METROLOGY OF RADON AND THORON CONCENTRATIONS

Matej Ďurčík and Magdaléna Vičanová
Institute of Preventive and Clinical Medicine
Limbová 14, 833 01 Bratislava, Slovak Republic

Introduction

Many methods have been developed for the measurements of radon (^{222}Rn) and thoron (^{220}Rn) concentrations in air. One of the current major problems of these methods could be separation of radon from thoron. For determination of the activity concentrations are used their properties as half-life, radiation and energy of emitted particles. All measuring methods are divided into next groups:

- alpha spectrometry with using semiconductor detector [1] or scintillation cell
- time analysis by delayed coincidences with taking advantage of the relatively short time delay between the alpha particle emitted by thoron and its first decay product [2]
- solid state nuclear track detectors with discrimination of thoron by diffusion barrier [3].

The alpha spectrometry measurements of radon and thoron concentrations by ionisation chamber, used only in laboratory conditions are described in this paper. For the measurements of radon and thoron in dwellings and work areas there was proposed diffusion double chamber detector with track detector.

Materials and methods

The standard system with ionisation chamber is used for laboratory measurements of radon and thoron concentrations and for calibration of radon and thoron meters and measuring techniques. The system consists of three basic parts [4]:

- filling part consists of radon and thoron generators, radon tank with volume of 40 L and working gas supply (argon or nitrogen), working pressure ranges from 500 to 2000 hPa;
- measuring part is cylindrical ionisation chamber with volume of 4 L. The ionisation chamber works in stationary and in flow modes. The resolution for radon alpha particles (5.5 MeV) is 180 keV and efficiencies for stationary and flow modes are in Table 1;
- sampling part consists of sampling station for filling external detectors and of experimental cylindrical stainless steel chamber with volume of 10 L for exposure of passive detectors.

Integral measurements of radon and thoron concentrations in the air of buildings and workplaces could be performed by double chamber dosimeter (Figure1) [5]. It consists of housing for the two chambers with wearing bracket, a track detector (CR-39) on each chamber bottom held by a ring and the chamber covers with openings for air exchange. Paper diffusion barrier (thickness 0.15 mm) was used for detection of radon and thoron concentrations and polyethylene filters (thickness 0.01 and 0.05) were used for detection of radon concentration. Chemical etching process (solution 25 % NaOH, temperature 70 °C and time 18 hours) was used for evaluating detectors.

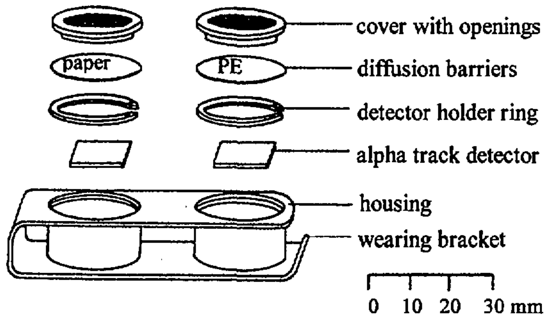

Fig.1 The double chamber dosimeter and its components

Results

The ionisation chamber is calibrated directly using ^{226}Ra source or using radon store tank [4]. The efficiencies for thoron measurements are calculated from efficiencies for radon and using properties of the thoron progenies. The Table 1 shows difference between radon and thoron calibration coefficients. The efficiencies of the ionisation chamber for the radon daughters in flow mode are less of 4 % as for stationary mode. The Figures 2 and 3 show the spectrum of mixed radon and thoron sample and theoretical analysis and fitting of the measured data by commercial software.

Tab.1 Calibration coefficient of ionisation chamber for radon and thoron measurements

Nuclide	Calibration coefficients [%]		
	Radon		Thoron
	Stationary	Flow	Flow
Rn	98,1	98,1	98,1
First daughter	45,5	43,7	53,9
Next daughter	45,5	43,7	43,7
Total	63,1	61,7	76,0*

* It is calculated only for thoron and its first daughter product

The density of the tracks on detector placed in diffusion chamber depends on radon and thoron diffusion into the chamber. The radon or thoron concentration inside of the diffusion chamber is given by equation

$$A_{DK}(t) = \frac{A_{OUT}.L}{(\lambda + L).\cosh\left(\frac{h}{R}\right)}.\left(1 - e^{-(\lambda+L).t}\right), \qquad (1)$$

where

$$L=\frac{\lambda.R..S}{V}.\frac{\cosh\left(\frac{h}{R}\right)}{\sinh\left(\frac{h}{R}\right)}$$

and h is thickness of diffusion barrier, R is diffusion length and V is volume of the chamber. The growing of the radon and thoron concentrations for different barriers is shown in Figure 4. For ellimination of the thoron in chamber it is possible to use polyethylene barrier with thickness of 0,01 mm. The discriminatory efficiencies of thoron by PE filters with thikness of 0,01 mm and of 0,05 mm are 99,5 % and 99,96 %, respectively.

