On the Radioactivity of Building Materials

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Abstract

The specific activities of natural radionuclides of various main building materials used in Greece have been measured. Considering these as models, the radiation exposure from gamma rays and radon was evaluated. It was estimated that concentrations of 8pCi/g of ^{226}Ra, 6 pCi/g of ^{232}Th and 85 pCi/g of ^{40}K in building materials will give an increase of 50 mrad/y in gonad dose if only one of the above radionuclides is present. Health effects of radon are also discussed.

1.Introduction

It is well known that many building materials used in the construction of dwellings contain radioactive elements {Hu56},{Kr71},{St76},{OR77},{UN77},{Ko78}, {OE79},{Za80}. The radionuclides which are present in them belong to the natural radioactive elements, such as uranium-238, radium-226, thorium-232 and their decay products, as well as potassium-40. The radiological implications from the above nuclides are due to irradiation of the body by gamma rays and irradiation of the lung tissues from inhalation of radon-222 and its daughters.

2.Experimental Procedures and Results

We have picked and measured a lot of samples of various building materials used in Greece, such as, red bricks, cement, concretes, tiles, gypsum etc . The sampling was made from Thessaloniki (North Greece), Valey of Tembi and Volos (Central Greece) and Tanagra, Chalkida, Etolikon (South Greece), see Table 1 .

The measurements of radioactivity in the building materials were performed by several methods, as: direct gamma spectroscopy using Ge-Li and intrinsinc Ge detectors, neutron activation analysis and delayed neutron technic.

The results of our measurements are summarized in Table 1. In this Table the specific activities of ^{226}Ra, ^{232}Th and ^{40}K are presented. The absorbed dose rate in air was calculated assuming 4π-geometry and infinite thickness (a factor 2) , and it is presented in Table 1, last column. These values are an index allowing the comparison between the building materials.

Polyurethane, which is used in the present days, as thermoisolating material in Building Technology,does not show any radioactivity (below detection level) . Wood was not considered in this work, since its low level radioactivity {UN77}. However, mean values were: ^{226}Ra and ^{232}Th below detection level, ($2x10^{-2}$pCi/g and $1x10^{-2}$ pCi/g, respectively), ^{40}K = 1.15 pCi/g and ^{137}Cs = $1.4x10^{-2}$ pCi/g.

3. Exposure to Gamma-Rays

The increase of gonad dose from building materials may be found from the following formula by subtracting the annual mean outdoor dose, ≈36 mrad {Kr71}.

$$\Delta D_y = 11.05\ C_{Ra} + 14.6\ C_{Th} + 1.0\ C_K - 36 \text{ mrad} \quad (3.1)$$

where: C_{Ra}, C_{Th} and C_K are the radioactive contents of building materials (measured in pCi/g) of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

In Table 2, the anual increase of gonad dose, ΔD_y, in dwellings, which would be built with high radioactive building materials examined, is presented. For the red brick BM-2, as well as for the tiles BM-4 and BM-7, ΔD_y is of the order of 25 mrads, while for the concrete BM-17, ΔD_y is negative. $\Delta D_y \approx 25$ mrads is about half of the ICRP recommended for the population {IC77}.

If only one of the radionuclides considered is present, a 50 mrad/year increase is caused in gonad dose with the following specific activities of building materials: 8pCi/g, 6 pCi/g and 85 pCi/g for ^{226}Ra, ^{232}Th and ^{40}K, respectively. Then, if all the above nuclides are present, their concentrations must fulfill the following expression:

$$\frac{C_{Ra}}{8} + \frac{C_{Th}}{6} + \frac{C_K}{85} \leq 1 \quad (3.2)$$

The denominators of (3.2) are slightly different for the same criterion suggested by Krisiuk et al {Kr71} and Stranden {St76}. This is due to the difference existing in models considered by Krisiuk et al (a hole in an infinite medium) and Zastawny (typical cubicoid room).

The sum of the three quotients of the formula (3.2) for the building materials examined, gives the higher values for the red brick, 0.73 (sample BM-2) and for the tiles, 0.70 (samples BM-4 and BM-7).

Measurements of the dose rate were made in modern, as also, in old dwellings. The measurements were performed by a Scintillometer NaI(Tl) 1"x1".5 crystal and a Cutie-Pie Survey meter with an ionization chamber of 580cc (2"7/8x5"1/2). About 50 houses were picked at the wide area of Thessaloniki to measure the dose rate in bedrooms and living rooms. A dose rate of 3.6 μR/hr for the cosmic rays {UN77}, were subtracted from each measurement.

The results are presented in Table 3. The Table 3 shows the mean as well as the minimum and maximum dose exposure that were measured. We observe that the maximum values of increase of gonad dose, are at the same level as those of Table 2.

4.Lung Dose Exposure from Radon and Radon Daughters and Health Effects of Radon.

Health effects of radon are expressed in terms of WLM (Working Level Months). Considering an occupancy factor of 0.8 indoors,{UN77},the annual time of exposure is 41 working months {Co80}. In Table 4, the annual indoor exposure, in WLM, is given in the last column, for a typical room 3.5x3.5x3.0 m^3 (A/V=1.81) with a wall of half thickness 15 cm, built by brick BM-2 (ρ=1.96 g/cm^3) or concrete BM-17 (ρ-2.35 g/cm^3), which are the most contributing in radon. In Fig.1 typical curves of annual lung dose exposure indoors for various ^{226}Ra concentrations (from 0.5 to 3 pCi/g) in bricks as a function of air rates are presented. The curves for concrete buildings have the same behavior and are slightly higher.

5·Conclusions

According to the ALARA (As Low As is Reasonably Achievable) Principle that the dose exposure should be as low as possible, and the above results and the discussion, we can suggest that the radioactive concentrations of the nuclides considered in the building materials should not exceed the values of 1.25, 0.5 and 15 pCi/g for ^{226}Ra, ^{232}Th and ^{40}K, respectively. These values give a sum of the quotients of the criterion, formula (3.2), equal to 0.4, i.e 40% lower that it was suggested in section 3. It is corresponding to an annual increase of gonad dose equal to 20 mrads.

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