THE STUDY ON EFFECTS (BIOCHEMICAL, MORBIDITY, AND MORTALITY) OF RADIOACTIVE CONSTITUENTS OF URANIUM ORE ON HEALTH OF MINERS

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GENERAL STUDIES

The project "The Study on Effects (Biochemical, Morbidity and Mortality) of Radioactive Constituents of Uranium Ore on Health of Miners" has performed in the last six years. In this period many problems were studied and here we would like to summarize the obtained results.

1. Morbidity and mortality of miners in the uranium and control mines.

All miners in the uranium and control mines were medically examined every year. In the medical examination we included the working anamnesis, smoking habits, the clinical examination, tests of pulmonary function, the ophtalmologic examination (each second year) and the roentgenography of lungs.

We examined a total of 1369 miners: 765 uranium miners and 604 miners from control mines. The duration of exposure is presented in Table 1. The average exposure duration of uranium miners is 5.3 years and the average age is 38.4 years (Table 2). In the control group the average exposure was 9.1 years and the average age 39 years. The analysis of smoking habits showed that 45.8% in the exposed group and 50.4% in the control group were smokers (Table 3).

The results of the morbidity examination and the analysis of the blood cells together with the results of the renal examination are presented in Table 4. These results suggest that there is an increased inflammation of the upper respiratory tract in the exposed group (exposed 55.8% and control 41.8%). It is also evident that smokers show an increased number of respiratory troubles (Table 5).

In this period one uranium miner died from microcylindriccellular carcinoma of bronchus after 12 years of exposure. We evaluated the average yearly exposure of this man as 0.8 of maximum allowable concentration (MAC: 3.10^{-10} Ci/liter) of radon and daughters in the working atmosphere. We established the polonium concentration in the lungs as 0.12 pCi per gram of fresh tissue, and the excretion of Po in the urine as 1.34 pCi/1.

The ophtalmologic examination was performed on 630 miners of the exposed group and 305 in the control group. Special attention was paid to the determination of the visual field. The results showed no changes in the visual field of the miners. Also, no differences in ophtalmologic disturbances were found in the exposed and control groups which could suggest any influence of the ionizing radiation on this organ.

2. Study of anaplasia and metaplasia of cellular elements in the sputum of exposed miners.

We sampled the sputum of the exposed uranium miners to perform a cytomorphologic analysis of malignant cells of the respiratory tract. This study has been in progress from 1964 to today. As a control group we chose miners from zinc and lead mines. The sputum samples were colored by the Papanicolau method and the results of the examination were systematized by the Saccomano method. In Table 6 we present the results obtained on exposed miners, and in Table 7 the results on the control group. The presented results are from 1964 to 1968, because the results obtained in 1969 are still being evaluated.

If we analyze the obtained results from the exposed and control groups we are not able to establish any significant difference. Some shifts in classes I-II/3 could be explained by differences in the status of bronchitis, taking in consideration the seasons and the exposure to dust in connection with the intensity of the mine operations.

In the examined material the coniocytes and neutrophil granulocytes are in majority. Very often lymphocytes and bacteria could be found. On the other hand, eosinophylic leucocytes were not found. Exfoliated cells of the respiratory tract cells were found in various numbers in connection with the type and intensity of the inflammation processes. No cases suspicious of malignancy were found.

In some cases we observed cells of class III in the sputum, but when new samplings were made they were not found. Such shifts to the right are in accordance with the clinically established acute bronchitis. As valid results of the examined sputum, we accepted the status of a quiet inflammatory phase.

During this work we established great differences in the cytomorphologic examination in connection with the season. As an illustration we present the results of the examinations of 27 miners in Table 8. The first examination was performed in June and the second one in November 1968. In both cases the same persons were examined. It is evident that in November we found 11% as Class III. In the next examination in 1969, we did not find any case in this class.

3. Study on influence of radon on the respiratory function.

We performed a routine spirometric analysis and also an examination of the respiratory function in the miners (uranium and control) before and after work. The aim of this study is to establish if the work in the atmosphere of radon has any influence on the respiratory function. We performed a parallel study on patients inhaling radon at Niška Banja.

This study showed that in 75% of cases in uranium miners (Gorenja Vas, Zletovska Reka) an increase in Vital Capacity (VC) and Forced Expiratory Volume (FEV_1) after the work started. On the other hand, such differences did not exist in the control group. Using statistical analysis we did not establish any statistically significant changes in the respiratory function (see report from 1965). On the other hand, in patients from Niška Banja we found a statistically significant increase of changes of the respiratory function after 1 hour of radon inhalation. A detailed statistical evaluation of the material in general did not show statistically significant changes in the VC value and the FEV_1 after radon inhalation in exposed miners as well as in patients from Niška Banja.

