Gamma exposure due to building materials in a residential building at Peruíbe, São Paulo, Brazil

C. D. Cazula; M. P. Campos; B. P. Mazzilli

Gamma exposure due to building materials in a residential building at Peruíbe, São Paulo, Brazil

Instituto de Pesquisas Energéticas e Nucleares, Av. Prof. Lineu Prestes 2242, CEP 05508-000, São Paulo, Brasil

cdcazula@ipen.br, mpcampos@ipen.br, mazzilli@ipen.br

Gamma exposure due to building materials in a residential building at Peruíbe, São Paulo, Brazil

C. D. Cazula[1]; M. P. Campos[1]; B. P. Mazzilli[1]

[1] Instituto de Pesquisas Energéticas e Nucleares
Av. Prof. Lineu Prestes 2242, CEP 05508-000, São Paulo, Brasil

Abstract

It is well known that most building materials contain traces of natural radionuclides. Exposure in dwellings depends on the concentration of building materials and soil down building. Building materials are an important source of indoor gamma exposure, especially in multistoried buildings, where the contribution of the soil radionuclides to the dwellers exposure is lower than at story houses. The aim of this study is to determine the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in materials and construction products used in the construction of a multistoried building in Peruíbe, São Paulo, Brazil by high-resolution gamma-ray spectrometry.
Keywords: Natural radioactivity; Building materials; Gamma-ray spectrometer

Introduction

Human beings are inevitably exposed to radiation from background sources. Radionuclides present in the Earth´s crust contribute to the population radiation exposure. According to the United Nations Scientific Committee on the Effects of Atomic Radiation, this contribution corresponds to 20% of the average worldwide radiation exposure (2.4 mSv y^{-1}) [1].

Knowledge of radioactivity levels in buildings is clearly of fundamental importance to the assessment of people exposure, since most of individuals spend most time indoors. It is well known that most building materials contain traces of natural radionuclides. Materials derived from rock and soils contain mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series and the radioactive isotope of potassium (^{40}K). In the uranium series, the decay chain segment starting from radium (^{226}Ra) is of radiological concern and, therefore, reference is often made to radium instead of uranium. The worldwide average concentrations of radium, thorium and potassium in the earth's crust are about 35 Bq kg^{-1}, 35 Bq $kg^{-1}$and 400 Bq kg^{-1}, respectively. Exposure in dwellings depends on the concentration of building materials and soil down building. Building materials are an important source of indoor gamma exposure, especially in multistoried buildings, where the contribution of the soil radionuclides to the dwellers exposure is lower than at story houses.

Radiological hazard of natural radioactivity in building materials can be assessed through the hazard estimating models, such as radium equivalent activity (Ra_{eq}) and activity concentration index (I).

The aim of this study is to determine the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in materials and construction products used in the construction of a multistoried building in Peruíbe, São Paulo, Brazil (Fig 1) by high-resolution gamma-ray spectrometry. These results were used to evaluate the activity concentration index (I) and the annual effective dose due to external gamma exposure for dwellers in order estimate the exposure risk arising due to the use of these materials.

