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An electronic radon dosimeter as a new multipurpose device – a bridge between dosimetry and monitoring

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RESUMEN

Un dosímetro electrónico para medir radón basado en el depósito de sus productos de decaimiento en un detector semiconductor acoplado a un espectómetro α, ofrece algunas ventajas con respecto a los dosímetros pasivos. La dosis y la concentración de radón se calculan y sus valores aparecen en la carátula durante la exposición y los límites de dosis preestablecidos pueden verse a través de una función de alerta. Los cambios rápidos en la concentración de radón pueden detectarse y la dosis correspondiente se mide, así como su distribución temporal. El tratamiento de datos por computadora permite cambiar las medidas de enlace como conversión de dosis o factor de equilibrio. Una interface permite la comunicación con la PC. El dosímetro electrónico de radón es fácil de manejar y capaz de responder en condiciones de trabajo rudo. Una segunda aplicación del dosímetro es la determinación de radón en objetos o áreas. La posibilidad de medir radón en el suelo o en agua permite al usuario resolver problemas de riesgo de radón, así como tópicos en geología, prospección de uranio o protección ambiental.

PALABRAS CLAVE: Radón, torón, dosimetría personal, monitor de radón, radón en agua y en suelo.

ABSTRACT

An electronic radon dosimeter based on deposition of radon decay products on a semiconductor detector coupled with an alpha spectroscopy offers some advantages compared to passive dosimeters. The dose value and the radon concentration is calculated and displayed online during the exposure time and preestablished dose limits can be watched by an alert function. Rapid changes of the radon concentration can be detected and the corresponding dose is available in its time distribution as well. The PC-based dose management provides an administrator desk for stuff planning and enables the change of measurement presets like dose conversion- or equilibrium factor. The standard infrared interface handles the data communication with a PC. The electronic radon dosimeter is, easy to handle and rugged enough to withstand the rough working conditions. A second application of an electronic automated radon dosimeter is monitoring of radon affected objects or areas. The possibility to measure the radon concentration in the soil gas or in water enables the user to solve questions concerning radon risk mapping and risk protection as well as topics in geology, searching for ore deposits or environmental protection.

KEY WORDS: Radon, thoron, personal dosimetry, radon monitor, radon in water, radon in soil gas.

INTRODUCTION

Health protection of the workers against the dangers of ionising radiation is one important aim of the directive 96/29EURATOM. Beside an external exposure or ingestion and inhalation of particles, the inhalation of radon and radon decay products is an important path too (Streil, 2000).

For geophysical applications radon is measured in the soil gas to study fault zones or search in the uranium prospecting radon anomalies. Radon anomalies before earthquakes near geophysical stress zones in well or spring water or in the soil gas can be used as precursors for prediction (Heinicke *et al.* 1995).Usually the radon concentration and / or the activity concentration of radon decay products are controlled using passive dosimeters and the integral dose value of exposure is calculated. An electronic radon dosimeter based on deposition of radon decay products on a semiconductor detector coupled with an alpha spectroscopy offers some advantages compared to passive dosimeters: The dose value and the radon concentration is calculated and displayed online during the exposure time and give pre establish dose limits can be watched by an alert function. Rapid changes of the radon concentration can be detected and the corresponding dose is available in its time distribution as well.

A wide field of new measurement methods, for example soil gas sampling and the direct measuring of radon in water, is opened by this new technology.

TECHNICAL PRINCIPALS AND SYSTEM DESIGN

The measurement of radon concentration is based on the alpha spectroscopy (Graetz *et al.,* 1997). The gas diffuses through a membrane into the measurement chamber. The semiconductor detector is placed opposite to the entry window. Detector and chamber wall form a pair of electrodes with applied voltage. Radon decay products inside the chamber, ionised after decay, is collected at the detector surface forced by the electric field. The system detects both, alpha decay from collected decay products and radon gas. A Multi Channel Analyser (MCA) processes all incoming events. An integral spectrum and a record of five peak-areas (each assigned to a single nuclide) at every time step are stored for computing concentration and dose values. In a 'Fast Mode' only the peak areas of Rn-222 and Po-218, in 'Slow Mode' additionally the Po-214 channel are used for further calculations. To calculate the dose values, the equilibrium factor and the dose conversion factor (dependence of particle size - lung model) must be available. These parameters can be changed by the user or transferred by the dose management system for perfect adapting to the local conditions.

