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William F. Bale, Radiobiologist
Biophysics Branch, Division of Biology and Medicine
MEASUREMENTS OF AIR-BORNE RADIOACTIVITY IN A COLORADO PLATEAU URANIUM MINE

The purpose of this note is to report data on air-carried radioactivity of Freedom No. 2 mine at Marysvale, Utah, obtained on June 26, 1951 during a visit with Mr. Duncan Holaday of the U. S. Public Health Service. This mine for the production of uranium ore is operated by the Vanadium Corporation of America.

This mine was selected for a visit and survey because it was relatively easy to reach by automobile and because, as a relatively new mine with few interconnecting shafts, it had a relatively poor natural circulation of air. In this respect it is not unlike many other mines of the Colorado plateau area. Potential artificial ventilation was provided by a ventilation fan with flexible conduit leading to the working faces of the mine. In practice it was customary at this mine to operate the fan only to clear out fumes following blasting operations. It was not in operation during the several hours of our visit there.

The mine interior was refreshingly cool and pleasant in contrast with the hot, semi-arid treeless hills outside. There was no obvious dust in the air. The corridors were dry, with no moisture or water in evidence. All in all the entrance decline and horizontal drifts resembled very much the drier passageways in many natural limestone caves as far as general atmosphere and comfort were concerned. It seemed likely that bringing the outside hot desert air in large amounts to the working faces would not substantially improve the comfort of the miners working there.

This visit was primarily for the purpose of making measurements of the concentration of the air-borne degradation products of radon to which miners are exposed, as compared with the air concentrations of radon itself. For the collection of radon degradation products an instrument devised at the University of Rochester and designed to measure lung retentions was used. Radioactivity measurements were made with a Hanford Zeuto modified to accept 18.5 cm filter paper in a dehydrated ionization chamber. Dust samples were also collected by Mr. Holaday with a hand-crank operated air pump. For radon concentration determinations air samples were collected in glass flasks and later measured with apparatus utilizing a vibrating reed electrometer that had been earlier provided to the U. S. Public Health Service by the New York Operations Office of the A. E. C.

Four sets of sample collections were made. Each set included samples for determinations of both radioactive dust and radon. The location of sampling and results of these measurements are shown in Table I. The first two sample collections were made during the noon luncheon period. Air drilling operations liberate substantial amounts of air, and in many mines provide the only substantial introduction of outside air. In order to evaluate the effect of such drilling

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on radon and radioactive dust concentrations, sampling at location two just back of the working face was repeated after drilling operations had been in progress about ten minutes. Sampling operation four took place at the base of a vertical shaft to the surface that represented a place of exit of mine air due to convection processes.

Drilling operations seemed to create a very slight mist at the working face but otherwise not to make the mine appreciably dusty.

Results of uranium analysis on the dust samples collected by Mr. Holaday are not yet available. Results of other analyses are reported in Table I.

Data shown in Table I indicate that not only are the radon concentrations high, but, probably of more importance, the long-lived degradation products of radon are present in appreciable percentages of the equilibrium value. The average concentration of radon found was 4.4×10^4 μμc per liter. This is 440 times the maximum permissible radon concentration value of 100 μμc per liter now in use by the A. E. C. and 4,400 times greater than the permissive value of 10 μμc per liter suggested by Dr. Robley D. Evans and now in use in the radium dial painting industry. This latter permissive value was based on the assumption that levels of 1,000 μμc per liter had led to an increased incidence of lung carcinoma among miners in European radium and uranium mines.

The average concentration of radon degradation products found was equivalent to an initial RaC' concentration of about 1.5×10^4 μμc per liter. Evaluation of resulting radiation dosage to the lungs as a whole, or to bronchial epithelium can only be carried out on the basis of assumptions, some of which have an uncertain validity. If one assumes:

1. That a worker spends 40 hours per week in the mines and breathes air at a rate of 20 liters per minute during that time.

2. That radon degradation products are present that give an average initial RaC' concentration of 1.5×10^4 μμc per liter.

3. That a worker retains 50 percent of the radon degradation products inhaled into the lungs. (Measurements made at the mines did not give consistent data on this subject. This assumed 50 percent comes from measurements made at the New York Operations Office.)

4. That the weight of healthy human lungs is 455 grams (Gray's Anatomy, page 1195, 1913 edition).

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5. That for alpha particles 1 rep = 20 rem.

Then the average dose to the lung tissue as a whole turns out to be:

18.2 rep per week or

364 rem per week.

This latter figure can be compared with the 0.3 rem per week sometimes considered an acceptable dose of radiation for an organ. It is greater by a factor of about 1200.

If one further assumes that one-half of this lung-retained radioactivity is deposited in bronchi and bronchioles down to 0.2 mm diameter and that the weight of tissue within effective alpha particle range of such activity is 19.6 grams, then the average dose to such bronchial tissues can be computed as:

211 rep per week, or

4220 rem per week.

Dogs and rats can withstand 60 r whole body X-radiation per week for about a year before there is any substantial increase in mortality over controls, or any obvious signs of radiation effect beyond minimal blood changes. Probably radiation dosage to a single organ with no special radiosensitivity, such as the lungs, can be several times greater before effects show up rapidly. Therefore, apparent good health of these miners is not inconsistent with the results of animal experiments.

