LONG-TERM MEASUREMENTS OF RADON DAUGHTER ACTIVITY IN MINES

B. Haider, W. Jacobi

Institut für Strahlenschutz

Gesellschaft für Strahlen- und Umweltforschung mbH

München - Neuherberg, Germany

Abstract

A rugged, portable filter monitor for the long-term measurement of Rn-daughter activity in mines with direct indication of the cumulative exposure is described. The monitor is equipped with rechargeable batteries and enables continuous or fractionated air sampling at preset time intervals over a period of 1 - 2 weeks with one battery charge. The results of continuous measurements over a one year-period in a fluorspar mine are discussed.

Introduction

A significant excess of lung cancer mortality with increasing accumulated Radon(Rn)-exposure has been observed among uranium miners in the USA and CSSR. This fact emphasizes the suspection that workers in mines with high Rn-content in air belong to that groups of radiation workers with the highest somatic radiation risk. Compared with this risk the surveillance of the radiation exposure of these miners is still not adequate. The main causes for this inconsistency are the complex distribution of Rn and its daughters in mine air, which varies with time and place, and the difficulties of personnel air monitoring under the abnormal working conditions in mines.

In the past air monitoring in these mines was restricted mainly on measurements of Rn or its daughters in single air probes, which were taken in more or less large intervals of time. Taking into account the varying air activity in a mine working area robust, portable and battery-operated monitors are needed which enable long-term measurements and indicate the accumulated exposure over a long time period. Several instruments of this type were proposed and tested in the last years.[1-6]

With respect to their applicability in uranium and fluorspar mines we have studied different methods to determine the time-integral of the activity concentration of Rn and its daughters. For the continuous measurement of Rn-gas itself we used the electrostatic deposition of RaA-ions, formed by decay of Rn-atoms in a chamber with Rn-permeable walls. The results however have indicated, that the Rn-sensitivity of this method depends strongly on the air humidity.[6] This method seems therefore not suitable for

Rn-monitoring in mines.

For long-term measurements of the accumulated exposure to Rn-daughters in mines we have developed on the basis of the filter method portable monitors with low-power consumption. In this paper the design and properties of this monitor and the results of test measurements in a fluorspar mine are described.

Description of the Air Monitor

Two types of surveying instruments were developed: A direct-indicating monitor with a Silicium-α-detector and a nondirect-indicating instrument using track etch foils as integrating α-detector.

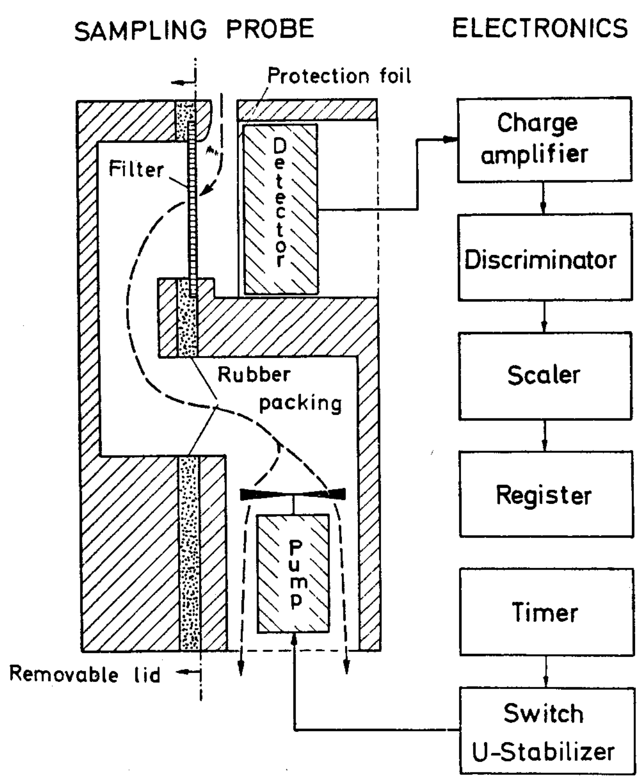

Fig. 1:

Cross section through the sampling probe of the monitor and block diagram of the electronics

Figure 1 shows a schematic cross section through the sampling probe of the direct-indicating instrument and a block diagram of its electronics. The outside air is sucked in through slits in the sampling probe, passes the fibrous filter and is exhausted on the other side of the probe. The sampling probe can be easily opened for filter replacement. The small air blower is mounted in the sampling probe; its operation voltage of 3,5 V is stabilized to assure a constant air flow-rate. With the normally used cellulose-asbestos filters (effective filter diameter 18 mm) a flow-rate of 2.5 liter/hour was adjusted. As α-detector a p-Silicium semiconductor with an active surface of 240 mm^2 (∅=17.5mm) is used, whose surface is protected by a thin mylar foil of 1 mg/cm^2 thickness. The distance between filter and detector surface is 5 mm.

