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Indoor radon and airborne particles

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RESUMEN

Se midieron las fluctuaciones de radón en casas del Estado de México y del Distrito Federal con la finalidad de evaluar fluctuaciones de corta duración. Para ello, se utilizaron detectores Honeywell A9000 A que registran el decaimiento alfa del radón y sus descendientes. Asimismo, se midieron los cambios en la concentración de partículas suspendidas utilizando un equipo Personal Data-Logging Real-time Aerosol Monitor. Los resultados indican un valor promedio de radón intramuros de 22 Bq/m^3 con incrementos esencialmente en la madrugada, que alcanzaron valores hasta un orden de magnitud mayor que el promedio. Las partículas suspendidas intramuros mostraron un valor promedio de 0.08 mg/m^3. Experimentos en habitaciones cerradas con fumadores mostraron una concentración de partículas suspendidas dependiente de la ventilación y del número de fumadores en el recinto.

PALABRAS CLAVE: Radón intramuros, equipos automáticos, medidas de corta duración, partículas suspendidas, fumadores.

ABSTRACT

Daily radon fluctuations were monitored in dwellings located in the State of Mexico and in Mexico City in order to assess the expected fluctuations in a short term monitoring basis. The radon monitoring was performed with Honeywell A9000 A devices that record radon and daughters using silicon detectors. Airborne particle fluctuations were also determined using a Personal Data-Logging Real-time Aerosol Monitor. The results indicate an indoor radon average value of 22 Bq/m^3. Discrete values one order of magnitude higher than the mean were observed, mainly between midnight and early morning. The airborne particles in the bedroom showed daily average values of 0.08 mg/m^3. Experiments with smokers indicated fluctuations in the airborne particle concentrations that depend on the ventilation and the number of smokers in the room.

KEYWORDS: Indoor radon, automatic devices, short term monitoring, airborne particles, smoking.

INTRODUCTION

The potential hazards posed by exposure to radiation from indoor radon are of great concern world-wide, specially associated with increased lung cancer risk. The association of radon, indoor aerosols together with the exposure to industrial and urban pollution, affect severely the population's health. The effect of this combined pollution pattern with smoking also enhances respiratory diseases (Doi *et al.,* 2001).

Smoking, the most important risk factor for lung cancer, has become an important public health problem in Mexico, with more than 14 million smokers and 48 million passive smokers. Malignant tumours, many associated with direct exposure to tobacco smoke, are the second cause of mortality in the general population, after cardiovascular diseases, and lung cancer is the leading neoplasm (SS, 1997).

In terms of public health, cumulative exposure to radon indoors together with its synergistic effect with tobacco smoke might be an important risk factor for lung cancer. The United States Environmental Protection Agency estimates that 14 000 annual lung cancer deaths in the United States are caused by radon, mostly attributable to radon plus smoking. In Mexico there is little information about the risk that radon represents in terms of health, although we have information about indoor radon concentrations found in some places of the country (Espinosa *et al.,* 1999; Franco Marina *et al.,* 2001).

In order to contribute with data about this health problem, we assessed the daily fluctuations of indoor radon in dwellings located in Central Mexico, where an important part of the population is settled, and we compared the radon behaviour with the fluctuations of indoor aerosols in order to determine eventual anomalous patterns that could have an association and increase the risk of lung cancer in Mexican population.

Experimental

The study area is located in the Central part of the Mexican Neovolcanic Belt (19°10'-19°30'N; 99° 00'-99 50'W) at altitudes between 2240 and 3065 meters. Thirty seven dwellings were monitored, 28 in the State of Mexico and 9 in Mexico City. The monitoring period comprised the months of April to June, 2000. Normal activities were done inside the dwellings.

Monitoring devices, A9000A Honeywell radon monitors, were installed indoors, mainly in the bedroom which is the place where people spend more time, and left in place during 1 to 12 days. The devices detect alpha particles from radon/radon progeny decay using silicon detectors. The monitors can integrate the radon decay information during established periods of time. The devices timer was fixed at one (in 32 dwellings) and 4 hours (only in 5 dwellings) during the monitoring period.

Indoor PM_{10} particles were also monitored in the bedroom of one Mexico City dwelling using a Personal Data-Logging Real-time Aerosol Monitor (MIE Inc.), during 26 non-consecutive days (December 2000-February 2001); records in an smoker´s office were also obtained in February-March, 2001.

RESULTS AND DISCUSSION

The average radon values for each studied dwelling are shown in Table 1. The results indicate an indoor radon average value in the zone of 22 Bq/m^3. Discrete values one order of magnitude higher than the mean were observed, those anomalous peaks were obtained at all the monitoring sites, mainly between midnight and early morning.

