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The Spanish experience on HBRA

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Abstract. During the last two decades, the Department of Medical Physics of the University of Cantabria has been involved in the development of a Radiation Protection Programme throughout Spain. In the framework of this Programme, over 5000 measurements of indoor radon were carried out nationwide. A geometric mean radon concentration in air of 45 Bq m^{-3} with a standard deviation of 2.7 and a range of variation from 10 to 15,400 Bq m^{-3} were found. After that, several regional surveys were conducted to determine exposure to natural sources of radiation for people living in the vicinity of the old Spanish Uranium Mines and the Spanish Nuclear Power Stations as well as for those living in the populated areas of Sierra de Guadarrama close to Madrid city and Villar de la Yegua town. This paper summarizes the main results obtained from the measurements performed paying special attention to those concerning the High Background Radiation Areas of the country.

Keywords: Dose; Radon; Radiation; Survey

1. Introduction

Environmental radioactivity, in special radon measurements, and radiation protection have been the subjects on which the Department of Applied and Medical Physics of the University of Cantabria (Santander, Spain) has focussed his research efforts during the last 20 years. From a nationwide point of view, it could be said that the Spanish Radon Programme began in 1988 with the development of a national survey in Spanish houses [1]. The data coming from the 2000 measurements carried out in this survey represented a valuable basis to face rigorously the radon issue in Spain.

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In addition, since 1991 the Spanish Nuclear Safety Council, together with the National Uranium Company and some Universities have developed the so-called MARNA project [2]. This project is a nationwide study with the aim of estimating potential radon emission from external gamma dose rates and radium calculations taking into consideration geological parameters and empirical correlations found between outdoor external gamma dose rates and ^{226}Ra concentration in soil.

Bearing in mind the information obtained from both studies, several regional surveys were conducted to get a more detailed knowledge of the exposure to natural sources of radiation for people living in specific areas. Not only indoor radon but also external gamma dose rate and radioactivity in soils were measured in the vicinity of the old Spanish Uranium Mines and of the Spanish Nuclear Power Stations, as well as in populated areas as Villar de la Yegua Town and the named Sierra de Guadarrama.

2. Methods

Exposure to natural sources of radiation to people living in the mentioned areas was determined from indoor radon measurements, external gamma dose rate and radioactivity in soils measurements. In all the surveys described in this paper, the following procedures were carried out.

Indoor radon measurements were performed by using track etched detectors CR-39 exposed for a 6-month period in order to evaluate average radon concentration values. In all the measurements, a seasonal correction factor was assumed in order to make the results obtained over a 6-month period representative of the actual mean annual indoor radon concentration [3].

External gamma radiation was measured with a Mini-Instruments Environmental Monitor type 6-80 with an energy compensated Geiger Muller tube MC-70, specially designed to measure environmental levels of gamma.

The radioactivity in soil determinations were focused on measuring the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K. All the soil samples were dried in an oven at 100 °C for 24 h, reweighed to determine the water content, sieved to remove stones and pebbles and crushed to pass through a 1-mm mesh sieve. Finally, the prepared sample was packed in a sealable 250 mL PVC can and left for at least 4 weeks before counting by gamma espectrometry in order to ensure that radioactive equilibrium between ^{226}Ra , ^{222}Rn, and short-lived radon progeny was reached. Gamma espectrometry measurements were made using a low background HPGe detector with a relative efficiency of 20% and a resolution of 1.86 keV at 1.33 MeV.

3. Description of surveys and results

3.1. Surroundings of the Spanish Nuclear Power Plants

During 1998 and 1999, financially supported by the Spanish Nuclear Safety Council, regional surveys were conducted to evaluate natural radiation exposure of the people living in the vicinity of the Spanish nuclear power stations. There are six facilities working in the country and the population of these regions is about 200,000.

