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Radioisotopes present in building materials of workplaces

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ABSTRACT

The isotope ^{222}Rn is responsible for approximately half of the effective annual dose received by the world population. The decay products of ^{222}Rn interacting with the cells of biological tissue of lungs have very high probability to induce cancer. The present survey was focused in the evaluation of activity concentration of ^{222}Rn and other radioisotopes related to the building materials at workplaces at Curitiba – Paraná State. For this purpose, the instant radon detector AlphaGUARD (Saphymo GmbH) was used to measure the average concentrations of ^{222}Rn in building materials, which were also submitted to gamma spectrometry analysis for qualitative and quantitative evaluation of the radionuclides present in samples of sand, mortar, blue crushed stone (Gneissic rock), red crushed stone (Granite), concrete and red bricks. The main radionuclides evaluated by gamma spectrometry in building material samples were ^{238}U/^{226}Ra, ^{232}Th and ^{40}K. These measurements were performed at the Laboratory of Applied Nuclear Physics of the Federal University of Technology – Paraná in collaboration with the Center of Nuclear Technology Development (CDTN – CNEN). The results of the survey present the concentration values of ^{222}Rn related to construction materials in a range from 427 ± 40.52 Bq/m³ to 2053 ± 90.06 Bq/m³. The results of gamma spectroscopy analysis show that specific activity values for the mentioned isotopes are similar to the results indicated by the literature. Nevertheless, the present survey is showing the need of further studies and indicates that building materials can contribute significantly to indoor concentration of ^{222}Rn.

1. Introduction

Radon (^{222}Rn) is a radioactive gas that can be found naturally in inhabited environments and dwellings. Its concentration and activity in air present the variation according to region and mineral composition of the soil. This radioactive gas is produced by alpha decay of radium (^{226}Ra), which belongs to the radioactive series of uranium (^{238}U).

^{222}Rn is about seven to eight times heavier than air and therefore it tends to accumulate at an altitude close to the ground level that corresponds to the air breathed by humans. The study of ^{222}Rn is important because it is a radioactive gas that emitting alpha particles (α) produce 8 radioactive successive decay products (one half undergoes alpha decay and another half is beta radioactive), which can interact with the cells of biological tissue of lungs. This radiation has very high probability to induce the lung cancer (Hopke et al., 2000).

According to the research conducted by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2006) radon and its decay products are responsible for approximately half of the effective dose received by the population from natural radiation sources.

Typical building materials may contain significant levels of radium as well as other natural radioactive isotopes of uranium and thorium. Considering the high porosity of construction materials this may cause rather exhalation rate of ^{222}Rn and its accumulation in air of dwellings. Thus, the building materials can represent an important source of indoor radon activity (IAEA, 2003).

Materials such as cement, concrete, sand, clay bricks, granite, marble, limestone and gypsum represent a source of exposure because they contain radionuclides like potassium (^{40}K), uranium (^{238}U), thorium (^{232}Th) and its decay products (Fathivand et al., 2006; Turhan et al., 2008; Mehdizadeh et al., 2011).

According to the European Commission (1999), when an individual inhabits an environment built from concrete blocks that contain an average concentrations of radium activity, thorium and potassium

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equal 40 Bq/kg, 30 Bq/kg and 400 Bq/kg, respectively, this will cause an increase of his effective annual dose of about 0.25 mSv/year.

International Agencies such as the Environmental Protection Agency of the United States (USEPA, 2016) and the International Commission on Radiological Protection (ICRP, 1993, 2010, 2014) have elaborated guides of protection measures and radon prevention as well as recommendations for reduction of radon levels in air of residential areas and workplaces.

The ICRP states that the value of 300 Bq/m^3 meets the basic standards of safety standards recommended by agencies such as the International Atomic Energy Agency (IAEA), United Nations Environment Programme (UNEP), World Health Organization (WHO), The European Atomic Agency Community (EURATOM), among others.

The Commission also states that the radon reference limits should be applied in mixed-use buildings that are used both by individuals and by the public workers (ICRP, 2014).

Radon surveys concluded in different regions of Brazil present results that confirm rather high concentrations of ^{222}Rn in air of dwellings (Corrêa, 2006; Veiga et al., 2003; Geraldo et al., 2005; Neman, 2000; Santos, 2010), which in some cases reaches the values from 200 to 600 Bq/m^3. During the last years, an increase of experimental studies concerning ^{222}Rn concentration in air of Brazilian homes and dwellings was observed. Unfortunately, it is not sufficient yet for the evaluation of the overall population exposure to this sort of radiation.

