Estimates of effective doses among Czech uranium miners

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Background

Radiogenic risk in uranium mines – historically linked to radon exposure

At present, radon levels 1-2 orders of magnitude lower

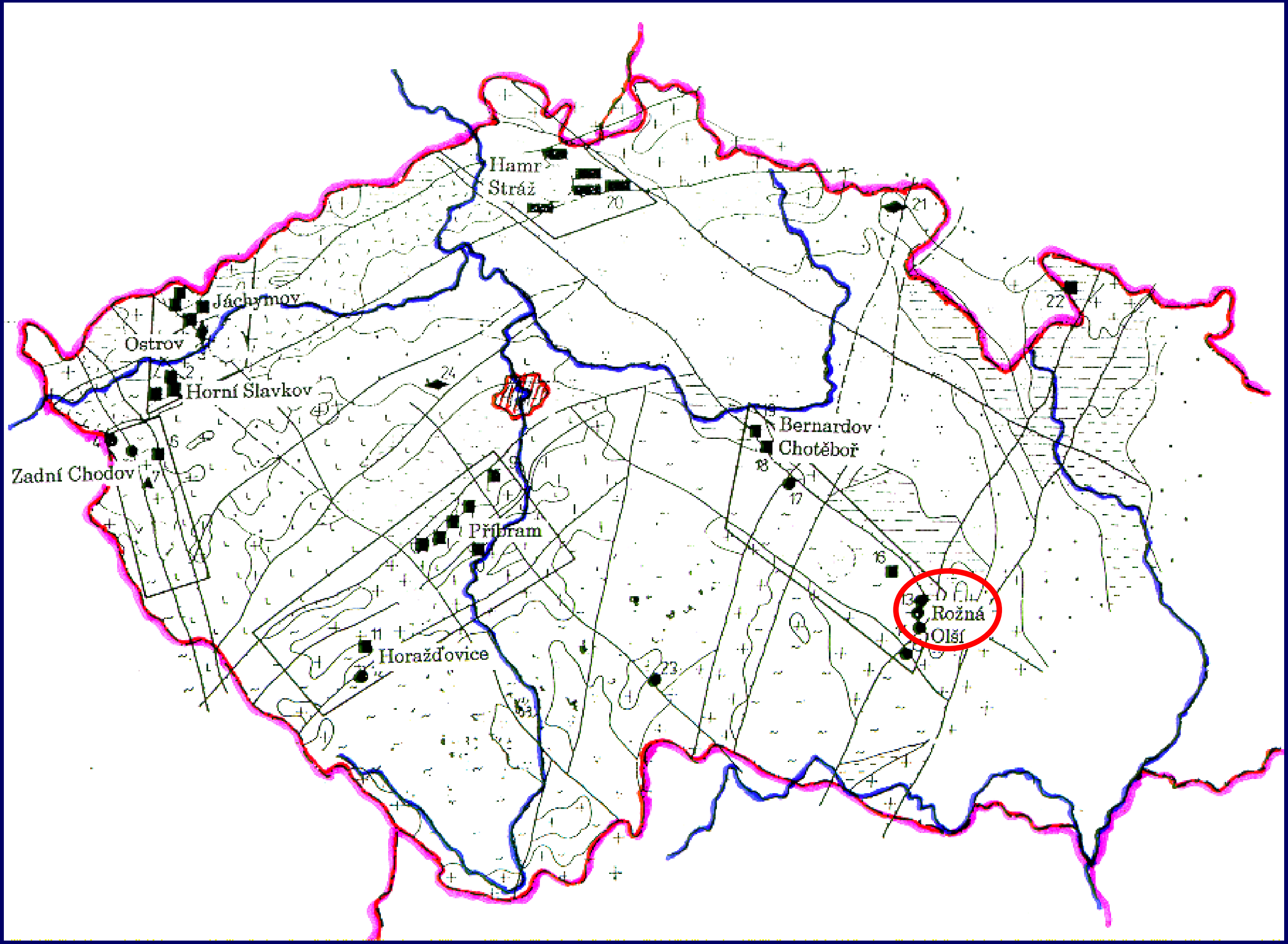
Exposures to other radiation components –

external gamma

and long lived radionuclides in mining aerosol

are of increased importance

U deposits in the Czech Republic



Mine Rožná I

Physical parameters of U dust

Isotopic composition,

including proportion of radon activity escaping from particles, which determines how the gross alpha activity is distributed into radionuclides of the uranium series.

