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RADON LEVELS AND RESULTING EFFECTIVE DOSES OF RESIDENTS IN GORNJA STUBLA AT KOSOVO APPLYING DOSIMETRIC LUNG MODELS BASED ON ICRP 65 AND ICRP 66 METHODOLOGY

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Abstract *The town Gornja Stubla, situated in the South-West part of Kosovo, is a community with high indoor radon level due to its geochemical background. Radon activity concentration in indoor air has been measured by exposing the 960 track-etch detectors for one year, in 172 rooms of 65 dwellings. Annual averages of concentration ranged from 35 Bq/m^3 to 6010 Bq/m^3. In a first attempt, the effective doses of residents have been calculated applying the ICRP 65 methodology, based on the average radon concentration for the dwelling and for concentrations in the rooms of a dwelling in which they spend fractions of the entire time spent indoors. Both seasonal and annual doses have been calculated. The annual values were in the range of 0.6–107 mSv/a with an average value of 8.6 mSv/a.*
As nest step we considered that effective dose, being influenced by a number of different parameters and divided into subject and aerosols related parameters, is connected with two crucial parameters, namely, the Dose Conversion Factor (DCF) [mSv/WLM] for a particular person (accounting for real gender, age and physical activity level) and indoor radon concentration and its short lived progeny at field area. Therefore, software based on ICRP Publication 66 was developed for determination of effective dose per unit inhaled activity of radon progeny, DCF. According to the results of indoor radon measurements in the area of Gornja Stubla, the effective dose for its population was estimated by using the dosimetric lung model. The results, obtained according to ICRP 66, were compared with results calculated according to ICRP Publication 65.

Key words (bold): dosimetry, lung model, indoor radon, dwellings, effective dose, real population, Gornja Stubla, Kosovo.

1. INTRODUCTION

In this work, the effective dose due to radon received by the population of the local community Gornja Stubla, Kosovo in South Serbia, was determined. The area is rich in natural radioactive isotopes and has an increased natural radiation background. Measurement of indoor radon concentration is an initial point for the determination of effective dose received by the local population. To determine the effective dose, it is necessary to know the *Dose Conversion Coefficient* (DCF) which depends on many parameters. The DCF is defined as the effective dose per unit exposure to radon progeny, and is traditionally given in mSv/WLM. Two values of the DCF were found in literature: the epidemiological DCF, derived from studies conducted on underground miners which is centered about 5 mSv/WLM, and the dosimetric DCF, about 15 mSv/WLM. It has been shown previously that DCF strongly depends on various parameters. Based on ICRP 66, whose results confirm the dosimetric approach, the authors of this work developed their own computer software for calculating the DCF. The software was partially described in our previous report on FERAS 2012, conference and published in (Romanian Journal of Physics Volume 58, Issue SUPPL., 2013, Pages S336-S347), so details will not be repeated here. The output result is a DCF for a given set of input parameters, gender, age, level of physical activity, and aerosol characteristics. Knowing the radon concentration and DCF, it is possible to determine the effective dose for real people. We performed the respective calculations for members of 65 families in the Gornja Stubla village. In addition, effective doses were calculated according to ICRP 65 [1].

2. Method

2.1. Determination of radon concentration

Gornja Stubla is a small town in Kosovo, South Serbia. The area is rich with natural radioactive isotopes for geological reasons. Radon measurements were performed with passive, SSI/NRPB CR-39 solid state nuclear track detectors. Detectors were applied four times, during one year, so that results were obtained for each season. Finally, each location was represented with one result which is the annual average. Detectors were applied in totally 65 houses of Gornja Stubla [2-6]. In each house at least two detectors were exposed, in the room where people spend most time during the day (living room or kitchen) and in the sleeping room (bedroom). Results obtained from two detectors were not averaged. We estimated the fraction of time which is spent in some particular room in respect to the total indoor time. The average value for the whole set houses was 485 Bq/m3, with range between 35 Bq/m3 (for one bedroom) and 6010 Bq/m3 (also for a bedroom). Seasonal oscillations are obvious: the smallest values were found during the summer season, and the largest in winter season due to poor ventilation and heating style. The results presented here do not reveal any correlation with construction style, neither with age of houses. This leads to the conclusion that construction materials do not contribute significantly to the indoor radon, and that the soil beneath the object is its main source.

2.2. *Determination of effective dose according to ICRP 66*

As said already, effective dose was estimated by the approach described in ICRP66 publication [7]. The computer programs written according to this publication was described before in [8]. The effective dose, i.e. Dose Conversion Coefficient (DCF), is calculated for each particular individual taking into account all relevant parameters, age, gender, level of physical activity etc. In addition, aerosol parameters were not available and the best estimates for them were taken into calculation. Input data for DCF calculation are presented below in Table 1. Other necessary information, like unattached fraction, equilibrium factor etc, were not available, and not used in analysis.