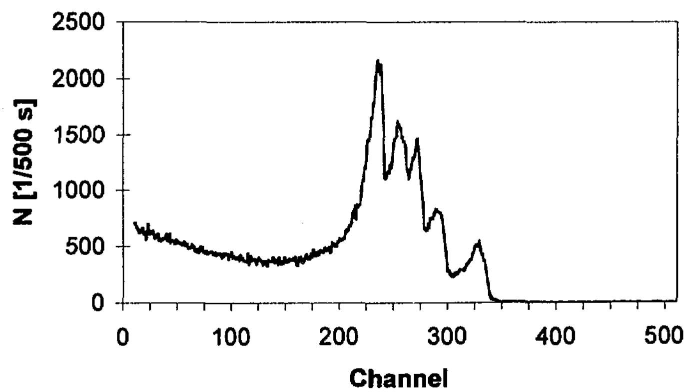

Fig.2 Alpha spectrum of radon thoron and them progenies measured by ionisation chamber

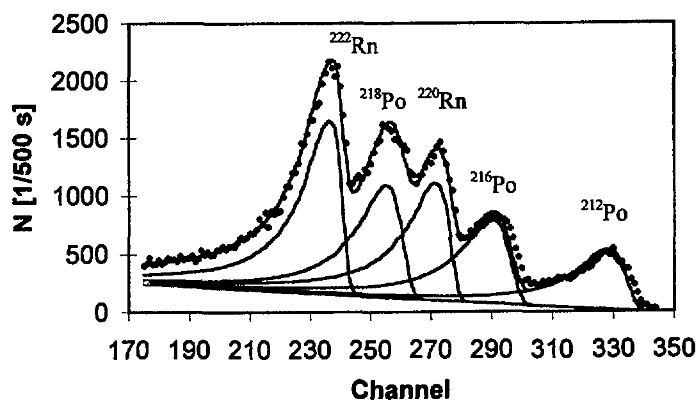

Fig. 3 Theoretical fit of the radon and thoron alpha spectra from ionisation chamber

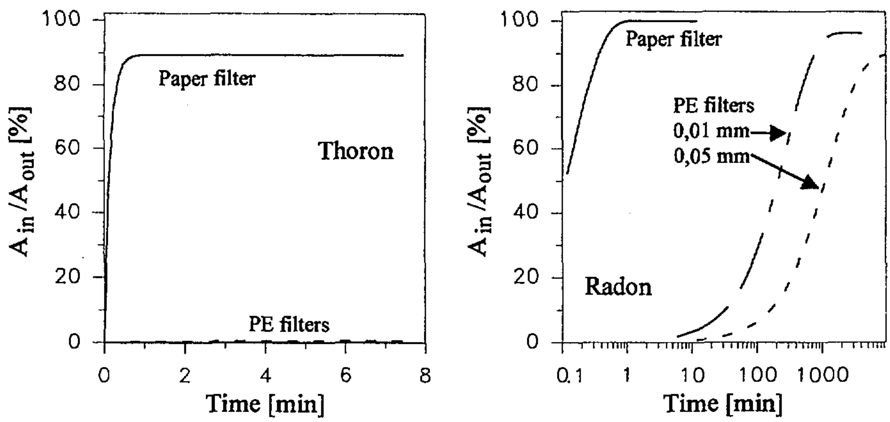

Fig.4 Radon and thoron concentration in the diffusion chamber for different barriers

Conclusion

The described dosimeter is very useful for routine measurement and would be applicated in measuring of radon and thoron concentrations in caves and dwellings. Big disadvantage of the dosimeter is small holes in cover and it could not be used in dusty areas.

From previous measurements of the equilibrium equivalent thoron concentrations by semiconductor detector the measured values ranged from 0,1 to 5,6 Bq.m^{-3} in the Slovak kindergartens were obtained.

References

[1] J. Bigu: Appl. Radiat. Isot. Vol. 37, No. 7, pp. 567-573, 1986

[2] F. Bochicchio, G. Campos Venuti, C. Nuccetelli, S. Risica and F. Tancredi: Environment International Vol. 22, Suppl. 1, pp. S633-S639, 1996

[3] C.S. Dudney, A.R. Hawthorne, R.G. Wallace and R.P. Reed: Health Physics Vol. 58, No. 3, pp. 297-311, 1990

[4] F. Havlík, M.Ďurčík and D. Nikodemová: The Safety of Nuclear Energy, Vol. 1(39), No. 3, pp. 107-111, 1993

[5] O. Sorenio and A. Guhr: Nucl. Tracks Radiat. Meas. Vol. 19, Nos. 1-4, pp. 395-400, 1991