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SERVIÇO DE PROTEÇÃO RADIOLÓGICA

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ABSTRACT

The indoor dose from natural radioactivity content in sand used in the concrete manufacture was estimated for the case of a 25 m^2 room with a concrete floor. The walls and ceiling are considered to be made of materials that present no contributions. The ^{40}K, ^{226}Ra and ^{228}Ac concentrations of four sand samples from the São Paulo region were measured. This preliminary estimation shows that the contribution of sand in concrete to the indoor dose is comparable to the outdoor dose due to the terrestrial radiation if the world average levels [1] for natural radioactivity are considered.

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RESUMO

A dose no interior de residências, resultante da concentração de radioatividade natural na areia utilizada no concreto, foi estimada para o caso de uma sala de 25 m^3 com piso de concreto Considerou-se que teto e paredes feitos de materiais que não contribuem para a dose As concentrações de ^{40}K ^{226}Ra e ^{228}Ac foram medidas em 4 amostras de areia da região de São Paulo Esta estimativa preliminar mostra que a contribuição da areia no concreto à dose no interior da sala pode ser comparável à dose no ambiente externo quando se leva em consideração os níveis médios mundiais [1] resultantes da radioatividade natural

INTRODUCTION

Natural radioactivity in building materials have been investigated by many authors [2, 3, 4, 5, 6] in order to identify materials with higher than the average concentrations of naturally occurring radionuclides. Primary attention has been given to concrete that is a basic building material and seems to be the strongest radon emanator. Ingersoll [7] studied ordinary concrete components (sand, cement and aggregates) and concluded that sand appears to be the main radon emanator. Sand is an important building material not only as a basic concrete component but also because of the large use of brick made mainly of sand in the construction of low cost homes.

This work intends to estimate the contribution of sand radioactivity in concrete to the indoor dose by using the experimental determination of the natural radioactivity of sand, an indoor air volume that is representative of our current constructions, and the related literature data. Typical rooms in São Paulo have dimensions 3 x 3 x 2.8 m. The model used in this calculation considers that the air volume is limited by ceiling and walls that do not contribute to the indoor dose, and by a 9 m^2 concrete floor. The ^{40}K, ^{226}Ra and ^{228}Ac concentrations of four sand samples from São Paulo region were measured. In order to have some information about the local background, three soil samples were also measured.

EXPERIMENTAL PROCEDURE

The natural radioactivity concentration of sand and soil samples were measured directly using an HPGe detector and a 4096 channel spectrometer The counting geometry was a 860 ml Marinelli beaker with 850 ml of sample The counting system efficiency curves for soil and sand were obtained separately because the samples varied in density from 1 0 to 1 5 g cm^{-3} The spectra were measured in the 50 - 2800 keV energy range The ^{228}Ac concentration was determined from the 583 keV and 911 keV gamma lines from ^{208}Tl and ^{228}Ac, respectively The ^{226}Ra concentration was determinated by measuring the 186 keV transition ^{226}Ra and ^{238}U were assumed to be in equilibrium ^{235}U and ^{238}U were supposed to be at their natural isotopic ratio Under such conditions, ^{226}Ra (0 038 gamma-rays per desintegration) and ^{235}U (0 547 gamma-rays per desintegration) contributions to the 186 keV peak are 60 2% and 30 8% respectively The gamma-ray transition of 1,461 keV was measured for ^{40}K

RESULTS AND DISCUSSION

In order to estimate the radiation exposure due to ^{238}U, ^{232}Th and ^{40}K uniformly distributed in the material, an index X was proposed to be the γ-ray exposure rate at 1 m above an infinite hemisphere or an infinitely extended and thick slab [3 8]

$$X = 1\ 90\ C_U + 2\ 82\ C_{Th} + 0\ 179\ C_K \quad \mu R\ h^{-1} \qquad (1)$$

where C_U C_{Th} and C_K are the concentrations of ^{238}U, ^{232}Th and ^{40}K in pCi g^{-1}, respectively The constants in the right side of Eq (1) are related to the average gamma-ray energies for the associated series or radionuclide

Since ^{226}Ra and ^{228}Ra precursors emit non-penetrating radiation ^{238}U and ^{232}Th can be replaced by ^{226}Ra and ^{228}Ac in Eq (1) Using the current units for absorbed dose (0 0087 Gy R^{-1}) and activity (Bq), the potential absorved dose rate in air due gamma-radiation is

$$D = (\ 4\ 46\ C_{Ra} + 6\ 62\ C_{Ac} + 0\ 48\ C_k\ ) \times 10^{-10} \quad Gy\ h^{-1} \qquad (2)$$

where C_{Ra} C_{Ac} and C_k are the concentrations of ^{226}Ra ^{228}Ra and ^{40}K in Bq kg^{-1} respectively Table 1 shows the radionuclide concentrations measured in the sand and soil samples

