RADIOACTIVITY IN BUILDING MATERIALS ÖNORM S 5200: A STANDARD IN AUSTRIA TO LIMIT NATURAL RADIOACTIVITY IN BUILDING MATERIALS (REVISED AND DEFINITE VERSION)

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The Austrian Standard ÖNORM S 5200, prepared in the early nineties after a prestandard phase (Steger F.) and in use in Austria since 1996, provides the criteria to assess the radiation dose of building materials. Gamma radiation of the radionuclides ^{40}K, ^{226}Ra and thorium are taken into account, as well as the dose due to the noble gas radon, which is released from building materials after the decay of ^{226}Ra. A type of building material is considered acceptable if its yearly effective dose in a room does not exceed 2.5 mSv.y^{-1}. Provisions are made to minimise the required experimental efforts to prove compliance with the standard. There is also a limit of 3.4 µSv.h^{-1} for external beta radiation due to surface radiation (from e.g. uranium-glazed tiles), which is derived from the limit of 10 mSv.a^{-1} as stated in the Austrian radiation protection regulations and 8 hours/day exposure time and corresponds to an activity concentration of about 1 Bq.cm^{-2} uranium in equilibrium with its progenies.

Key words: Building materials, Regulation, Standard, Radiation dose, Dose limitation

INTRODUCTION

Until the beginning of the nineties the International Commission for Radiological Protection (ICRP) was more or less engaged in regulations of man-made sources of radioactivity. Meanwhile civilisation enhanced natural radioactivity has become a matter of consideration. Examples are high altitude flights, mining and living in buildings.

The question of radioactive dose in buildings is of particular interest, as it has become clear that the use of certain building material components can result in a significant increase of the radioactive burden for a large number of persons. The reasons for the use of industrial waste products as admixtures in building materials are cost reduction, saving of natural resources and recycling.

Building materials contribute to environmental radioactivity in two ways. First, by gamma radiation, mainly ^{40}K, ^{226}Ra, ^{232}Th and their progenies to a whole body dose and in some cases by beta radiation to a skin dose e.g. from tiles, glazed with uranium, and secondly by releasing the noble gas radon, the radioactive daughters of which are deposited in the human respiratory tract.

The radon problem became prominent, when it was discovered that radon and its daughters account for the largest portion of public dose and that it is enhanced substantially by the reduction of room ventilation to conserve heat energy.

In response, the specific Austrian situation was investigated by an interdisciplinary study group, consisting of scientists from the Austrian Research Center Seibersdorf, the Federal

Testing and Research Institute Arsenal in Vienna, and the University of Salzburg in a project which was financed by the former Ministry of Building and Technology in Austria (ARCS 1985). Although it was found that the vast majority of Austrian building materials increased the natural level of radioactivity only slightly, it seemed desirable to establish criteria to judge and limit the dose rate delivered to inhabitants of buildings due to construction materials (Tschirf 1984). This was accomplished by a working group set up by the Austrian Standards Institute ON consisting of members of the Austrian Research Center Seibersdorf, of the Federal Testing and Research Institute Arsenal in Vienna, of the Austrian Universities of Vienna, Salzburg and Graz and members of the Building Trade in Austria. A pre-standard of ÖNORM S 5200: "Radioactivity in building materials" came into force in Austria in 1988 (Steger F.).

After a 4 year observation the working group of experts revised this standard taking the report of NEA-OECD (NEA 1979) for a new external dose calculation into account and also the experiences of the last 4 years of builders and constructors, of governments and – of course – of building owners. The revised standard has been in use in Austria since 1996.

A certain building material is considered acceptable if its contribution to yearly effective dose in a room does not exceed 2.5 mSv.y^{-1}. This value is more or less high-handed and is derived from the yearly dose of 200 Bq.m^{-3} radon gas, allowed in a dwelling as prescribed for new buildings by the Austrian Radiation Protection Commission (OESSK 1992). 2.5 mSv.y^{-1} is about 1/3 of 7 mSv.y^{-1}, calculated from 200 Bq.m^{-3} and the conversion factor of 35 µSv.y^{-1} per Bq.m^{-3} radon gas (ICRP 1987).

