DOSE AND RISK ASSESSMENT FROM RADON IN THE URAL

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INTRODUCTION

The radiation situation in the South and Middle Urals is quite complicated due to two main reasons:

- High radon exposure levels derived from the geological structure of Ural region (relatively high concentrations of U and Th in lithosphere, ground waters with high Rn concentration, increased permeability areas etc.).
- Consequences of radiation accident at "Mayak" nuclear plant in 1957. As a result of this accident a considerable territory of Chelyabinsk and Sverdlovsk regions was polluted by mixture of nuclear fission products $^{90}Sr+^{90}Y$ - 5.4%, $^{95}Zr+^{95}Nb$ - 24.9%, $^{144}Ce+^{144}Pr$- 66%, $^{106}Ru+^{106}Rh$ - 3.7%, ^{137}Cs - 0.036% (the so called East Ural Radioactive Trace - EURT).

The main purpose of this paper is to compare the radiation risks due to equivalent doses in different organs and effective doses resulting from radiation pollution and radon and thoron daughters exposure.

METHODS OF MEASURING Rn AND Tn CONCENTRATIONS

The survey was made by the following two methods: aspiration technique of measuring of equivalent equilibrium concentration of radon and thoron and determination of season mean concentrations of Rn by applying the nuclear track nitrocellulose detectors. The cellulose nitrate films were used as sensitive materials. The cellulose nitrate detector was placed in special plastic chamber, provided with silicon rubber filter preventing the penetration of ^{220}Rn and radon daughters into chamber space. The measuring chambers with detectors were exposed for 1-3 months. Detectors were etched in 6N NaOH solution after exposition and track density was determined by spark counter.

The equilibrium equivalent concentration EEC of radon and thoron was determined by Markov modified method [1].of measuring filter α-activity after deposition of radioactive aerosols on it. For measuring of equivalent equilibrium concentration of radon and thoron we used both serial alpha-radiometers and devises developed at our Institute together with the Urals State Technical University. The results obtained by both methods correlate well.

DOSE ASSESSMENT

The intake of radionuclides for EURT zone due to inhalation and food chains was estimated by the official Methodical Recommendations [2]. Equivalent doses for different organs and effective doses were calculated using ICRP Publication 56 data [3].

The data on average annual gaseous radon activity (C_{Rn}), equilibrium equivalent concentration of thoron (EEC_{Tn}) and annual exposure effective doses (E_{Rn}, E_{Tn}) in various districts for village types of buildings are shown in table 1. Doses due to radon and thoron daughters exposure were calculated using ICRP Publications 50 and 65 [4,5].

During our investigation we obtained that the very high concentrations of thoron daughters are characteristic for the Urals region. Average world value of annual effective exposure dose due to thoron is listed in Report of UNSCEAR, 1993 [6] and is equal to 0.067 mSv/a. So, we can see that the thoron exposure in the Urals is an order of magnitude higher than the average world values.

Table 1

Average annual gaseous radon activity, equilibrium equivalent concentration of thoron and annual exposure effective doses in Sverdlovsk region

District	C_{Rn}, Bq/m^3	E_{Rn}, mSv/a	EEC_{Tn} Bq/m^3	E_{Tn}, mSv/a
Bogdanovich	117.1	2.1	3.7	1.3
Kamensk	110.7	2.0	2.6	0.91
Rezh	231.6	4.1	3.8	1.3

RISKS ASSESSMENT

During our work we used some assumptions and risk projection models :

1. Absolute risk model for risk assessment of leukemia [7].
2. Constant relative risk model for assessment of total cancer risk excluding leukemia and some internal organs [7].
3. Modified relative risk model (Jakobi model) for risk assessment of lung cancer due to radon and thoron daughters exposure [5].
4. For all risk projection models we assumed linear no-threshold dose response.

Risk comparing was made for rural districts of Sverdlovsk region: Kamensk and Bogdanovich which were polluted during the radiation accident on “Mayak” nuclear plant in 1957. For considered in this paper territories the average surface contamination by ^{90}Sr was ~3 Ci/km^2. The Rezh district was chosen because it’s the district with maximum radon exposure rate in Sverdlovsk region. Statistical data on survival probability, mean life expectancy (L_m=59.7, L_f=71.4 years) and baseline cancer risks typical for Sverdlovsk region were used for risks assessment. Relatively low regional survival probability and mean life expectancy decreases radiation cancer risks in comparison with thatin the developed countries.

