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DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
~~FEDERAL SECURITY AGENCY~~
PUBLIC HEALTH SERVICE
WASHINGTON 25, D. C.

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IN REPLYING, ADDRESS THE
PUBLIC HEALTH SERVICE

REFER TO: DOH

May 8, 1953

Dr. K. Z. Morgan, Chairman
Sub-committee on Internal Dose of the
Committee on Radiation Protection
Health Physics Division
Oak Ridge Laboratory
Oak Ridge, Tennessee

Dear Dr. Morgan:

Enclosed is a report on the "Investigation of Radon and Radon Decay Products in the Uranium Mines of the Colorado Plateau." This study was carried out by our Salt Lake City office in cooperation with the Atomic Energy Commission during the summer of 1952. Mr. Holaday has requested that a copy be sent to you for your information.

With best regards, I am

Yours very truly,

Henry N. Doyle

Henry N. Doyle, Chief
State Aid Branch
Division of Occupational Health

Enclosure

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Human Studies Project

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INVESTIGATION

of

RADON AND RADON DECAY PRODUCTS

in the

URANIUM MINES OF The COLORADO PLATEAU

by the

FEDERAL SECURITY AGENCY
Public Health Service
Division of Occupational Health

Chief Investigator:
Duncan A. Holaday

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INVESTIGATION OF RADON AND RADON DECAY PRODUCTS IN THE URANIUM MINES OF COLORADO*

INTRODUCTION

The uranium mining industry in the Colorado Plateau consists of numerous comparatively small mines, primarily operated by independent owners and lessees. A few companies own a large number of mines, but the majority of these are leased out to small operators. Although the total number of mines is probably over a thousand, those in operation at any particular moment are considerably fewer. The mines are scattered for several hundred miles over one of the most inaccessible areas in the United States. Steep canyons of the San Miguel and Dolores Rivers cut through the heart of the Plateau, which ranges in elevation from 5,000 to 7,500 feet. Roads consist primarily of bulldozer trails, and normal community facilities are conspicuously absent. In most of the area, the miners are the only inhabitants, although some of the land is utilized for grazing. Despite heavy snows which usually bog down winter activity, and occasional flash floods, the climate is definitely on the arid side. Water often has to be hauled many miles to the mine operations.

The Division of Occupational Health, U. S. Public Health Service, in cooperation with the Colorado State Health Department, began a survey of the uranium mines and mills in July 1950 to evaluate the health hazards in the industry. Preliminary studies showed that in mining uranium ores the primary health hazard is probably that created by the presence of radon and its immediate daughters in mine atmospheres. Radon samples taken in some 60 mines gave a median atmospheric concentration of 3,100 micromicrocuries per liter and correspondingly high figures for its short-lived daughters. These concentrations were so far in excess of any recommended maximum allowable concentration for radon that it was apparent that if the mines surveyed were representative of the whole industry, a potentially serious situation existed.

Conferences were held with the interested agencies in the several states concerned to discuss the results, and formulate programs that the states should institute. Colorado, as the largest producer of uranium ores, was confronted with the biggest problem. The state agencies logically decided that, to

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*Conducted by the Division of Occupational Health, Public Health Service, under contract to the Division of Biology and Medicine, Atomic Energy Commission, according to an agreement dated June 16, 1952.

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develop an effective control program, it would be necessary for them to have information, similar to that obtained in the preliminary study, on all their uranium mines. It was estimated there were 200 to 300 uranium mines in the Colorado Plateau Area operating at some time during the year and that it would take all the available state personnel twelve months to visit the operating mines and obtain one series of samples in each. After consideration of all methods of obtaining sufficient personnel and equipment to conduct a study of the uranium mines, the Colorado agencies decided to ask the Atomic Energy Commission for a grant of funds to carry out this project. The Division of Biology and Medicine of the A.E.C. was in agreement with the objectives of the program, but could not legally make grants to a state. It was therefore suggested that a contract be executed with the Division of Occupational Health of the Public Health Service to conduct a study extending to the States of Colorado, New Mexico, Arizona, and Utah.

A contract was accordingly executed and this report covers the work done under the terms of that contract.

