A REPRESENTATIVE SURVEY OF INDOOR RADON IN THE SIXTEEN REGIONS IN MEXICO CITY

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Abstract — Mexico City, also called Federal District, covers an area of 1504 km^2, and has more than 8 million inhabitants. It is located more than 2200 m above sea level in a zone of high seismic activity, and founded on an ancient lake. At present it is one of the most crowded and contaminated cities in the world, with thermal inversions. Chemical contaminants and aerosol particles in the environmental air are high most of the year. Due to these geological, environmental and socioeconomic conditions, Federal District presents very peculiar characteristics, which are important for understanding the distribution and measurements of indoor radon concentration. In this work the results of 3 year (1998-2000) measurements of indoor radon levels in the Federal District are presented. For the detector distribution and measurements, the actual political administrative divisions of the Federal District, consisting of 16 very well defined zones, was used. Nuclear track detection methodology was selected for the measurement, with a passive device close-end-cup system with CR-39 (Lantrack®) polycarbonate as the detection material, with one step chemical etching, following a very well established protocol developed at the Instituto de Física, UNAM. Calibration was carried out at the Oak Ridge National Laboratory, and verification at the Instituto de Física chamber. The results show that the arithmetical mean values of the indoor radon concentration for each region of the Federal District follow a non-homogenous distribution.

INTRODUCTION

It is estimated that radon gas is the largest contributor to the collective exposure to natural radioactivity of the population in the world[1,2]. The inhalation of short-lived decay products of radon (^{222}Rn) accounts on average for about 50% of the effective dose to humans[3].

In European countries and the USA, indoor exposure to radon has received much attention, and national institutions dedicated to the study of radon have been established. In most of these cases, the goal is to reduce indoor radon levels below the recommended limit[4,5]. The general concern is that radon is perhaps the greatest environmental cancer threat[6]. There have also been extensive measurements to establish geographic patterns of indoor radon levels in developed countries[7,8]. Moreover, the legislation in some countries considers that indoor radon levels in working areas are a health risk. In Mexico, there have been few attempts to investigate the problem of indoor radon. But efforts need to be more consistent in developing countries in order to establish the radiological levels, and to determine the real health risk to the population.

In this work, measurements of radon levels during a 3 year period inside the metropolitan area are reported.

To obtain the measurements, the 16 political administrative regions were used as a reference for the survey. Modern houses, multifamily apartments and other buildings were considered in this work, in order to identify geological characteristics of the Federal District, for the emission of radon gas.

Two basic objectives are followed in this work: (a) to have representative results on indoor radon in the Federal District, and (b) to try to understand the correlation between geological and environmental characteristics and the radon emanations in the Federal District.

The Federal District is divided into 16 political administrative regions. It is located 2200 m above sea level, and as a consequence the oxygen concentration in the air is low. The city was founded on a lake bed, where water is still found underground (50 m deep) and the city is sinking an average of 12 cm a year. Moreover, Mexico City is considered a zone of high seismic activity with five earthquakes stronger than 7.5 on the Richter scale in the past 20 years. In addition, it feels the effects of the seismic zone on the Pacific coast of Mexico, where more than 1079 earthquakes were registered in 1998[9]. The predominant construction materials in Mexico City are clay bricks, adobe, concrete, granite and gypsum. All these materials have a relative high radon exhalation compared with other types of building materials such as wood and/or synthetic materials. Additionally, in Mexico City there are thermal inversions and aerosol contaminants most of the year.

The problem of indoor radon is aggravated by the high level of chemical contaminants in Mexico City, and also because of the high population density in areas where people live in densely packed high-rise apartments with poor ventilation especially on the first and second floors. All these environmental conditions need

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to be considered in connection with the measurements of indoor radon in order to understand the possible effects and health risks.

