

Radon leakage assessment in a controlled radon laboratory

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RESUMEN

Como parte de las actividades para tener un laboratorio calibrado de radón en México, se utilizaron detectores DOSEman, Alpha GUARD y de Germanio para medir la concentración de radón en una cámara fuente de radón. Los primeros dos detectores se usaron también para determinar la concentración de radón durante la operación normal de la cámara y en un experimento controlado de fuga de radón.

La concentración de radón en la cámara se determinó con el detector de Germanio midiendo la emisión γ de los productos de decaimiento ^{214}Bi y ^{214}Pb . El error en la actividad fue del 3.5%. La diferencia de esa medida con los DOSEman fue del 3%. La curva experimental de decaimiento del radón, determinada con el detector alpha GUARD, difiere 2% del valor esperado.

La cámara de radón está en un laboratorio licenciado de 280 m³ de volumen. Esta se dejó abierta durante un fin de semana para investigar el incremento de la concentración de radón en el laboratorio en un caso extremo de fuga.

El incremento de la concentración de radón fue del 60% encima del fondo, lo cual muestra que no existe riesgo para el personal en el peor caso de fuga del radón.

PALABRAS CLAVE: Detección de radón, fuga de radón, cámara de radón.

ABSTRACT

As part of the activities to have a radon calibrated laboratory in Mexico, a DOSEman, an Alpha GUARD and a Germanium detector were used to measure the radon concentration of a radon source chamber. The two first detectors were also used to determine the radon concentration in the laboratory during normal operation of the chamber and under a controlled radon leakage experiment.

Radon concentration in the chamber was determined with the Germanium detector through the γ -emission from the radon decay products ^{214}Bi and ^{214}Pb . The error in those activity measurements was 3.5%. The difference between these measurements and the DOSEman was 3%. The experimental radon decay curve, as determined from the Alpha GUARD detector, differs 2% from the expected value.

The source radon chamber is located in a licensed 280 m³ volume laboratory. The radon chamber was left opened during a weekend to investigate the increase of the radon concentration in an extreme radon leakage case. The highest radon-concentration increase was 60% above background showing no working risk in the worst radon leakage case.

KEY WORDS: Radon detection, radon leakage, radon chamber.

1. INTRODUCTION

Fast reliable results of radon measurements requires fast electronic devices (Balcázar, 1999) having time integration selection. It also requires a calibration as accurate as possible of such measurements.

As part of the activities to have a radon calibrated laboratory in Mexico, a DOSEman, an Alpha GUARD and a Germanium detector were used to measure the radon concentration of a radon source chamber. The source radon chamber is in a licensed 280 m³ volume laboratory.

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tion of the chamber and under a controlled radon leakage experiment.

2. CALIBRATION PROCEDURE

Six DOSEman (DM) detectors and one Alpha GUARD (AG) detector were exposed together to a known radon atmosphere inside an exposure chamber in two experiments. The exposure chamber, aluminium made in a cylindrical shape 39.5 cm height and 24.5 cm in diameter, is large enough to allocate all the detectors. An o-ring in an acrylic cover closes it hermetically and has a small tube coupled to a valve, to perform a light vacuum. The acrylic cover has also a self-sealed rubber entrance to inject the radon gas. A second chamber containing uranium mineral was used as source radon

chamber (Tavera, 1993), from which a known Rn volume was extracted for injection into the exposure chamber

The DM is a small portable detector powered by a battery, having one month autonomy. The radon gas diffuses through a membrane into a measurement chamber, where a semiconductor detector convert the decay alpha energies from ^{222}Rn and their short living daughter products ^{218}Po and ^{214}Po , into electric pulses which are stored in an internal multichannel analyser. The DM calculates the radon concentration from the count sums of ^{222}Rn , ^{218}Po and ^{214}Po using the so-called Slow Mode. The Fast Mode excludes the ^{214}Po fraction to get a shorter response time but with a certain loss of accuracy.

