Methods for the experimental study of ^{220}Rn homogeneity in calibration chambers

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1. Introduction

Thoron (^{220}Rn) is an isotope of the noble gas radon with 55.8 s half-life. Its short half-life makes it difficult to ensure that it is homogeneously distributed in the chamber volume when thoron exposures are performed. Therefore, experimental methods able to probe thoron homogeneity are highly necessary.

The objective of this work is to present two newly proposed methods for evaluation of thoron homogeneity:

- The first method is based on a capture of thoron decay products in silica aerogel grains and subsequent liquid scintillation counting (LSC) of the aerogel.
- The second method is based on the measurement of the density of tracks formed by ^{220}Rn and ^{216}Po in Kodak Pathe LR-115/II solid state nuclear track detectors (SSNTDs).

2. Evaluation of thoron homogeneity by LSC of silica aerogel

This method uses specially designed thoron samplers to capture the thoron decay products in silica aerogel (Figures 1-4). The idea of the sampler is to allow thoron to enter freely from the environmental air into the cylindrical volume through the filters and to stop the thoron decay products on the filters. Thus, when ^{220}Rn decays inside the sampler, its decay products (^{216}Po, ^{212}Pb, ^{212}Bi, ^{212}Po and ^{208}Tl) attach to the silica aerogel and their activity in the aerogel is proportional to the ^{220}Rn activity that has entered in the cylinder. The latter is proportional to the ambient ^{220}Rn activity concentration in the air surrounding the sampler.

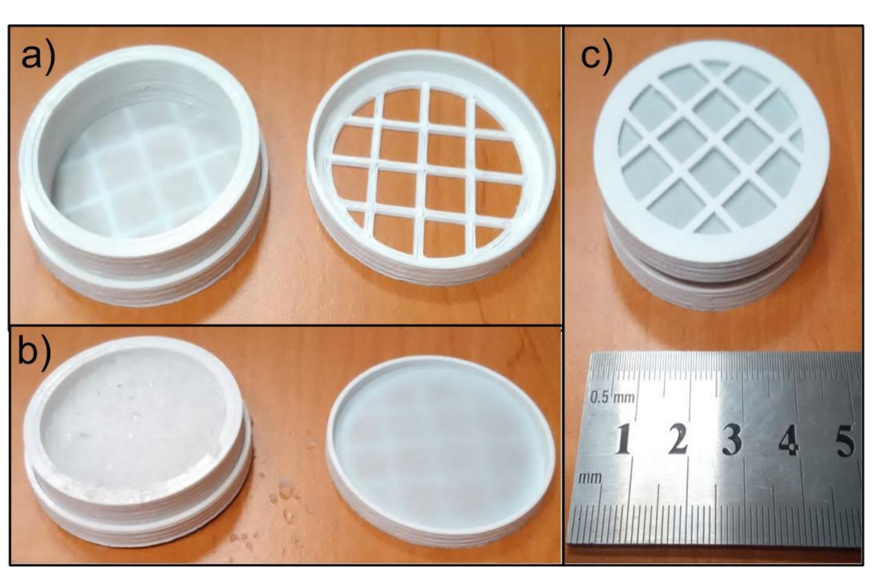

Fig. 1. Photos of a thoron sampler. a) Empty sampler ready to be filled with silica aerogel; b) the sampler filled with aerogel; c) closed sampler ready to be placed in a thoron chamber.

Fig. 2. High performance LS glass vials (20 mL) filled with silica aerogel and Ultima Gold LLT LS cocktail.