RADON MEASUREMENT METHODOLOGY

Nuclear track methodology is very useful for large-scale indoor radon measurements[10]. A passive close-end-cup system[11] with the CR-39 (Lantrack®) as detector material was used. One step chemical etching: 6.25 M KOH solution, at 60 ± 1°C for 16 h was done. This process is well established, with a protocol that is highly reliable[12]. The detection system was calibrated in the Oak Ridge National Laboratory (USA) radon chamber[13]. This calibration is certified each year at the Oak Ridge National Laboratory and verified every 6 months in our radon chamber. The detectors were automatically read with a digital image analysis system (DIAS)[14] and the data were automatically analysed by using a PC, with Microsoft Excel® software.

The measurement time was 3 years, with exposure times for the detectors of 3 months (84 days) during these 3 years (from January 1998 until December 2000). A total of 150 dwellings in each political administrative region (16) of the Federal District were measured, with a grand total of 2400 measurements per each period of 3 months, during the 3 years. The passive devices with the detection material CR-39 (Lantrack®) were hung and exposed in the living rooms of the appartments or houses. The selection of dwellings was random, as determined by public interest and participation.

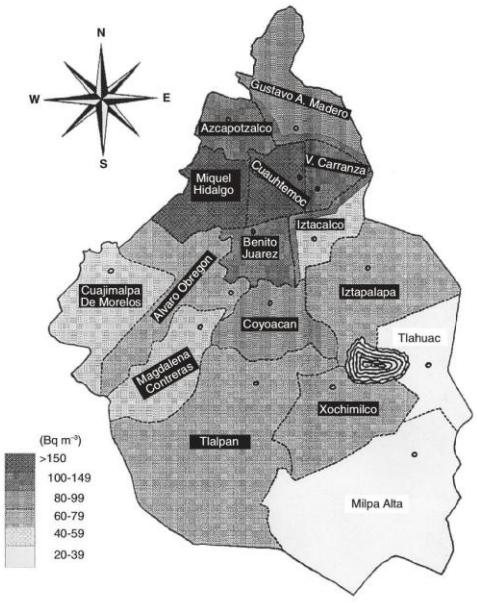

Figure 1. The distribution of indoor radon in the 16 administration regions of Mexico City. Results are given as the arithmetic mean values of the concentration.

CLIMATE

In general, the climate of the Federal District is similar throughout the year, with a variation from 12.2°C to 17.4°C, with an average of 15.1°C[15]; this is very important because the climate is the cause of the patterns of behaviour in the ventilation habits. On the other hand, Mexico City has a great variety of building styles depending of the different zones and on the economic and social level. In general there are no air conditioning systems in the dwellings.

Alvaro Obregón, Benito Juarez, Coyoacán, Iztacalco, Iztapalapa, Magdalena Contreras, Tlalpan and Xochimilco districts were considered rural until 1965, but are now part of the city. Tlahuac, Milpa Alta and Cuajimalpa are the new developing city areas, but until 1990 the rustic style of dwellings was predominant.

RESULTS

The 16 political administrative zones of the Federal District included in this study (Figure 1) cover a total area of 1504 km^2[16], with a population of 8,605,239 inhabitants, and a total of 2,132,413 dwellings[17]. The population and dwelling distribution, the name of each political administrative zone, the code used for this work and the mean arithmetical and their arithmetical standard deviation, high and low radon concentration values, measured during the three years are given at the Table 1.

INDOOR RADON DISTRIBUTION

From the analysis of the data, the indoor radon concentration distributions associated with the political administrative zones can be established as shown in Figure 2, with arithmetical mean values.

The highest radon concentration mean values found in the Federal District after 3 years of measurements corresponding to 155 Bq m^{-3} in Cuauhtemoc, 150 Bq m^{-3} in Miguel Hidalgo, 132 Bq m^{-3} in Venustiano Carranza and 121 Bq m^{-3} in Benito Juárez. This will be called region I, and is the north of the city, where the ancient lake was located with similar geological characteristics. It is also the oldest area of the city with some dwellings that are 150 or more years old. Local values are confirmed by other authors with measurements in these zones[18–21]. The maximum values of radon concentration levels were also found in this region (Table 1).

The neighbouring area of Azcapotzalco and Gustavo A. Madero (region II), located in the north and north-

west of region I, show radon concentration mean values of 100 Bq m^{-3} and 97 Bq m^{-3}, respectively. The higher values of radon concentration in this zone, occur in the border areas with the region I (Figure 2).