SCOPE OF STUDY

As previously indicated, radon samples taken in some 60 mines gave a median atmospheric concentration of 3,100 micromicrocuries per liter with correspondingly high figures for its short-lived daughters. These concentrations were alarmingly high in view of the recommended value of 100 micromicrocuries per liter as the operating level. The 60 mines surveyed represented only 20 to 25 percent of the total mines in the area. In order to obtain a comprehensive picture of the over-all problem in the uranium mines, it was therefore obvious that there was need to determine the concentrations of radon and its short-lived daughters in as many mines as could be located.

DESCRIPTION OF STUDY

Surveys were carried out in 157 mines, believed to represent approximately 90 percent of those in operation on the Plateau during the survey period.

The field work was carried out by six men organized in three teams. The personnel used were mining and chemical engineering students from the Colorado School of Mines and the University of Utah. The entire group was given a week's indoctrination course at the Salt Lake City Field Station of

the Public Health Service, to familiarize them with the objectives of the study and the procedures to be used (appendix A). The Colorado State Health Department furnished an additional full-time man who was in immediate charge of the parties (took care of supplies and transportation and assembled field data as they were turned in). Staff members from either the Field Station or the Colorado State Health Department also met with the field teams each week end to discuss the past week's work and assign schedules for the next one. As far as possible, operations were centered in Grand Junction, Colorado, in quarters made available by the U. S. Forest Service.

Mine names and locations were obtained from ore buying station operators, state mine inspectors, mine supervisors employed by the larger companies, A.E.C. Raw Materials Office records, and by local inquiry.

The field teams collected samples for radon daughter products and radon in each mine visited. Data were obtained on ventilation and operating conditions at each sample location (appendix B-1 and B-2). The radon samples were taken in flasks and analyzed at the Salt Lake City Field Station. Samples for radon daughters were taken by the filter paper method described in the interim report (appendix C).

Final calculation of all samples was done in Salt Lake City, and the results of the samples were not discussed with the individual mine operators at the time of the survey. Information on each mine was transmitted to the appropriate state or federal agency and to the mine owners after the close of the field season.

SUMMARY RESULTS OF SURVEY

All summary results were recorded according to mining district. There were 20 mining districts covered by this project, which are as follows:

Uravan	Durango
Temple Mountain	Calamity Mesa
Polar Mesa	Black Rock
Outlaw Mesa	Paradox Valley
Monument Valley	Grants
Monticello	Long Park
Moab	East Reservation
Gypsum Valley	Eastern Slope
Marysvale	Cottonwood Wash
Gateway	Bull Canyon

The results of all samples taken are listed by district and mine in tables 1 to 20, while table 21 summarizes the results of the samples for radon daughters by areas. In tables 22 and 23 the data on radon daughters are presented in comparison with other significant factors.

CONCLUSIONS

One general conclusion which can be drawn by inspection of the tables is that high concentrations of radon and its daughters are the rule in uranium mines. Table 22 shows that 77.7 percent of the mines, employing 84.2 percent of the miners, had concentrations of RaA + RaC' of more than 100 uuc/l, while 55.4 percent of the mines with 64 percent of the miners had atmospheric concentrations of these elements higher than 1000 uuc/l. These figures show that much work must be done to reduce the atmospheric concentrations of radon and its daughters to any reasonable levels.

Not enough of the mines were using mechanical ventilation methods to permit the drawing of definite conclusions on the effectiveness of such programs in reducing atmospheric concentrations of radon and its daughters. However, a study of four mines which was previously reported (Ventilation Studies in Uranium Mines)* showed that forced ventilation is capable of reducing by large factors the amounts of these elements present in the working areas of mines.

As a result of the work done under this contract, much valuable data were assembled. For the first time information on the number of working mines, their owners and operators, the number of employees, and similar figures were made available. The samples taken for radioactive dust and gas definitely show that methods to control the amounts of these elements present in the air should be provided in uranium mines.

* "An Interim Report of a Health Study of the Uranium Mines and Mills," Federal Security Agency, Public Health Service, Division of Occupational Health and the Colorado State Department of Public Health, May 1952, p. 12.