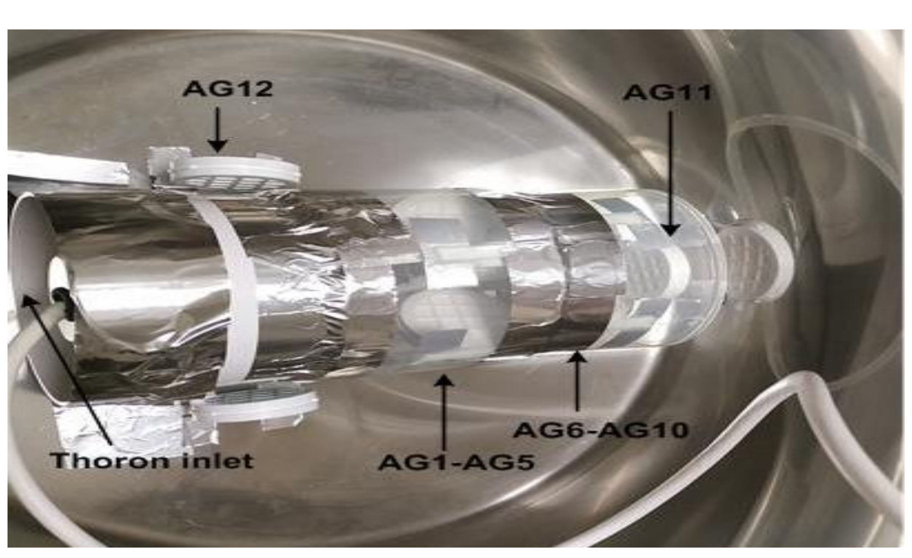

Fig. 3. Photograph of the exposure set-up used to test the repeatability of the method. The fan and the tube with the samplers are placed in a 50 L vessel.

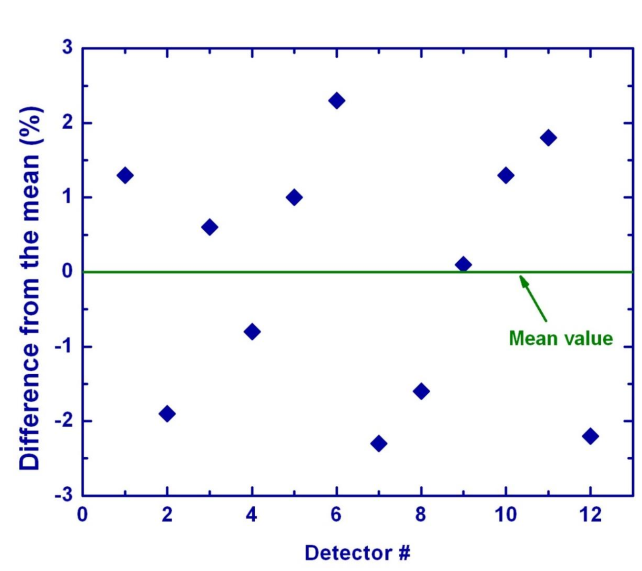

Fig. 4. Study of the repeatability of ^{220}Rn homogeneity evaluation with thoron samplers. All results are within ± 2.3%.

3. Evaluation of thoron homogeneity by SSNTDs

The second approach is based on the use of bare SSNTDs, placed at different points inside. Normally, the air contains a mixture of ^{220}Rn and its progeny atoms ^{216}Po, ^{212}Pb and ^{212}Bi, ^{212}Po. However, in an exposure chamber with air turbulence created by a fan, a substantial part of the progeny atoms is deposited on the walls.

When in the chamber ^{220}Rn + progeny is created, due to the longer half-life of ^{212}Pb (10.64 h) and ^{212}Bi (60.55 min) one can expect that practically all of the ^{212}Pb and ^{212}Bi+^{212}Po atoms are deposited on the walls and their air fraction is negligible. Therefore, within the SSNTDs approach we assume that the isotopes in the air are ^{220}Rn and ^{216}Po, and due to the short half-life of ^{216}Po (0.15 s) it is of the same volume distribution as ^{220}Rn. In experiments SSNTDs of Kodak-Pathe LR-115 type II were used. The air volumes from which the alpha particles of different isotopes can be detected are schematically shown in Fig. 5.

