INVESTIGATIONS ON THE INCREASE OF NATURAL RADIATION EXPOSURE IN BUILDINGS DUE TO THE INHALATION OF Rn-222- AND Rn-220-DAUGHTERS.

G.Keller, K.H.Folkerts, H.Muth
Institut für Biophysik
der Universität des Saarlandes
D 6650 Homburg/Saar

Abstract

Results of measurements of the Rn-222 and Rn-222- and Rn-220-daughter product concentrations in dwellings and in the open air are presented. Comparison was made between the experimentally obtained activity concentrations and the concentrations derived from model calculations using measuring data of Rn-222- and Rn-220-exhalation rates from building materials as input data. The results agreed well with the experimentally data obtained from random sampling. Dose calculations gave a range of the mean effective dose equivalent by residence in dwellings of 0.2-0.8 $mSv \cdot a^{-1}$ for Rn-222-daughters and about 0.1 $mSv \cdot a^{-1}$ by Rn-220-daughters.

Introduction

The highest contribution to the natural radiation exposure is delivered by inhalation of the short lived Rn-222- and Rn-220-daughters(1).These natural radionuclides arrive to the breathing air by exhalation of Rn-222 and Rn-220 from the soil and from the building materials. Especially in room air an enrichment of Rn-222, Rn-220 and their short lived daughters can be observed. In order to obtain a more comprehensive understanding of the mechanisms, which lead to the observed enrichment of radon and radon daughters in dwellings, we performed measurements of the activity concentrations of Rn-222, its short lived daughters and the Pb-212/Bi-212-concentrations in dwellings and in the open air. The concentrations of Rn-222 were measured by electrostatic deposition of Po-218, whereas the concentrations of the short lived daughters were determined by air sampling and alpha-spectroscopy (2). Furthermore, we performed laboratory investigations on the exhalation rates of Rn-222 and Rn-220 (3). The results were used as input data for model calculations of the Rn-222-concentrations in dwellings and were compared with the results of the experimental study from random sampling in dwellings.

Results

Figure 1 shows the results of the measurements of the radon and daughter product concentrations from random sampling in dwellings and in the open air. The values for the activity concentrations of short lived Rn-222- and Rn-220-daughters are given as equilibrium equivalent concentrations Ceq. The graphic representation shows, that the median value for the Rn-222-concentrations indoors is about a factor of 4 higher, than the corresponding value for the open air. In the case of the short lived Rn-222-daughters, this ratio amounts to about a factor of 3.

Using our measuring data, we investigated, whether the potential alpha energy concentrations of the Rn-222- and Rn-220-daughters are correlated. Figure 2 shows the relation obtained for Rn-222- and Rn-220-daughters in dwellings.

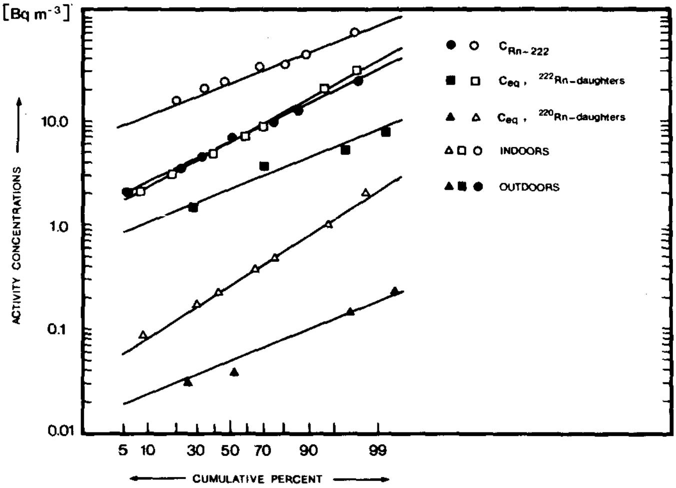

Figure 1: Cumulative frequency distribution of the Rn-222 and daughter product concentrations in dwellings and in the open air. (C_{eq} [$Bq\cdot m^{-3}$] = $3.7\cdot 10^{3}$ $C_{pot,\alpha}$ [WL] for Rn-222-daughters and C_{eq} [$Bq\cdot m^{-3}$] = 280 $C_{pot,\alpha}$ [WL] for Rn-220-daughters.)

