DOSE CALCULATIONS FOR INFANTS AND YOUTHS DUE TO THE INHALATION OF RADON AND ITS DECAY PRODUCTS IN THE NORMAL ENVIRONMENT

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1. INTRODUCTION

^{222}Rn and its decay products in the atmosphere of normal working- and living rooms contribute to parts of our respiratory tract the highest radiation burden from all the natural radioactive environment (1, 2). The base of todays lung dose calculations are the physiological data of the ICRP-Reference Man (3) and the deposition and retention models of the ICRP-Task Group on Lung Dynamics (4). Both deal extensively with the problems associated with the adult, but much less consideration is given to the physiological properties of the growing organism and none to the resulting radiation dose. The aim of this paper was to determine the influence of age-dependent variables on dose calculations.

2. PHYSIOLOGICAL DATA

In general few data are available on the change of physiological parameters in dependence of age, except for the new data published by Hötter (5). Furthermore the published data show large differences for one and the same parameter. For our calculations we defined age dependent parameters, comprising geometrical dimensions of lung parts as well as respiratory standards. Due to the lack of data, resp. for the interpolation of missing data from published results the following assumption was made: the lung of a child is the miniature version of the fully developed lung of an adult. Whenever large differences were found in the literature for one and the same parameter, either a mean value was calculated or the single values were fitted to a monotonously increasing function. In general the curves of most lung parameters showed the same tendency: steep increase during the first 10 years of life and continuing slowly into a saturation curve with the end value (age 30 years) represented by data for the Reference Man.

3. DEPOSITION PROBABILITIES

Due to the different geometry of the respiratory tract of an adult as compared to a child, there is also a change in the flow conditions and depositon probabilities. For all calculations the Landahl-lung model was used, since there were too many physiological age dependent data missing in order to use the more detailed Weibel-lung model. For the calculations of the deposition probabilities in the various regions of the respiratory tract, the Landahl method (6) was applied with minor alterations. The calculations were based on the following reference atmosphere:

activity median aerodynamic diameter (AMAD) of attached nuclides:
0.2 μm
AMAD of unattached nuclides (8.5% of RaA, 1.0% of RaB, 0.6% of RaC):
0.001 μm

The results of these calculations showed that - despite the large geometrical changes of the growing organism - both the absolute values (for a defined respiratory minute volume, RMV) and the distribution within the single regions differed only slightly from the values for an adult. In general the functions for the deposition probability of the different nuclides show a decline during the first few years, approximating a constant value later on. In accordance to the assignment of the various regions to the ICRP-lung model compartments, the calculated regional deposition probabilities were summed up over the compartments.

4. RADIOACTIVITY INHALED

For the determination of the inhaled radioactivity, age dependent daily life patterns were defined. With respect to the individual physical activity, influencing the RMV to a large extent, these life patterns were divided into periods of rest, light and heavy work. Furthermore the percentage of time spent indoors and outdoors was considered, since the atmospheric nuclide concentration within buildings is increased as compared to outdoors. In this manner the annual inhaled radioactivity was calculated for different ages. Fig. 1a, b represent these activity functions for 2 extreme cases showing large differences of the annual inhaled activity. For children and youths no differences in individual physical activities were assumed.

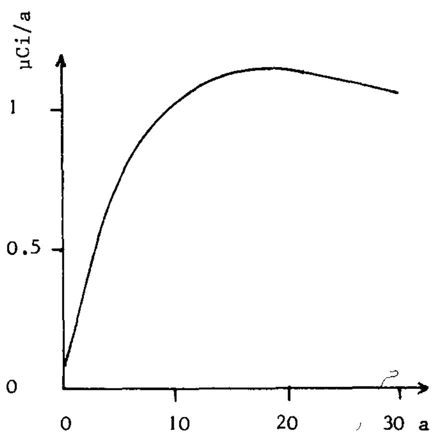

FIG. 1 a

Annual Inhaled Radioactivity due to Rn under Favourable Conditions:
<u>Rn concentration:</u>
indoors: 0.1 pCi/l
RaA:RaB:RaC = 0.9:0.6:0.4
outdoors: 0.1 pCi/l
RaA:RaB:RaC = 0.9:0.5:0.4
<u>Adult physical activity:</u> light work

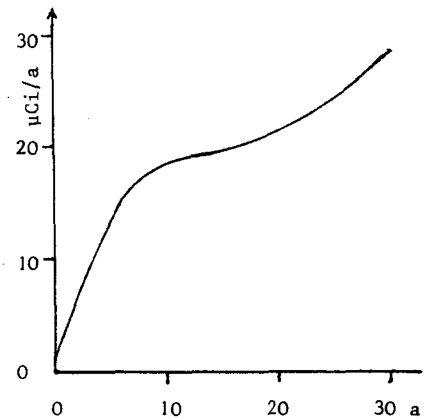

FIG. 1 b

Annual Inhaled Radioactivity due to Rn under Disadvantageous Conditions:
<u>Rn concentration:</u>
indoors: 2.0 pCi/l
RaA:RaB:RaC = 1:0.7:0.5
outdoors: 0.5 pCi/l
RaA:RaB:RaC = 1:0.6:0.5
<u>Adult physical activity:</u> heavy work

5. AGE DEPENCENT DOSE CALCULATIONS

With the use of a hybrid computer the influence of age-dependent deposition probabilities and activity functions were investigated for the steady-state activities in the single compartments. Since there are no data available for the age dependence of the clearance processes, a possible age dependence was studied by varying single parameters. Experiments with animals and man reveiled, that the half life of 0.5 days for the transport from pulmonary compartment region to blood of the revised ICRP-clearance model (7) is far too large and the true value is less or equal 30 mins (8, 9). Applying the smaller value for the half life the activity within the pulmonary compartment is reduced approximately by a factor 2.