COTTONWOOD WASH

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks*
Cottonwood No. 2	V.C.A.	2	Natural	6,250	26,300	1 yr.
Cottonwood No. 36	V.C.A.	4	Natural	19,900	14,180	1 yr.
Cottonwood No. 3a	V.C.A.	2	Natural	4,500	11,500	1 yr.
Shale Claim	V.C.A.	5	Natural	3,100	5,220	12 yrs.
Big Hole	V.C.A.	4	Natural		356	14 yrs.
Blanding Mines Operation	V.C.A.	2	Natural		0	≤6 mo.
Basin No. 1	M.E. Aiken	6	Forced (500cfm)		144 10	1 yr.

* Period of mine operation

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CALAMITY MESA

Mine	Owner	No. Emp.	Ventilation	Radon mc/l	RaA-RaC' mc/l	Remarks
Arrowhead No. 1	Climax Uranium	2	Natural (1000 cfm)	570	66	2-1/2 yrs.
Arrowhead Incline No. 6	Climax Uranium	7	Natural	23,000	16,000	6 mo.
Yellowjacket No. 8	Climax Uranium	3	Natural		20,400 14,500	7 mo.
Belmont	Carrice	2	Natural	4,000	2,530	2 yrs.
Matchless	U.S.V.	3	Natural (1000 cfm at portal)		4,025	3 yrs.
Yellowjacket Incline No. 9	Climax Uranium	2	Natural	81	119	3 mo.
Arrowhead No. 10	Climax Uranium	5	Natural	390	310	5 wk.
Calamity No. 17	A.E.C.	3	Natural (good) (Forced air system not in operation)		4,020 4,040	5 yrs.
Queen of the Hills	U.S.V.	2	Natural (3500 cfm at entry)		1,190	10 mo.
Arrowhead No. 7	Climax Uranium	2	Natural (200 cfm through churn drill hole)	67	687	6 mo.

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BULL CANYON

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Fawn Springs No. 9	U.S.V.	3	Natural (poor)	2,400	3,260	< 2 yrs.
Fawn Springs No. 12	U.S.V.	3	Natural (poor)	5,300	8,020 8,070	8 mo.
Joe Dandy	U.S.V.	2	Natural (good)		3,780	3 yrs.
Mineral Joe No. 2	Climax Uranium	4	Natural (poor)	8,400	5,580 3,800	< 1 yr.
East Opera Box	U.S.V.	2	Natural (poor)	2,900	1,280	< 1 yr.
Opera Box	U.S.V.	3	500 cfm	1,085		6 mo.
Hummer	U.S.V.	7	Natural (poor) (1500 cfm) (900 cfm) (2000 cfm)		12,300 4,600 370 170	4 yrs.
Oversight	U.S.V.	3	Natural (poor)	4,100	525 5,400	6 mo.
North Hummer No. 2	U.S.V.	2	Forced (500 cfm) (400 cfm) (200 cfm)	59,000 2,700	29,200 43,500 23,800	5 mo.
J. J. Mine	U.S.V.	4	Natural		6,500	< 1 yr.
Wild Steer (Vaden View)	V.C.A.	3	Natural (good)		36	10 yrs.
Happy Thought	U.S.V.	4	Natural (poor)	5,300	9,400 5,500	4 yrs.

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URVAN

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Ophir	U.S.V.	8	Natural	1,900	660	5 yrs.
Star No. 3	U.S.V.	2	Natural		210	4 mo.
Blackfoot	Denver Uranium Development Co.	4	Natural		820 4,000	1 yr.
Little Basin	U.S.V.	3	Natural	4,900	2,700	3 mo.
Dolores	U.S.V.	3	Natural	23	23,000 130	2 yrs.
The Fox	U.S.V.	2	Natural		160	6 mo.
Little Dick	U.S.V.	2	Natural	7,100	3,100	6 yrs.