The results of radiation risk assessment and the attributable excess cancer death frequency F_r are listed in table 2. For individual organs the equivalent doses are shown, for total cancer risk assessment - the effective doses without contribution of red bone marrow. For radon and thoron exposure the average annual effective doses are shown.

As one can see from the table 2 the lifetime radiation risks due to radon exposure in the village houses in Sverdlovsk region are comparable to or exceed the radiation risks due to serious radiation accident.

REFERENCES

1. Krisiuk E.M. Radiation background in apartments. Moscow. Energoatomizdat. 1989. (in Russian).
2. Reconstruction of a commitment dose for inhabitants of pool of the Techa river and zone of accident in 1957 at “Mayak” nuclear plant. Methodical Recommendations. State Committee on Sanitary and Epidemiological Supervision. Moscow. 1995.(in Russian).
3. *Annals of the ICRP*, 1989, **20**(2).
4. *Annals of the ICRP*, 1987, **17**(1).
5. *Annals of the ICRP*, 1993, **23**(2).
6. Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 1993 Report to the General Assembly, with scientific annexes, United Nations, New York.
7. Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 1988 Report to the General Assembly, with annexes, United Nations, New York.

Table 2

Comparison of radiation risks due to radon exposure and consequences of accident on "Mayak" nuclear plant in 1957 (surface contamination by ^{90}Sr 3 Ci/km^2)

Organ	Age of exposure	Dose (mSv)	Baseline cancer risk		Radiation risk		Attributable excess frequency F_r (10^{-5} a^{-1})	
			Males	Females	Males	Females	Males	Females
All cancers excluding leukemia	0-9	69,5	0,140	0,121	0,0059	0,0089	9,84	12,52
	10-19	47,9	0,140	0,121	0,0025	0,0038	4,25	5,29
	20-29	41,2	0,140	0,121	0,0020	0,0028	3,34	3,96
	30-39	41,2	0,135	0,119	0,0009	0,0012	1,50	1,69
Leukemia	0-9	125,0	0,0022	0,0029	0,00091	0,00075	1,52	1,05
	10-19	164,7			0,00059	0,00033	0,99	0,46
	20-29	80,9			0,00056	0,00037	0,93	0,52
	30-39	80,9			0,00071	0,00027	1,19	0,38
Stomach	0-9	15,0	0,024	0,020	0,00019	0,00031	0,32	0,43
	10-19	10,9			0,000085	0,00014	0,14	0,19
	20-29	9,8			0,000067	0,00011	0,11	0,15
	30-39	9,8			0,000028	0,000047	0,047	0,066
Small intestine	0-9	44,1	0,00036	0,00029	0,0000084	0,000013	0,014	0,018
	10-19	25,8			0,0000030	0,0000047	0,005	0,007
	20-29	20,5			0,0000021	0,0000032	0,004	0,005
	30-39	20,5			0,0000009	0,0000014	0,001	0,002
Upper large intestine	0-9	221,9	0,0072	0,0123	0,00085	0,0028	1,42	3,93
	10-19	132,3			0,00031	0,00103	0,52	1,45
	20-29	97,3			0,00020	0,00066	0,34	0,93
	30-39	97,3			0,00008	0,00029	0,14	0,40
Lower large intestine	0-9	635,3	0,0052	0,0068	0,0018	0,0044	2,93	6,22
	10-19	385,3			0,0007	0,0017	1,09	2,32
	20-29	283,7			0,0004	0,0011	0,70	1,50
	30-39	283,7			0,0002	0,0005	0,30	0,65
Liver	0-9	14,8	0,011	0,012	0,000087	0,00019	0,15	0,27
	10-19	13,5			0,000049	0,00011	0,082	0,15
	20-29	13,6			0,000043	0,000094	0,073	0,13
	30-39	13,6			0,000018	0,000041	0,031	0,057
Lungs	0-9	47,0	0,052	0,0097	0,00130	0,00047	2,17	0,66
	10-19	40,1			0,00068	0,00025	1,14	0,35
	20-29	32,9			0,00049	0,00018	0,82	0,25
	30-39	32,9			0,00021	0,00008	0,34	0,11
Lifetime radon exposure (EURT zone)		3.1 mSv/a	0,052	0,0097	0.013	0.0077	21.2	10.7
Lifetime radon exposure (Rezh district)		5.4 mSv/a	0,052	0,0097	0,022	0,013	36.2	18.4