Considering the age dependence of the mass of the tracheobronchial (TB) and pulmonary compartment (P), the integral α-dose was calculated. Fig.2 a, b represent the dose in dependence of age, for the TB- and P-compartment using the activity functions as defined in Fig. 1 a.

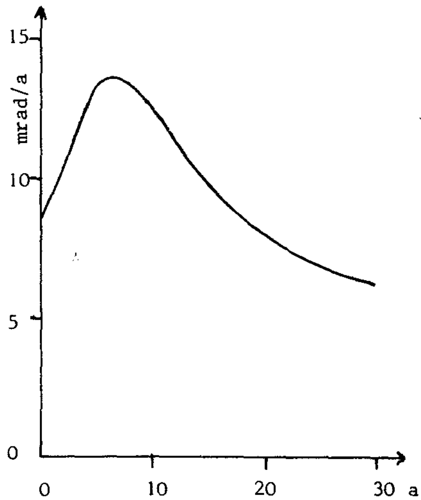

FIG. 2 a

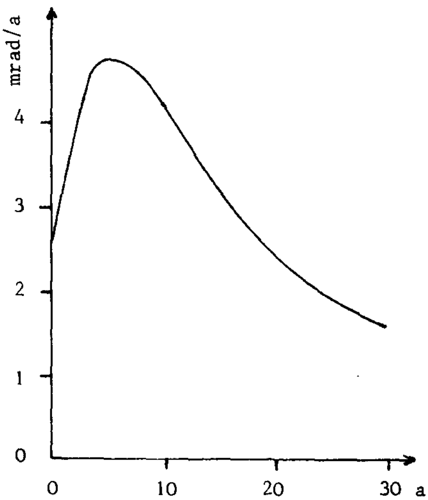

FIG. 2 b

Integral α-Dose (mrad/a) in Dependence of Age (a) for the Tracheobronchial (TB)- and Pulmonary (P)-Compartment

For both compartments there is a significant maximum dose, which is received at the age of about 6 years. It is approximately 2 - 3 times higher than the corresponding dose of an adult. The calculations for the disadvantageous conditions (see Fig. 1 b) reveiled that up to the age of about 16 years the shape of the dose curves for TB- and P-compartment is similar as for the favourable conditions, but with no further decrease with progressing age. Again the maximum dose is reached at the age of 6 years, however, the values are 313 mrad/a and 101 mrad/a for the TB- and P-compartment.

In all calculations we determined only the integral dose according to the ICRP-compartment model. Within the tracheobronchial compartment, however, there is a very non-uniform α-dose distribution. From studies on adults it is known that the highest dose is received by the basal cells of the segmental and subsegmental bronchi (10). In the case of children and youths the different geometrical dimensions (e. g. thickness of mucus and cell layers) and different physiological processes (e. g. ciliary-movement) have to be taken into consideration. Further detailed calculations are in progress concerning this problem.

In some special cases (e. g. in regions of Brazil and India) also the atmospheric content of ^{220}Rn and its decay products in the environment is not neglegible. Calculations will be extended to this problem as well.

6. CONCLUSIONS

From our results it can be seen that there is a pronounced age dependence of the integral α-dose to the lung due to inhalation of Rn and its decay products. A maximum dose is reached at the age of about 6 years. This dose is up to a factor 3 higher than the corresponding dose value for an adult, living under the same conditions.

Therefore lung dose calculations of a given population for radiation protection purposes should rather consider age dependence than using a "reference man" as a representative for the whole population.

REFERENCES

(1) POHL, E., et al., Biological and Environmental Effects of Low-Level Radiation, Vol. II (Proc. Symp. Chicago, 1975), IAEA (1976) 305
(2) STEINHÄUSLER F., et al., Proc. Health Phys. Soc. Tenth Midyear Topical Symp. on Nat. Radioact. in Man's Environ., Saratoga Springs, New York (1976)
(3) Report of the Task Group on Reference Man, ICRP No. 23 (1975)
(4) Task Group on Lung Dynamics, Health Phys. 13 (1967) 1251
(5) HÖTTER, G. J., Die Lungenfunktion unter besonderer Berücksichtigung des wachsenden Organismus, Steinkopff Verlag (1975)
(6) LANDAHL, H. D., Bull. Math. Biophys. 12 (1950) 43
(7) JACOBI, W., Health Phys. 23 (1972) 3
(8) POHL, E., et al., Strahlentherapie 136 (1968) 738
(9) POHL, E., et al., Health Phys. 31 (1976) 343
(10) HARLEY, N., et a., Health Phys. 23 (1972) 771