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In-situ alpha spectrometry from air filters at ambient air pressure

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HIGHLIGHTS

- ► We measured good-resolution alpha spectra from air filters at ambient air pressure.
- ► Good energy resolution was obtained by collimation.
- ► Novel spectrum analysis tools facilitates radionuclide identification.

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ABSTRACT

The effect of collimation to the alpha-particle energy spectra was investigated for two different types of air filters, when the measurements were performed at ambient air pressure. Significant improvement of the energy resolution is possible if appropriate collimator is used. This is because only those alpha particles are detected entering the detector almost perpendicularly. We also show that although *in-situ* alpha spectrometry from air filters at ambient air pressure and with good energy resolution is possible, the accumulation of alpha-particle emitting aerosols in the surface of the collimator and the detector may deteriorate the registered spectrum. Therefore, the presence of possible spurious alpha peaks must be taken into account in continuous air monitoring.

1. Introduction

Alpha-particle spectrometry is a widely used method to detect and identify the presence of alpha-particle emitting radionuclides in a sample. It is usually applied for radiochemically processed (i.e. thin) samples in vacuum. This is because of the prominent energy loss of the alpha particles in a medium.

High-resolution alpha spectrometry from air filters were proven suitable for field measurements (Pöllänen and Siiskonen, 2006). The filters were measured in the vacuum chamber as such, i.e., without radiochemical sample processing. Equipment, basically similar to those used in a laboratory, was also mounted in moving vehicles (Hoffman et al., 2011; Smolander and Toivonen, 2004). More rugged portable instruments were constructed allowing measurements either in vacuum or at ambient air pressure (Lidström and Tjärnhage, 2001; Martín Sánchez and de la Torre Pérez, 2012).

Commercial equipment exists for alpha-particle counting from air filters at ambient air pressure. Hand-held alpha spectrometers have also been elaborated that enable to measure alpha spectra from air filters, swipes and other smooth surfaces (Streil et al., 2000; SAIC, 2000). They use collimation to obtain spectra with good energy resolution. Alpha spectrometry was used to quantify short-lived radon progeny from air filters (Bem et al., 2002). A metal net collimator was used to improve the energy resolution.

Portable instruments operating in continuous monitoring mode have been developed to conduct rapid surveys (Hayes et al., 2005). Continuous air monitors mounted in a mobile laboratory were tested in the field (McIsaac et al., 1993). The monitors were equipped with the collimators to enhance spectral resolution. Light-weight personal samplers capable to register alpha spectra from the filters have been developed, too (Kasper, 2004; Streil and Oeser, 2005).

Recently, an approach that allows to measure alpha spectra with good energy resolution at ambient air pressure was introduced (Pöllänen et al., 2012). The prototype hand-held device known as ADONIS (ADvanced ON-site Investigation using alpha Spectrometry) is equipped with a honeycomb collimator. The operation principles were illustrated and tested in the case of radiochemically processed thin (with respect to alpha particle range) sources. Primary advantage of the method is that neither vacuum pumps/chambers nor complex radiochemical sample processing are

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necessary. Ideal sources are flat, smooth, thin and homogeneous surfaces. Although air filters are not necessarily thin, they may be appropriate for high-quality measurements at ambient air pressure. In the present paper ADONIS was applied for air samples to demonstrate the approach. Short-lived radon progeny were used in testing.

2. Alpha-particle collimation

Operation principle of ADONIS was presented by Pöllänen et al. (2012) and only a brief summary is given in the following. Good energy resolution of ADONIS was obtained by collimation (Fig. 1a), which means that there is almost constant energy loss of the alpha particles in the medium (air and the dead layer of the detector) provided that the source-detector distance is constant.

The dimensions of the honeycomb collimator and the overall measurement geometry mainly determine the energy resolution and the efficiency. Especially the cell size is important. If alpha particles are emitted below the cell walls some of them (such as α_5 in Fig. 1a) hit the wall instead of entering the detector almost perpendicularly. This may lead to notable loss of efficiency especially when the size of the cells is small. Thus, optimization between the desired energy resolution and the cell size (i.e. the efficiency) is essential.

Alpha particles entering the detector on the slant (α_7) produce peak tailing in the alpha spectrum when there is no collimation (Fig. 1b). These alphas may mask the peaks of transuranium (or other interesting) nuclides in the alpha spectrum. Another important factor is the alpha particle energy absorption in the source material, often referred to as self-absorption. This phenomenon is of particular importance for thick sources when some of the alpha particles (α_8) may be totally absorbed in the source. Even when the alpha particles enter the detector perpendicularly (α_9), the energy loss is of relevance. Collimation has no particular advantage in the case of thick sources.