4. The lung clearance after radon inhalation.

In order to get exact data about the elimination of radon from the lung in relation to the status of the function of the respiratory tract after inhalation, we studied the lung clearance in healthy persons and patients with respiratory injuries. We examined four healthy persons and 28 patients with lung emphysema, chronic bronchitis, and bronchial asthma. We divided the patients into three groups: low, medium and high degree of respiratory insufficiency. The examined persons spent 40 minutes in the atmosphere of radon and daughters in a concentration of 2×10^{-8} Ci/l of radon.

Breath samples were taken every 30 minutes during 4 hours of exposure and the measurement of radon and daughters was performed after the achievement of an equilibrium. The obtained results are presented in Tables 9, 10, 11, and 12.

The analysis of the results was performed according to Harley, taking into consideration only the value of K constant for the fourth phase of expiration. From the tables it is evident that K_4 for healthy persons is 0.21 ± 0.02, for patients from the first group 0.39 ± 0.06, and for those from the third group 0.40 ± 0.12.

The results show the existence of a disturbance in the fourth phase of expiration in the examined patients having an injury of the respiratory function. These results point out the fact that miners with changes in the respiratory tract retain radon and daughters in the lung for a longer period of time. Obviously, further studies are necessary for the evaluation of disturbances in phases I, II and III.

5. Study in chromosome aberrations in lymphocytes of the peripheral blood.

In this project great attention was paid to chromosome aberrations in persons professionally exposed to ionizing radiations:

a. in a group of uranium miners;

b. in radiologists and roentgen technicians;

c. workers on dial painting (using Ra-226);

d. a control group.

The uranium miners (41) were exposed 5-15 years with an **average** duration of exposure of seven years. The average age of the exposed group was 35 years.

The average concentration of radon in Kalna was 1.75×10^{-10} to 19.67×10^{-10} Ci/1, in Gorenja Vas 3.85×10^{-10} Ci/1 to 14.85×10^{-10} Ci/1, and in Zletovska Reka 3.61×10^{-10} to 19.97×10^{-10} Ci/1.

We examined 16 radiologists and 16 roentgen technicians between 31-55 years of age (average 42 years). The duration of exposure varied from 5 to 25 years (average 10 years and 8 months). The examined persons underwent a clinical, hematologic, and dermatologic examination together with an analysis of chromosome aberrations. In two persons anhydrosis of the palm skin and distrophic changes of nails were found. Clinical signs of palms radiodermatitis of first degree were evident in six persons. The standard hematologic examination showed lymphocytosis in four persons. In 18 persons no clinical signs of radiation injury were found. The dosimetric control of the exposure to ionizing radiation has been performed for 10 years. The yearly exposure doses did not reach the maximum allowable doses. All persons were exposed to X-rays.

A group of eight women between 31 and 41 years of age worked on dial painting with an average exposure duration of 7 years and 7 months. The concentration of Po-210 and Ra-226 in the urine was high only in two persons (Po-210 to 75 pCi/liter and Ra-226 to 68 pCi/l). In other women the concentrations were so low that it was impossible to detect them. The control group consisted of seven persons who were not professionally exposed to the ionizing radiation, their age being 26-42 years.

The results of this study showed that in uranium miners the presence of cells of type B (chromatid gap, isochromatid gap) was 1.6%, of cells Cu (chromosomal fragments and ruptures) 0.4% and of cells Cs (abnormal monocentric chromosomes) 0.07%. Dicentric chromosomes and chromosome rings were lacking.

Taking into consideration the results obtained in the control group (B cells 1.5%, Cu cells 0.5%) it is possible to conclude that the frequency of chromosome aberrations in the examined exposed uranium miners is not greater than in the control group.

In radiologists and technicians with an exposure of more than 16 years, the frequency was higher (B cells 3.9%, Cu 1.9% and Cs 3.2%) than in the control group.

In dial painters a relatively small number of cells were examined, but here also there is an evident increase of chromosomal aberrations in relation to the control group. In this group the most frequent types of chromosomal aberrations were chromatid and isochromatid gaps, chromatid rupture, acentric fragment, translocation, and deletion.

6. Examination of binuclear lymphocytes

The frequency of binuclear lymphocytes was studied in 154 uranium miners and 44 workers of a control group. In the exposed group binuclear lymphocytes were found in 16 cases (10.3%) and in the control group in 17 cases (18.6%).