A remarkable result was found in the surroundings of Almaraz nuclear power plant in the province of Caceres where the highest mean annual effective dose to the population was found [4]. The estimated value, of 4.07 mSv $year^{-1}$, is 1.6 times higher than the national average value. The reason of this significant difference in dose value with the other nuclear power stations was the high radon concentrations found in homes. Thus, in order to perform a more accurate assessment of the dose coming from radon in this area, a new and more extensive survey on indoor radon was carried out in the named Campo Arañuelo region around the Almaraz nuclear power station. This study revealed the presence of a high radon level area called La Vera in the northern side of the Campo Arañuelo region. It was found in La Vera a 9% of houses with indoor radon concentrations higher than 400 Bq m^{-3}. In addition, the new dose assesment gave a value of 6 mSv per year in La Vera, with a maximum of 25 mSv per year estimated in Jarandilla, a town belonging to the former area where 30% of houses had radon concentrations over 400 Bq m^{-3}.

3.2. Vicinity of the Spanish old Uranium Mines

From 2000 to 2001 and under the sponsorship of the Spanish Nuclear Safety Council, the surveys in the six uranium-mining areas in the country were carried out. The exploitation period ranged from 1950 to 1980, and between 1987 and 1996, a general decommissioning plan was carried out. One of the main objectives of the plan was to reduce and control radon flow and contamination of water. The population of these areas is over 400,000 inhabitants.

The highest geometric mean radon concentration and annual effective dose for natural sources, of 111 Bq m^{-3} and 5.1 mSv $year^{-1}$, respectively, were found in the surroundings of Albala uranium mine [5]. Estimated mean annual effective doses for the six areas studied ranged between 3.2 and 5.1 mSv per year, which is between 1.2 and 2 times higher than the national average value. A 14% of houses over 400 Bq m^{-3} were found in the vicinity of the Albala uranium mine.

3.3. Sierra de Guadarrama

The area called Sierra de Guadarrama situated in the North of the province of Madrid have been subject of another regional survey. The first national study showed high percentages of houses with radon concentrations higher than 200 and 400 Bq m^{-3} (European Union recommendation concerning radon concentrations in new and old houses, respectively) [6]. Due to the prevalence of granitic rocks in the soil composition of this area and the considerable residential growth (the population of this region has been increased from about 500,000 people in 1990 to 1.5 million in 2000) a regional survey is now ongoing from 2002.

Until now, the indoor radon measurements indicate that the 14% of houses have levels above 400 Bq m^{-3} and 30% above 200 Bq m^{-3}. In addition, the geometric mean radon concentration is 180 Bq m^{-3} which is about four times higher than the national average value.

3.4. Villar de la Yegua town

Perhaps the most important high background radiation area in Spain is the Villar de la Yegua town where the highest indoor radon concentration, up to 25,000 Bq m^{-3}, have

been found, and effective doses coming from natural sources as high as 40 mSv per year has been estimated. Several surveys have been carried out from 1988 to now, confirming Villar de la Yegua as a high radon level area [7]. The main results concerning radon concentration show a geometric mean of 818 Bq m^{-3}, 18.2 times higher than the national value, and percentages of houses with concentrations above 400 and 1000 Bq m^{-3}, of 75% and 25%, respectively.

4. Conclusions

The results of the presented surveys will be used as a data base source for the development of even more specific studies in the regions where high radon levels have been detected in order to get a better knowledge of the sources of radon in houses and decide if countermeasures for radon remediation in dwellings should be taken.

The comparison between the MARNA Project's predicted map of potential indoor radon concentration and those obtained from the above mentioned surveys shows a good correlation [8]. This agreement has been found on a national basis (scale 1:1,000,000) showing the interest of maps as those from MARNA Project when data as shown are available, minimizing costs and efforts in the development of national radon programme.

Nevertheless, it is interesting to test the correlation between predicted and measured average indoor radon concentration for lower scales (1:50,000). To this end, a collaborative project between the research groups MARNA (Nuclear Safety Council) and RADON (University of Cantabria) is now ongoing in a geographical area for which enough geological information exists and present-day measurements of radon concentrations in the air are available.

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