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TEMPLE MOUNTAIN

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Little Devil No. 6	Consolidated	2	Natural		430	3 mos.
Little Devil No. 1	Consolidated	3	Natural		2	1 mo.
Lucky Strike	Farran Uranium Mining Co.	4	Natural		51	2 yrs.
North Mesa No. 2	Consolidated	3	Natural		≤2	6 mos.
Kaess and Cline	Consolidated	2	Natural		310	4 yrs.
Kaylex No. 2	Consolidated	4	Natural		2,800	2 mos.
Rex No. 2	Consolidated	6	Natural		300	34 yrs.
Kaylex No. 3	Consolidated	3	Forced (100-150 cfm)		110	1 mo.
Marsh Banks Incline	Consolidated	3	Natural		580	3 mos.

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POLAR MESA

Mine	Owner	No. of Employees	Ventilation	Radon mc/l	RaA-RaC' mc/l	Remarks
Captain John	U.S.V.	2	Natural		440	1-1/2 yrs.
Sgt. Mine	U.S.V.	3	Natural		7,700	9 mos.
Thomas B.	U.S.V.	3	Natural		1,200 10,200	9 mos.
Elva M No. 2	U.S.V.	3	Natural	7,300	1,200	11 mos.
Elva M No. 1	U.S.V.	2	Natural	3,000	5,500	10 yrs.
Jumbo	U.S.V.	3	Natural		38	16 yrs.
Petrified Tree	U.S.V.	2	Natural	6,800	2,400	Unknown

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SLICK ROCK

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Charles T No. 1	A.E.C.	5	Natural	1,100	2,980	1 yr.
Rimrock	U.S.V.	3	Natural	7,200	7,120 2,910	1 yr.
Burro Point No. 1	McKee	3	Natural (good)		92	1 yr.
Black Jack	Dulaney	4	Forced (good)		29	1 mo.
Golden Rod No. 3	A.E.C.	3	Natural		46	5 yrs.
Norma Jean No. 1	U.S.V.	4	Natural (good)		2,520	5 yrs.
Eloyse	A.E.C.	8	Forced (not oper.)	4,800	4,860	7 mos.
Jupiter	V.C.A.	2	Natural	130	35	6 mos.
Falcon	Dr. Kemp		Natural	3,900	1,920 2,280	
Legin No. 2	A.E.C.	9	Forced	13,900	4,220 5,100	2 yrs.
Legin No. 4	A.E.C.	3	Natural	170	26	
Legin No. 3	A.E.C.	4	Natural	780	174 340	1 yr.
King No. 1	A.E.C.	4	Forced		1,035 222	3 yrs.
Ann	A.E.C.	3	Natural		4,760	6 mos.

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Slick Rock (Cont.)

Charles T No. 2	A.E.C.	2	Forced (not in operation)	22,000	29,600	2 mos.
Hawk No. 1	Dulaney	2	Forced and Natural (Forced inoperative) 1000 cfm		480	4 yrs.
Macheal Bray	A.E.C.	3	Natural (good)	4,800	3,920 2,720	40 yrs.
Easton B.	A.E.C.	2	Natural	82	1,900 3,880	34 yrs.
San Juan Lease	A.E.C.	4	Natural and Forced (good)	400	187 187	2 yrs.
Merchantile	A.E.C.	8	Natural	2,400	2,080 124	2 yrs.
George To	A.E.C.	12	Natural	3,100	1,725 1,310	2 yrs.
Couger	A.E.C.	11	Natural (good)		1,360 8,500 238	4 yrs.
Juniper	Silver Bell Mining Co.	4	Natural		2,530	3 mos.
Tail Hole	John Dunning and Snider	5	Natural		0	5 mos.
Grant Mine	A.E.C.	9	Natural		18 145 391	4 mos.
Veta Mad	A.E.C.	7	Forced and Natural 1200 cfm	610	1,140	3 yrs.

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MONTICELLO

Mine	Owner	No. of Employees	Ventilation	Radon μμc/l	RaA-RaC' μμc/l	Remarks
Blue No. 1	G. and L. Shumway	4	Natural		15	3 mos.
Big Buck	Adams and Hays	2	Natural		1,900	6 mos.