These results showed that a higher frequency of binuclear lymphocytes was evident in miners of lead and zinc mines exposed to a low concentration of radon. It would be necessary to find out how the combination of radon with heavy metals (lead, mercury, zinc) influences the frequency of binuclear lymphocytes in the peripheral blood.

RADIOTOXICOLOGICAL STUDIES

During six years of this project, we introduced the methods for determination of uranium, Radium-226 and Polonium 210 in biological material. In this period we examined 901 urine samples for uranium and 856 urine samples for Polonium 210.

The results of these determinations showed that uranium miners in Yugoslavia eliminate up to 30 micrograms of uranium per liter of urine (average value 10 μ/1), 3.8 pCi of Ra-226, and 4.5 pCi of Po-210 per liter as average values. In 70% of cases the elimination of Po-210 was under 1 pCi/1.

1. Studies on body burden and excretion of Po-210 in the urine of miners

Studies in radioactive contamination and excretion of Po-210 in miners showed that the contamination in uranium mines depends on many factors. The body burden of Po-210 in uranium miners is about 2.25×10^{-8} Ci/1 due to the exposure to radon and daughters. By food and drink they introduce daily about 7.25 pCi Po-210, by smoking a further 1.5 pCi, and due to inhalation in the mine 10.13 pCi/day.

Our studies showed that 31.3% of miners excreted from 0.6 to 1.0 pCi/1 Po-210 by the urine. Only 10.1% of miners excreted more than 2.5 pCi. These results showed that uranium miners excreted 2-8 times more Po in the urine than non-exposed persons (0.3 pCi/1). We established also that smoking of 20 cigarettes a day will increase the Po excretion in urine by 0.23 pCi/1.

We also determined the Po in the urine before and after weekends. The results showed a statistically significant decrease of Po excretion after the weekend. That means the weekend has an important effect on the Po elmination from the organism.

Our studies showed there is no correlation between the concentration of radon in the working atmosphere and the excretion of Po-210 in the urine of exposed miners (correlation co-efficient r = 0.308).

We established that polonium concentrations in the urine were about five times greater than expected (values) due to radon and daughters in the mine. The elimination of 1.5 pCi of Po in the urine can be tolerated in miners exposed to a radon concentration up to $3x10^{-10}$ pCi/1. We took into consideration quantities of Po-210 introduced by inhalation, smoking, and by ingestion of food and beverages. More data will be sent during 1970 after the evaluation of all obtained results.

2. Studies on deposition of Pb-210 and Po-210.

We studied the deposition of Pb-210 and Po-210 after inhalation of radon in experiments with rats. In the exposed animals the highest quantity of Pb-210 was found in the skeleton (0.198 $\pm$ 0.36 pCi/gr) and of Po-210 in the kidneys (0.553 pCi/gr). The exposure was 900 hours by an average daily activity of 0.4×10^{-8} pCi/1 of radon.

A detailed report was prepared for the Symposium in Richland (Washington), 15-17 May 1967, and for the European Radiological Symposium in Czechoslovakia in 1967.

3. Studies on Po-210 excretion after exposure to radon.

We studied the excretion of Po-210 in the urine and feces after exposure to radon on rats and rabbits. The animals were exposed for 30 days to an average daily radon concentration of 10^{-8} pCi/1 in the air for six hours a day. The urine and feces were sampled every 24 hours and the Po-210 determined from the beginning of exposure until 40 days later.

The results showed an increase in excretion of Po in the urine and feces of the exposed animals. The average daily excretion of Po in the urine of rats was 1.9 pCi/1 and in feces 7.26 pCi/gr. In the control group these values were 0.07 pCi for urine, and 1.34 pCi for feces.

The statistical evaluation by the t-test showed a statistically significant difference in excretion of the exposed and control group in urine and feces. Similar results were obtained in 12 rabbits. The relation between the excretion of Po in feces and urine was 3.84:1 which is in accordance with other authors (Berke and Dispasqua, 1961).

4. Study on Po-210 excretion after intratracheal application of Po-210 and SiO_2.

We studied the excretion of Po-210 after the application of Po-210 together with the quartz dust in rats. After an intratracheal application we followed the excretion for 40 days.

The results showed an increase in the feces excretion which is about 300 times greater than in urine in relation with the excretion after the inhalation of pure polonium. This fact suggests a different distribution of Po-210 when it is applied by inhalation with SiO_2 than by inhalation of pure radon.