The AG is based on a design-optimised pulse ionisation chamber; the radon gas diffuses into a cylindrical chamber through a glass fibre filter stopping all radon decay products. The center electrode (at 0 V with respect to the walls at +750 V) collects the ionisation charges as pulses, which are then processed by a highly sensitive preamplifier unit. Three independent channels in a digital processing network allow: 1) to perform a highly effective differentiation between real alpha events and different interference effects, 2) to measure high radon concentrations and 3) to asses extremely high radon concentrations.

A low background Ge(Hp) detector in a Marinelli geometry was used to measure the specific radon activity in the exposure chamber. Energy and activity calibration in the marinelli geometry is obtained by using a certified multi isotopic standard source of ^{109}Cd , ^{57}Co , ^{137}Cs and ^{60}Co .

Two experiments were carried out; in the first one, one litre of gas sample was taken from the source chamber. From this 0.7 l were introduced into the exposure chamber and 0.3 l into the Marinelli container to asses the initial radon concentration. Table 1 shows the ^{222}Rn specific activity as calculated from the γ -energy photo peaks of ^{214}Pb (295 and 352) keV and ^{214}Bi (609 and 1120) keV, after three hours of injecting ^{222}Rn sample into Marinelli container at secular equilibrium. The average activity for the exposure chamber was $(10.540 \pm 6\%) \text{ kBq/m}^3$; all calculations took into account the energy efficiency dependence of the Ge(Hp) detector and volume corrections.

The average specific activity for the exposure chamber as determined from the six DM had a 6% standard error as can be seen in Table 2, and had a 0.3% difference with the results from the Ge(Hp) detector.

In a second experiment 1.5 l were taken from the radon source and immediately injected into the exposure chamber. After 1.78 days, 0.42 l from the exposure cham-

Table 1

Rn Specific Activity of Exposure Chamber from Ge(Hp) Detector

ISOTOPE (keV)	SPECIFIC ACTIVITY (Bq/m ³)
^{214}Pb (295)	9760
^{214}Pb (352)	10600
^{214}Bi (609)	10340
^{214}Bi (1120)	11460
AVERAGE	10540 \pm 6%

Table 2

Rn Specific Activity of Exposure Chamber from DOSEman Detector

DOSEman	SPECIFIC ACTIVITY (Bq/m ³)
15	10864
16	11410
18	9611
19	10639
20	10639
31	9867
AVERAGE	10504 \pm 6%

ber was introduced into the marinelli geometry for radon activity assessment. Table 3 shows the specific activity of ^{214}Pb and ^{214}Bi photo peaks, at a secular equilibrium (after three hours of injecting Rn sample into the marinelli container). The average activity was $(111.041\pm 1\%) \text{ kBq/m}^3$, considering the decay and the dilution factor corrections.

The specific activity of the exposure chamber from the six DM had a 4% standard error as can be seen in Table 4, and had a 1% difference with the Ge (Hp) detector.

The radon activity decay inside the exposure chamber recorded with the AG detector, shows a 2% difference with the theoretical decay constant, confirming that no radon leakage takes place from the exposure chamber (see Figure 1).

3. CONTROLLED RADON LEAKAGE TEST

The radon source chamber is in a licensed laboratory. The exposure chamber was left open during a weekend with

Table 3²²²Rn Specific Activity of Exposure Chamber from Ge(Hp) Detector

ISOTOPE (keV)	SPECIFIC ACTIVITY (Bq/m ³)
²¹⁴ Pb (295)	109333
²¹⁴ Pb (352)	110845
²¹⁴ Bi (609)	112949
²¹⁴ Bi (1120)	
AVERAGE	111041±1%

