

Radon in dwellings and laboratories from central Mexico

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Abstract. Average indoor radon and airborne particles concentration levels have been measured in family houses, offices and laboratories within a survey protocol related to smoking health effects. The radon measurements were performed with Honeywell A9000A devices. Airborne particle fluctuations were determined using a Personal Data Logging Real Time Aerosol Monitor. The indoor radon average value obtained in the family houses was 40 Bq m^{-3} . However, short term peaks higher than 150 Bq m^{-3} were eventually observed. At the offices and laboratories indoor radon behaviour showed several values higher than the limits, particularly for those rooms having no external windows. Airborne PM10 average particulate matter indoors at a smoker house was $0.751 \pm 0.420 \text{ mg m}^{-3}$ in 24 h, reaching concentrations as high as 1.6 mg m^{-3} , one order of magnitude higher than the maximum permissible limit of outdoor PM10 (0.150 mg m^{-3}) established by the Mexican legislation.

1 Introduction

The deposition of radioactive particulate from the inhaled air in the lungs, their further transport into the tissue, and the accompanying irradiation of cells due to radioactive decay has been studied intensively during the last decade (Vaupotic and Kobal, 2002). The association of radon, indoor aerosols and the exposure to industrial and urban pollution combined with smoking, can severely enhance respiratory diseases (Doi et al., 2001). Domestic radon has been identified as the most important environmental risk factor for lung cancer; Wichmann et al. (2002) report that 7% of all lung cancers in Germany could be due to indoor radon. Currently, about 50% of all exogenous cancers worldwide can be attributed to smoking, according to recent WHO estimates (Becker, 2002).

In Mexico, smoking is a recognised public health problem with increasing rates in women and teenagers (Franco-Marina et al., 2001). Currently there are 14 million smokers and 48 millions passive smokers. Environmental tobacco smoke (ETS) is the term used to describe the material in indoor air, which results from tobacco smoking. This material is a complex mixture, which changes with time and with

environmental conditions, and usually contains radioactive aerosols.

The main purpose of the present paper was the evaluation of average and daily fluctuations of indoor radon and airborne particles concentration levels obtained in family houses, offices and laboratories located in Central Mexico, within a survey protocol related to smoking health effects.

2 Experimental

The study area is located in the State of Mexico located in the Central part of the Mexican Neovolcanic Belt ($19^{\circ}10' - 19^{\circ}30' \text{ N}$; $99^{\circ}00' - 99^{\circ}50' \text{ W}$) at altitudes between 2500 and 3000 m. Indoor radon was measured in 30 family houses randomly selected. The survey was performed within the normal family activities. Twelve offices and 12 laboratories, having no radioactive sources, belonging to a Nuclear Research Centre located in the region of study at 2800 m altitude were also monitored for radon. The radon measurements were performed during 2002-2003 with Honeywell A9000A devices that record radon and daughters using silicon detectors. Finally, measurements during several days in April 2002 at the living room of a smoker house were performed during different daily periods. The average number of cigarettes consumed indoors was 60 daily. During the sampling normal activities and ventilation were done at the house. Airborne particle fluctuations were determined using a Personal Data Logging Real Time Aerosol Monitor.

3 Results and discussion

The indoor radon average value ($40 \pm 26 \text{ Bq m}^{-3}$) obtained in the family houses ($N = 1250$; range $11 - 440 \text{ Bq m}^{-3}$) was below the permissible limit established by international agencies (150 Bq m^{-3}). Radon increases during the night-time were systematically observed. In seven houses peaks higher than the limits were observed reaching a maximum value of 440 Bq m^{-3} in early morning. This behaviour has been reported previously at similar regions (Segovia et al., 2002a, b) and explained as an effect due to the radon concentration in the rooms when windows are closed during the

night, since the climate is semi-cold. On the contrary, during the light hours, an important air exchange indoor-outdoor plus the air movement associated with the daily activities inside the dwellings and ventilation of the house occurs, promoting the indoor radon dilution during the day. Radon concentration in a room have been shown to fluctuate by a factor up to 500 depending on ventilation and other factors (Becker, 2002).

At the offices the total average indoor radon value was $73 \pm 39 \text{ Bq m}^{-3}$ ($N = 1300$; range $15\text{--}392 \text{ Bq m}^{-3}$), but all of them showed maximum values higher than the limits, essentially during the night, reaching 392 Bq m^{-3} . From the 12 studied laboratories, the overall average value was $104 \pm 57 \text{ Bq m}^{-3}$. Eight of them had maximum values during the night higher than the limits reaching 1591 Bq m^{-3} ($N = 1200$; range $11\text{--}1591 \text{ Bq m}^{-3}$).

The higher radon values were systematically obtained in rooms having no external windows or very low ventilation rate.