Details were given in Panov's doctor's thesis (1970)

5. Study on the influence of radon, daughters, and quartz dust on the respiratory system of animals.

We performed many experiments studying the influence of radon, daughters, and quartz dust on the respiratory system of experimental animals (rats). These results were reported at the Symposium in Richland (May 1967) at the Fifth International Symposium on Radiology in Czechoslovakia, 1967 at First European Congress on Radiological Protection in Menton, France, October 1968.

The results showed that the presence of radon and daughters did not change the development of the experimental silicosis. We did not confirm the results of other authors who stated that radon and daughters increase fibrotic processes in the lungs of experimental animals.

These studies have been continued in order to perform a long-term exposure (2 years) of the experimental animals to radon, daughters, and quartz dust. We hope to draw certain conclusions about the effects of radon, daughters, and quartz dust. This work has partially been financed by IAEA in Vienna and the Yugoslav Scientific Fund.

STUDIES ON CONTAMINATION OF THE BIOSPHERE IN URANIUM AND CONTROL MINES

In the study period we performed measurements of the concentration of radon in the working atmosphere, determinations of short-lived daughters, as well as measurements of concentrations of uranium, Radium-226 and Po-210 in the dust.

1. Determination of radon in the air.

We measured radon by balloon scintillators and recalculated the results on MAC which is $3x10^{-10}$ Ci/1 for a 42 hour working week. The results of these measurements are presented in Tables 13, 14, and 15. These results showed an exposure of uranium miners of 7.86×10^{-10} Ci/1 radon as an average yearly value in Kalna, 7.36×10^{-10} Ci/1 for Gorenja Vas, and 7.43×10^{-10} Ci/1 for Zletovska Reka. In the control mine "Rudnik" the average value was 2.2×10^{-11} Ci/1.

2. Determination of short-lived daughters of radon.

We measured the short-lived radon daughters applying the method of Kusnetz (1956) and recalculated them in working levels (WL). The first measurements in Kalna and Gorenja Vas as well as the measurements of radon were performed together with Mr. Duncan Holaday in October 1964. The results are presented in Table 16. It is obvious that the contamination of the working environment at that time was much higher in Gorenja Vas, due to the lack of artificial ventilation in this mine.

We performed parallel measurements with membrane and "Rose" filters. The results are presented in Table 17. These results show that the measurements with membrane filters are slightly higher than with "Rose" filters due to the self-absorption of the latter. In 1968 we performed similar measurements which are presented in Tables 18, 19, and 20.

These results show that the concentrations are over maximal allowable concentrations (MAC) values. Only in operation H_1/H_2 is the situation opposite. In the future measurements of radioactivity will be performed applying the French and Kusnetz methods.

3. Determination of concentration of uranium Ra-226 and Po-210 in the dust.

In order to establish the content of the long-lived radon daughters and other radionuclides in the dusts of uranium mines, we introduced a method of determination of uranium, Ra-226 and Po-210 in the same sample. The method was developed by our French scientists.

Samples were taken continuously for 10 days on chosen spots with "Delbag" filters. In the dust were parallelly determined uranium, Ra-226 and Po-210. These studies showed that the concentration of Po-210 in the dust was about 100 times higher than Ra-226, which indicates that these two nuclides are not in an equilibrium. Po-210 is also increased due to the presence of radon daughters.

We are continuing this **study** in order to find out the relation of these radionuclides in the ore and dust, and to discuss safety regulations for these radionuclides in the occupational exposure.

4. Study on dustness in uranium and control mines

We performed a study to determine the number and size of dust particles. Samples were taken from various mines by thermoprecipitators and by gravimetric determinations of the dustness. The results showed that the greatest concentration of the dust exists in Gorenja Vas (32.7 mg/m^3), in Zletovska Reka it is only 8.6 mg/m^3 and in Kalna 6.7 mg/m^3.

The study on size distribution showed that about 50% of particles are of the size under 0.3 microns, and 80% up to 1 micron.

The number of particles was $1817/cm^3$ for Gorenja Vas, 1225 for Zletovska Reka, and 973 for Kalna. The SiO_2 concentration showed 60% of free silica.

The results suggest a high degree of dustness which could influence injuries of the respiratory system of exposed miners.

5. Study on Po-210 content of food and cigarettes

In order to evaluate the radioactive contamination of miners to Po-210 by food and smoking, we studied the concentration of Po-210 in food and cigarettes.

The results of our studies showed that the miners in the Kalna region were introducing into the body daily 16.6 pCi of Po-210 by food and 1.5 pCi by smoking. The highest content of Po-210 was in the flour (1.98 ± 0.28 pCi/100 gr) and in cigarettes (0.38 ± 0.13 pCi/gr), and tobacco 0.48 ± 0.18 pCi/gr.

