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Long term indoor radon measurements in the pelletron laboratory at the UNAM physics institute

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The results of six months of continuous measurement of the indoor radon concentration levels in the building where the Instituto de Física 3 MV Pelletron particle accelerator is located are presented. This study has three major objectives: (a) to know the actual values of the levels of indoor radon in this installation, where personnel spend many hours and sometimes days; (b) assess the radiological risk from radon inhalation for personnel working permanently in the laboratory, as well as incidental users; and (c) establish, if necessary, time limits for continuous permanence on the location for indoor radon exposure.

Passive nuclear track detectors and dynamic systems were employed, covering six months (August, 2009 to January, 2010). For the calculation of internal dose the "Radon Individual Dose Calculator" was used. The results indicate that the indoor radon levels are below the USEPA recommended levels (400 Bq/m^3) in workplaces. The measurements help to establish levels for workplaces in Mexico.

Keywords: Indoor radon; radon; workplaces; risk; pelletron.

En este trabajo se presentan los resultados de seis meses de mediciones constantes del nivel de concentración de radón intramuros en el edificio donde se encuentra albergado el acelerador de partículas Pelletron. El estudio tiene tres objetivos básicos: (a) el de tener los valores reales del contenido de radón intramuros en esta instalación, donde académicos y técnicos pasan muchas horas, y a veces hasta días enteros; (b) evaluar el riesgo radiológico por inhalación de radón que tienen tanto el personal que labora directamente en el Pelletron, así como los usuarios eventuales; y (c) establecer, de ser necesario, los límites de tiempo de estancia continua dentro de las instalaciones establecidas para radón intramuros en lugares de trabajo.

Para realizar este estudio, se usaron detectores pasivos de "Trazas Nucleares en Sólidos (TNS)" y sistemas dinámicos, abarcando seis meses (agosto del 2009 a enero del 2010). Para el cálculo de dosis interna se utilizó un algoritmo de cálculo de dosis de radón individual. Los resultados indican, a diferencia con otras instituciones y laboratorios, que los niveles de radón intramuros están por debajo de los niveles recomendados por la agencia USEPA (400 Bq/m^3) para lugares de trabajo. Este estudio también puede ayudar a establecer estos niveles para lugares de trabajo en México.

Descriptores: Radón intramuros; lugares de trabajo; riesgo radiológico; peletrón.

PACS: 87.56.bg; 91.67.Qr; 61.80.-x; 29.40.-n.

1. Introduction

Exposure to radon and its radioactive progeny present in the environment results in a large contribution to average effective dose received by human beings [1,2]. Natural radon and its airborne progeny can cause a significant internal health hazard, especially when they build up in enclosed areas, such as dwellings, caves and mines. Epidemiological studies and the assessment of lung cancer risks have concluded that radon and its decay products affect the general public living with high radon concentrations. The implementation of EURATOM directive 96/29 [3] creates new scenarios in the field of natural radioactivity, with particular regard to radon measurements in workplaces.

Workplaces may differ from homes in terms of building structure, microclimatic conditions and occupancy factors. Some of the peculiarities of workplaces are: (a) multi-storeyed buildings with large entrance hall; (b) presence of air conditioning or forced ventilation; (c) widespread use of ground floor or basements; (d) high probability of finding elevated temperatures and high levels of humidity, dust and aerosols. Such workplace characteristics might result in large spatial and time variations of radon, thus requiring an appropriate monitoring strategy.

In previous works the Dosimetry Applications Project of the Instituto de Física, UNAM has measured indoor radon levels in public offices [4], with the unexpected results that indoor radon levels were half or less than the values found in homes and dwellings [5], and these effects were associated with the use of air conditioning systems.

The Pelletron building is located at the Instituto de Física, UNAM, in the ciudad Universitaria campus, Coyoacán political administrative region, in the south of Mexico City. The area is found on the slopes of hills of recent volcanic origin.

FIGURE 1. Front and inside of the building.