From Fig. 5 the following rules for the measurement design can be drawn: To avoid contribution from the atoms deposited on the surface, the SSNTD face should look to air being at a distance of at least 8 cm from any surface – i.e. outside the range of ^{212}Po alphas. Under these conditions the tracks will be due only to the alpha particles from the sources in the air (^{220}Rn and ^{216}Po) and the registered tracks will be from a small volume 2.4 – 5 cm in front of the detector surface.

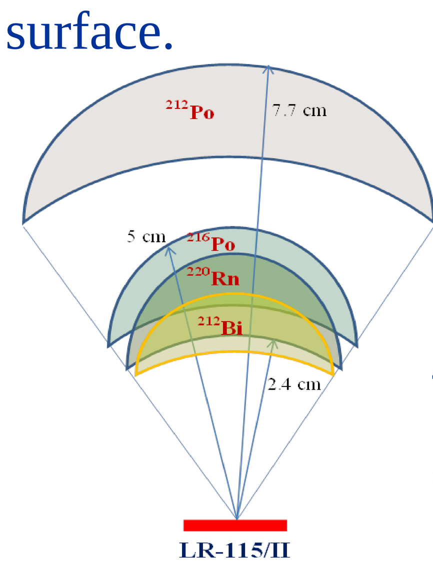

Fig. 5. Air-volumes from which alpha particles can be detected by LR-115/II detectors.

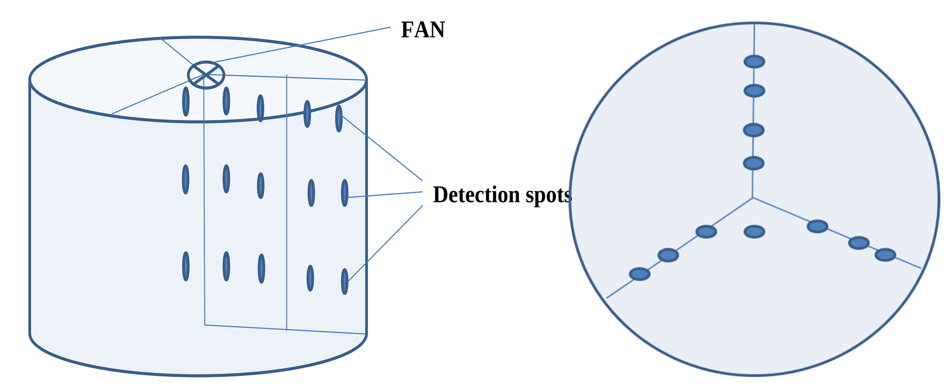

Fig. 6. The picture shows the spots in the chamber volume from where activity can be detected by the placed in a grid Kodak Pathe LR-115/II detectors.

Respecting the above rule, a ^{220}Rn thoron exposure was made in a 50 L cylindrical chamber with 33 Kodak-Pathe LR-115/II detectors placed inside. The map of the "detection volumes" is shown in Fig. 6. The analysis of the results showed that the distribution of ^{220}Rn in the air is homogeneous within 10%.

4. Application of the methods during the thoron calibration exercise, performed at BACCARA chamber at IRSN, France

Both methods are applied to test the ^{220}Rn homogeneity in the BACCARA chamber during the ^{220}Rn calibration exercise that was carried out in the framework of the MetroRADON Euramet EMPIR project. 12 aerogel thoron samplers and 22 pieces of SSNTDs were placed at different positions in the BACCARA chamber during the calibration exercise in the chamber. The results are shown in Fig. 7.