Effective dose, E, was calculated with the formula:

$$E = C/3700 \times F \times t/170 \times RR \times DCF$$

where C is radon concentration in Bq/m³, F equilibrium factor, usually taken as 0.4, t all time indoor exposure in hours (8760 h per year), RR room ratio (fraction of time per day that is spend indoor), and DCF dose conversion factor in mSv/WLM.

Table 1. DCF for adult, according to the different levels of physical activity. PA physical activity, LE light exercise, SS sitting and sleeping, Vt tidal volume in ml, Fr breathing frequency in min^{-1}, VS inhalation rate in ml s^{-1}, FRC functional residual capacity in ml, DCF dose conversion factor in mSv/WLM.

Sex	PA	Vt	Fr	VS	FRC	DCF
M	LE	1250	20	833	3301	15.85
F	LE	992	21	694	2681	14.18
M	SS	750	12	300	3301	10.82
F	SS	464	14	217	2681	6.56

3. Results

Radon concentration found in Gornja Stubla dwellings are given in Table 2. Due to the limited space, only a small fraction of results is presented here.

The first column in the Table 2 gives the id. index of a house, the second column the index of a room in a given house. For example, in house No3 radon was measured only in one room, while in house No1, detectors were placed in seven rooms. L and B denote living and bedrooms. Results are given for four seasons in the third column, and arithmetical mean (i.e. the annual mean) in fourth. Room ratio (in respect to the total indoor occupancy) is given in the last column. Radon concentrations are in the range between 35 and 6010 Bq/m3 with arithmetical mean AM=485 Bq/m3, and standard deviation 330 Bq/m³.

3.1. Effective dose calculation

Determination of DCF was conducted for each room where the radon concentration was measured. DCF was calculated with abovementioned programs, for specific persons who live in that room. Relevant input parameters that were available are gender, age of subject and level of physical activity. ICRP 66 recommended parameters of inhalation based on age and physical activity, which are given in Table 1. For other parameters, which are not available, namely aerosol distribution, equilibrium factor, thickness of tissue level in respiratory tract best estimates were taken. For the list of best estimation of various parameters (more than 20 various parameters) see Marsh et al [9]

Population of Gornja Stubla is mostly between 15 years to 65 years old and in equal proportion male and female. We assumed light exercise in living rooms and kitchens, while in bedroom the activity level is “sitting and sleeping”. DCFs were calculated for each person who spent some time in the rooms where radon concentration was measured. Based on calculated DCF obtained from ICRP66, the annual effective doses **E** for men and women in 65 houses were estimated. The annual range of effective dose is between 3.75 mSv up to 104 mSv. The arithmetical average is 30 mSv/a, standard deviation 24 mSv/a.

Table 2. Radon concentrations (C_{Rn}) in Gornja Stubla houses: Code is the index of house; Room is the index of room in a given house; L living room; B bedroom. I spring, II autumn, III winter, IV summer. Only a small fraction of data is presented in this table, from 5 out of 65 locations.

Code	Room		C_{Rn} [Bq/m^3]				C_{Rn} [Bq/m^3]	Room ratio
	No	Type	I (Spring)	II (Aut)	III (W)	IV(Sum)		
1	1	L	893	468	871	638	**718**	0.4
1	2	B	307	494	490	459	**438**	0.1
1	3	B	319	283	203	321	**282**	0.1
1	4	B	481	111	589	456	**409**	0.1
1	5	B	646	808	3348	1332	**1534**	0.1
1	6	B	2674	2909	8864	9591	**6010**	0.1
1a	1	L	317	133	96	199	**186**	0.1
2	1	L	767	1700	2169	2543	**1795**	0.5
2	2	B	982	606	-	2082	**1223**	0.5
3	1	L	238	857	936	1151	**796**	1.0
4	1	L	267	74	529	317	**297**	0.5
4	2	L	210	139	595	255	**300**	0.5
5	1	L	1241	909	387	586	**781**	0.4
5	2	B	966	411	251	193	**455**	0.15
5	3	B	390	69	623	407	**372**	0.15
5	4	B	795	648	374	450	**567**	0.15
5	5	B	159	141	114	136	**138**	0.15
etc.								

Table 3. Summary of radon concentration (C_{Rn}) in Gornja Stubla area, and effective dose (E) determined according to ICRP65 [1] and ICRP66 [7]

	C_{Rn} [Bq/m^3]	E (ICRP 65) [mSv/a]	E (ICRP 66) [mSv/a]
Minimum	35	0.62	3.75
Maximum	6010	107	104
Arithmetic mean AM	485	8.6	30
Arithmetic SD	330	10.9	24

4. Discussion

Table 2 shows that the range of radon concentration values is very wide, from 35 up to 6010 Bq/m^3. Extremely high values are caused by uranium in the ground beneath the houses.

Also, as one can see in Table 3, the effective doses calculated by ICRP 66 is much larger than those obtained by ICRP 65. The reason for such large discrepancy is the much larger DCF, up to 4 times obtained by the ICRP 66 dosimetric model compared to the one used in ICRP65.

It is worth to notice that radon concentrations in investigated area are very large. This is not surprising because the village is situated on the hill which could be considered as a deposit of uranium ore.

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