A limit of 3.4 µSv.h^{-1} for external beta radiation due to surface radiation e.g. uranium-glazed tiles is also given, which is derived from the limit of 10 mSv.a^{-1} as stated in Austrian radiation protection regulations (OEStrSchVO 1972) and 8 hours/day exposure time and corresponds to an activity concentration of about 1 Bq.cm^{-2} uranium in equilibrium with its progenies.

ASSESSMENT OF THE DOSE RATE CONTRIBUTIONS

Contribution of the External Radiation

From a report of NEA-OECD (NEA 1979) conversion factors can be derived for external radiation dose in dwellings from the natural radioactivity of building material (^{40}K: 0.25 µSv.y^{-1} per Bq.kg^{-1}, ^{226}Ra: 2.5 µSv.y^{-1} per Bq.kg^{-1} and ^{232}Th: 3.7 µSv.y^{-1} per Bq.kg^{-1}) so that a formula can be stated, which ensures that the dose rate in a room does not exceed 2.5 mSv.y^{-1} if it meets the following conditions (a_i: specific activity of the radionuclide i of the material [Bq.kg^{-1}]):

$$\frac{a_{K-40}}{10000} + \frac{a_{Ra-226}}{1000} + \frac{a_{Th-232}}{670} \leq 1 \qquad (1)$$

Contribution of the internal dose rate

^{222}Rn and its daughters are the reason of an additional inhalation dose rate from building materials (ICRP 1987). The activity concentration c_{Rn-222} [Bq.m^{-3}] in a room can be rough estimated from Equation 2 (Wicke 1979) with the ratio O/V [m^{-1}]of a room (surface to volume) of about 2,

λ [h^{-1}]: decay constant of ^{222}Rn - $7.56.10^{-3}$, ε: emanation factor, ν [h^{-1}]: ventilation rate - 0.7,

ρ [$kg.m^{-3}$]: density of the building material and d [m]: thickness of the building elements.

$$c_{Rn-222} = a_{Ra-226} \cdot \frac{O}{V} \cdot \frac{\lambda \cdot \varepsilon}{\upsilon} \cdot \frac{\rho \cdot d}{2} \tag{2}$$

If the ratio O/V is 2 m^{-1} – practically all rooms have ratios between 1.5 m^{-1} to 2.5 m^{-1} – the connection with the equation can be simplified expressed as:

$$c_{Rn-222} = a_{Ra-226} \cdot \frac{\lambda \cdot \varepsilon \cdot \rho}{\nu} \cdot d \tag{3}$$

If 1 $Bq.m^{-3}$ radon gas in dwellings results in 35 $\mu Sv.y^{-1}$ [ICRP 1987] (equilibrium factor 0.5, occupancy factor 0.8) and the ventilation rate is 0.7 h^{-1}, and 70 $Bq.m^{-3}$ ^{222}Rn from building material are allowed (without external radiation) [OESSK 1992], then the dose, that inhabitants of dwellings receive, does not exceed 2.5 $mSv.y^{-1}$ if the inequality in Equation 4 is satisfied:

$$\frac{a_{Ra-226}}{70}(0{,}0108 \cdot \varepsilon \cdot \rho \cdot d) \le 1 \tag{4}$$

Total dose rate

The radiation exposure in a dwelling of a certain building material consists of an external dose rate and an internal dose rate. Following formula (5) contains both and the observation of this formula guarantees that inhabitants of dwellings do not receive a higher dose from natural radioactivity as 2.5 $mSv.y^{-1}$.

$$\frac{a_{K-40}}{10000} + \frac{a_{Ra-226}}{1000} \cdot (1 + 0{,}15 \cdot \varepsilon \cdot \rho \cdot d) + \frac{a_{Th-232}}{600} \le 1 \tag{5}$$

The denominator of a_{Th-232} in (5) compared with the formula (1) has been reduced from 670 to 600 taking a small influence of ^{220}Rn into account. The contribution of ^{219}R is negligible.
Because the radioactive equilibrium of thorium can be disturbed (enrichment of radium or dis-enrichment of thorium) for a $_{Th-232}$, the mean of the specific activity of ^{228}Th and ^{228}Ra has to be inserted:

$$a_{Th-232} = \frac{a_{Ra-228} + a_{Th-228}}{2} \tag{6}$$

This approximate value for this application is sufficient enough taking into account all the other approximations.