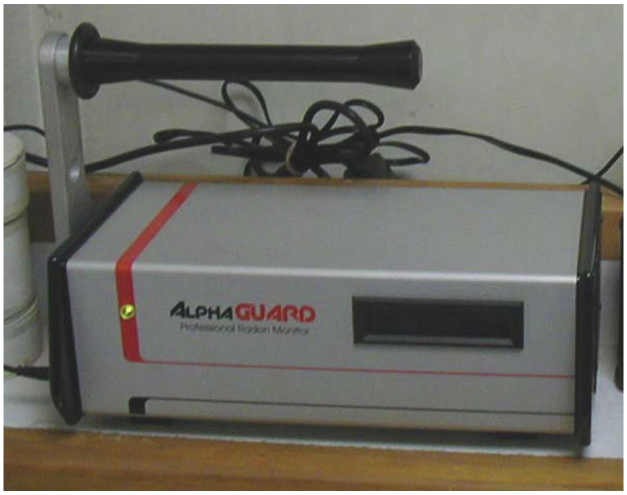

FIGURE 2. AlphaGUARD monitor

The accelerator is housed in a 10×20×8 m bunker, with no separate control room. The walls are 1 and 2 m thick high density concrete, with only upper windows, which are permanently closed. There is one 1×2 m entrance from the open exterior, and it is normally kept open during machine operation, but closed at night, on weekends, and during holidays. It is a very massive building with several tons of concrete of potential radon exhalation. Due to the low beam energy and operating characteristics, no airborne radioactive nuclides are produced. Fig. 1 shows the front and inside of the building.

1.1. Regulations and action levels

Due to the differences between workplaces and dwellings, they must be considered separately when it comes to evaluating the radiological risk associated with indoor radon exposure, and implementing relevant regulation. Regulations vary greatly between countries. The European Union (EU) accepts the recommended action level, the radiation level above which preventive action must be taken, included in ICRP-65 of between 500 and 1500 Bq/m^3 [6]. The Unites States of America (USA) use a reference level of 148 Bq/m^3 for dwellings and 400 Bq/m^3 for workplaces [1]. In the United Kingdom (UK) the Health and Safety Executive (HSE) [7] has adopted a radon action level of 400 Bq/m^3 for workplaces [6].

The action level for workplaces in Hungary is 1000 Bq/m^3 [7]. Israel uses a mandatory reference level of 200 Bq/m^3 for existing schools, and for new schools and baby day care homes an advisory reference level of 40 Bq/m^3 [8]. There are no specific regulations in Mexico relating to indoor radon levels in either homes or workplaces.