Iztacalco is a low economic level zone, where dwellings are rustic and windows and doors are not well sealed. In general, this region had a low radon concentration level with a mean value of 53 Bq m^{-3}. Again its higher concentration values occur in the border areas with region I.

Coyoacan, Alvaro Obregón and Tlalpan are three political administrative zones located in the south and southwest of the city, and we call it region III. Their measured concentration mean values are 83 Bq m^{-3}, 72 Bq m^{-3} and 77 Bq m^{-3}, respectively. This region was founded on the slopes of the hills of volcanic origin, bordering the ancient lake, with the corresponding geological differences compared to region I.

In the political administrative zones of Iztapalapa and Xochimilco, a lake and water channels have persisted up to now, and some of the houses are built on the borders of the channels. The radon concentration measurements show mean values of 65 Bq m^{-3} for both zones. Because the houses are built in rustic styles, and the windows and doors are not sealed, remaining open most of the day, with the wind circulating through the rooms, the radon concentrations are low.

Magdalena Contreras and Cuajimalpa in the southwest and Milpa Alta and Tlahuac, in the southeast of the city, presented low radon concentration mean values between 35 Bq m^{-3} and 52 Bq m^{-3}. The same explanation based on the ventilation habits of the people, living in rustic dwellings is also valid. These political administrative regions are considered suburban areas with small towns surrounded by country zones. Cuajimalpa is undergoing fast development, with high department buildings, and the conditions of indoor radon can change in the near future.

CONCLUSIONS

This work presents the results of 3 years of indoor radon levels, measured in periods of 3 months of exposure time during the 3 years in the 16 political administrative regions, with the same methodology and protocols, involving a total of 2400 dwellings in Mexico City only.

From the mean values calculated, one zone presents an indoor radon concentration of 155 Bq m^{-3}, only 5 Bq m^{-3} above the 150 Bq m^{-3} recommended limit.

Considering the mean values of radon concentration found, the Federal District can be considered as a location of low radiological risk from indoor radon.

The multiple telluric movements and the formation of the ancient lake are not specific factors that influence the indoor radon concentration in the Federal District.

The benign climate in the Federal District is the

Table 1. Name, code, population and number of dwellings in each political administrative region; and its high, low and arithmetic mean with their standard deviation, of the indoor radon levels measured in the living room.

	Code	Political administrative zone	Population (in habitants) (×1000)	Total number of dwellings (×1000)	Radon concentration (Bq m^{-3})		
					High	Low	Arithmetic mean
1	AO	Alvaro Obregón	687	165	98	55	72 ± 7.8
2	AZ	Azcapotzalco	441	111	147	60	100 ± 9.9
3	BJ	Benito Juárez	360	116	168	69	121 ± 6.3
4	CY	Coyoacan	640	165	138	29	83 ± 9.3
5	CJ	Cuajimalpa	151	34	54	15	49 ± 4.7
6	CH	Cuauhtemoc	516	150	173	58	155 ± 8.1
7	GM	Gustavo A. Madero	1236	298	143	40	97 ± 7.5
8	IC	Iztacalco	411	100	82	28	53 ± 6.9
9	IZ	Iztapalapa	1773	408	87	37	65 ± 6.3
10	MC	Magdalena Contreras	222	53	72	23	52 ± 6.3
11	MH	Miguel Hidalgo	353	97	224	53	150 ± 8.7
12	MA	Milpa Alta	97	22	63	20	35 ± 4.5
13	TL	Tlahuac	303	70	55	17	39 ± 4.3
14	TP	Tlalpan	582	142	91	33	77 ± 7.2
15	VC	Venustiano Carranza	463	118	186	42	132 ± 7.1
16	XC	Xochimilco	370	83	79	15	65 ± 4.3

cause of the ventilation habits, with open windows and doors most of the day. The socioeconomic level makes the people live in rustic style dwellings with unsealed windows and doors. Both conditions make the Federal District special regarding indoor radon measurements.

Finally, this information about the 3 year measurements of the indoor radon levels in dwellings of Mexico City will be very useful for future studies.

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