Beta dose rate

In some cases the colouring of tiles results in high radioactivity (mostly ^{238}U and progenies). The dose rates in the vicinity can contribute significantly to the total dose rate of the inhabitants. For the calculation of the permissible dose rate it is assumed that the main part of radiation is produced by beta radiation and that there is direct bodily contact to the tiles 8 hours per day.

For the maximum value of the skin dose of 10 $mSv.y^{-1}$ as stated in Austrian radiation protection regulations [OEStrSchVO 1972] and 8 hours/day exposure time, there is a limit of 3.4 $\mu Sv.h^{-1}$ and corresponds roughly to an activity concentration of about 1 $Bq.cm^{-2}$ uranium in equilibrium with its progenies.

BUILDING MATERIALS TESTING

For gamma dose rate and radon inhalation the Standard ÖNORM S 5200 formulates three criteria, A,B and C to simplify the method of proving a certain type of building material meets the requirements.

The test are performed as follows:

- For building material and building elements/component parts: *Test A*
- For building material and building elements/component parts which fail to meet the requirements of Test A of Equation 5 but are still used only for part of the room *Test B*
- For tiles: *Test C*

Test A

Measure the specific activity of ^{40}K, ^{226}Ra and ^{232}Th in building material or building elements/ component parts. Insert the measured values in Equation 5.

For the parameters ”wall thickness (d)”, ”emanation factor (ε)” and ”density (ρ)” the following values have to be used:

- Wall thickness d:
  For building material: The usual wall thickness, but not more than the preconditional value for d.

  For building elements/ component parts (walls, ceilings etc.) The real thickness, but not more than the preconditional value for d. If the thickness is not known than use the preconditional value.

- Density ρ: The real density, but not more than the precondition value for ρ. If the density is not known than use the preconditional value.

- Emanation factor ε: The real emanation factor but not more than the precondition value for ε. If the emanation factor is not known than use the preconditional value.

The preconditional values for the wall thickness d = 0.3 m, for the density ρ = 2000 kg.m^{-3} and for the emanation factor ε = 0.1.

If the inequality of Equation 5 is fulfilled, the building material or the building elements/ component parts comply with the standard.

Test B

If the building material or building elements/component parts of a part of a surface in a room are known but fail to meet the requirements of Test A and the building material of the other parts of the surface are also known and meet the requirements of Test A, then Test B can be applied:

Calculate the value of the inequality of inequality 5 for the building material of every part of the surface of the room according to Test A. No value is allowed to be more than ”2” according to Fig 5. The values have to be weighted and added up corresponding to the ratio of the surfaces in the room. If the result does not exceed ”1” then the material meets the regulation.

Test C

The area related activity of beta radiation of building material (e.g. uranium glazed tiles etc.) is not allowed to be more than 1 Bq.cm^{-2}. The measurement can be performed with a contamination monitor, which is in contact with the material and also if the push button for high energy beta radiation has been pressed.

APPLICATION OF THE STANDARD

The fulfilment of the used test criteria is necessary for the radiation safety of ”building material” or ”building elements/component parts” or ”building elements/component parts in a room” in this sense of the standard.

It is expressly pointed out that Test A and Test B are equally good.

The results in a test report can only be stated as:

”Building material” or ”building elements/component parts” or ”building elements/component parts in a room”

- agree with ÖNORM S 5200
  or
- do not agree with ÖNORM S 5200.

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