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COMPARISON OF A CONTINUOUS WORKING LEVEL MONITOR FOR RADON DAUGHTERS WITH CONVENTIONAL GRAB-SAMPLING

by

J. Bigu* and M. Grenier**

ABSTRACT

An evaluation of a radon daughter monitor was carried out under laboratory controlled conditions. The monitor operates on continuous sampling and time integrating principles and was tested in conjunction with a newly designed, large, radon/thoron room calibration facility. The monitor was tested under constant and rapidly fluctuating radiation conditions. Experimental data obtained with the monitor were compared with data obtained by conventional grab-sampling and with an automated radon daughter/thoron daughter 'grab-sampler'. The Working Level used in the tests ranged from less than 0.01 WL to approximately 10 WL. The measurements were carried out under low aerosol concentration ($1 \times 10^3 - 2 \times 10^3$ cm^{-3}, approximately) to study plate-out effects in the sampling head. Good agreement (within about 10%) was found between the monitor, conventional grab-sampling and the automated grab-sampler. This work is a continuation of previous work conducted in a radon/thoron 'box' and in an underground uranium mine. The monitor should prove quite flexible, useful and reliable for monitoring underground and surface environments in the uranium mining industry.

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INTRODUCTION

Monitoring of radon daughters, and other radioactive airborne contaminants, in uranium mines is essentially of two kinds: discrete sampling, i.e., grab-sampling, and continuous sampling.

A number of instruments has been developed in recent years to monitor radiation levels of the decay products of radon and thoron. However, although the field of radiation instrumentation has proliferated, there is a need for an automated area monitoring instrument with memory storage capabilities suitable for unattended monitoring for extended periods of time. Such an instrument could be used extensively in underground environments for air quality monitoring purposes. An instrument of this kind, operating on time integrating principles, is available and has been tested under controlled laboratory conditions in a large radon/thoron room designed for calibration purposes.

This report presents data pertaining to a technical evaluation of the instrument referred to above. Work conducted previously with the same instrument has been reported elsewhere (1,2). In previous work experimental data was obtained using an early sampling head design that exhibited plate-out problems, particularly at low aerosol concentration. Data were obtained under laboratory-controlled conditions in a radon/thoron box designed for calibration purposes (1) and in an underground uranium mine (2). The data reported here have been obtained with a newly designed sampling head with substantially improved plate-out characteristics in a recently designed and built large radon/thoron room for calibrating and testing radiation instrumentation. The instrument has been described in detail elsewhere (1,2), but will be described here again for completeness. The instrument has been designed and built by EDA Instruments (Toronto) and is commercially available under the name WLM-300.

DESCRIPTION OF THE APPARATUS

The EDA WLM-300 basically consists of a sampling-detection system, a memory unit to store data, and read-out and print-out capabilities. The instrument operates by sampling air in a continuous fashion. Decay products are deposited on a sampling filter facing the detector and the α-count is integrated in a manner described below. The instrument is claimed to be dust-proof, moisture-proof and shock-proof.

The detection-sampling 'head' consists of a sample holder housing a filter (Millipore 0.8 μm AA) supported by a fine stainless steel mesh screen. A ruggedized silicon-barrier detector (450 mm^2 active area) faces the active side of the filter. The detector-filter separation is about 3.2 mm, according to the manufacturer's specifications.

The front-end electronic circuitry of the detector has a voltage threshold corresponding to an α-energy of about 2 MeV to eliminate contributions from electronic noise and β-radiation. α-particles in the 2 MeV to 10 MeV energy range are in principle detected and counted. Although the apparatus has no pulse height analysis capabilities, it is provided with an output jack to enable interfacing with an external multi-channel analyzer (MCA) for pulse height analysis.

The new filter-detector holder is cylindrically shaped and is made of a plastic material (Teflon) consisting of an upper and a lower part. In the normal operating mode, the upper part is fitted, leak-free,by means of an 'O'-ring, to the lower part by screwing the former into the latter. The upper part has four exhaust holes leading to the inlet of a small self-regulated sampling pump (1 L/min) which draws air in and passes it through the sampling filter facing the detector. The lower part has a circular inset where the detector is located about 1 mm below two inlet slits of rectangular crosssection, approximately 9 mm x 2 mm and symmetrically oriented at 180° from each other, permitting air to be sampled to pass through a filter facing the detector.