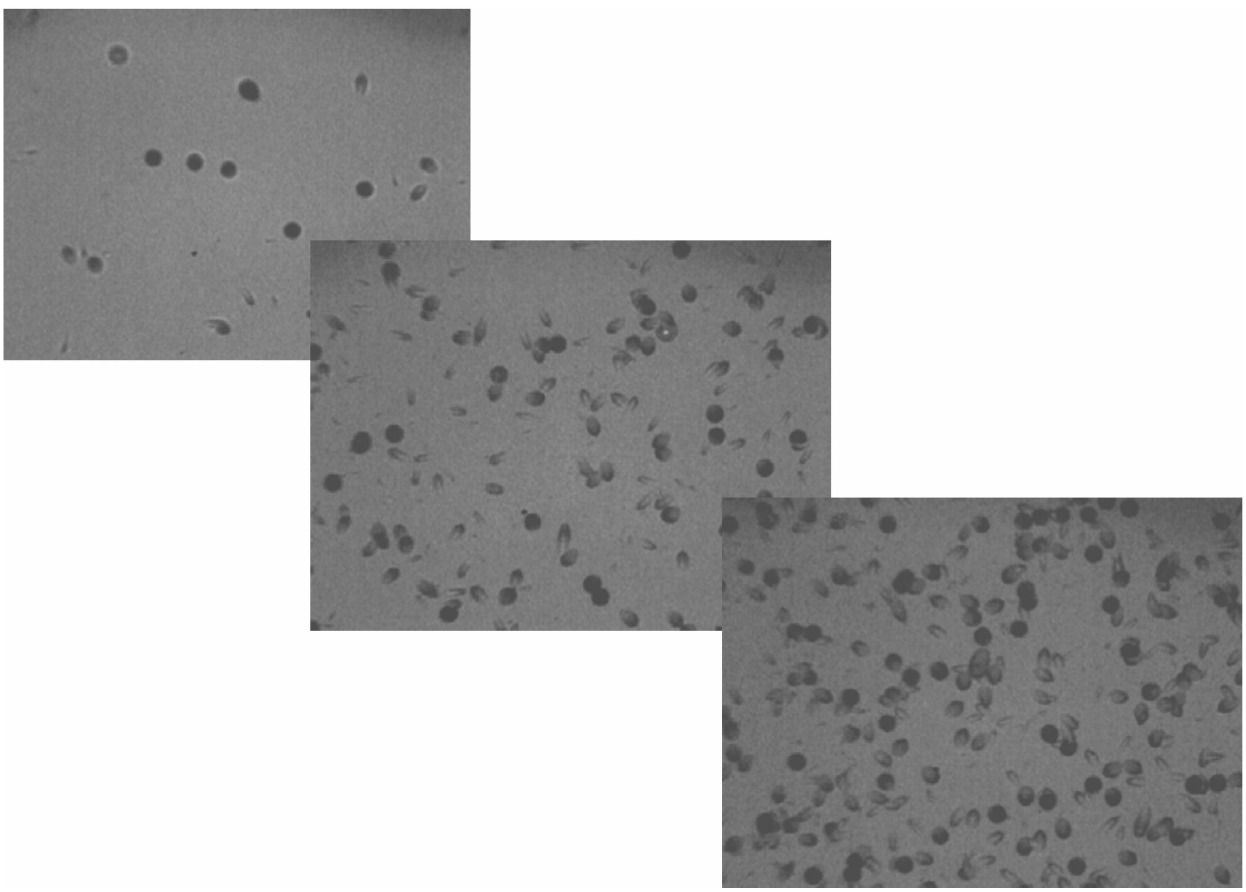

FIGURE 3. CR-39 Nuclear Tracks Detectors.

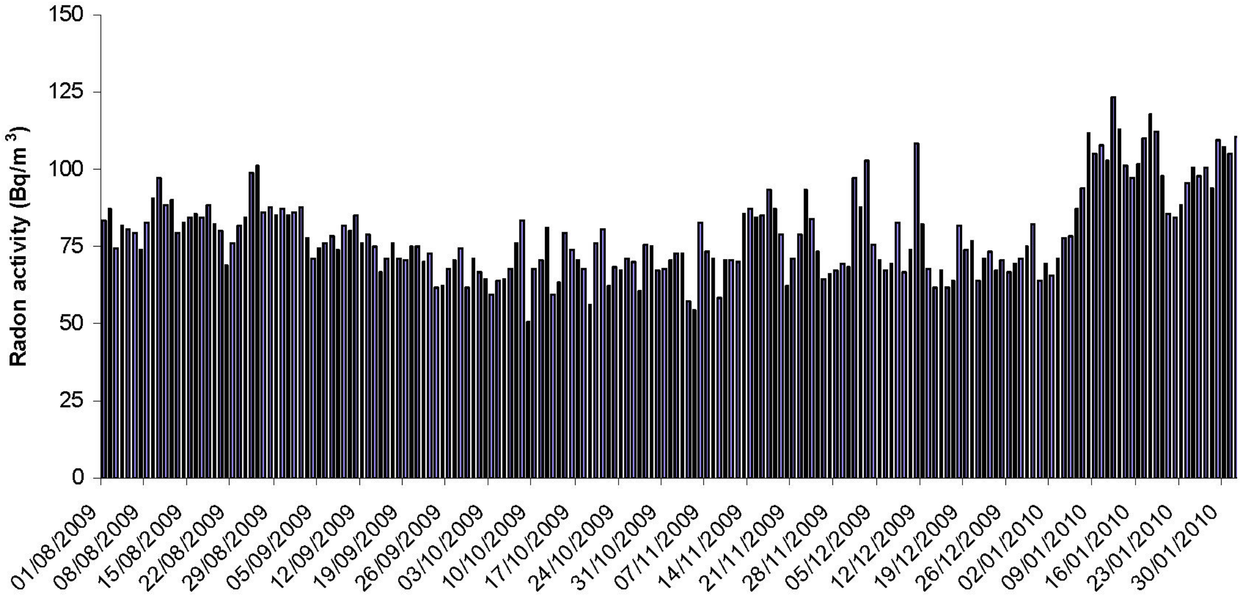

FIGURE 4. Indoor radon levels in the Pelletron laboratory.

