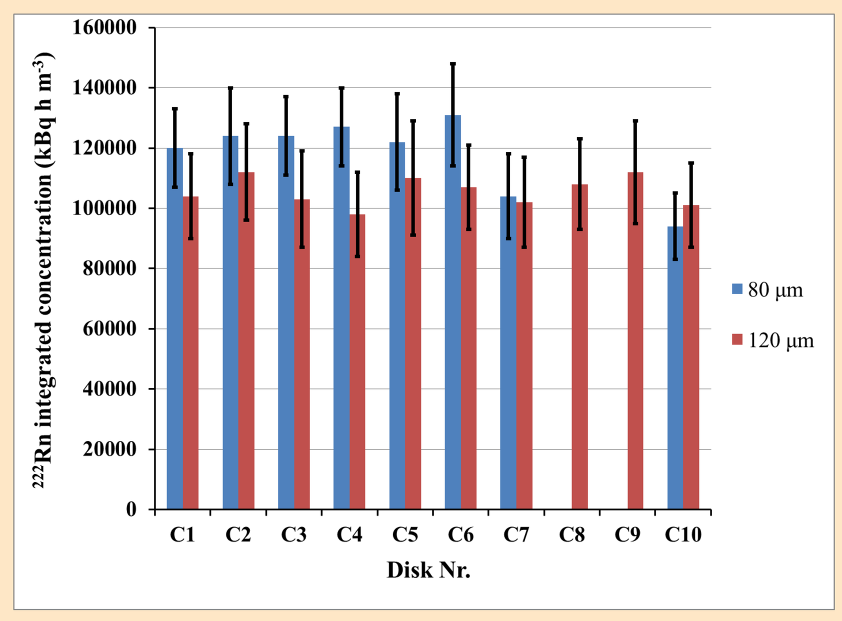

Figure 6. Variation of individual results between disks from one set at depths 80 µm and 120 µm. Disks C8 and C9 were analyzed only at 120 µm.

4. Conclusions

There is a very good correspondence between the results obtained by CDs and the reference concentrations despite the large variations in the activity concentration of radon and the temperature and the high integrated radon activity concentration. The small systematic bias of 3.7% at 80 µm and 13.5% at 120 µm can be explained by great temperature variability during exposure. Theoretical modelling revealed that the influence of the temperature variability is greater at depth of 120 µm. We conclude that, when an appropriate temperature correction is applied, the CD method provides reliable estimate of the integrated radon concentration even under extremely variable conditions. Further investigations will focus on the effect of variable temperature at different exposure regimes.

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