The detection-sampling head is located in a re-entrant 'cavity' built on one side of the instrument case. The inlet access slits, detector and sampling filter are located at an approximate depth of 15 mm from the surface of the case.

The instrument has a liquid crystal display (LCD) which displays the α-count rate internally obtained by dividing the total number of α-counts by the total sampling time, and the WL obtained from the above α-count rate and a given numerical conversion factor.

A memory unit enables data storage which can be later retrieved by an external printer. Data are gathered every 6 min or 60 min. The memory capacity is 4.1 days if data are gathered every 6 min, or 41 days if data are gathered every 60 min.

The data stored can be retrieved in the following forms:

a) As differential α-count at any given time. This is the α-count obtained by subtracting the total α-count stored up to the last (previous) count, from the total α-count up to this time;

b) As total α-count. This is the total, accumulated, α-count up to the time data are retrieved;

c) As differential WL. This is calculated from item (a) and a given numerical conversion factor; and

d) As a time integrated WL which is calculated from the integral, total α-count obtained, the total counting time, and the same conversion factor as that indicated (see above and item (c)).

For simplicity the WLM-300 will be referred to hereafter as the monitor.

EXPERIMENTAL PROCEDURE

The monitor was tested under laboratory-controlled conditions in a large radon/thoron room designed for calibration purposes. Experimental data obtained with the monitor were compared with data obtained by conventional grab-sampling and by two automated Working Level monitors of the grab-sampling type. The Thomas-Tsivoglou, Markov and Kusnetz methods were used in conventional grab-sampling (3 to 7). The automated Working Level monitors used were the WL-1000C, a radon daughter/thoron daughter grab-sampler manufactured by Pylon Electronic Development (Ottawa) and a semi-continuous radon daughter Working Level Meter manufactured by Harshaw Instruments (U.S.A.) under the commercial name of Radon Daughter Detector model 101 and Radiation Computer model 100. The results obtained with the Harshaw instrument will be given elsewhere.

The monitor was tested under constant and rapidly fluctuating radiation conditions in order to compare the time response of the monitor with that of conventional grab-sampling by different methods and of other automated systems.

EXPERIMENTAL RESULTS AND DISCUSSION

Figures 1, 2 and 3 show experimental data obtained with the WLM-300, the Markov method (conventional sampling) and with the Pylon WL-1000C using three of its programmable methods (8), e.g., the Rolle and Kusnetz methods and a short α-spectroscopy method for determining radon daughter concentration and Working Level, WL(Rn).

The first portion of the monitor's WL-profile shown in Fig. 1 shows the initial increase of radon daughter activity in the filter, under constant WL(Rn), until a steady-state condition is reached where a further activity