The results for PM10 airborne particulate matter monitored in the living room of an apartment from a smoker family showed interesting results. An average number of 60 cigarettes were smoked per day. The average concentration of PM10 was $0.751 \pm 0.420 \text{ mg m}^{-3}$ in 24 h, reaching concentrations as high as 1.6 mg m^{-3} , one order of magnitude higher than the maximum permissible limit of outdoor PM10 (0.150 mg m^{-3}) established by the Mexican legislation. These maximum concentration values were observed at the middle of the morning around 10:00 LT (Local Time), and at night, between 20:00 and 00:00 LT. The smoker has been smoking during the last 40 years inside his home, together with his family. This fact is important, in terms of health effects, since chronic inhalation of extremely high concentrations of particulate matter and pulmonary deposition, can exceed the capacity of macrophage clearance, generating the accumulation of large amounts of particles in the lungs.

If we assume a lifetime average ventilation equal of the NCRP value of 11.25 L min^{-1} for an adult during light work, an individual would inhale approximately $0.675 \text{ m}^3 \text{ h}^{-1}$, or $443\,475 \text{ m}^3$ during a lifetime of 75 years. Under these conditions and assuming a pulmonary deposition fraction of 20%, a total of $32.4 \mu\text{g day}^{-1}$ would be deposited in the lung for each $10 \mu\text{g m}^{-3}$ of inhaled particle concentration. At a common particulate matter concentration for urban environments of $30 \mu\text{g m}^{-3}$ of respirable particulate, such an individual might deposit approximately $100 \mu\text{g}$ in the lung each day, or 2.7 g in a 75 year lifetime.

It has been reported (Porstendorfer, 2002) that in most places with a dominant aerosol source such as cigarette smoking or combustion, the dose conversion factor for unattached and attached radon decay products can suffer striking differences. If we consider the dose conversion factor for radon as $3.2 \times 10^{-6} \text{ mSv Bq}^{-1} \text{ h}^{-1}$ (ICRP, 1993), a radon concentration indoors of 40 Bq m^{-3} and an occupation factor at home of 14 h day^{-1} , the annual effective dose can be estimated as $0.65 \text{ mSv year}^{-1}$. Considering different aerosol

conditions, previous estimations in Mexico indicate that the equilibrium factor between radon and daughters can evolve from $F = 0.02$ to $F = 0.77$; in these conditions the annual effective dose can suffer an increase by a factor of 750 for the same original radon concentration due to differences in aerosols conditions at home, at work and outdoors (Chavez et al., 2003).

The results found in the present study indicate that the exposure to respirable suspended particulate matter in a smoker dwelling can represent a very important risk for the respiratory and cardiovascular health of the passive smokers sharing the same home, and this can be extrapolated and added, to the exposure to ETS in the working areas.

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References

- Becker, K.: Residential radon and the LNT hypothesis, in: High Levels of Natural Radiation and Radon Areas: Radiation Dose and Health Effects, edited by W. Burkart, M. Sohrabi, A. Bayer, Elsevier, Amsterdam, 259–266, 2002.
- Chavez, A., Balcazar, M., and Camacho, M. E.: Equilibrium factor F and effective dose equivalent with SSNTD. Environmental Radiochemical Analysis, Royal Society of Chemistry, Cambridge, in press, 2003.
- Doi, M., Nakamura, Y., Sakashita, T., Ohio, N., Lagarde, F., and Falk, R.: Lifetime risk of lung cancer due to radon exposure projected to Japanese and Swedish populations, *Health. Phys.* 80, 552–562, 2001.
- Franco-Marina, F., Segovia, N., Ruiz, W., Godnez, L., Tavera, L., López, A., Chavez, A., Peña, P., and Ponciano, G.: Short and long term indoor radon survey in Mexico City, *Radiat. Meas.* 34, 545–548, 2001.
- ICRP: Protection against radon-222 at home and at work, Pergamon Press, Oxford; ICRP Publication 65, 1993.
- Porstendorfer J.: Influence of physical parameters on doses from radon exposures, in: High Levels of Natural Radiation and Radon Areas: Radiation Dose and Health Effects, edited by W. Burkart, M. Sohrabi, A. Bayer, Elsevier, Amsterdam, 149–160, 2002.
- Segovia, N., Ponciano, G., Ruiz, W., and Godinez, L.: Indoor radon and airborne particles. *Geof. Int.* 41, 255–259, 2002a.
- Segovia, N., Ponciano, G., Ruiz, W., Morales, V., Peña, P., and Godinez, L.: Fluctuations in indoor radon levels in dwellings in a volcanic area of a temperate tropical region, in: High Levels of Natural Radiation and Radon Areas: Radiation Dose and Health Effects, edited by J. Peter, G. Scghneidre, A. Bayer, Vol II, Salzgitte, 183–185, 2002b.
- Vaupotic, J. and Kobal, I.: Radon dose estimates assisted by continuous measurements, *J. Radioanal. Nucl. Chem.* 253, 267–274, 2002.
- Wichmann, H. E., Heinrich, J., Gerken, M., Kreuzer, M., Wellmann, J., Keller, G., and Kreienbrock L.: Domestic radon and lung cancer-current status including new evidence from Germany, in: High Levels of Natural Radiation and Radon Areas: Radiation Dose and Health Effects, edited by W. Burkart, M. Sohrabi, A. Bayer, Elsevier, Amsterdam, 247–252, 2002.