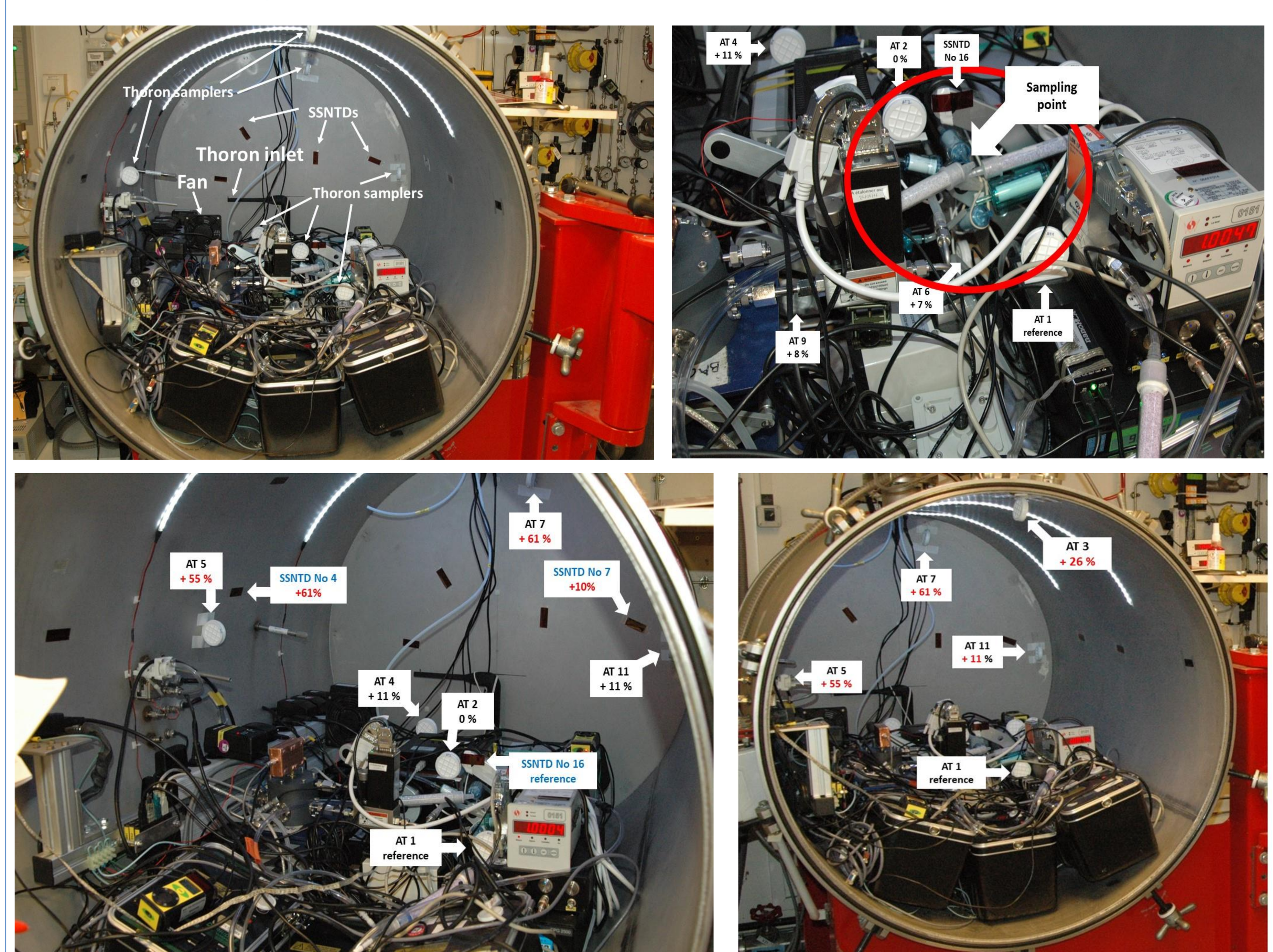

Fig. 7. Thoron homogeneity study during the BACCARA calibration exercise.

5. Conclusions

Two experimental methods for evaluation of ^{220}Rn homogeneity in calibration chambers are proposed and studied. The results from the thoron calibration exercise at the BACCARA chamber show that, at the center of the chamber where the inputs of the instruments sampling systems were put close to each other, the thoron inhomogeneity is less than 10%. However, regions of higher thoron concentrations are clearly identified near the walls and the upper part of BACCARA, with ^{220}Rn concentrations being up to 60% higher compared to that at the reference point. These results highlight the importance of the assessment of homogeneity in ^{220}Rn calibrations and in the case when radon monitors are checked for ^{220}Rn influence.

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