After amplification and pulse height discrimination the detector pulses are counted by a combination of an electronic scaler and a 4-digit mechanical register. The electronic part includes also a timer and switching circuit for the air blower, which enables automatic, fractionated air sampling in preset time intervals. All electronic parts are designed for low power consumption. The total power consumption of the monitor is about 300 mW, from which about 200 mW are required for the air blower. For the power supply rechargeable dryfit PC-accumulators are used, which enable with one battery charge an operation time of 8 - 9 days at continuous sampling and of about 18 days at fractionated sampling.

The electronics, the counter and the accumulators are enclosed by a stable, water and dust protected metal housing, to which the sampling probe is flanged on. All operating elements and plug sockets for external connections (rate meter, pulse height analyser) are mounted behind a lid to prevent contamination by dust and undesired changes of the adjusted operation values. Only the mechanical register can be read through a window in the metal housing. The instrument dimensions are 23 cm x 12 cm x 32 cm (height). Its total weight is 7 kg, from which about 5 kg falls to the accumulators.

In a second type of this instrument the Si-α-detector is substituted by a track etch foil with the same effective diameter; in this type the detector electronics and the counter are omitted. Foil etching and α-track counting is done by the usual techniques and are described in detail elsewhere.[6]

Instrument Calibration

For the monitoring of Rn-daughter mixtures in mines and room air the concept of potential α-energy concentration and the unit 1 WL = 1.3×10^5 (pot.α-) MeV/liter air have been introduced. As described earlier the described instrument was constructed with the aspect to determine the time integral over this energy concentration over long exposure periods. The total number $Z_\alpha(T)$ of α-tracks or α-pulses, respectively, counted with the instrument during a time period T is connected with this integral or accumulated exposure E(T) by the equation[6]:

$$Z_\alpha(T) = \frac{\beta \eta f v}{p} \cdot E(T)$$

In this equation means η the counting efficiency of the used type of detector, f>0.99 the deposition efficiency of the filter, v = 2.5 ± 0.3 liter/hour the air flow rate and p = 7.68 MeV the potential α-energy of one ^{218}Pb (RaB)- or ^{214}Bi(RaC)-atom.

The correction factor β depends on the relative composition of the Rn-daughter mixture in the measured air, which varies with the ventilation rate λ_v and the rate constant λ_a for the attachment of free daughter atoms to particles in the considered mine area.[6] It was calculated on the basis of the box model for Rn-atmospheres which was developed by one of the authors[7] and is given in figure 2. This graph shows that the variation range of the correction factor β is rather small and a constant value β = 1.05 can be applied to most mine and room atmospheres with sufficient accuracy.

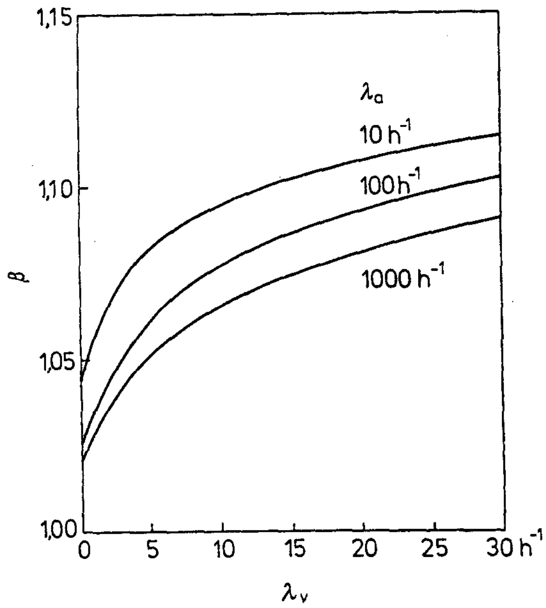

Fig. 2:

Correction factor β for instrument sensitivity (see text)

The counting efficiency η of the direct-indicating instrument with a Si-α-detector was determined by comparison with calibrated α-sources. At the normal operational conditions used it results η_{Si} = 0.18 ± 0.01. With this value it follows an instrument sensitivity in the case of continuous sampling:

$S = Z_\alpha(T)/E(T)$

= 0.061 ± 0.011 counts per (pot.α)MeV•hour/liter air

= 7900 ± 1400 counts per WL•hour

This corresponds to a sensitivity of 79 ± 14 counts per pCi•hour/liter air of each daughter nuclide in the case of radioactive equilibrium in air. The built-in scaler enables a reduction of this sensitivity in steps of 1/2 to a 1/128 of this value or 62 counts per WL•hour. In addition the sensitivity can be reduced by the built-in timer for fractionated air sampling. The background counting rate is about 5 counts per hour. The lower detection limit of the instrument is therefore comparable with the mean concentration of Rn-daughters in atmospheric air.