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MOAB

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Memphis Hill No. 2	Utah Alloys Co.	2	Natural		310	5 mos.
Blue Jay	Howard Bassley	2	Natural (25 cfm)		460	4 mos.
Clara B	Plateau Mining Co.	2	Natural		1,100	2 mos.
Shinroof No. 2A	Excalibur Uranium	4	Forced (250 cfm) Natural (drilling)		180 790	2 yrs.
School Section No. 16	State of Utah	2	Natural		2	8 mos.
Serviceberry	Patterson	1	Natural		9	12 yrs.
School Section No. 2	State of Utah	3	Natural		54	1 yr.
Red Van No. 1	U.S.V.	2	Natural	470	3,400	Unknown
L.P. No. 5	Utah Alloys Co.	2	Natural		1,500	20 yrs.
Carol B	Plateau Mining Co.	3	Natural (drilling)		140	6 wks.

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MARYSVALE

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Freedom No. 2	V.C.A.	50	Natural	110,000	230,000	2 yrs.
			Natural		220,000	
			Natural	23,800	27,000	
			Mechanical (1200 cfm)		510	
Prospector	V.C.A.	Operated with Freedom No.2	Natural	3,360	4,900	2 yrs.
			Natural		1,400	
			Natural		11,000	
			Natural	840	8,100	
			Natural	25,900	25,000	
Buddy	Lane Bertelsen	0	Natural		44,000	Unknown
Bunny K	A. K. Wilson	2	Mechanical (700 cfm)		180	Unknown
La Veta	Uranium Exploration Co.	2	Natural		4,200	Unknown
					5,400	
Papsy's Hope	ASandR	0	Natural		240	Unknown
Plumbic	Plumbic Mining Co.	2	Natural		260	2 yrs.
					210	
Bullion Monarch	Bullion Monarch Mining Co.		Natural		21,000	2 yrs. Forced air system not operating.

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LONG PARK

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Long Park No. 10	U.S.V.	2	Natural	22,000	36,600	14 yrs.
Donald L	V.C.A.	7	Natural	43,000	27,200	7 yrs.
Henry Clay	U.S.V.	3	Natural	3,200	2,700 6,370	30 yrs.
Coloradium	U.S.V.	2	Natural (2000 cfm)		1,420 1,020	20 yrs.
Whitney	U.S.V.	2	Natural		4,760 12,000	1 yr.
Grass Roots	U.S.V.	4	Natural		15	
Great Western	U.S.V.	4	Natural		3,680	50 yrs.
Sphinx	U.S.V.	4	Natural		4,500 1,890	15 yrs.
St. Patrick	U.S.V.	3	Natural	8,300	3,220	
Republican	V.C.A.	5	Natural	9,600	8,280	11 yrs.
Tripod and LVS	U.S.V.	3	Natural	90	6,970	2 mos.
Dusty	V.C.A.	3	Natural	1,900	540	1 yr.
Production	U.S.V.	2	Natural	12,000	4,920	1 yr.
Hidden Basin	V.C.A.	4	Forced (not in operation)	7,600	6,020 6,750	1 yr.

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Long Park (cont.)

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
TNT No. 3	V.C.A.	3	Natural	1,900	936	7 mos.
LaSalle Mine	A.E.C.	28	Forced (300 cfm)		0 818	2 yrs.
C.F.C.	U.S.V.	3	Natural (4000 cfm)		398 2,850	9 yrs.
Long Park No. 6	U.S.V.	11	Natural	56,000	48,700 34,000 15,100	15 yrs.
Bitter Creek	V.C.A.	5	Natural	[illegible] 1,900	5,870 6,700	13 yrs.
Triangulation	U.S.V.	4	Natural and forced (forced broken down)	1,300	755 1,150	1 yr.
Long Park No. 1	U.S.V.	6	Natural and Forced	17,400	8,500 14,300	1 yr.
Mill No. 2	U.S.V.	7	Natural (100 cfm)	13,000	1,045 6,880	1 yr.
Mill No. 1	U.S.V.	2	Natural (poor)	14,000	8,100	10 yrs.
Tramp	U.S.V.	3	Natural		263	3 yrs.
Reserve Block No. 1	A.E.C.	6	Forced and Natural	2,300	11,100 227	1 yr.