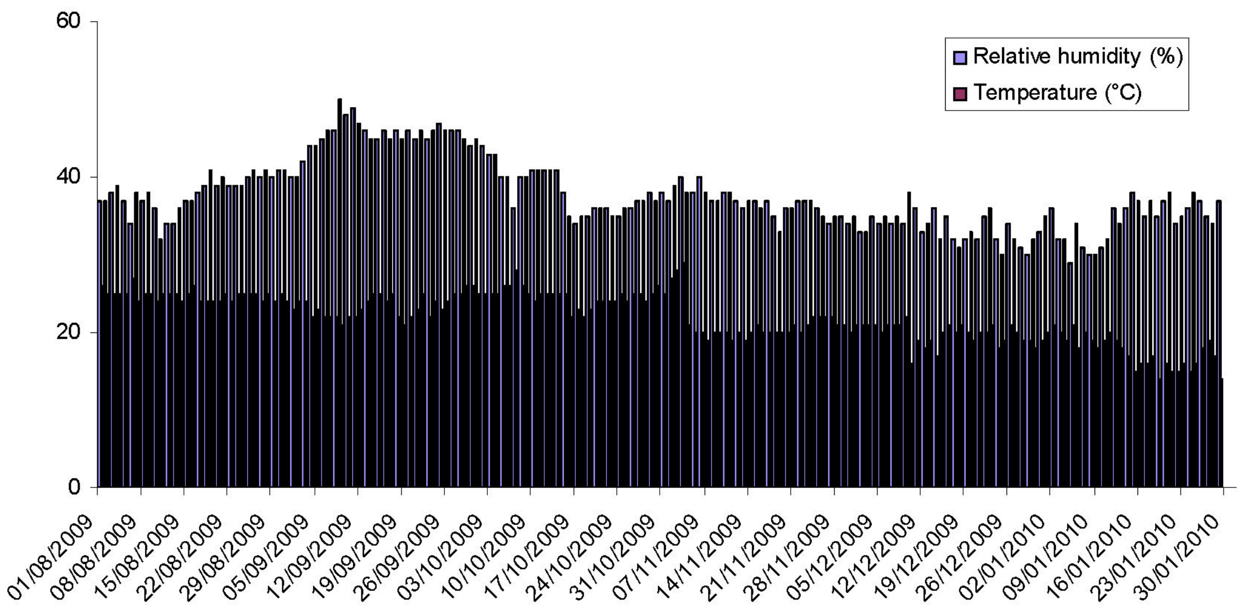

FIGURE 5. Climatic conditions during the measured period.

2. Experiment

2.1. Dynamic

Dynamic methods provide continuous measurements of radon. An AlphaGUARD monitor based on a design-optimized ionization chamber, with a range from 2 to 2 M Bq/m^3, was chosen for this work. Indoor radon measurements were taken every 24 hours, with a non-stop system, during six months. Figure 2 shows the AlphaGUARD monitor used. The basic advantages of the dynamic methods are non-stop reading, relatively good precision ($\pm$3%), and the results are loaded directly to the PC. The temperature and humidity are also recorded by the instrument. The disadvantages of the dynamic system are the power requirements and the cost, but since this experiment was done inside an accelerator laboratory, these were not a problem.

2.2. Passive

For comparison a passive closed-end cup system with nuclear track methods was chosen. Polycarbonate CR-39 (Lantrack®) was selected as detector material, because of the energy response, high sensitivity and easy handling [9].