The sensitivity of the instrument with track etch foils was determined by simultaneous field measurements with both types of instruments. Depending on etching conditions and the used foil material it is about a factor 0.2 - 0.6 lower than the sensitivity for the direct-indicating instrument.

Test Measurements

Test measurements with 2 instruments of each type were performed so far in 3 fluorspar mines in East Bavaria.[6] One direct-indicating monitor was continuously in use for one year at the same working area in a mine drift and was operated and controlled by the foreman of the miners in this area. He read off the counting register of the instrument normally at the beginning and the end of each working shift. The resulting time variation of the potential energy concentration in the mine air during this one year-period is shown in figure 3. The annual mean value was about 1 WL, whereas the daily mean values are varying in the range from 0.4 - 3 WL. Figure 3 indicates that the short-time variations from day to day in this mine area are rather small. However, a rather strong long-term variation of the Rn-daughter level is observed.

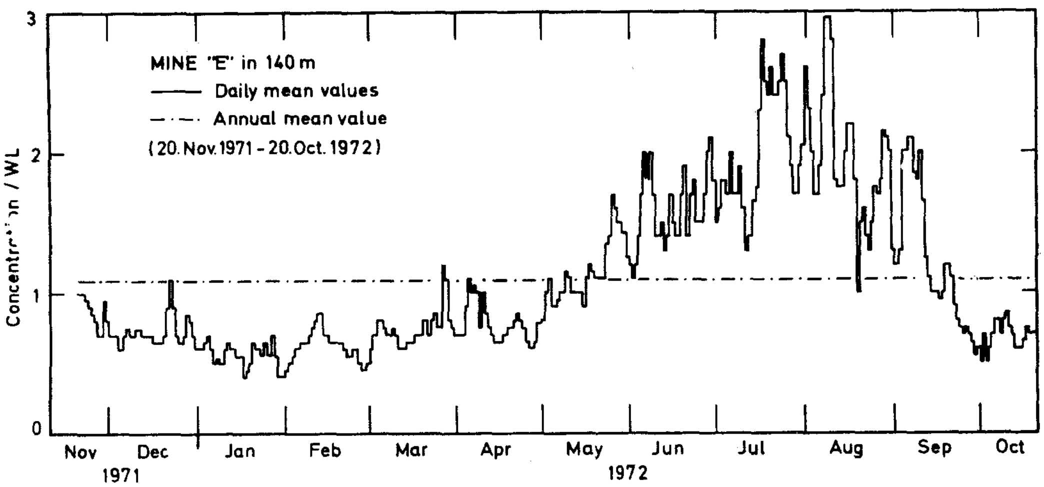

Fig. 3: Variation of the continuously measured Rn-daughter activity in a working area of a fluorspar mine in East Bavaria (Nov. 1971 - Oct. 1972).

This variation is mainly due to the change of the air ventilation during the extension of the mine gallery. During the period from November 1971 till about May 1972 a rather constant activity level of about 0.5 - 1.0 WL was observed. In the following months the fresh-air supply to the driving gallery was reduced. During this period the air-activity increased and reached rather high values of 2 - 3 WL in July - September 1972. After break-through of a new wind gate the supply with air of low Rn-content increased. Subsequently the Rn-level in the working area decreased strongly and reched a rather constant level of about 0.6 WL in October 1972.

The variation of the Rn-exhalation from the walls of the gallery due to the mining activity was probably not so significant in this fluorspar gallery, but might be certainly of more importance in other galleries, especially in uranium mines.

In either case, these test measurements indicate the necessity of long-term Rn-monitoring to get more information about the real cumulative exposure of miners.

This work was financially supported by the Ministerium für Bildung und Wissenschaft of the Federal Republic of Germany.

References

1 BECKER, K.: Health Phys. 16, 113-123 (1969)

2 ROCK, R.L., D.B. LOVETT, S.C. NELSON: Health Phys. 16, 617-621 (1969)

3 BEDROSIAN, P.H.: Health Phys. 16, 800-802 (1969)

4 COSTA-RIBEIRO, C., J. THOMAS, R.T. DREW, Mc D.E. WRENN, M. EISENBUD: Health Phys. 17, 193-198 (1969)

5 Mc CURDY, D.E., K.J. SCHIAGER, E.D. FLACK: Health Phys. 17, 415-422 (1969)

6 HAIDER, B., W. JACOBI: Entwicklung von Verfahren und Geräten zur langzeitigen Radon-Überwachung im Bergbau; Research Rep. BMBW-FB-K 72-14, August 1972

7 JACOBI, W.: Health Phys. 22, 441-450 (1972)