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GYPSUM VALLEY

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Pawn	U.S.V.	2	Natural (poor)	18,900	15,500	1 yr.
Long Ridge	U.S.V.	3	Natural	1,200	2,000	4 yrs.
Tiny	U.S.V.	2	Natural		500	4 mos.
American Eagle	Oliver Bros.	3	Natural (1000 cfm)	14,700	18,000	2 yrs.

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GATEWAY

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Packrat	S. V. Crewley	2	Natural	3,200	4,770	1 yr. 8 mos.
Lumsden No. 2	U.S.V.	3	Natural (4000 cfm)	2,800	1,830 1,640	3 mos.
Prospect No. 9	Ponds and Schubert	2	Natural		21	4 wks.
Captain Jinx	U.S.V.	3	Natural		8	2 wks.
Laplaz No. 1	C. T. Ward	2	Natural		6	1-1/2 yrs.
Granco No. 3	Roy Stone	2	Natural	1,100	6,000	2 yrs.
Corvusite	Roy Stone	3	Natural (1000 cfm)	160	297	4 yrs.
Prospect No. 2	Roy Stone	2	Natural		5,670	2 yrs.

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EAST INDIAN RESERVATION

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
King Tut Point	V.C.A.	4	Natural (500 cfm)		22	2 yrs.
Frank No. 1	Frank Nacheendetah	6	Forced (3000 cfm)	390	150 426	1 yr.
Nelson Point	V.C A.	3	Forced (not used)		155	3 yrs.
No. 23	Navajo	8	Forced and Natural (2500 cfm)	100	4,340 2,000	3 yrs.
Shadyside No. 1	V.C.A.	2	Natural (250 cfm)		1,090	3 yrs.
Shadyside No. 2	V.C.A.	3	Natural (600 cfm)	170	26	6 mos.
No. 12	Navajo	10	Natural (1000 cfm)	2,200	3,140	3 yrs.
No. 24	Navajo	5	Natural (1000 cfm)	150	16 23	2 yrs.
Lookout Point	V.C.A.	5	Natural (1500 cfm)	110	11	1 yr.

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DURANGO

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Nevada	F. W. Pinkerton	2	Natural		11	3 yrs.
Grace Hill No. 3	V.C.A.	3	Natural (50-75 cfm)		41	4-5 yrs.
Grace Hill No. 9	V.C.A.	6	Natural (50-75 cfm)		135 96	4-5 yrs.
Grace Hill No. 8	V.C.A.	3	Natural (50-75 cfm)		18	4-5 yrs.
Grace Hill No. 5	V.C.A.	3	Natural		<3	4-5 yrs.

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OUTLAW MESA

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
July Load Lease	H. L. Arbogast	2	Natural		3,800	1 yr.
Arbogast	H. L. Arbogast	1	Natural		18	2 yrs.
Outlaw G-1	Climax Uranium	12	Natural	1,300	1,100 4,900	3 yrs.

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MONUMENT VALLEY

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Yazzie	John Yazzie	4	Natural	170	9	1 yr.
Cato Sells Claim	Navajo Tribe	10	Natural	6,100	11,000	2 yrs.
Monument No. 2	V.C.A.	80	Natural (400 cfm)	5,900	1,200	4 yrs.
			Natural (poor)		1,900	
			Natural (600 cfm)		1,500	
			Natural (400 cfm)		22	

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PARADOX VALLEY

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Evening Star	Gramlick Minerals	3	Forced (500 cfm)		1,115	2 yrs.
Last Chance No. 4	Oliver and Buss	2	Natural (poor)	520	42 32	2 yrs.
Vanadium Queen	Abe Day	4	Natural		490	10 yrs.
Wedge	U.S.V.	2	Natural	3,800	5,600 7,450	2 yrs.

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EASTERN SLOPE

Mine	Owner	No. of Employees	Ventilation	Radon uμc/l	RaA-RaC' uμc/l	Remarks
Lydon Shaft	Marino Cripple Creek	4	Natural		8	Coal mine being reworked for uranium.

