EVALUATION OF GAMMA RAY DOSE RATES FROM BUILDING MATERIALS IN POPULAR DWELLINGS OF SANTO ANDRÉ, SP, BRAZIL

Marcia Pires de Campos and Brigitte R. S. Pecequilo

Instituto de Pesquisas Energéticas e Nucleares
P.O. Box 11049
05422-970, São Paulo, SP., Brasil

ABSTRACT

A total of 36 samples of Brazilian raw materials and building products were analysed by high resolution gamma spectrometry for their ^{226}Ra, ^{232}Th and ^{40}K content. The effective dose equivalent rate due to the indoor gamma radiation from those materials was performed following the 1988 UNSCEAR procedures. The values obtained ranged from 4.0×10^{-3} mSv/y (concrete beam) to 0.3 mSv/y (concrete) which are below the 0.8 mSv/y assumed UNSCEAR value for natural radiation sources.

INTRODUCTION

Natural radiation sources include external sources such as cosmic rays and Earth natural radioactivity and internal sources from inhalation and ingestion of naturally occuring radionuclides in air and diet and represent the major contribution to the radiation exposure by the general population[1].

Mankind's interest in the level of natural radiation exposure has strongly increased over the past forty years, as people became aware that exposures from the use of nuclear technology for medicine, energy and weapons have been far below those from natural sources.

The external radiation exposure from natural radioactivity by the human body represents almost 50% of the average annual dose from all natural and artificial radiation sources [1].

The main natural contributors to external exposure from gamma radiation are several members of the ^{238}U and ^{232}Th decay chains together with ^{40}K, nuclides which are universally present in small quantities in Earth and in building materials.

As general population lives in dwellings, the radioactivity of building materials is the most important source of external radiation exposure which can be increased appreciably by the use of materials with abnormal levels of natural radioactivity [2].

The specific activity of construction materials has been determined by several authors[3, 4, 5, 6] and the results showed great variation with the material type (highest levels for concrete, lowest levels for wood) and strong dependence with their origin. However, even knowing that some localities of Brazil present abnormaly high concentrations of radioactive minerals in the local soils and igneous rocks [7], there are very few informations [8] about the Brazilian raw materials and building products derived from those soil and rocks.

In 1991, the prefecture of Santo André district of São Paulo, Brazil, started a popular housing programme for homeless people, building almost of concrete a hundred houses. All houses were built with the same materials, in the same manner, an unique 15m^2 bedroom and bathroom, with one door and one window. The walls are of concrete, the floor of cement and the roof is a concrete beam.

As concrete is one of the potential sources of elevated gamma radiation exposure, our group was charged by the mayor of Santo André to assess the exposure rates of those ordinary houses, knowing the building materials activity [9].

The specific activities obtained for the naturally occuring radionuclides in the construction materials used for the condominium are summarized along with the effective dose equivalent rate due to gamma indoor exposures to those materials.

MATERIALS AND METHODS OF MEASUREMENT

A total of 36 samples were prepared for 2 raw materials and 4 building products of the same origin furnished by the Santo André district prefecture. Solid samples as concrete and concrete by-products were crushed into about 10mm particles before sealed in 860 mL Marinelli polyethylene beakers for a 4 weeks ingrowth period for the ^{226}Ra and ^{232}Th equilibrium. The cement, sand and broken stones samples were directly sealed in the Marinelli beakers.

The specific activity measurements were performed by using a high resolution 15 cm^3 HPGe detector (EG&G, Ortec, USA), coupled to a 4K memory Ortec 918-A ADCAM multichannel buffer and 476-8 multiplexer and to a 386 PC/AT computer. The HPGe spectrometer has an energy resolution of 1.7 keV for the 1.33 MeV ^{60}Co energy.

The background distribution was obtained by measuring de-ionized water in the same sample geometry of an 860 mL Marinelli polyethylene beaker.

All spectra were analysed with the MicroSAMPO software for personal computer analysis of gamma-ray spectra from HPGe detectors [10]. As the densities of the samples varied over a broad interval (1.06 g/cm^3 for concrete to 1.59 g/cm^3 for sand), it was necessary to correct the self-absorption of the samples by using efficiency calibration curves obtained with calibration matrices in the same density interval [11].

RESULTS AND DISCUSSION

Radionuclides Specific Activities

For the evaluation of the external gamma-ray indoor exposure it was necessary to obtain the ^{226}Ra, ^{232}Th and ^{40}K specific activities of the building materials.

The ^{226}Ra specific activity was determined assuming radioactive equilibrium in the ^{238}U chain, through the ^{214}Pb gamma transition of 352 keV and the ^{214}Bi gamma transition of 609 keV.The radium specific activity for each sample was calculated as the mean value of those two gamma transitions. The medium specific activity for all samples of the same material was calculated as the mean value of the radium specific activity of each sample.