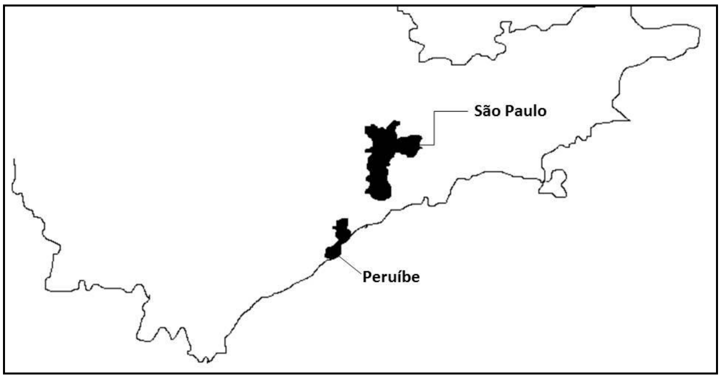

Figure 1: Peruíbe, State of São Paulo, Brazil

Material and methods

A total of 10 samples of building materials (red brick, cement, grout, clay brick and sand) were crushed and packed in 100 mL polyethylene flask and sealed for about four weeks prior to the measurement in order to ensure that the secular equilibrium has been reached between ^{226}Ra and its short half-life decay products.
Activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the samples of building materials were measured by gamma-ray spectrometry with a hyperpure germanium detector Canberra model GX2518 associated to a DSA1000 electronic module, comprising high voltage supplier and multichannel analyzer. The relative efficiency of the detector is 25% and the effective energy resolution for the 1.33 MeV ^{60}Co gamma transition is 1.9 keV. The detection efficiency curve was calculated for aqueous solutions containing certified activity concentrations of gamma-ray emitters covering a wide range of energies, encompassing the radionuclides energies determined in the samples. Background measurements were taken and subtracted in order to get net counts for the sample. Samples were measured during an accumulation time of 86000 seconds. All spectra were analyzed with the Interwinner 4.0 of Eurisys Measurements Incorporation software for personal computer analysis of gamma-ray spectra from HPGe detectors. The activity concentration of ^{40}K was determined directly by its own gamma-ray peak at 1460.8 keV, while concentrations of ^{226}Ra and ^{232}Th were calculated based on the weighted mean value of their respective decay products in equilibrium. The activity concentration of ^{226}Ra was determined using the 295.2 and 351.9 keV gamma rays from ^{214}Pb and the 609.3 and 1120.3 keV from ^{214}Bi. The activity concentration of ^{232}Th was

determined using the 338.5, 911.1 and 968.9 keV photopeaks from ^{228}Ac and the 727.2 keV photopeak from ^{212}Bi [2].

Results and discussion

Radionuclides Activity Concentration

Building materials samples were analyzed for ^{226}Ra, ^{232}Th and ^{40}K activity concentrations. Table 1 presents the average results of concentrations and respective standard deviations, as well as the range of literature values [3, 4, 5, 6] for the similar materials. Samples were collected and analyzed in triplicate.

Table 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in building materials

Building material	Radionuclides activity concentration (Bq kg^{-1})					
	Ra-226		Th-232		K-40	
	This work	Data from literature [3, 4, 5, 6]	This work	Data from literature [3, 4, 5, 6]	This work	Data from literature [3, 4, 5, 6]
Red brick	73 ± 0.3	54 – 205	97 ± 1	27 – 93	735 ± 1	377 - 1256
Cement	14 ± 0.1	40 - 268	42 ± 4	20-192	243 ± 2	160 – 629
Grout	16 ± 2	------	13 ± 2	------	207 ± 23	-------
Clay brick	60 ± 0.3	27 - 37	42 ± 1	31 – 62	1279 ± 176	731 - 897
Sand	73 ± 4	15 - 180	173 ± 7	28 - 61	550 ± 3	180 - 1118

Radiological parameters

Since the distribution of natural radionuclides in building materials is not uniform, a common radiological index (Raeq) had been introduced to represent the specific radioactivity level of ^{226}Ra, ^{232}Th and ^{40}K by a common index, which takes into account the radiation hazards associated with them [7].
The radium equivalent activity was calculated based on the estimation that 1 Bq kg^{-1} of ^{226}Ra, 0,7 Bq kg^{-1} of ^{232}Th and 13 Bq kg^{-1} of ^{40}K produce the same equivalent gamma-ray dose.

$$Ra_{eq} = C_{Ra} + 1.43\, C_{Th} + 0.07\, k \tag{1}$$

Where:

C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq kg^{-1}.

The activity concentration index (*I*) was calculated as suggested by the European Commission [8]:

$$I = \frac{C_{Ra}}{300} + \frac{C_{Th}}{200} + \frac{C_K}{3000} \quad (2)$$

where

C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq kg^{-1}.

According to the European Commission recommendations, for materials used in bulk amounts (e.g. concrete), the activity concentration index (*I*) must be less than 1 and for superficial and other materials with restricted use, *I* must be less than 6 to keep the external dose below 1 mSv y^{-1}.

The indoor effective dose for external exposure due to building materials was performed following UNSCEAR procedures through the standard room concept, according to equation:

$$E = T \cdot f \cdot b \cdot 10^{-6} \cdot \mathrm{D}_R \cdot mi \quad (3)$$

Where:

E is the effective dose for external exposure, *T* is 8760 hours per year, *f* is the fraction on time spent indoors (0.8), *b* is the conversion factor of absorbed dose in air to effective dose (0.7 Sv Gy^{-1}), D_R is gamma absorbed dose rate in air and m_i is the mass fraction of material in the standard room.