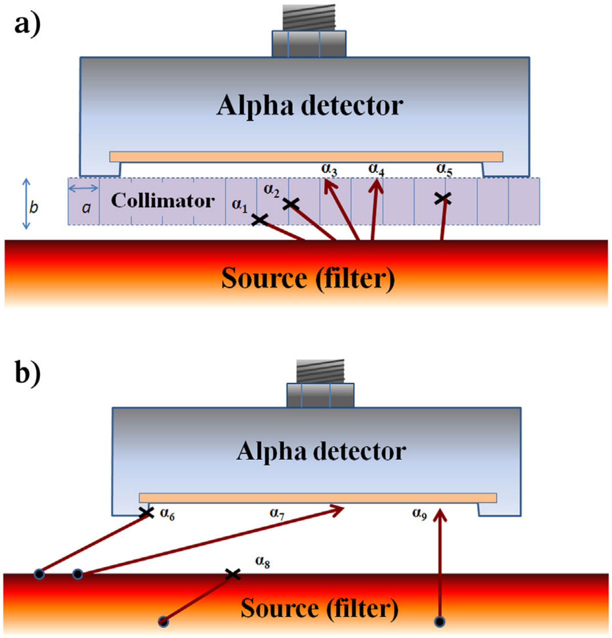

Fig. 1. Schematic representation of the detection of alpha particles in ADONIS. a) The measurements are performed at ambient air pressure using a honeycomb collimator between the source and the detector. Notations *a* and *b* refer to the cell size and collimator thickness, respectively. Alpha particles emitted towards the sensitive layer of the detector are detected (alphas α_3 and α_4) provided that their energy is not fully absorbed in air. The collimator prevents α_1 and α_2 to reach the detector because their entering angle is too small. Alpha particle α_5 is emitted just below the collimator wall and does not enter the detector. b) The measurements can also be performed without the collimator. The detector supporting structure may absorb some of the alphas (α_6) that otherwise would be detected. Some of the alpha particles, such as α_7, may enter the detector on the slant producing notable tailing to the alpha peaks. In the case of air filters, the alpha particle energy absorption in the filter material (α_8) poses a special problem even if the alpha particle (α_9) enters the detector perpendicularly.

3. Sampling and data acquisition

In the following, we investigate the effect of honeycomb collimation to the alpha spectra when there is air between the filter and the detector. Three measurement techniques for two different types of air filters were compared:

1) The alpha spectra were measured at ambient air without collimation, i.e. at Normal Temperature and Pressure, NTP.
2) Alpha spectra from air filters were measured in vacuum without collimation. The filters were placed into the vacuum chamber as such.
3) The spectra were measured at ambient air with collimation.

Radon progeny were used as test material because of their well-known characteristics. Short lived ^{218}Po ($t_{1/2} = 3.10$ min, energy of the main alpha peak 6.002 MeV), ^{214}Po (164 μs, 7.687 MeV), ^{212}Po (0.299 μs, 8.784 MeV) and ^{212}Bi (60.6 min, 6.051 MeV, 6.090 MeV) are of special interest here.

Sampling was done using glass-fibre (Camfil Farr) and Fluoropore membrane filters (Millipore). Properties of the filters with respect to the measured alpha spectra were previously investigated by Pöllänen and Siiskonen (2006). Three samples may be collected simultaneously as described by Smolander and Toivonen (2004).

The test samples were collected in a room, where the radon concentration is of the order of 100 Bq/m^3 or more. Sampling was performed with portable Lilliput (Senya Ltd.) sampler. The diameter of each individual filter was 32 mm (Fig. 2). The air flow rates through the individual glass-fibre and membrane filters were 1.2 m^3 h^{-1} (sampling time 16.6 h) and 1.1 m^3 h^{-1} (23.7 h), respectively.

Standard NIM electronics and commercially available alpha detectors were used in the data acquisition. The measurements were performed using three sets of equipment with almost equal

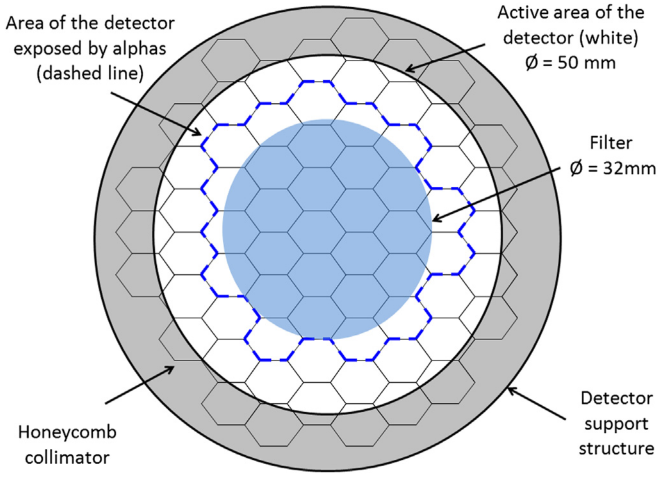

Fig. 2. The area from which the information on alpha particle energies may be obtained in ADONIS (schematic representation). Only part of the detector (dashed line) is exposed to alphas when the filter is considerably smaller than the active area of the detector.