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Indoor ^{222}Rn survey in Zacatecas State, Mexico

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Abstract

As part of a program for discovering whether afflicted areas exist, indoor ^{222}Rn concentrations in the State of Zacatecas were surveyed, ^{222}Rn concentration being measured by γ-ray spectrometry of radon decay products adsorbed into charcoal canisters. A survey was implemented during Summer 2001: 228 dwellings in the state were tested by taking mean 254 measurements. Concentrations exhibited a left-skewed distribution of indoor ^{222}Rn, showing overall average, minimum, and maximum concentrations of 67, 26, and 511 Bq m^{-3}, respectively. Only seven of the measurements (2.7%) were found equal to or greater than the US EPA action limit (148 Bq m^{-3}). Thus, we conclude that the indoor radon environment in Zacatecas State is under US EPA action limit. The few high concentration spots suggest that geological conditions rather than construction materials may be the determinant factor.

Keywords: ^{222}Rn; Radon progeny; Charcoal adsorption; Canister; γ-ray spectrometry

1. Introduction

From a human perspective, ^{222}Rn and its progeny are one of the most significant natural sources of radiation exposure to the population (Oikawa et al., 2003). Lack of information in Mexico makes it necessary to assess indoor ^{222}Rn concentrations levels. The radioactive gas ^{222}Rn is generated from ^{226}Ra contained in minerals that are widely distributed in the Earth's crust and are released into the surrounding air. Production rates from the soil depend upon the geological characteristics of the soil itself and its underlying geological strata (Lévesque et al., 1997). Detailed analysis of the geological environment of house foundations has been related to the radon concentration of air; permeability of soil and house design are determinants to the risk for high radon concentrations (Friis et al., 1999). Inhalation of radon decay products has been linked to an increase risk of lung cancer (NRC, 1999).

Distribution of environmental ^{222}Rn concentration in many countries has been reported; for the US indoor concentration is documented as 54 Bq m^{-3} average (Steck et al., 1999). In Mexico, we found a lack of data and have therefore carried out this study to establish whether high concentration of ^{222}Rn could be found in certain municipalities of Zacatecas State.

2. Material and methods

2.1. Radon survey and the State of Zacatecas

The State of Zacatecas is located in north central Mexico; it covers an area of 75,040 km^2, is divided into 57 municipalities, and is mostly desert or semi-desert characterized by sedimentary rocks with predominance of volcanic Mesozoic and Cenozoic plutonic rock. The northwestern part appears to have some Paleozoic metaformic rocks. In addition to effusive rocks, igneous intrusive rocks from the Cenozoic cover part of the state (Secretaria de Energía y Minas e Industria Paraestatal (SEMIP), 1991). The State of Zacatecas is one of Mexico's largest producers of silver, it has an annual average temperature of 16 °C and the rainfall average is 510 mm. The ^{222}Rn survey was implemented with the collaboration of State governmental health ministries, thus radon detectors were installed in the all municipalities across the State. The target population consisted of dwellings inhabitants. Survey participants received introductory

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brochures explaining the radon concern and the survey procedures. Subsequently, they received radon detectors with instruction and data sheets. Indoor detectors were placed at least 1.5 m above ground and at least 1 m away from doors or windows, and were located mainly in bedrooms and living rooms.

Dwellings surveyed for indoor radon can be characterized by referring to their construction materials as follows. The floors were 63% cement, 33% ceramic tile, and 4% earth. The walls were 43% of brick, 37% of adobe, and 20% cement block. The roof were 42% concrete, 40% brick, 10% metal sheet, and 8% earth with wood frame. The dwellings have a typical distribution such as one floor, a kitchen, a bath, two or three bedrooms, patio, and natural ventilation through windows.

2.2. Diffusion barrier charcoal canister (DBCC) and radon measurement

The ^{222}Rn concentration measurements were performed using an assembly of DBCC, which contain 70 ± 1 g of activated carbon ($1.18 \times 3.35\,mm^2$ mesh). They have a diameter of 10 cm and height (including the lid) of 4 cm, and are made by F&J Specialty Products (Ocala, Florida). The DBCC are passive detectors based on the adsorption of gases that includes radon by activated charcoal. At the time of exposure to an atmosphere containing radon, the latter is adsorbed and desorbed at a rate dependent on environmental factors such as temperature, other present gases, and humidity. Passive collection of ^{222}Rn is described by Cohen and Cohen (1983); George (1984); Prichard and Mariën (1985). Once inside the DBCC, ^{222}Rn decays reaching radioactive equilibrium with its short-lived radon progeny whose activity can be measured by counting γ-ray emissions. The measurements are of a passive nature, not requiring any energy, and allow continuous adsorption and desorption of gases and integration over the variation of the concentration, yielding an average that reproduces the conditions of ^{222}Rn concentration in the atmosphere divided by the exposure time. After exposing a DBCC, we waited for at least 3.5 h to allow radon daughters to reach the radioactive equilibrium between radon and its short-lived decay products; then canisters were taken to the acquisition γ-ray system Fig. 1.