The gamma absorbed dose rate in air (D_R) due to gamma ray emissions from natural radionuclides in the building materials was calculated according to the following equation [1]:

$$D_R = (q_{Ra} \cdot C_{Ra} + q_{Th} \cdot C_{Th} + q_K \cdot C_K) \quad (4)$$

Where:

q_{Ra}, q_{Th} e q_K are conversion factors from activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively to absorbed dose in indoor air (nGy h^{-1} per Bq kg^{-1})

C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq kg^{-1}.

The choice of the conversion factors from activity concentration to absorbed dose is the most important factor for evaluating the external dose from building materials. The gamma radiation from walls is strongly dependent upon wall thickness and density of building material, so it is useful to adopt the standard room concept to estimate the dose. The qi values take into account the gamma transitions of ^{40}K and of ^{226}Ra and ^{232}Th respective decay series, the wall thickness of the studied house and the density of building materials. In this work, values of q_{Ra}, q_{Th} e q_K reported by European Commission [8] were used.

The calculations were performed considering an average of 50 nGy h^{-1} for the background [8].

Table 2 shows values of radiological hazard index and effective dose for gamma external exposure.

Table 2: Radiological hazard index and effective dose for gamma external exposure

Building material	Ra_{eq}	Activity concentration index (I)	Effective dose (mSv y^{-1})
Red brick	263.5	0.9	0.22
Cement	91.2	0.3	0.01
Grout/mortar	48.3	0.2	0
Clay brick	209.9	0.8	0.19
Sand	358.3	1.3	0.37

The effective dose for external exposure due to building materials for dwellers in a residential building at Peruíbe, São Paulo, Brazil is 0.8 mSv y^{-1}.

Conclusion

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were measured by gamma ray spectrometry in building materials used for the construction of multistoried residential building in the cost of Peruíbe, State of São Paulo, Brazil. The results show that the building materials analyzed present activity concentration within the range of average world values, except for clay bricks and sand. The activity concentrations of ^{226}Ra and ^{40}K for clay brick and ^{232}Th for sand are higher than the average world. Values of radium equivalent activity calculated for all the building materials measured are lower than the recommended maximum level of 370 Bq kg^{-1}. Applying dose criteria recommended by the European Commission for building materials, four structural building materials meet the activity concentration index (*I*) less than 1 and only sand slightly exceeds this criterion. The effective dose for dweller due to external exposure was 0.8 mSv y^{-1}, lower than the annual dose limit for general public of 1 mSv y^{-1} [10].

As a conclusion, the present study shows that the building materials analyzed are within the recommended safety dose limit and do not pose any significant source of radiation hazard.

Acknowledgements

Camila Dias Cazula is indebted to FAPESP (Process- 13/01841-9) for the financial support as fellowship student during this work.

References

[1] UNSCEAR (2000), United Nations Scientific Committee on the Effects of Atomic Radiation, The 2000 Report to the General Assembly with Scientific Annexes, New York, United Nations.

[2] Máduar MF Campos MP Mazzilli BP Villaverde FL (2011) Journal of Hazardous Materials 190: 1063-1067

[3] Campos MP Pecequilo BRS (2003) Rev Bras Pesq Des 5: 60-65

[4] El-Mageed AIA (2014, Journal of Geochemical Exploration 140 41–45

[5] Lu X (2014) Radiation Physics and Chemistry 99 : 62–67

[6] Venturini L Nisti MB (1997) Radiation Protection Dosimetry 71:227-229

[7] Turhan SX (2008) Journal of Environmental Radioactivity 99:404-414

[8] European Commission (1999) Radiation protection 112 – Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials, Directorate General Environment, Nuclear Safety and Civil Protection, Finland.

[9] Campos MP (1994) Avaliação do impacto radiológico provocado por materiais de construção em moradores de casas populares, IPEN-USP Ms. Dissertation, São Paulo, 1994

[10] International Commission on Radiological Protection, 2007. The 2007 recommendations of the International Commission on Radiological Protection. Elsevier, New York. Publication 103 of the ICRP 37(2–4).