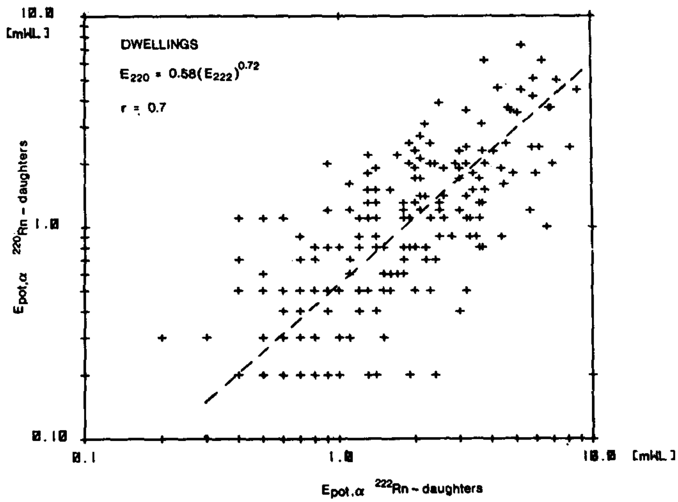

Figure 2: Correlation between Rn-220- and Rn-222-daughter product concentrations in dwellings.

The regression coefficient of r = 0.7 and the graphic representation indicates, that the Rn-220-daughter product concentrations in dwellings are correlated with the corresponding Rn-222-daughters. Moreover, our data show, that the contribution of the Rn-220-daughters to the total potential alpha energy concentration is not to be neglected compared with the Rn-222-daughters. This is a finding, similar to that of STRANDEN (4).

Another important quantity is the ratio between the equilibrium equivalent concentration Ceq of the daughters and the concentration of its parent nuclide C(Rn-222). This ratio is called the equilibrium factor F. In dwellings the median value of F was determined at $F = 0.3 \pm 0.1$ and in the open air F was $F = 0.4 \pm 0.1$. This values agree well with results from theoretical considerations (5).

In order to obtain a better understanding of the results found in dwellings by random sampling, we performed measurements of the exhalation rates of Rn-222 and Rn-220 from building materials. The results are shown in table 1.

Table 1: Rn-222- and Rn-220-exhalation rates from building materials.

Material	Φ_{Rn-222} 10^{-3} $\{Bq \cdot m^{-2} \cdot s^{-1}\}$			Φ_{Rn-220} 10^{-3} $\{Bq \cdot m^{-2} \cdot s^{-1}\}$		
	min	mean	max	min	mean	max
Pumice	0.13	0.74	1.75	27	112	565
Gypsum	0.05	0.79	5.10*	10	123	277
Lime stone	0.35	1.33	3.00	24	62	120
Heavy concrete	0.05	0.35	0.55	10	43	107
Aerated concrete	0.12	0.27	0.51	15	24	44
Slag stone	-	0.18	-	-	33	-
Brick	-	0.05	-	-	10	-
Quarry st. (Phorphyry)	-	0.57	-	-	82	-
Sandstone	-	0.26	-	-	51	-
Marble	-	0.05	-	-	10	-

If less than five different samples were measured, only the arithmetic mean is given.
* This value was measured for chemical gypsum.

As can be seen from table 1, the measured activity exhalation rates of Rn-220 are higher by about a factor of 100 than the values for Rn-222, as is expected by diffusion theory (6). Using the median values of all exhalation measurements, which were determined at $\Phi(\text{Rn-222}) = 0.5 \cdot 10^{-3}\ Bq \cdot m^{-2} \cdot s^{-1}$ and $\Phi(\text{Rn-220}) = 50 \cdot 10^{-3}\ Bq \cdot m^{-2} \cdot s^{-1}$ as input data for model calculations of the resulting indoor concentrations, one obtains for an interval of possible ventilation rates of $0.1\text{-}1.0\ h^{-1}$ the following intervals of possible Rn-222- and Rn-220-indoor concentrations.