Estimates of this proportions in terms of activities of

Rn deacy products (Bi-214, Pb-214) and Ra-226

based on gamma spectrometry as above.

Particle size in terms of activity median aerodynamic diameter (AMAD)

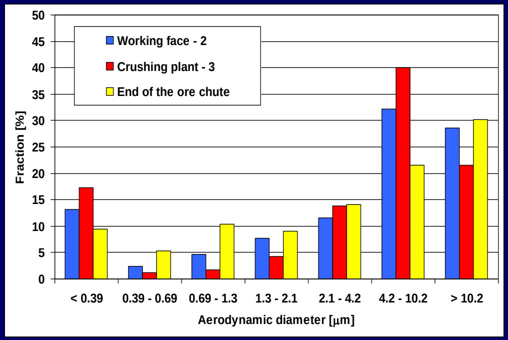
estimated assuming log-normal distribution of activities

corresponding to 7 stages of cascade impactors

The mine dosimetrist and research team

Sampling device and cascade impactor at a stope

Physical parameters - results



Samplings from 14 data sets at different working places

The highest fraction of activities
in categories 4.2-10.2 and >10.2 µm
and lowest fraction
in category 0.39-0.69 µm.

Surprisingly, the activity in the very low category (<0.39 µm) is higher then in next categories - suggesting bi-modal distribution

Analyses were conducted ignoring the first category (about 20% of activities) and parameters (AMAD and GSD) estimated from the limited data

Particle size for different working sites

	range	mean
AMAD (µm)	2.0 – 9.2	7.3
GSD	2.1 – 6.5	3.2

The fraction of escaped radon

	range	mean
	32% – 63%	43%.

Isotopic composition and numbers of alpha emitters

	Emiter type [a]	weight
U-238	LL	1
U-234	LL	1
Th-230	LL	1
Ra-226	LL	1
Rn-222	SL	0.57
Po-218	SL	0.57
Po-214	SL	0.57
Po-210	LL	0.57
Total		6.28
U-235	LL	0.0526
Pa-231	LL	0.0526
Th-227	LL	0.0526
Ra-223	LL	0.0526
Rn-219	SL	0.0526
Po-215	SL	0.0526
Bi-211	SL	0.0526
Total		0.3682

The weights in this table indicate fractions of alpha radionuclides long (LL) and short (SL) lived in the gross alpha activity.