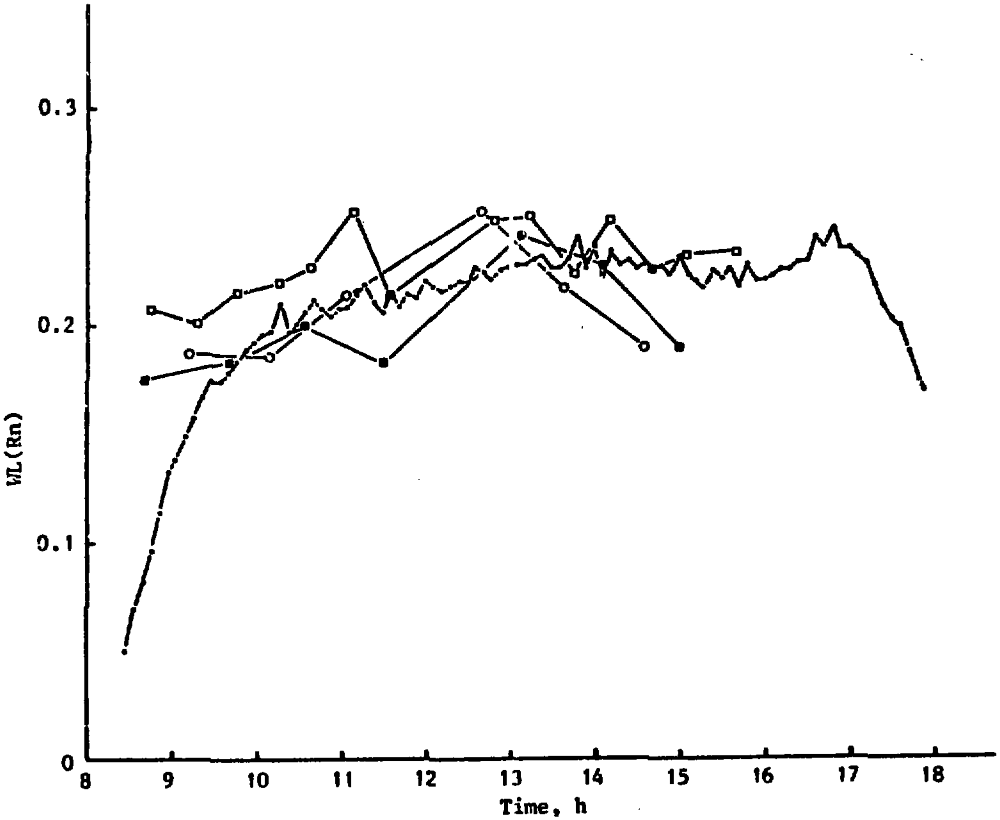

Fig. 1 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rolle method, -○-), the Markov method (-□-) and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

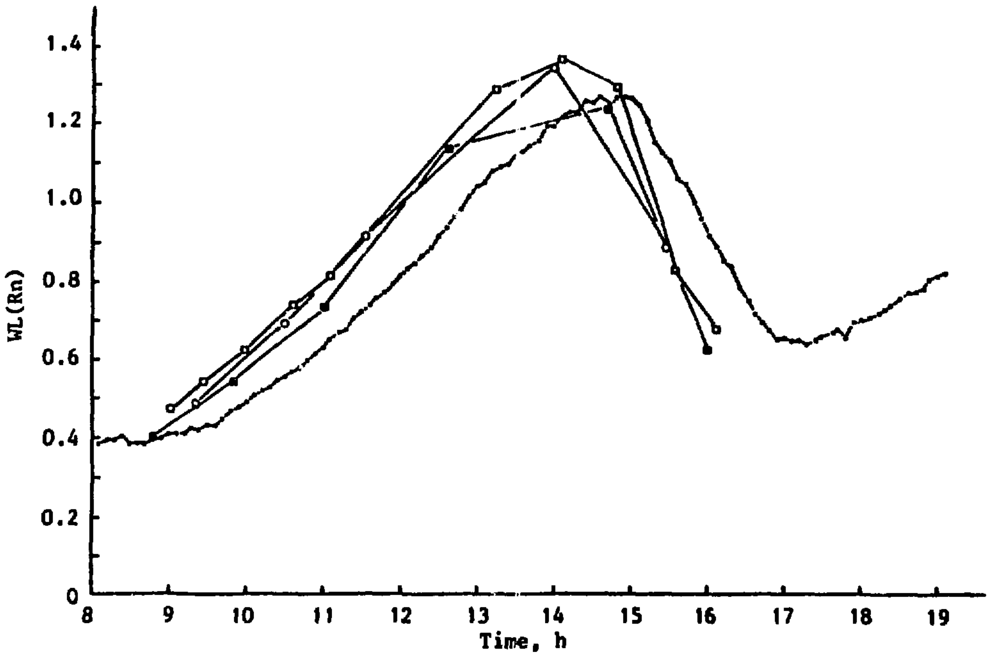

Fig. 2 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, and Rolle method, -○-), the Markov method, -□-, and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