Figure 1 shows an example of the daily radon fluctuations observed indoors. Only in two dwellings maximum radon values (296 Bq/m^3 and 229.4 Bq/m^3) higher than the permissible limits established by international agencies (148 Bq/m^3) were found. Those values were recorded in April which, together with May, are the hottest months in the year, with temperatures reaching 32°C. During this hot time of the year dwellings are usually well ventilated so we infer that, during winter with lower temperatures and therefore less ventilation, higher radon levels could be found.

It is important to mention that the average radon pattern obtained in hourly monitoring (Figure 1) shows a bimodal behaviour with an enhancement from 02:00 to 07:00 and a second increase between 9:00 to 11:00, those peaks are coincident with the period during the night in which most people are at home, sleeping in their bedroom usually with doors closed, and therefore the radon exposure is increased. The lowest radon levels were found during the afternoon (after 12:00). This reduction is probably determined by an important air exchange indoor-outdoor plus the air movement associated with the daily activities inside the dwellings and therefore with a dilution of radon in the indoor atmosphere. This daily pattern has been reported by

Table 1

Average and maximum radon concentrations in the studied dwellings.

Dwellings	Average (Bq/m^3)	Maximum (Bq/m^3)	Monitoring Period (days)
H1	14.72	77.70	3
H2	20.62	66.60	3
H3	17.00	66.60	4
H4	20.30	77.70	3
H5	15.42	44.40	10
H6	25.36	92.50	3
H7	17.42	77.70	3
H8	14.80	51.80	1
H9	22.44	107.30	3
H10	6.46	25.90	3
H11	39.40	114.70	10
H12	9.84	25.90	3
H13	6.97	37.00	3
H14	12.73	51.80	4
H15	14.98	66.60	3
H16	10.45	37.00	3
H17	4.72	37.00	4
H18	21.45	107.30	4
H19	15.17	66.60	4
H20	41.69	133.20	4
H21	10.27	51.80	3
H22	15.42	77.70	2
H23	27.00	77.70	3
H24	41.69	133.20	4
H25	18.73	51.80	2
H26	8.42	37.00	3
H27	11.67	66.60	3
H28	87.67	296.00	3
H29	48.18	229.40	3
H30	49.31	133.20	3
H31	59.54	92.50	3
H32	11.71	44.40	12
H33	21.68	77.70	4
H34	10.95	22.20	4
H35	15.08	37.00	2
H36	19.36	92.50	5
H37	10.61	51.80	5