The sensitivity of the device was determined to be 0.38 (Slow Mode) and 0.22 (Fast Mode) counts/(min/kBq/m^3). The statistical error for each 1-hour value at 1000 Bq/m^3 is ±25%. An average concentration of 200 Bq/m^3 during an eight-hours workday gives an error of ±20%.

The application at very low radon levels (< 50 Bq/m^3) shows excellent results. Increasing and decreasing radon concentrations forced by different ventilation conditions are clearly visible. The perfect shape of the acquired summary spectrum indicates an error-free operation.

Further tests at high levels (up to several MBq/m^3) were carried out successfully during direct soil gas and water measurements.

The device is designed similar to a standard radon monitor. At the front the biased measurement chamber with the semiconductor detector is located. An amplifier generates equivalent to alpha energy leading to an alpha spectrum acquired by the MCA. A microprocessor core, including a non-volatile memory and a real time clock, operates the device. The dosimeter can be controlled directly by the user with a push button. All-important information is available at the dot matrix display. A buzzer and a flashlight indicate alert states. The standard infrared interface handles the data communication with a personal computer. The power supply and the high voltage generator with battery management circuit complete the system. The size of the device is in the range of a small mobile phone, weighting 250 g and therefore easy and comfortable to wear during the timework.

EXPERIMENTAL RESULTS

Performance of the radon measurement

Figure 1 displays a typical radon spectrum with the radon continuum in the left part and the Po-218 and Po-214 peaks at the right side. Because of the chamber size, the maximum energy lost of an alpha particle is approximately 2 MeV (refers to a flight distance of 20 mm in air). Therefore, the radon continuum, which normally drops down to zero, is cut at 3.5 MeV.

Also, a large number of Polonium atoms are attached at the chamber walls, which forces large tailing shapes. The screen of the entry window performs a large parallel plane very close to the detector surface (the distance is about 15 mm). This gives a constant energy level for particles emitted from this area, which explains the small peaks at the slope. The gas entry window of the chamber is sealed with a leather membrane.

Figure 2 shows the device response to a radon concentration step. To test this feature, the dosimeter was placed in a small sealed container. The radon gas was injected about 25 minutes after starting the sample. A closed circuit, in-

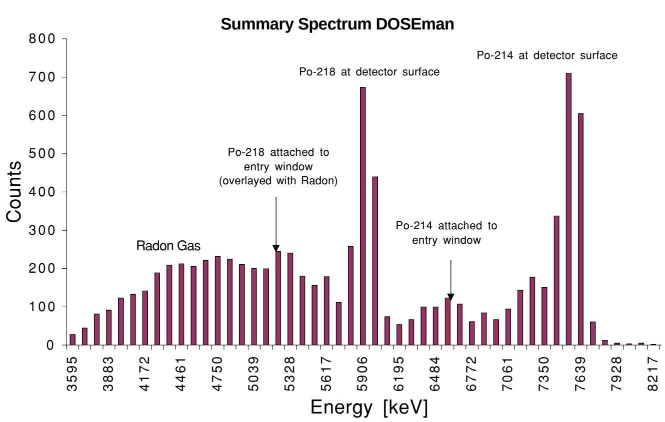

Fig. 1. Summary spectrum of a radon measurement carried out using the electronic radon dosimeter.

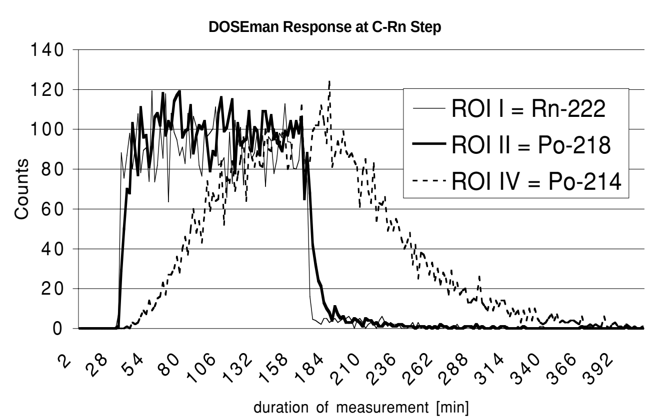

Fig. 2. Rapid response of the electronic radon dosimeter upon changes in the radon activity concentration.

cluding the high flow rate pump, the radon source and the container ensures rapidly increasing of the concentration. The thin line represents the radon gas component, which arises immediately after injection. No delay could be observed (the time resolution was set to 2 minutes). Both, the Po-218 (thick line) and the Po-214 (dotted thin line) fraction show the typical step responses, determined by their decay constants. After five Po-214 half-live times, the Polonium isotopes are in equilibrium. Then, the dosimeter was removed from the container and given into fresh air. The falling slopes of the nuclides show again a prompt reply.