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GRANTS, NEW MEXICO

Mine	Owner	No. of Employees	Ventilation	Radon uuc/l	RaA-RaC' uuc/l	Remarks
Blue Peak	Shattuck Denn Mining Co.	10	Natural	870	55 20	<6 mos.
Thompson and Williams (Indians)	Thomson and Williams	2	Natural	940	2,760	<6 mos.
Poison Canyon	Santa Fe	5	Natural (400 cfm) (poor)	2,000	336 13,700	1 yr.

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TABLE 21

By Areas:

Area	No. Mines	Median (RaA + RaC')	Max.	Min.
Uravan	7	820	12,000	160
Temple Mountain	9	300	2,800	< 2
Polar Mesa	7	2,400	7,700	38
Outlaw Mesa	3	3,000	3,800	18
Monument Valley	3	1,200	11,000	9
Monticello	2	950	1,900	15
Moab	10	380	3,400	2
Gypsum Valley	4	9,000	18,000	500
Marysvale	4**	2,500	59,000*	180
Gateway	8	1,000	6,000	6
Durango	5	18	120	< 3
Calamity Mesa	10	1,800	17,000	66
Slick Rock	25	1,100	30,000	< 2
Paradox Valley	4	800	6,500	37
Grants	3	2,800	7,000	38
Long Park	25	4,600	37,000	15
East Reservation	9	160	3,200	11
Eastern Slope	1	8	8	8
Cottonwood Wash	7	520	26,000	< 2
Bull Canyon	11	4,500	32,000	36

** Working Mines

* (Some very high samples in the Freedom-Prospector were taken in areas not being worked and are not reported in this table.)

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TABLE 22

NO. OF MINES AND MINERS VERSUS RADON DAUGHTER CONCENTRATIONS

uuc/1 RaA + RaC'	0 - 100	100-490	500-990	1000-1900	2000-4900	5000-10,000	10,000
No. of Mines 157	35	27	8	17	36	18	16
%	22.3	17.2	5.1	10.8	22.9	11.5	10.2
Cumulative No.	157	122	95	87	70	34	16
Cumulative %	100.0	77.7	60.5	55.4	44.6	21.7	10.2
No. of Miners 733	116	117	31	140	153	60	116
%	15.8	16.0	4.2	19.1	20.9	8.2	15.8
Cumulative No.	733	617	500	469	329	176	116
Cumulative %	100.0	84.2	68.2	64.0	44.9	24.0	15.8

TABLE 23

AGE OF WORKINGS VERSUS RADON DAUGHTER CONCENTRATIONS

RaA + RaC' uuc/1	No. of Miners		No. of Mines	
	Less than 1 yr.	1 yr. or more	Less than 1 yr.	1 yr. or more
Less than 100	47	66	13	20
Less than 500	81	145	24	36
Less than 1000	89	169	27	41

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APPENDIX A

Schedule

MONDAY, June 16th

Mr. Holaday	8:30 - 9:30	Introduction. Uranium study.
Mr. Woolrich	9:45 - 11:45	Chemistry. Atomic structure.
Mr. Woolrich	1:00 - 2:00	Nuclear Physics (introduction)
Mr. Holaday	2:00 - 3:00	Radiation units
Staff	3:00 - 4:30	Laboratory: adjust hats, prepare and light lamps, use of pumps, etc.

TUESDAY, June 17th

Mr. Pott	8:30 - 9:30	Mine practices and terminology
Mr. Holaday	9:45 - 10:45	Nuclear particles
Mr. Woolrich	10:45 - 11:45	Natural and artificial radioactivity
Mr. Holaday	1:00 - 2:00	Radium and uranium decay series
Mr. Woolrich	2:00 - 3:00	Absorption of radiation and ionization
Mr. Woolrich	3:00 - 4:30	Theory of instruments

WEDNESDAY, June 18th

Mr. Woolrich	8:30 - 9:30	Scalers and counting erros (with demonstration of plateau determination).
Staff	9:45 - 11:45	Survey meters. Calibration of Juno
Mr. Jacoe	1:00 - 1:30	Use of Juno in mine surveys
Mr. Jacoe	1:30 - 4:30	Laboratory exercise; mine survey (f-p samples from box, periodic readings, compilation and plotting data.)