The aim of the present research was to study the correlation between the radon activity in air of workplaces and concentration of other radionuclides present in collected samples of building materials from those locations.

2. Materials and methods

The present survey was focused in the evaluation of activities concentration of ^{222}Rn and other radioisotopes related to the building materials at workplaces at Curitiba – Paraná State (Brazil), which is a big industrial city located in Southern Brazil. The urban area of the city is situated at the First Paraná Plateau located between the Serra do Mar Mountain and Devonian Cliff which makes part of the hydrographic basin of Alto Iguaçu River. The substrate soil of Paraná, contains rocks, which are mostly classified as metamorphic. At this region a great variety of igneous intrusive rocks could be found, including granites and granitoids (MINEROPAR, 2001; Pereira et al., 2013; Salamuni et al., 2003). This fact leads to the conclusion that building materials from this region could contribute considerably to the concentration of radon in air of dwellings and workplaces of this region since granites usually contain significant amount of the precursor (parent) radioisotopes as uranium and thorium.

The samples of sand, mortar, blue crushed stone (Gneissic rock, mesh size of approximately 30 mm), red crushed stone (Granite, mesh size of approximately 38 mm), crushed concrete and red bricks (characteristic size of 80 mm) were randomly chosen and separated from different construction places of Curitiba metropolitan area, mainly from recently build new academic sciences, research and laboratory buildings of the Federal University of Technology – Paraná (UTFPR). All samples were submitted to analysis concerning the exhalation of ^{222}Rn as well as the evaluation of radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K, which are the main elements associated with human exposure to radiation from building materials.

From collected building materials samples of 1 kg were separated and stored in sealed in glass vessels (Fig. 1) for 40 days while ^{222}Rn reaches the secular equilibrium. Accumulated radon activity in air of sealed bottles was measured using the instant radon detector AlphaGUARD (Saphymo GmbH).

For the purpose of background evaluation, an empty glass vessel was separated and used as reference in each measurement being stored at the same conditions as the glass vessels with material samples. Filters, hose and connectors were added in the air circuit measurement as shown in Fig. 2. All components and connections were tested for possible points of entry of external air as well as leakage of accumulated gas that could alternate the results obtained with the AlphaGUARD.

Fig. 1. Brick sample stored in a glass vessel to measure the ^{222}Rn concentration.

Every measurement consists of three major steps: (1) AlphaGUARD ventilation using the open circuit, (2) background measurements, and (3) measurements of ^{222}Rn liberated by building material sample and accumulated within the internal volume of the sealed bottles. All steps were performed using the air pump (AlphaPUMP), supplied together with the AlphaGUARD, which operated with air flow rate of 0.5 L/min. The AlphaGUARD was set to operate in mode of "1 min/flow" suggested by the User Manual.

The ventilation of the AlphaGUARD was done using open-air circuit when the air pump remained turned on for 40 min approximately, so that the detected alpha activity reaches the lowest level before the background evaluation step (Fig. 3).

Background measurements were performed during 1 h using a closed air circuit that prevents the entry of external air into measurement system. In this second step the air circulation circuit contains the precision rotameter, two dust filters and safety glass vessel that is included in Aquakit of AlphaGUARD system. All those elements were used in the measurements in order to ensure that possible dust particles from the samples will not penetrate inside the ionization chamber of AlphaGUARD.

At the third step, the glass vessels with building materials samples were connected to the AlphaGUARD and submitted to evaluation during two hours. This step was executed using the air pump operated with airflow rate of 0.5 L/min. The AlphaGUARD detector was set to operate in mode of "1 min/flow" following the recommendations of the User Manual. Every step of materials evaluation was concluded by background control measurement to ensure that there was no contamination of the AlphaGUARD by any particles or dust from the samples.

The volume of each sample of building materials, because of its irregular form, was found using the Archimedes' principle by measuring their weight with a precision-scale in air and when they were immersed in water.

Other samples of the same building materials were sent to the Laboratory of Natural Radioactivity of the Center of Nuclear Technology Development (CDTN) for qualitative and quantitative assessment of natural radionuclides using gamma spectrometry. This analysis was performed using a gamma spectroscopy system (CANBERRA) with hyper pure germanium semiconductor detector (HPGe) solid state with high efficiency (15%) and resolution, located

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