Two measurement series inside an office (Figure 3) demonstrate the dosimeter performance in the low level region. The office was closed from 6 p.m. to 8 a. m. next morning. The radon concentration increase over night to a saturation level of about 200 Bq/m^3 by radon emission of the walls.

During the office time, the opening the door and the windows naturally ventilated the room. Therefore, the radon concentration decreases to an average of 50 Bq/m^3.

Till now, several measurements of the radon concentrations under different working conditions in radon prone areas demand manifold types of underground work places,

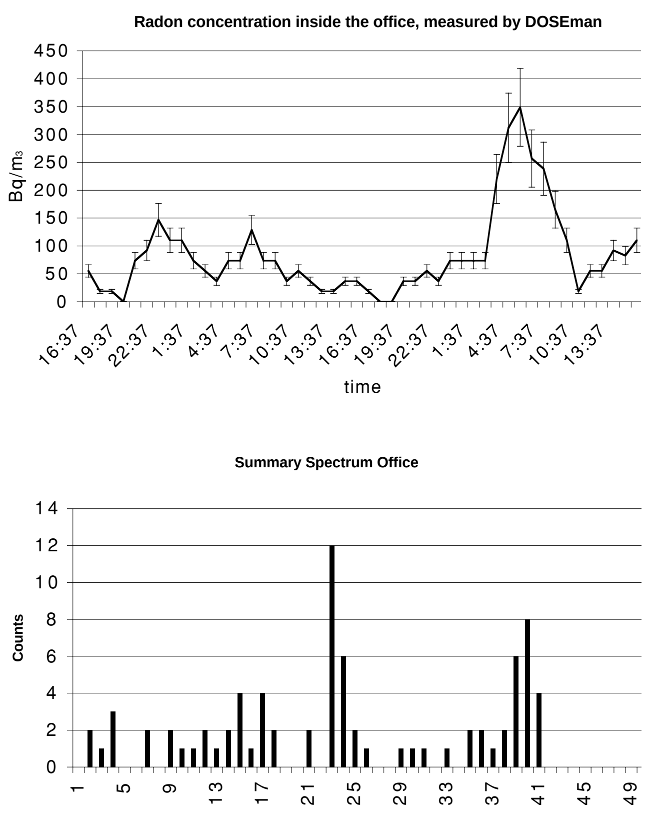

Fig. 3. Time distribution and spectrum of a measurement (office) performed with DOSEman.

e.g. coal mining, ore mining; radioactive waste storage facilities (salt cavern storage and underground storage in hard rock).

SOIL GAS RADON MEASUREMENTS

Due to the fact, that soil gas radon concentrations usually reach several kBq/m^3, the electronic radon dosimeter DOSEman opens new dimensions for soil gas testing as well. This time we prepared the application of the device for soil gas testing. The quick response ensured a good time resolution; the expected error would be satisfactory low because of the excellent counting statistic due to the "high" radon concentration. The DOSEman was mounted on the head of a probe that is inserted into a small drilling hole. Standard diameters for drill holes with 10 cm are width enough to be used for radon testing.

The IR interface enables a quasi-continuous read-out of the instrument without removal of the device out of the drill hole; thus, the conditions in the surrounding media will stay constant and undisturbed. The internal power supply guarantee a long working time, up to 700 data cycles can be stored in the memory, i.e. nearly a month in case of an integration time of 60 minutes. At least, the purchase costs enables the user to install a measuring net with several detectors for continuous measurement, e.g. geological survey in the vicinity of active faults or earthquake prediction at a really low price level.

In Brazilian uranium mine two DOSEman monitors were used for the prospection of radon anomalies, which correspond to possible new uranium deposits.