From these results it is obvious that we have to keep in mind these factors when evaluating the radioactive contamination of miners.

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Table 1

Time of Exposure in Mine

		Duration of exposure in years							
		0-3	4-6	7-9	10-12	13-15	16 and +	Unknown	Total
Number	Exposed group	340	174	155	39	21	24	12	765
	Control group	120	117	69	102	98	89	9	604
%	Exposed group	44.4	22.7	20.2	5.0	2.7	3.1	1.5	100%
	Control group	19.8	19.3	11.4	16.8	16.2	14.7	1.4	100%

Average duration of exposure - Exposed group 5.3 year
- Control group 9.1 year

Table 2

Age of Miners

		Age in Years								
		20-25	26-30	31-35	36-40	41-45	46-50	50 and +	Unknown	Total
Number	Exposed Group	17	84	208	158	111	97	66	24	765
	Control Group	- -	81	144	142	73	78	70	16	604
%	Exposed Group	2.2	10.9	27.1	20.6	14.5	12.6	8.6	3.1	100.0%
	Control Group	- -	13.4	23.8	23.5	12.0	12.9	11.5	2.6	100.0%

Average Age - Exposed Group = 38.4 year
- Control Group = 39.0 year

Table 3

Occupational Structure of Miners

		Occupation						Smoking			
		Miners	Aid of Miners	Drivers	Others	Unkown	Total	Smokers	Non Smokers	Unkown	Total
Number	Exposed Group	160	95	299	207	4	765	351	342	72	765
	Control Group	149	81	126	248	-	604	305	214	85	604
%	Exposed Group	20.9	12.4	39.0	27.0	0.5	100.0	45.8	44.7	9.4	100.0
	Control Group	24.6	13.4	20.8	41.0	-	100.0	50.4	35.4	14.0	100.0

Table 4

Respiratory Diseases, Changes in Blood Picture and Urine

Diseases	Number		Average Incidence in Percents	
	Exposed Group	Control Group	Exposed Group (765)	Control Group (604)
Pharyngitis chr.	427	253	55.8	41.8
Bronchitis chr.	40	22	5.2	3.6
Emphysema pulm.	125	122	16.3	20.4
Bronchitis + emphysema	31	57	4.0	9.4
Pneumoconiosis O-I	112	138	14.6	22.8
Pneumoconiosis I	7	9	0.9	1.4
Pneumoconiosis I-II	4	0	0.5	-
Total	746	601	-	-
Anaemia	16	9	2.0	1.4
Leucocytosis	58	59	7.5	9.7
Leucopenia	23	11	3.0	1.8
Trombocytopenia	2	4	0.2	0.6
Lymphocytosis	30	18	3.9	2.9
Total	129	101	-	-
Albumen	5	1	0.6	0.1
Cylindres	1	0	0.1	-
Erytrocites	1	0	0.1	-
Total	7	1	-	-

Table 5

Respiratory Diseases

	Smokers	Non-Smokers	Total
Diseases, Total	305	214	519
Pharyngitis	157 51.4%	67 31.3%	224 43.1%
Bronchitis chr.	17 5.5%	4 1.8%	21 4.0%
Emphysema	75 24.5%	39 18.2%	114 21.9%
Bronchitis + Emphysema	37 12.1%	13 6.0%	50 9.6%
Pneumoconiosis 0-I	78 25.5%	45 21.0%	123 23.6%
Pneumoconiosis I	5 1.6%	2 0.9%	7 1.3%

Table 6

Sputum's Cells Classification of Experimental Group

Year	No. of Miners	Class I	Class II		
			Group 1	Group 2	Group 3
1964	161 100%	58 36%	65 40.3%	37 22.9%	1 1%
1965	222 100%	65 29.2%	69 31.8%	82 36.9%	6 2.7%
1966	140 100%	53 37.8%	60 42.8%	24 17%	3 2.1%
1967	132 100%	39 29.5%	73 55.3%	20 15.1%	
1968	125 100%	74 60%	35 28%	15 12%	1 1%
Total	780 100%	289 36.6%	302 38.2%	178 22.5%	11 1.4%

Table 7

Sputum's Cells Classification of the Control Group

Year	No. of Miners	Class I	Class II		
			Group 1	Group 2	Group 3
1965	177 100%	42 23.7%	64 36%	58 32.7%	13 7.4%
1966	170 100%	65 38.2%	61 35.8%	36 21%	8 5%
1967	156 100%	54 34.6%	72 46%	26 16.6%	4 2.5%
1968	69 100%	34 49.2%	20 29.0%	13 18.8%	2 3%
Total	572 100%	195 34%	217 38%	133 23%	27 5%