Rn-222: $C(\text{Rn-222}) \approx 10 - 42\ Bq \cdot m^{-3}$

Rn-220: $C(\text{Rn-220}) \approx 8\ Bq \cdot m^{-3}$

The result for Rn-222 agrees very well with the results of our own measurements in dwellings (c.f. Figure 1) and with results of investigations of a long term study, presently performed in the Federal Republic of Germany. Unfortunately there are only a little experimental data on Rn-220-concentrations in dwellings. But the few data available, seem to confirm this calculations.

Applying the dose conversion factors recommended by UNSCEAR (1), one now can estimate the probable range of the annual effective dose equivalents due to inhalation of short lived Rn-222- and Rn-220-daughters for members of the public. From the calculated indoor concentrations an equilibrium equivalent Rn-222-concentration of Ceq = F·C(Rn-222) = 3.0-12.6 $Bq \cdot m^{-3}$ and for the Rn-220-daughters of Ceq = 0.4 $Bq \cdot m^{-3}$ results (F(Rn-220) = 0.05 (1)). The dose conversion factors D are given in Sievert per Joule inhaled potential alpha energy. D(Rn-222) = 2·$Sv \cdot J^{-1}$ and D(Rn-220) = 0.7 $Sv \cdot J^{-1}$ for the effective dose equivalent (1). Under consideration of a breathing volume of 15 $m^3 \cdot d^{-1}$ indoors, a range of the effective dose equivalent of H(Rn-222) = 0.2-0.8 $mSv \cdot a^{-1}$ and about H(Rn-220) = 0.1 $mSv \cdot a^{-1}$ by inhalation of short lived Rn-222- and Rn-220-daughters in dwellings can be expected. This values, which were derived from the results of the exhalation measurements agree well with the results obtained from the direct measurements in dwellings. Furthermore, the results show, that the contribution of the Rn-220-daughters should not be neglected when estimates of the effective dose equivalent from natural airborne radioactivity in dwellings are performed. Another important result, which can be derived from this investigations is, that the exhalation from the walls and, therefore, the activity concentration of Ra-226 and Ra-224 in the building materials seems to be the main source for indoor radon in the western part of the Federal Republic of Germany, thus causing the enhancement of the natural radiation exposure. The higher values of the activity concentrations found in cellar rooms (about a factor of two on average) could be attributed to the higher exhalation rates of the cellar walls, mainly caused by the moisture insulation outsides(6). Therefore, influences from the soil and sources like tap water or water from showers seem to be only in regions with special geological structures of significance.

References

1.) UNSCEAR'82: "Ionizing radiations; sources and biological effects", United Nations Scientific Committee on the Effects of Atomic Radiations, Report 1982, New York, United Nations Publication, Sales No. E82,IX,8 06300 p, 141-210, (1982).

2.) Keller,G., Folkerts,K.H., Muth,H.: "Activity concentrations of Rn-222, Rn-220 and their decay products in German dwellings, dose calculations and estimate of risk", Radiat. Environ. Biophys. 20, 263 274, (1982).

3.) Keller,G., Folkerts,K.H., Muth,H.: "Method for the determination of Rn-222 (Radon)- and Rn-220 (Thoron)-exhalation rates using alpha spectroscopy", Rad. Prot. Dos., Vol.3, No.1/2, 83-89, (1982).

4.) Stranden,E.: "Thoron and Radon Daughters in Different Atmospheres", Health Physics 38, 777-785, (1980).

5.) Jacobi,W.: "Activity and Potential Alpha Energy of Rn-222, Rn-220 Daughters in Different Air Atmospheres", Health Physics 22, 441-450, (1972).

6.) Folkerts,K.H.: "Theoretische und experimentelle Untersuchungen über Diffusion und Exhalation der natürlich radioaktiven Edelgase Rn-222 (Radon) und Rn-220 (Thoron) aus Baustoffen und deren Bedeutung für die Strahlenexposition in Wohnräumen", Ph.D.Thesis, Universität des Saarlandes, Saarbrücken/Homburg, (1983).