At 20 cm depth, the radon and thoron soil gas concentration was measured firstly in measuring point 2 and 3 and in a second step in 1 and 4 (see Figure 4). The surface distance between the measuring points was 5 m appart. The profile distribution had an average counting time of 40 and 50 min after starting the measurement. In Figure 5 the profile of uranium anomaly is shown.

CONCLUSIONS

The electronic radon dosimeter offers three outstanding features :

- The integral dose value, and the time distribution of the dose power is available by the internal data logger.
- The actual dose value and the radon activity concentration are calculated and displayed online during the exposure time.
- The direct computer interface enables full automatic data handling in connection with a PC-based.

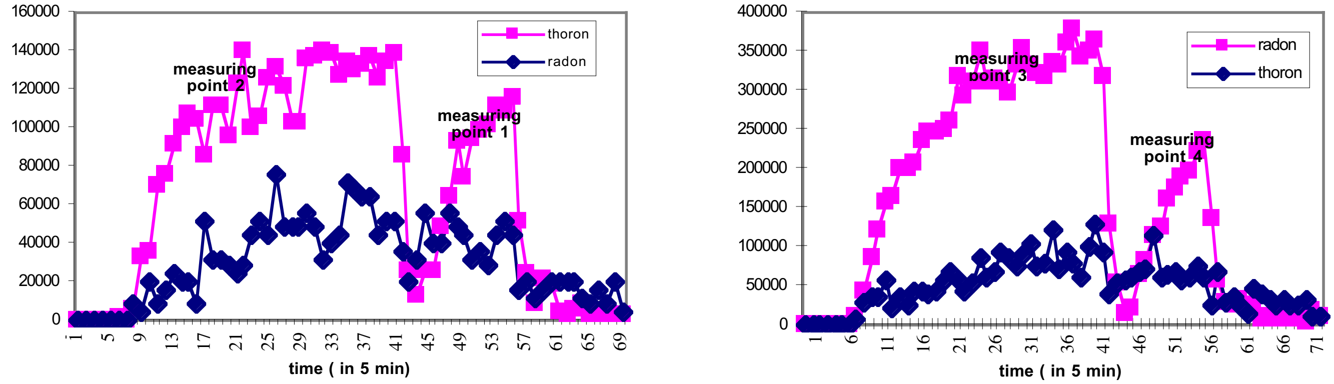

Fig. 4. Radon and thoron time distribution of soil gas measurements with SARAD DOSEman on 4 measuring point with 5 m distance for the study of an uranium anomaly.

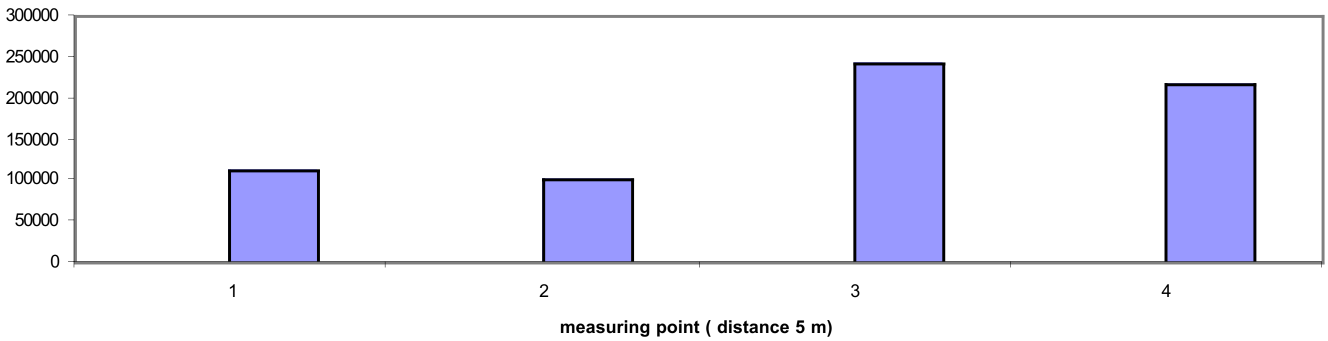

Fig. 5. Profile of an uranium anomaly in caetite gamelera-soil gas measurement with SARAD DOSEman in 20 cm depth.

Some advantages are:

- Dose limit exceeding are detected immediately by alert functions.
- No delay times by outsource analysis procedures.
- Individual short time dose measurements are possible.
- Independent using of the dosimeter by different persons and locations.

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