Table 4²²²Rn Specific Activity of Exposure Chamber from DOSEman Detector

DOSEman	SPECIFIC ACTIVITY (Bq/m ³)
15	107000
16	109000
18	103000
19	116000
20	107000
31	102900
AVERAGE	107483±4%

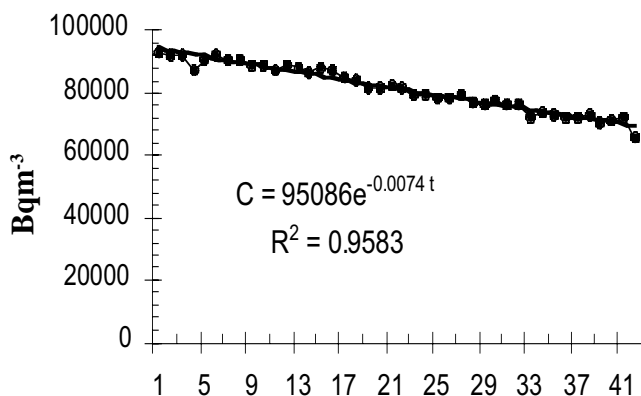


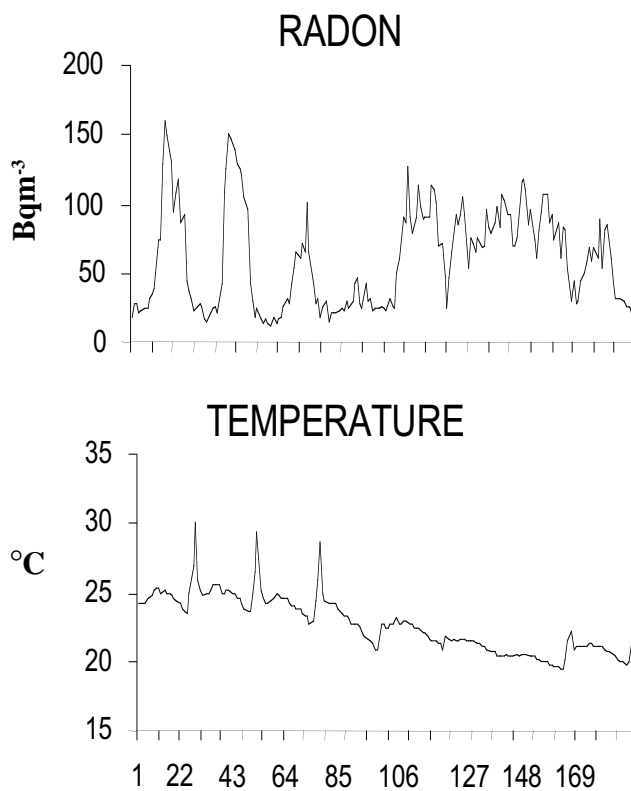
Fig. 1. The experimental radon decay curve fits the expected one, showing no leakage from the exposure chamber.

no workers around and with the access door closed, to observe the effect of an uncontrolled release of the radon atmosphere in the worse case. Seven DOSEman and the Alpha GUARD were placed in the laboratory.

During the total release of radon from the radon chamber to the laboratory, the seven DM showed an increase in the signal from 5 h pm (106 h) to 3 h am (116 h) next day (see Figure 2). After then, radon fluctuations were governed by temperature and humidity conditions in the laboratory. During the whole leakage experiment (106 h-169 h), radon concentration in the laboratory increased from 88 Bq/m³ to 113 Bq/m³ as determined in seven places with the DM whereas for the AG the average value was 79 Bq/m³; for a single point. Figure 3 shows typical spectra for a DM.

CONCLUSIONS

Evaluation of radon concentration in an exposure chamber using a calibrated Germanium detector agrees withing

Fig. 2. Temperature (°C) and humidity (%) affect environmental radon concentration (Bq/m³) in the laboratory, during the 190 hours monitoring, by the AG.

an error of 3%, with that measured by six DOSEman detectors. The exposure chamber kept the radon atmosphere hermetically closed as determined from the experimental decay curve obtained with an Alpha GUARD detector, which differs 2% from the theoretical one in.