Table 8

Cytomorphologic Changes in Sputum in Dependence of Season

Year	Month	No. of Miners	Class I	Class II			Class III
				Group 1	Group 2	Group 3	
1968	June	27 100%	24 88.8%	1	1	1	
1968	November	27 100%	11 40%	10 37%	3 11%		3 11%

Table 9

Normal Values

No.	Examined Persons	imp/min/l		time/h		
		A_1	A_2	t_1	t_2	K_4
1	J.D.	93	69	2	4	0.19
2	Ž.S.	204	151	2	4	0.18
3	J.M.	130	81	2	4	0.23
4	P.D.	96	55	2	4	0.23
		72	38	3	24	- - -
Mean						0.21 ± 0.02(SD)

Table 10

Patients Group 1

No.	Examined Patients	imp/min/l		time/h		K_4
		A_1	A_2	t_1	t_2	
1	A.V.	0.27	0.007	2	4	0.52
2	T.L.	0.27	0.10	2	4	0.37
3	R.J.	0.24	0.08	2	4	0.32
4	T.R.	0.21	0.10	2	4	0.28
5	P.Z.	0.13	0.06	2	4	0.29
6	R.S.	0.14	0.07	2	4	0.27
7	B.S.	0.18	0.07	2	4	0.35
8	D.P.	0.26	0.09	2	4	0.39
9	P.B.	0.27	0.11	2	4	0.32
10	V.V.	0.23	0.11	2	4	0.28
Mean						0.34 ± 0.07

Table 11

Patients Group 2

No.	Examined Patients	imp/min/l		time/h		K_4
		A_1	A_2	t_1	t_2	
1	S.D.	0.22	0.07	2	4	0.48
2	M.I.	0.17	0.07	2	4	0.33
3	A.S.	0.18	0.07	2	4	0.35
4	P.C.	0.13	0.04	2	4	0.44
5	R.B.	0.18	0.07	2	4	0.35
6	M.R.	0.18	0.12	2	4	0.19
7	Dj.P.	0.24	0.09	2	4	0.36
8	J.M.	0.17	0.65	2	4	0.46
9	A.G.	0.17	0.07	2	4	0.33
Mean						0.39 ± 0.06

Table 12

Patients Group 3

No.	Examined Patients	imp/min/1		time/h		K_4
		A_1	A_2	t_1	t_2	
1	J.M.	0.24	0.09	2	4	0.36
2	T.J.	0.32	0.09	2	4	0.61
3	V.G.	0.22	0.09	2	4	0.33
4	I.D.	0.27	0.12	2	4	0.30
5	P.S.	0.24	0.08	2	4	0.32
6	M.R.	0.26	0.07	2	4	0.63
7	T.S.	0.15	0.05	2	4	0.40
8	J.D.	0.39	0.14	2	4	0.37
9	K.D.	0.24	0.08	2	4	0.32
Mean						0.40 ± 0.12

Table 13

Radon Concentrations in Uranium Mine Kalna (1963 - 1966)

Month	1963 Median Month Values Ci/1	1964 Median Month Values Ci/1	1965 Median Month Values Ci/1	1966 Median Month Values Ci/1	Total Average Values Ci/1
January		2.77×10^{-10}	15.37×10^{-10}		
February		3.31×10^{-10}	12.73×10^{-10}		
March		3.14×10^{-10}	26.99×10^{-10}		
April		3.95×10^{-10}	23.61×10^{-10}	20.02×10^{-10}	
May	1.38×10^{-10}	2.46×10^{-10}			
June	1.58×10^{-10}	2.69×10^{-10}			
July	1.28×10^{-10}	1.72×10^{-10}			
August	1.85×10^{-10}	3.30×10^{-10}			
September	2.03×10^{-10}	2.86×10^{-10}			
October	2.02×10^{-10}	3.65×10^{-10}			
November	2.13×10^{-10}	30.99×10^{-10}	5.22×10^{-10}		
December		19.48×10^{-10}			
Median Year Value	1.75×10^{-10}	6.69×10^{-10}	19.67×10^{-10}	20.02×10^{-10}	
Min.	1.28×10^{-10}	2.46×10^{-10}	12.73×10^{-10}		7.86×10^{-10}
Max.	2.13×10^{-10}	30.99×10^{-10}	26.99×10^{-10}		

Table 14

Radon Concentrations in Uranium Mine Gorenja Vas
(1964 - 1968)