Assuming 43% Rn-222 escape

Assuming fraction $^{235}U/^{238}U = 0.0526$ and no escape of Rn-219

Total number of alpha emitters
n=6.65 alpha emitters

Chemical parameters of particles

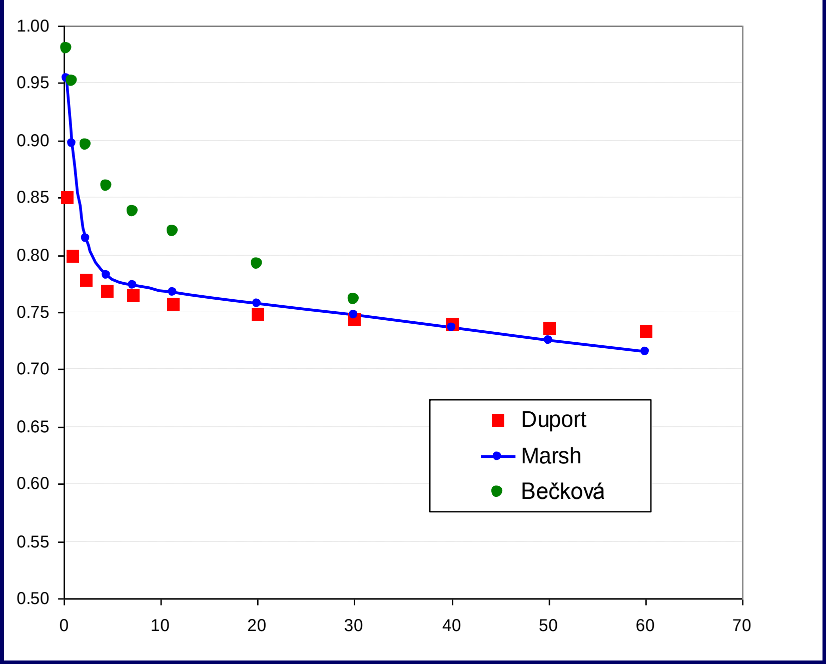
solubility of particles in lung fluid

estimated by own measurements for U-234 and U-238

(Beckova & Malatova 2008)

parameters for other radionuclides taken from

(Duport et al 1991)



Absorption parameters of long lived radionuclides

	f_r [a]	s_r (d^{-1}) [b]	s_s (d^{-1}) [c]	f_1 [d]
^{224}Ra, ^{226}Ra, ^{228}Ra	0.11	7.32	0.000412	0.2
^{210}Pb	0.26	3.91	0.00101	0.2
^{228}Th, ^{230}Th, ^{232}Th	0.14	4.56	0.000683	0.0005
^{234}U, ^{235}U, ^{238}U	0.22	0.78	0.00144	0.2
^{231}Pa	0.18	4.1	0.000886	0.0005
^{227}Ac	0.18	4.1	0.000886	0.0005
^{210}Po	0.18	4.1	0.000886	0.1

[a] Rapid fraction

[b] Solubility of rapid component

[c] Solubility of slow component

[d] Fraction of activity absorbed in blood from intestines

Conversion of unit intakes into effective doses

Software IMBA (Integrated Modules for Bioassay Analysis)
implementing the biokinetic and dosimetric models
currently recommended by the ICRP
enables the users to specify their own parameter values
to the customized internal dose calculations (IMBA 2005)

Estimates of conversion coefficients (mSv/kBq) for different long lived radionuclides and particle size (AMAD)

assuming 46% radon escape

AMAD	<0.4µm	5µm	10µm	7µm	5µm [a]	10µm [a]	7µm [a]
U-238	5.84	3.09	1.87	2.50	3.72	2.75	3.25
U-234	6.79	3.98	2.41	3.23	4.64	3.38	4.04
Th-230	8.78	4.96	3.06	4.04	5.83	4.34	5.09
Ra-226	10.6	6.18	3.92	5.09	7.18	5.38	6.31
Po-210	5.15	3.32	1.80	2.60	3.78	2.56	3.20
Pb-210	0.76	1.10	0.94	1.02	1.03	0.90	0.97
U-235	6.19	3.41	2.07	2.76	4.05	2.98	3.53
Pa-231	10.3	5.82	3.56	4.73	6.84	5.03	5.96
Ac-227	36.2	24.5	15.0	19.9	27.1	19.5	23.5
weighted sum	38.09	22.46	13.88	18.33	26.07	19.20	22.76
conversion	5.8	3.4	2.1	2.8	3.9	2.9	3.4

[a] Correction for 20% fraction of fine particles (<0.4 µm)

Conclusions

Resulting conversion of unit intakes into effective doses corresponding to central values of parameters
3.4 mSv/kBq is about 1/3 in comparison to value 11mSv/kBq that is currently used in Czech mines

Mean annual effective doses at mine Rozna (2000-2009)
1.9 mSv from long lived radionuclides.
4.1 mSv from radon and its decay products (according to latest ICRP on radon)
2.2 mSv from external gamma radiaton

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