THURSDAY, June 19th

Mr. Jacoe	8:30 - 9:30	"Survival" on the Colorado Plateau
Mr. Woolrich	9:45 - 10:45	Mine ventilation
Mr. Holaday	10:45 - 11:45	Use of radon flasks and recording sample information
Staff	1:00 - 4:30	Laboratory: preparation of personal equipment a. instrument cases b. filter papers c. water and gasoline cans

FRIDAY, June 20th

Staff	8:30 - 11:45	Review and miscellaneous subjects
Staff	1:00 - 4:30	Complete survey of the "Tough Luck" Mine

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Mine Name TOUGH LUCK Date June 20, 1952

Mine No. B-1 Team B - Pat and Mike

Location Long Park Area, Between Long Park #13 and Honeymoon

Owner U. S. Vanadium Corp., Uravan, Colorado

Operator Al. L. Wet, Nucla, Colorado

Age of Workings 13 months No. Employees 6

Description and Type of Mining:

Room and pillar. 2 men were drilling and 2 men were mucking by hand at point "A" on lower level. Pillars were being removed on first level.

Description of Ventilation:

Natural ventilation through air shaft to point "B" (room, ore extracted leaving pillars) was 11,000 cfm. Forced ventilation through churn-drill hole to lower level was 6750 cfm. Very poor ventilation at point "A" at working breast.

Samples Taken:

Filter Paper No.	Radon Samples		
	Sample No.	Flask No.	Time
B-1-F-1	B-1-R-1	#311	1:50 p.m.
B-1-F-2	--	--	--

APPENDIX B-1

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Mine No. B-1 Sample No. B-1-F-1

Date June 20, 1952 Team B

Sample Location and Operating Conditions:

Sample taken at working face, lower level. 2 men drilling and 2 mucking by hand into car. Point "A" on sketch.

Description of Ventilation:

Forced ventilation through churn-drill hole 50 feet from face. 6750 cfm. Actual ventilation at working face was poor.

Length of Sample 10 minutes Sampling Rate 21 liters per minute

Time Sampling Ended 1:47 p.m. Pump No. 125 Juno No. 229

Time	Elapsed Time	Meter Reading	Scale	dpm	Corr. Factor	dpm at T o
2:13	26	4.5	10	24100	1.95	47000
2:47	60	28	1	13900	3.50	48700
3:12	85	16	1	8000	5.8	46400
						142100

$$\frac{142100}{3} = 47333$$

$$\frac{(47333)\ (.065)}{21} = 150 \text{ uuc/l} \quad \text{RaA plus RaC'}$$

Radon sample B-1-R-1 = 280 uuc/l

APPENDIX B-2

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APPENDIX C

A field method has been developed for the measurement of RaA and RaC' which is relatively simple and may be used by the mines for control work. This method consists essentially of the following steps:

1. Air is drawn through a one-inch diameter circle of Whatman 41 or Millipore filter paper contained in a special adapter at a measured rate (14-23 liters per minute) by a hand-cranked pump for either a 5- or 10-minute period. In order to simplify calculation, tables have been prepared for these two sampling intervals.

2. The filter paper is then removed from the mine and the alpha activity on the paper is measured by a field instrument (the Juno is a satisfactory instrument for this purpose). This instrument needs to be calibrated against a laboratory counter so that the scale may be read in alpha disintegrations per minute. In order to prevent contamination, this instrument should never be taken into the mines.

3. The activity obtained by reading the instrument must be converted to time zero, which is obtained from the correction curve (see sample calculation below). This value is substituted in one of the following equations:

$$\text{uuc/l of RaA and RaC'} = \frac{0.12\ (\text{dpm})}{V} \quad \text{for 5 minute sample}$$

$$\text{uuc/l of RaA and RaC'} = \frac{.066\ (\text{dpm})}{V} \quad \text{for 10 minute sample}$$

where dpm equals alpha disintegrations per minute at time zero. V equals sampling rate in liters per minute.

Appendix B-2 is an illustrative example of this method.

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