The γ-ray spectrometry system consisted of a high purity germanium (HPGe) detector (EG&G-ORTEC, Oak Ridge, Tennessee) connected to a multi-channel acquisition card using GammaVision-32 software; the acquisition system was surrounded by a lead shield to reduce the background

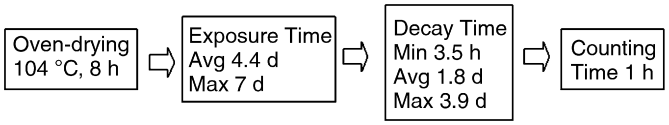

Fig. 1. Diffusion barrier charcoal canisters (DBCC) undergoing process for each test, showing oven-drying, exposure, decay, and counting times.

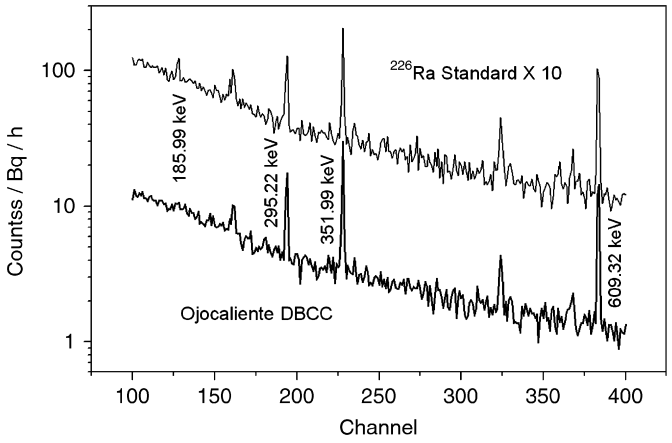

Fig. 2. γ-ray spectra of ^{226}Ra standard for comparison against a typical ^{222}Rn progeny of an exposed DBCC at Ojocaliente City, main town of Ojocaliente municipality.

counting rate. Standard procedure by Gray and Windham (1987, 1990) for ^{222}Rn measurements was used with slightly modifications. Final activities of the ^{222}Rn progeny ^{214}Pb, and ^{214}Bi were measured by counting their γ-ray energies 295.22, 351.99, and 609.32 keV. Fig. 2 shows typical γ-rays spectra produced by the HPGe spectrometry system; 1024 channels were used to acquire the spectra using 1 h as counting time.

Our reference standard consisted of a radium-226 aliquot of calibrated solution (NIST SRM 4965) with an activity of 31.4 ± 0.6 Bq, added uniformly onto charcoal using 0.1 M HCl aqueous solution. The DBCC was then oven-dried at 104 °C for 8 h and allowed to cool. It was reassembled and tightly closed with silicon and plastic rubber tape, and stored for 30 days to ensure secular equilibrium with ^{222}Rn and short-lived ^{222}Rn progeny.

Quantitative determination of the ^{222}Rn concentration was made by comparing an exposed DBCC with the γ-ray spectra coming from the standard with radium-226. The minimum detectable activity (MDA) was set to 22.7 Bq m^{-3} for 7 days exposed DBCC counted within 4 decay days. Duplicate measurements were applied to evaluate the precision of the measurement (US Environmental Protection Agency (EPA), 1993). Precision was evaluated with the statistic parameter of coefficient of variation (CV) taken 10% of the measurements.

3. Results and discussion

Evaluated measurements precision CV gives a value of 4.9%, implying good agreement with the real value, which were made for indoor concentrations below 148 Bq m^{-3}. Uncertainty of ^{222}Rn measured concentrations agrees with Cohen (1986) to be in within +/−20% for this procedure. Our findings are showing in the Table 1.

Concentrations, exposing, decaying, and counting times conducted to 45.6% of all measurements were above the MDA. The distribution of indoor ^{222}Rn concentrations of