1964		1965		1966		1967		1968		Total Average Value Ci/l
Month	U 10^{-10} Ci/l	Month	U 10^{-10} Ci/l	Month	U 10^{-10} Ci/l	Month	U 10^{-10} Ci/l	Month	U 10^{-10} Ci/l	
July	9.09×10^{-10}	July Aug. Oct.	26.01×10^{-10} 10.77×10^{-10} 7.61×10^{-10}	June Nov.	2.89×10^{-10} 4.69×10^{-10}	July Sept. Nov.	4.13×10^{-10} 1.97×10^{-10} 5.44×10^{-10}	July Nov.	5.44×10^{-10} 1.87×10^{-10}	
Median Year Value	9.09×10^{-10}		14.85×10^{-10}		3.80×10^{-10}		3.84×10^{-10}		3.65×10^{-10}	
Min.			7.61×10^{-10}		2.89×10^{-10}		1.97×10^{-10}		1.87×10^{-10}	7.36×10^{-10}
Max.			26.01×10^{-10}		4.69×10^{-10}		5.44×10^{-10}		5.44×10^{-10}	

U - Uranium

Table 15

Radon Concentrations in Uranium Mine Zletovska Reka
(1965 - 1968)

1965		1966		1967		1968		Total Average Value Ci/l
Month	Ci/l	Month	Ci/l	Month	Ci/l	Month	Ci/l	
June	17.97×10^{-10}	July Nov.	3.57×10^{-10} 3.65×10^{-10}	June Nov.	5.40×10^{-10} 1.97×10^{-10}	June Nov.	22.68×10^{-10} 16.78×10^{-10}	
Median Year Value	17.97×10^{-10}		3.61×10^{-10}		3.68×10^{-10}		9.73×10^{-10}	
Min.			3.57×10^{-10}		1.97×10^{-10}		16.78×10^{-10}	7.43×10^{-10}
Max.			3.65×10^{-10}		5.40×10^{-10}		22.68×10^{-10}	

Table 16

Concentration of Short-Lived Products of Decay in Kalna (1964)

Operation	Radon pCi/l	Radon's Descendants xW.L.
C.H.	280	1.6
P.S. (tunnel)	10	In trace
R.	30	0.44
	Gorenja Vas	
1.	It was not measured	9.1
2.	It was not measured	8.4
3.	It was not measured	7.7

Table 17

Parallel Results of Measurements in Kalna (1964)

Operation	Radon pCi/l	JUNO jon. com.		DT 12	
		Membrane xW.L.	"Rose" xW.L.	Membrane xW.L.	"Rose" xW.L.
H387	2040	10.	8.55	12.5	9.5
	382	4.1	4.10	4.56	4.26
	700	5.0	4.10	5.72	4.57
H387	897	5.45	4.25	6.1	5.04
	858	0.35	5.0	6.35	6.0

Table 18

Concentrations of Short-Lived Products of Decay Gorenja Vas (1968)

Operation	Radon pCi/l	Gamma WR/h	xW.L.	W.L.M. (W.L.h.)
H27	24	30	0.08	14.56
H259	1020	1100	2.32	422.00
H2	577	150	2.41	438.00
H260	561	130	2.13	388.00
H249	320	50	1.65	300.00

Table 19

Concentrations of Short-Lived Products of Decay Zletovska Reka

Operation	Radon pCi/l	Gamma WR/h	xW.L.	W.L.M. (W.L.h.)
H76	15	30	0.02	3.64
H761	21	30	0.10	18.20
H14	740	70	4.66	850.00
H12	1820	1400 to 1700	16.00	290.00

Table 20

Concentration of Radon's Products
Gorenja Vas (1969)

Operation	Radon pCi/l	Gamma W.R./h	xW.L.	W.L.M. (W.L.h)	RaH	RaD pCi/l	RaL
H 269	78	28 to 30	0.825	150.00	34	10	7
H 271	94	30	1.07	195.00	54	13	9
H 2	78	30	1.16	212.00	19	10	9
H 267	159	60	1.935	353.00	80	20	8
H1/H2	404	1100	11.36	2.067	360	240	120

DISCUSSION AFTER DR. KILIBARDA'S PAPER:

Dr. Cralley:

Dr. Kilibarda, have you had a chance to look at the paper given at the London Conference on the subject of radon. It was reported that the exposure to radon alone and to radon with uranium ore (some radon concentrations) gave different degrees of biologic response.

Dr. Kilibarda:

Yes, I saw these reports today.

Dr. Cralley:

Mr. Holiday was at this meeting. He was very impressed with the set up of the study and the findings, and believed it's going to give valuable information. This may explain some of the differences in biological response not otherwise apparent.