The indoor dose has two components the external gamma radiation due to primordial radionuclides and their decay products present mainly in the building materials and the internal irradiation due to the α-emitting radon progeny

Sand in concrete occupies from 25 to 30% of the total volume (9) So it may represent about 20% of the concrete mass Therefore the natural radioactivity content of concrete was considered to be 20% of the average values of the measured sand concentrations (21 38 and 477 Bq kg^{-1} of ^{226}Ra, ^{228}Ac and ^{40}K respectively) Using Eq (2) and taking into account the indoor occupancy factor of 0 8 [1], and the conversion factor 0 7 Sv Gy^{-1} for environmental radiation of mean energy [1], the annual indoor effective dose equivalent due to the gamma component from concrete was found to be 27×10^{-5} Sv This value is to be compared with the world average annual effective dose equivalent from outdoor terrestrial gamma radiation that is estimated to be $5\ 1\times10^{-5}$ Sv [1]

Table 1

Radionuclide concentration in sand and soil The statistical erros are given in parenthesis

Material	^{226}Ra (Bq/kg)	^{228}Ac (Bq/kg)	^{40}K (Bq/kg)
sand 1	5 7 (5)	13 2 (7)	109 (11)
sand 2	25 1 (18)	46 3 (17)	442 (42)
sand 3	15 7 (11)	13 5 (7)	53 (5)
sand 4	37 7 (24)	78 1 (27)	1302 (130)
soil 1	31 9 (20)	74 3 (35)	67 (7)
soil 2	68 7 (43)	92 5 (44)	441 (44)
soil 3	55 8 (41)	104 3 (48)	1191 (119)

If the UNSCEAR [1] conversion factors (4 27x10^{-10}, 6 62x10^{-10} and 0 43x10^{-10} Gy h^{-1}per Bq kg^{-1} of ^{238}U, ^{232}Th - here replaced by ^{226}Ra and ^{228}Ac - and ^{40}K respectively) and the average values of the measured soil concentrations are used (52 90 and 566 Bq kg^{-1} of ^{226}Ra, ^{228}Ac and ^{40}K, respectively) then the annual average outdoor effective dose equivalent would be 1 3x10^{-4} Sv

The second component to the indoor dose is due to Rn progeny The Rn indoor concentration due to gas emanation from the concrete floor is given by [10]

$$C = E\ F\ (v\ V)^{-1} \qquad (3)$$

where C = indoor radon concentration (Bq m^{-3}),

E = Rn emanation rate from concrete (Bq m^{-2} h^{-1}),

v = ventilation rate (h^{-1})

F = emanation surface (m^2),

V = indoor air volume (m^3)

Ingersol [7] found that ^{220}Rn emanation appears to be less than 3% Therefore only ^{222}Rn will be considered Ventilation rates vary from 0 1 to 3 h^{-1} [1] The average value of 1 5 h^{-1} was assumed to be used in Eq (3) together with F = 9 m^2 and V = 25 2 m^3 from the used model The emanation rate was considered to be 0 41 Bq m^{-2} h^{-1} per Bq kg^{-1} of ^{226}Ra in concrete This value was obtained by averaging the individual values reported by Mustonen [4] in his study of several concrete samples ranging in thickness from 10 to 20 cm From Eq (3) the average indoor radon concentration due to sand in concrete was found to be 0 48 Bq m^{-3} Taking into account the Rn equilibrium factor of 0 43 (that corresponds to v = 1 5 h^{-1}[1]) the reference man indoor breathing rate of 0 8 m^{3} h^{-1} [1], the conversion factor of 1 1 $\times$ 10^{-8} Sv Bq^{-1} [1] and the indoor occupancy factor of 0 8 [1] the average annual indoor effective dose equivalent due to inhalation was found to be 1 2×10^{-5} Sv The annual effective dose equivalent, from outdoor exposure, corresponding to the average equilibrium equivalent concentration of Rn outdoor is estimated to be 0 08 mSv (0 06 mSv from inhaled ^{222}Rn daughters and 0 02 mSv from inhaled ^{220}Rn daughters) [1]

CONCLUSION

This preliminary estimation shows that the sand radioactivity in concrete can contribute significantly to the indoor dose and that a survey on the natural radioactivity content of the sand used in the concrete manufacture can be useful to prevent higher potential doses from building materials such as concrete or brick Further measurements of the natural radioactivity and properties of the local building materials are planned in order to perform a representative evaluation of their contribution to the indoor dose in São Paulo city where about 12 million inhabitants live

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