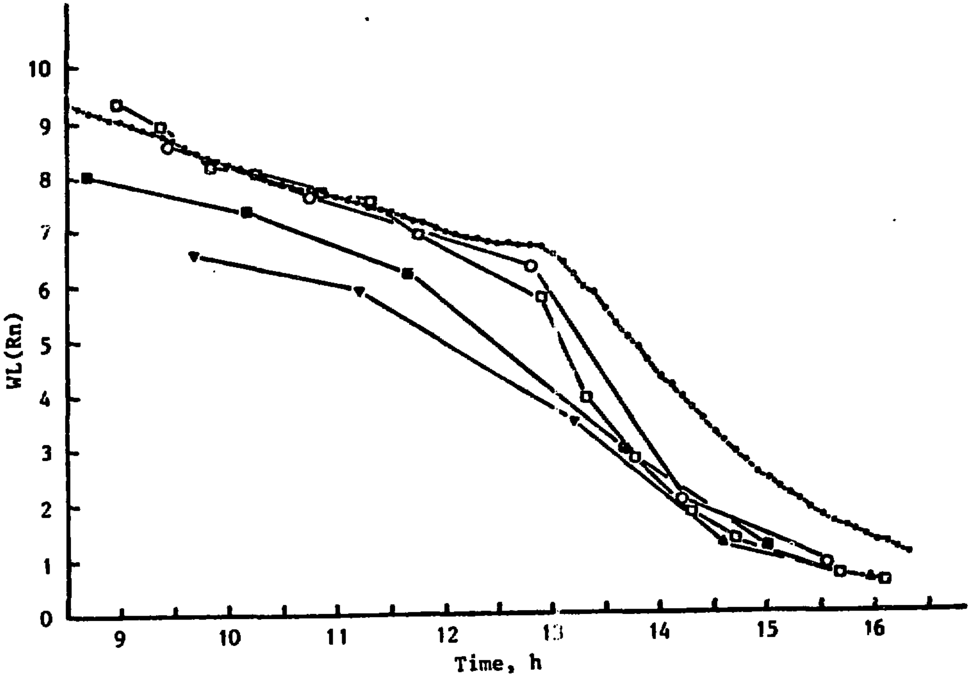

Fig. 3 - WL(Rn) versus time for the WL-1000C (Rn α-spectroscopy, -■-, Rolle method, -○-, and Kusnetz method, -▲-), the Markov method (-□-) and the EDA WLM-300 (-·-). Measurements were carried out in a radon room.

increase in the filter is compensated by radioactive decay.

The WL(Rn) in the radon/thoron room was changed by varying the air exhaust rate in the room and/or by changing the ventilation rate in the room by means of a mixing fan, e.g., see Fig. 1 and 3.

Figure 1 shows that if the average of grab-sampling data, including the WL-1000C, is taken, the agreement with WLM-300 data is quite good provided WL(Rn) in the room remains relatively constant during the sampling period.

Good agreement is also obtained from Fig. 1, 2 and 3, where the monitor's data lag behind grab-sampling data by about 1 h. This effect can be clearly seen under changing WL(Rn) conditions. However, this result agrees with theoretical predictions as indicated elsewhere (1,2).

In summary, the agreement between the WLM-300, with the new sampling head, and grab-sampling data is quite good even at low aerosol concentration conditions as those of the present series of measurements. We now use the instrument in our large radon/thoron calibration room for continuous WL(Rn) monitoring purposes in conjunction with a laboratory technical evaluation of personal α-dosimeters. Furthermore, the monitor is also used at tailings sites to monitor the sub-surface WL(Rn) by methods that will be described elsewhere.

CONCLUSIONS

The data presented in this report show that the monitor agrees fairly well with grab-sampling measurements. Because of the physical principle on which the monitor is based, its response to fast changes in radiation levels is somewhat limited showing a time-lag for radon daughters of about 1 h.

The WLM-300 should prove a quite flexible and useful instrument for monitoring underground and surface environments in the uranium mining industry.

The memory capabilities of the instrument are particularly noteworthy and its flexibility ideally suitable for experimental and theoretical applications.

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