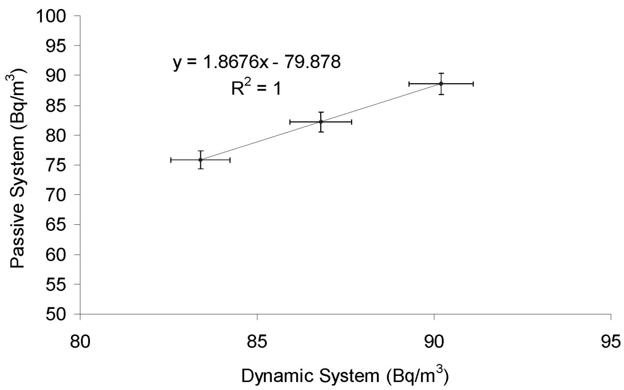

FIGURE 6. Scatter diagram of the indoor radon level data of two independent measurement systems (dynamic and passive)

TABLE I. Comparative values between the dynamic and passive methods.

	August 2009 to September 2009	September 2009 to November 2009	December 2009 to January 2010
Dynamic	75.9±10.2 Bq/m^3	88.6±17.8 Bq/m^3	81.2±15.0 Bq/m^3
Passive	83.4±6.7 Bq/m^3	90.2±7.3 Bq/m^3	86.8±7.1 Bq/m^3

TABLE II. Calculated dose for 81.2 Bq/m3 exposition, considering 1760 hours

Dose rate	255.0 nSv/h
Annual dose rate	448.8 μSv/y (0.090 WLM/y)
Excess lifetime cancer risk	0.004% (1 : 22281)

A highly reliable and very well established protocol was followed for developing the tracks, consisting of one step chemical etching in a 6.25 M KOH solution at 60±1°C with an etching time of 18 hours. Figure 3 shows the nuclear tracks formed in the CR-39 material for different exposure times.

The detection devices were calibrated at the ORNL-USA radon chamber facilities [10], and the process is verified every three months using the Instituto de Física facilities, and every time when a new CR-39 batch arrives. The detectors were read automatically by a Digital Image Analysis System DIAS [11], and the data analyzed using a PC. The indoor radon measurements were done three times in periods of 60 days each.

The advantages of the passive method are small size, easy handling and low cost. Long term measurements can be made unobtrusively, with no gamma ray background, and no power required. The disadvantages are the long period of time required for the measurement.

3. Results

Figure 4 shows the everyday indoor radon measurements with the dynamic system. The monthly average values are:

August	84.5±8.1 Bq/m^3
September	74.2±7.4 Bq/m^3
October	69.2±8.6 Bq/m^3
November	72.7±11.9 Bq/m^3
December	84.9±11.0 Bq/m^3
January	101.8±10.6 Bq/m^3

The indoor radon average level of the first two month period was 75.9±10.2 Bq/m^3, for the second period was 88.6±17.8 Bq/m^3, and for the third period was 81.2±15.0. The temperature and relative humidity for the same period are shown in Fig. 5. No radon dependence on these parameters is observed.

Table I shows the comparative values between the dynamic and passive methods. The uncertainty of the average values shows the temporal variation on the indoor radon in the Pelletron building, not the uncertainty of the measurements.

4. Correlation determination

In order to evaluate the passive and dynamic methods used, the correlation factor was obtained with the average of indoor radon concentration values found. The uncertainties for the dynamic system are 3% [12], and for the passive methods 5% was considered. The linear regression equation is: Y_e = 1.9 - 79.9X. The correlation coefficient (R), was 1.0, indicating a strong linear relationship. This relationship is shown in Fig. 6.

Using the value of 81.2 Bq/m^3 for the radon level in the Pelletron building, and considering 1760 working hours/year (220 days/year and 8 hours/day) and an equilibrium factor of 0.4, the "Radon Individual Dose Calculator" [13] yields the values of Table II.

5. Conclusions

Low values of indoor radon were found in the Pelletron Accelerator building. The highest (123.5 Bq/m^3), lowest (50.7 Bq/m^3) and average (81.2 Bq/m^3) values are below the 400 Bq/m^3 indoor working action level. The calculated dose rate of 225 nSv/h gives an excess lifetime cancer risk of 0.004%. The low indoor radon level in Mexico City is mostly due to the ample ventilation that the benign climate permits.

Acknowledgments

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