NATURAL RADIOACTIVITY IN SLOVAK CONSTRUCTION MATERIALS AND THE INDOORS DOSE RATE FROM BUILDING MATERIALS

H. Cabáňeková, M. Vladár
Institute of Preventive and Clinical Medicine, Limbová 14, 833 01 Bratislava
Slovak Republic

Introduction

The radioactivity in the building materials, together with the radiation from the ground and the cosmic radiation, are the main sources of external radiation to the people. The increasing use of industrial wastes as building materials, which often contain enhanced levels of the radioactivity, has increased the interest in this source of population exposure [1].

For the evaluation of the external γ-ray contribution to the exposure of population, the estimation of the $^{226}\text{Ra}$ content as well as of the $^{232}\text{Th}$ and $^{40}\text{K}$ concentration in building materials and products, is essential. The building materials with high values of $^{226}\text{Ra}$ coupled with the pronounced porosity of the final products, make them potential indoor Rn sources too.

For keeping the population exposure as low as reasonably achievable, (recommended by the Slovak regulations), the radioactive content of primordial radionuclides in building materials and products have not to exceed 370 Bq.kg$^{-1}$ of radium equivalent activity and 120 Bq.kg$^{-1}$ of $^{226}\text{Ra}$ [2].

Materials and methods

Samples of building materials (cement, stone, fly-ash, light concrete, slag, dross, sand, dolomite, etc.) used for construction of the residential buildings were collected, milled and screened with 2-3 cm sieve. After drying, the samples were stored in 450 cm$^3$ sealed polyethylene containers for a 30 day period. All samples were measured in a $4\pi$ geometry (Marinelli type samples) usually for 60.000 seconds. Measurements of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ concentrations were carried out by high resolution γ-ray spectrometry.

The primordial radionuclides $^{226}\text{Ra}$ and $^{232}\text{Th}$ were assessed through their progeny photopeaks $^{214}\text{Bi}$ (609 keV), $^{214}\text{Pb}$ (295 keV, 351 keV) $^{228}\text{Ac}$ (338 keV, 911 keV) and $^{212}\text{Pb}$ (238 keV). The specific activity of both nuclides has been determined as weighted average of their photopeaks. $^{40}\text{K}$ was measured directly via its 1460 keV peak [3,4].

Usually the natural radioactivity of building materials is specified on a common index called "Radium Equivalent Activity" estimated as

$$a_{eq} = a_{Ra} + 1.43 a_{Th} + 0.077a_{K}$$

where $a_{eq}$ - radium equivalent activity in building material, Bq.kg$^{-1}$
$a_{Ra}, a_{Th}, a_{K}$ - specific activities of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in building material, Bq.kg$^{-1}$
External dose from building materials

The annual indoor effective dose resulting from building materials was calculated following the procedures described by UNSCEAR [5]. The total dose fraction, expressed in mSv.y\(^{-1}\), results from the addition of three terms. The first represents the dose rate resulting from irradiation by external sources and the second and third concern the dose rate from inhaled radon and thoron progeny in the indoor air [6].

The determination of the external irradiation from building materials is described by the expression:

\[
D = p \cdot T \cdot b \cdot 10^{-6} \Sigma_i (q_{K_i} \cdot a_{K_i} + q_{Ra_i} \cdot a_{Ra_i} + q_{Th} \cdot a_{Th_i}) \cdot m_i
\]

where
- \(D\) - external irradiation dose rate (mSv.y\(^{-1}\))
- \(p\) - fraction of time spent indoors, 0.8
- \(T\) - 8760 h per year
- \(b\) - conversion from absorbed dose in air to effective dose equivalent, 0.7 Sv per Gy
- \(m_i\) - mass fraction of type i material in reference room
- \(a_{K_i}\) - specific activity of \(^{226}\text{Ra}\), \(^{232}\text{Th}\) and \(^{40}\text{K}\) (Bq.kg\(^{-1}\)) in type i building material
- \(a_{Th_i}\) and \(q_{K_i}, q_{Ra_i}, q_{Th}\) are the conversion factors from the specific activity of the building materials to absorbed dose rate in indoor air (nGy.h\(^{-1}\) per Bq.kg\(^{-1}\)).

The choice of these conversion factors is the most important factor for evaluating the external dose from building materials. Because the gamma radiation from walls is strongly dependent on the wall thickness and on the density of building materials, a standard room must be assumed to estimate the dose rate. Table 1. shows some values of these coefficients for different model rooms.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Room geometry</th>
<th>Wall density [g.cm(^{-2})]</th>
<th>Specific dose rate [nGy.h(^{-1}) per Bq.kg(^{-1})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stranden</td>
<td>6x4x3 m(^3)</td>
<td>2.32</td>
<td>0.62</td>
</tr>
<tr>
<td>Stranden</td>
<td>6x4x3 m(^3)</td>
<td>2.0 cm</td>
<td>0.59</td>
</tr>
<tr>
<td>Koblinger</td>
<td>4x5x2.8 m(^3)</td>
<td>2.35</td>
<td>0.7</td>
</tr>
<tr>
<td>Koblinger</td>
<td>4x5x2.8 m(^3)</td>
<td>20 cm</td>
<td>0.59</td>
</tr>
<tr>
<td>Ackers</td>
<td>4x5x2.8 m(^3)</td>
<td>1</td>
<td>0.59</td>
</tr>
<tr>
<td>Ackers</td>
<td>4x5x2.8 m(^3)</td>
<td>20 cm</td>
<td>0.59</td>
</tr>
</tbody>
</table>
Results and discussion

Until now, in our Institute about 600 samples of building materials have been measured. The measured activity concentrations and calculated radium equivalent activities of the materials, which are one of the most used in the Slovak building trade are given in the Table 2. The average values of natural radioactivity for some Slovak building materials (cement, fly-ash, concrete, brick) are approximately on the same level as in other countries [10, 11, 12].

The data in Table 2. show broad range of concentrations of the natural radionuclides. This fact reflects their natural origin and geological conditions at the site of their production. The construction materials with concentrations higher than recommended in Slovak regulations, are forbidden for using in the building trade.

For a typical Slovak home made basically of brick, brick(slag) and concrete with the mean concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ given in the Table 2., the mean annually effective doses are shown in Table 3. The external dose rates were calculated by Acker's conversion factors and the values are in the range between 0.58 and 0.69 mSv.y$^{-1}$. These values are a little higher as the data from the Spanish houses [6].

The philosophy of radiation protection suppose that radiation doses from all sources should be kept as low as achievable. Our control mechanism can regulate that part of the radiation exposure to the public which is due to the natural radioactivity present in building materials. From the measured levels of $^{226}\text{Ra}$ and from the knowledge of the contribution of the external terrestrial radiation, of the building design, of the ventilation rate and of the exhalation rate of the final products, the equilibrium equivalent concentration of $^{222}\text{Rn}$ can be also assessed.
References


5. UNSCEAR Report 1988