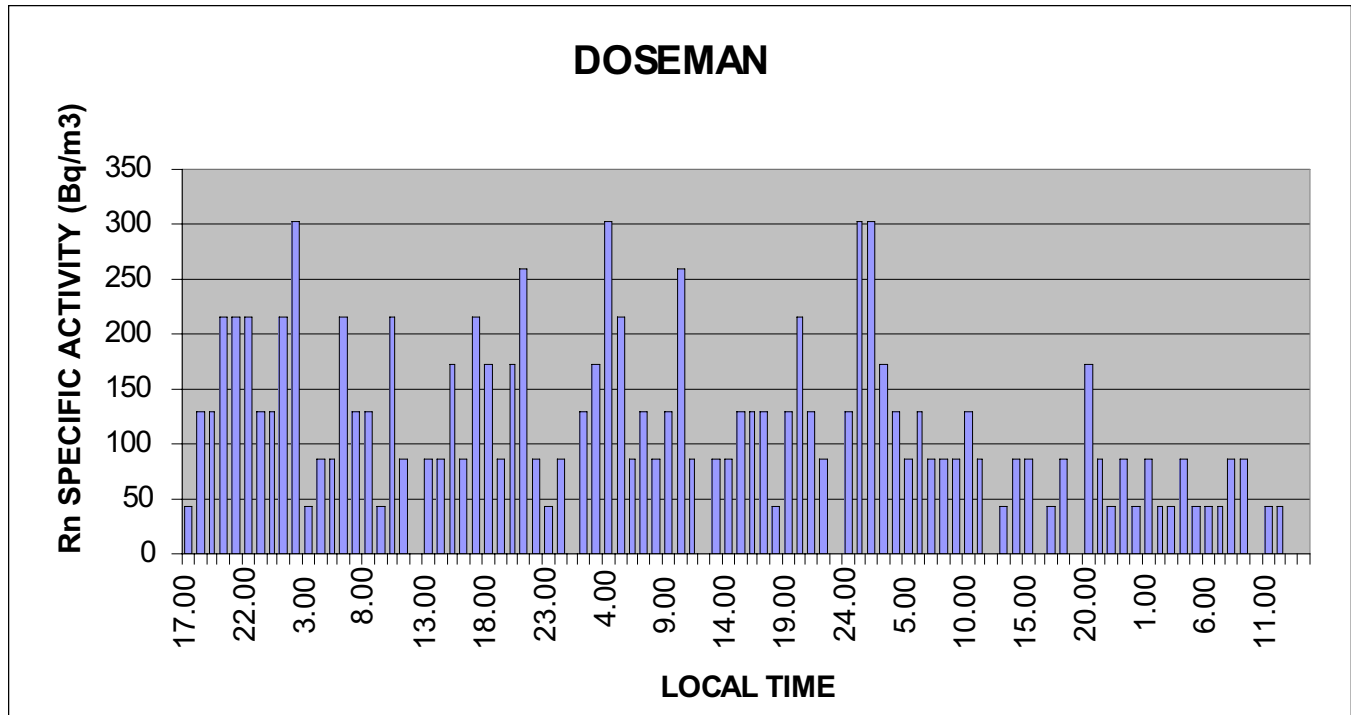


Fig. 3. The highest radon increase for the weekend leakage-experiment was 60% above background (Friday 17th to Monday 5 h), as determined by one of the DOSEman. Rn concentration drops at 10h when door of laboratory is opened.

A long-term environmental radon concentration in a licensed radon laboratory shows a ²²²Rn activity from a minimum of 25 Bq/m³ to a maximum of 150 Bq/m³ as determined with an Alpha GUARD detector. A total radon release from the source radon chamber increased a maximum of 60% the radon concentration in the laboratory as detected by one of the DOSEman, showing no risk in the worst possible accident.

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