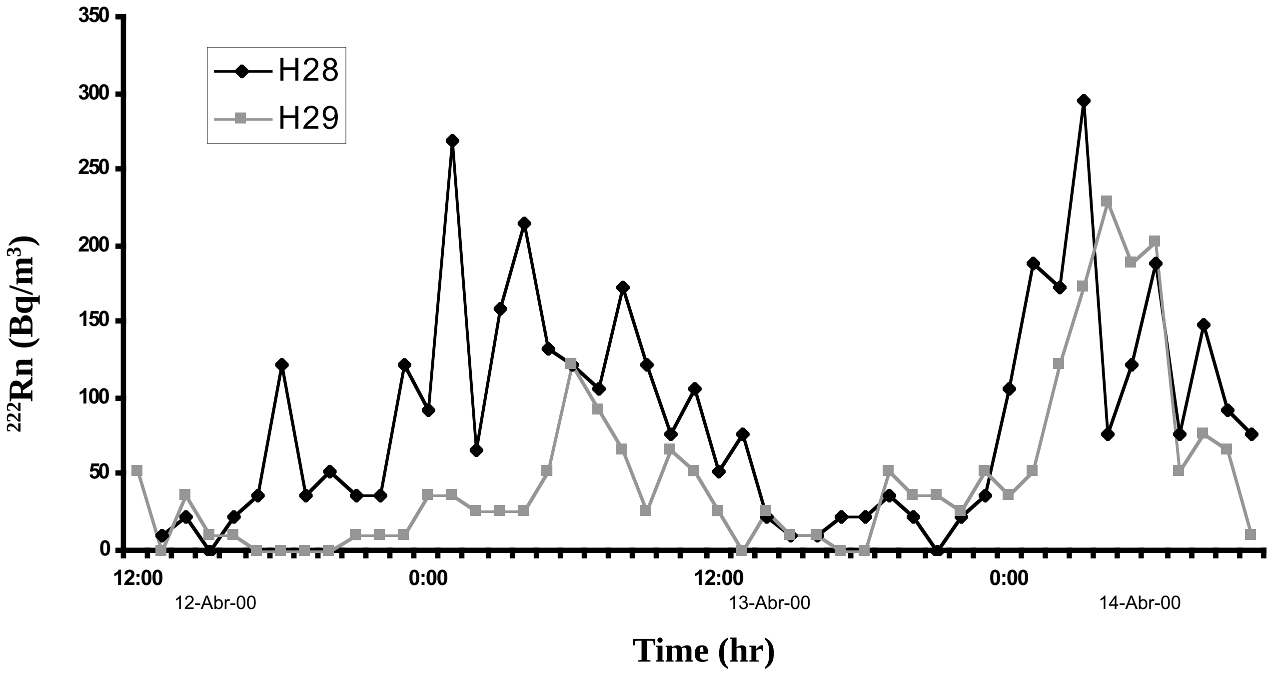

Fig.1. Short term radon fluctuations (Bq/m^3) in two dwellings (H28 and H29).

several authors and it agrees with values found in different buildings where the maximum levels occur in the early morning and the minimum ones in the afternoon; additionally, radon concentrations have been shown to increase during periods of weather stability, as it is the case during early morning hours (Merril and Farhang, 1998; Segovia *et al.,* 2001).

Even if most of the values of radon found in the present work are lower than the intervention level accepted by the International Radiological Agencies, the indoor radon behavior obtained in the short term monitoring with the Honeywell detectors gave important information about the radon peaks found at night and early morning. Even when the average daily values found were low in most dwellings, during the peaks the radon concentration increases in a striking way.

In Figure 2 (a and b) the daily average of indoor particles during the 26 monitored days in the bedroom located in Mexico City are shown, together with an example of their hourly behaviour in the short term. The daily average values (Figure 2a) has a mean of 0.06± 0.04 mg/m^3. Figure 2b indicates the one day-hourly results showing spot values as high as 0.42 mg/m^3, five times higher than the average (0.08 ± 0.07 mg/m^3). The short term increase could be explained by a high indoor-outdoor air exchange rate. Because of temperate weather in Mexico, ventilation in dwellings is very common through existing openings like windows and doors. In the dwelling studied there was not insulation or air conditioning system and the peak in Figure 2b corresponds to the highest traffic hour in Mexico City. The origin of indoor aerosol particles in temperate regions can be from the urban pollution (cars, industrial activities, etc.) and from very local indoors sources (dust, gas stoves, smoking, fungi, etc). It is worth mentioning that the maximum permissible limit of outdoor PM_{10} established by the Mexican legislation is 0.15 mg/m^3 in 24 hours once in a year.

In the short time, the particles behaviour have also a bimodal pattern, in close association with indoor activities like cleaning and outdoors pollution. Even if indoor particles are expected to provide a surface where radon and its daughters can attach and be inhaled, getting into the human respiratory tract, no evidence of correlation was found in the present study.

The results for PM_{10} in the smoker's office are shown in Figure 3. In this figure, the hourly average indicates a mean of 0.338 ± 0.127 mg/m^3, higher that the average found in the bedroom. It is worth mentioning that at 14:00, three simultaneous smokers were inside the room that was scarcely ventilated and, between 12:00 and 13:00 only one smoker was inside the office.

Other authors (Huet *et al.,* 2001; Segovia *et al.,* 2001) indicate a strong influence exerted by size and particle concentration of aerosols on the typical indoor domestic expo-