Dr. Henschel:

How do your exposure levels, that you now have in your mines, compare to the permissible levels that are now in our TLV for uranium miners?

Dr. Kilibarda:

We were on many occasions in a situation to have higher concentrations above the maximal permissible level. So we could find different results in different mines and also on different working places. Comparing with French and American conditions, we had many times more concentration of radon daughters, sometimes three times more than MPL.

Dr. Henschel:

What is your opinion in connection with pulmonary diseases and incidence of cancer?

Dr. Kilibarda:

We had no evidence of cancer of the lungs, except one case. By analysis of the sputum findings up to now there is no evidence of the cancer which we can speak about. But I must say that our workers in the first years were not exposed continuously as in some other uranium mines, namely in the first year of exposure we had more experimental work in mines. Sometimes the work was stopped or the workers changed the places for some period of time. I also want to point out that we are able now to follow one big group of miners, which is now no longer exposed, because the first mine was closed seven years ago. We show some interesting results about the correlationship between Polonium in the atmosphere and Polonium in the body. I mean the situation in this case is quite different. We can say something about the body burden of Polonium for that group of workers, but we can't say the same about the correlationship between the body burden in continuously exposed groups, i.e., for the group of the workers who are still working in the uranium mine.

Dr. Djuric:

You established that determination of Polonium in the urine is not a good exposure test. Can you recommend at this moment a better test, for example, perhaps determination of radon in the breath or Polonium in the feces. What is at this moment relatively the best exposure test?

Dr. Kilibarda:

It is difficult to answer precisely, but probably excretion of Polonium 210 could be some kind of test.

Dr. Potkonjak:

I am interested in the problems of lung function. As your study has been continued, what is your opinion of studying the relationship of the lung function and absorption of radon? Rumors are heard, as far as I know from Switzerland, that the subject with impaired lung function is at an advantage because the absorption of toxic materials is lower; the lower ventilation, the lower the absorption of toxic materials. I believe it could be very interesting to try to see whether it was true.

Dr. Kilibarda:

You mean any toxic material or material which could induce cancer?

Dr. Potkonjak:

All material that enter the body by the respiratory tract.

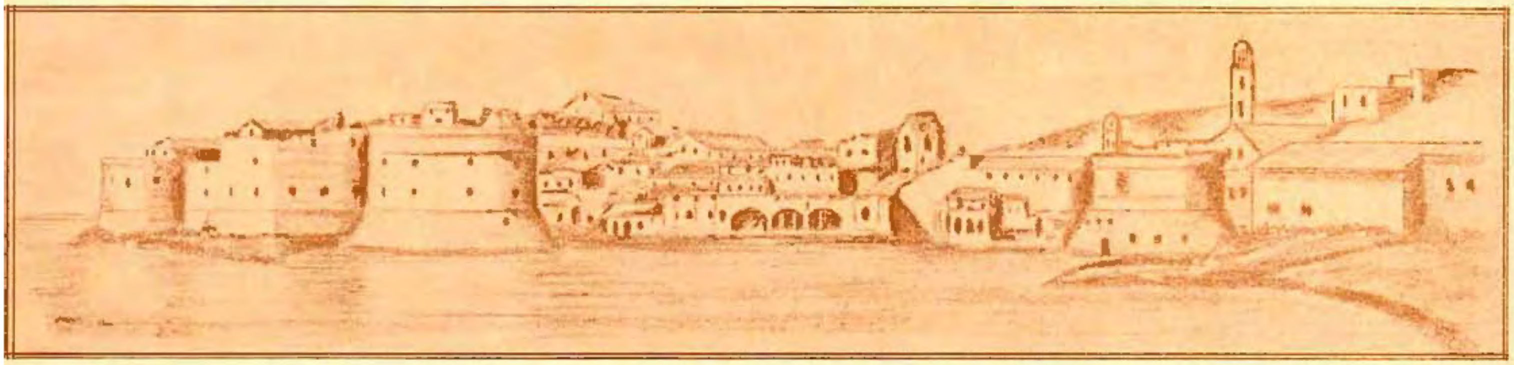
Dr. Kilibarda:

As we said we established that the miners with changes in the respiratory tract retain radon and daughters in the lung for a longer period of time.

PROCEEDINGS

OF THE SPECIAL FOREIGN CURRENCY PROGRAM SYMPOSIUM

DUBROVNIK



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PUBLIC HEALTH SERVICE
HEALTH SERVICES AND MENTAL HEALTH ADMINISTRATION
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