The ^{232}Th specific activity was determined assuming radioactive equilibrium in the ^{232}Th chain through the ^{212}Pb gamma transition of 238 keV, the ^{212}Bi gamma transition of 727 keV and the ^{228}Ac gamma transition of 911 keV. Calculations for thorium specific activity were performed like the radium ones.

The ^{40}K specific activity for each sample was determined from its unique 1460 keV gamma transition and the medium specific activity was calculated by using the same radium and thorium calculation procedures.

Table 1 shows the construction materials studied and their ^{226}Ra, ^{232}Th and ^{40}K content, as well as literature values [8, 4, 3, 6]. All the materials used in Santo André present specific activities within the range of values obtained in other countries.

TABLE 1 - : Radionuclide Medium Specific Activity of Building Materials Used in Santo André District and Literature Values

Building Materials	Radionuclide Specific Activity (Bq/kg)					
	^{226}Ra		^{232}Th		^{40}K	
	this work	lit.	this work	lit.	this work	lit.
sand	31.2	7 - 81	56.6	9 - 104	349	37 - 666
cement	53.3	1 - 204	18.7	11 - 192	160	18 - 555
broken stones	14.0	2 - 56	64.3	2 - 93	866	26 - 1262
concrete	21.5	8 - 146	98.3	9 - 225	1050	394 - 1856
roofing brick	28.8	-----	25.4	-----	332	------
concrete beam	41.4	-----	58.8	-----	605	------

Indoor Effective Dose Equivalent Rate from Building Materials

The indoor effective dose equivalent rate by gamma radiation emitted from the building materials employed in the construction of the popular houses in the Santo André district of São Paulo, Brazil, was performed following the UNSCEAR [1] procedures, using the radionuclide specific activity and introducing a so-called reference room concept. Ackers [12] defined a reference-room by the requirement that the effective dose equivalent rate for a person in this room is equal to the average effective dose equivalent rate experimented by a person living in a house of the type to be represented.

The indoor effective dose equivalent rate D, in mSv/y, was calculated considering the Quindos expression[13]:

$$D = p\,T\,b \times 10^{-6}\,\Sigma\,[(q_{Ra}\,C_{Rai} + q_{Th}\,C_{Thi} + q_K\,C_{Ki}) \times m_i] \quad (1)$$

where:
p = fraction of time spent indoors
T = hours per year
b = conversion of absorbed dose in air to effective dose equivalent, (Sv/Gy)
i = index for type of building material
q_{Ra} = conversion factor from ^{226}Ra specific activity of building materials to absorbed dose rate in indoor air, $[(nGy/h)(Bq/kg)^{-1}]$
q_{Th} = id. for ^{232}Th
q_K = id. for ^{40}K
C_{Rai} = ^{226}Ra specific activity in type i of building material
C_{Thi} = id. for ^{232}Th
C_{Ki} = id. for ^{40}K
m_i = mass fraction of type i material in reference room

For the ^{226}Ra, ^{232}Th and ^{40}K specific activities we used the Table 1 values. For the fraction of time spent indoors, p, and the conversion of absorbed dose in air to effective dose equivalent, b, we considered the UNSCEAR [1] values of 0.8 and 0.7 Sv/Gy, respectively.

The conversion factors q_{Ra}, q_{Th} and q_K used were the Koblinger values [14], as the studied houses in Santo André had dimensions and wall thickness similar to his theoretical room model. In the calculation, Koblinger considered the ^{40}K isotope and all elements in the ^{238}U (^{226}Ra) and ^{232}Th series, assuming equilibrium of the daughters and not taking into account the effect of Rn emanation from the walls. The conversion factors values used were 0.79, 0.89 and 0.07 $[(nGy/h)(Bq/kg)^{-1}]$ for q_{Ra}, q_{Th} and q_K, respectively.

The mass fractions m_i were obtained from the civil engineer responsible for the construction of the Santo André houses.

The indoor effective dose equivalent rates calculated for all building materials used in Santo André are presented in Table 2.

TABLE 2 - Indoor effective dose equivalent rate from Santo André building materials

Building material	Indoor effective dose equivalent rate (mSv/y)
sand	0.17
cement	0.03
broken stone	0.14
concrete	0.31
roofing brick	0.02
concrete beam	0.004

The total efective dose equivalent rate by natural gamma radiation emitted from the building materials used in the Santo André ordinary houses construction was calculated by summing the rates of each particular material, disregarding the concrete beam rate for its relatively low value. So, the total gamma indoor effective dose received by the dwellers is 0.67 mSv/y, slightly lower than the value of 0.8 mSv/y assumed by UNSCEAR for natural gamma radiation sources. However, we must point out the importance of knowing the contribution of naturally occuring radionuclides in building materials, since the effective dose equivalent rate due to terrestrial gammas disregarding building materials assumed by UNSCEAR is only 0.34 mSv/y.

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