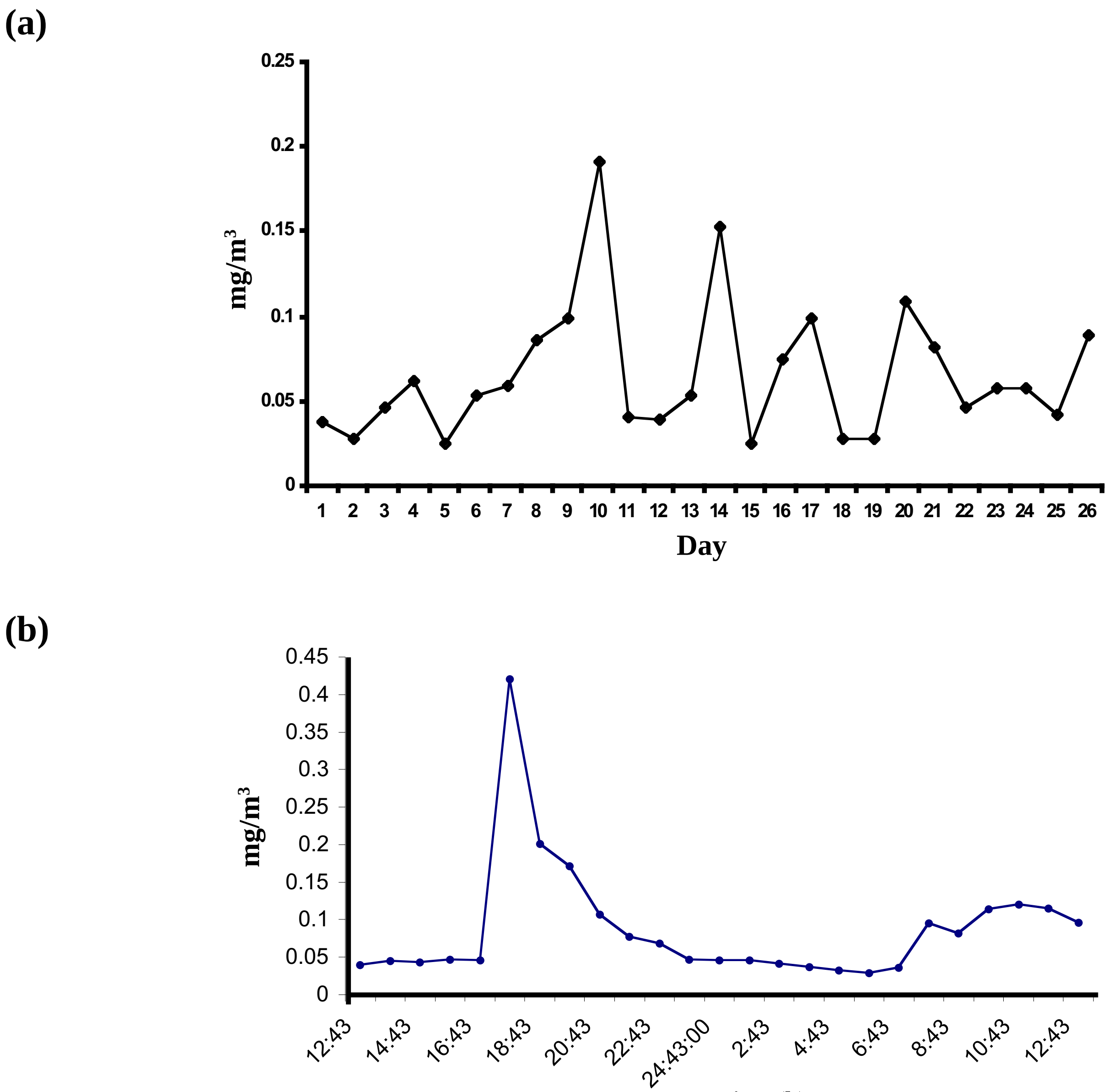

Fig. 2. PM_{10} in a bedroom located in Mexico City, during 26 non-consecutive days (December 2000-February 2001). (a) Daily PM_{10} average. (b) Hourly PM_{10} average.

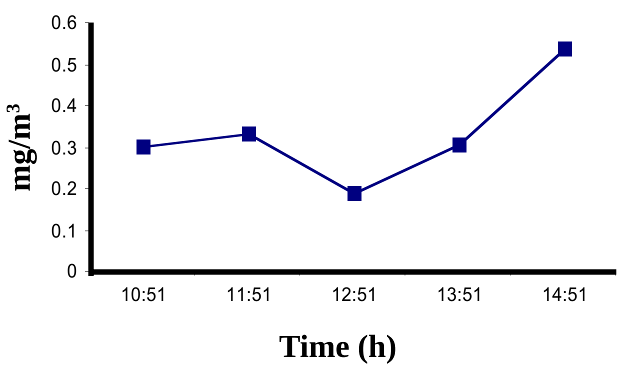

Fig. 3. Indoor particles (PM_{10}) in a smoker's office.

sure to radon. The synergetic effect of radon and smoking has to be evaluated, especially for populations living in highly polluted rooms with low ventilation, such as smoker's dwellings and offices.

CONCLUSIONS

In terms of public health, tobacco smoking represents a serious risk not only for lung cancer but also for respiratory and other diseases, both for active and passive smokers. Tobacco smoke is the main source of indoor particles, therefore regulations that prohibit smoking in public places must be encouraged.

From the public health point of view the radon cumulative exposure is important since the maximum values occur during the period when most people are sleeping at home. Lung cancer is the result of cumulative exposures to carcinogens like radon during the entire life, therefore it is important to generate more information about the magnitude of this risk.

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