Also the validity of some of the assumptions made above is doubtful. The rem to rep ratio for alpha particles on the basis of ability to damage lung tissue may be substantially less than 20. Lung retention under mine conditions may be less than 50 percent, and less than 50 percent of material retained may be deposited initially in the bronchi and bronchioles. Dr. Norton Nelson of New York University has kindly called my attention to theoretical studies by H. D. Landahl that suggest that dust deposition of this type may be largely in the alveoli. If so, average radiation dosage to bronchial epithelium may not differ substantially from average radiation dose to the lungs as a whole.

Nevertheless there may well exist substantial risk to miners working for long periods under conditions approximating Freedom No. 2 mine, or even indeed under conditions considerably more favorable.

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Plans to visit and make measurements at one other mine, at least, in this area, were abandoned because of automobile trouble and a request for Mr. Holaday to attend a meeting at Los Alamos.

Conclusions based upon data collected: The fact that radon degradation products were found in amounts equivalent to equilibrium with a substantial fraction of the radon present gives confirming evidence to the hypothesis that the hazard associated with radon is largely from the air-borne degradation products rather than from radon itself.

This conclusion, in turn, suggests that a realistic and useful monitoring procedure in mines may consist of the collection and radioactive measurement of atmospheric dust samples. Such dust sampling might supplement or replace radon concentration determinations.

Before making definite recommendations on the above point, it would seem desirable to extend measurements of the type made at Freedom No. 2 mine to other representative radon-producing mines of the Colorado plateau area. As a step in this direction I propose to return the retention apparatus to Mr. Holaday on loan for his use after some indicated modification of the apparatus has been completed.

As a result of preliminary survey carried out by Mr. Holaday and his associates of the U. S. P. H. S., it seems apparent that not only are high radon concentrations common in uranium mines in operation today, but that radon in considerable amounts has probably been present in Colorado plateau mines for many years, including mines not producing uranium or radium. Theoretical considerations indicate that polonium concentrations in the urine may be closely correlated with integrated radon and radon degradation product exposure in such individuals. It seems worthwhile to conduct an experimental study along these lines to find out whether in fact determinations of **lifetime** integrated exposures can be made by such means.

Such miners represent the only substantial group of human individuals with long standing lung exposure to substantial doses of radiation. As such, their potential worth in setting permissible values of lung exposure to radiation may be comparable to that of the intentional or unintentional human recipients of radium in setting permissible limits for the radioactivity burden of bone.

I believe Mr. Holaday and his associates of the U. S. P. H. S. are to be commended for the inauguration of a conservative and useful exploration of radiation hazards among uranium miners of the Colorado plateau. They seem to

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have conducted their work so far without unduly alarming miners as to hidden hazards that may exist, or in any way impeding mining operations. They appreciate, I am sure, the assistance given them by members of the Health and Safety Division, NYOO, particularly in instrumentation for measuring the integrated exposure of miners to radon under actual working conditions. They deserve the future assistance of competent AEC personnel in formulating adequate safety measures for miners as far as exposure to radiation and other toxic materials is concerned and in gaining their acceptance as a part of routine mining practice.

Attachment: Table 1

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TABLE 1

Results of Measurements on Dust Samples
Collected at Freedom No. 2 Mine, June 26, 1951

(1) Sample No.	(2) d/m breathed into lungs in 2.5 minutes	(3) d/m per liter air	(4) $\mu\mu$curies dust-borne activity per liter	(5) radon concentrations $\mu\mu$curies/liter	(6) Percent equilibrium RaC' with radon
1	8.2×10^5	3.2×10^4	1.45×10^4	5.33×10^4	27.
2	8.6×10^5	3.4×10^4	1.55×10^4	$4. \times 10^4$	39.
3	6.1×10^5	2.4×10^4	1.1×10^4	2.9×10^4	38.
4	9.2×10^5	3.7×10^4	1.7×10^4	5.33×10^4	32.

Comments and explanation of columns in above table.

(1) Sample No.

No. 1 - Taken at foot of incline, station no. 1, at 12:18 p.m. This sample, as well as sample no. 2, was taken during noon lunch period, with no forced ventilation or air drills in operation.

No. 2 - Taken at station 2, 12:37 p.m., about 20 feet back of working face of left drift, no forced ventilation or air drills.

No. 3 - Taken at station 2, same location as previous sample at 1:03 p.m. after air drills at face had been in operation about 10 minutes. No other ventilation.

No. 4 - Taken at station 3, 1:30 p.m., at base of ventilation incline about midway left drift. Air drills had been in operation about 30 minutes.

(2) The readings are in terms of calibrations previously carried out at Rochester and at NYOO. Activities were too high to read with the modified Zeuto until after radioactive decay by about a factor of 15. In computing decay corrections the figures provided by Meyer and Schweidler in their book, Radioaktivät, page 437, 2nd Edition, Teubner, Berlin, were used. Use instead of an assumed 33 minute half-life would give substantially higher calculated activities.

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(3) This calculation is based on a calibration indicating about 10 liters of air per minute breathed through the dust collection and retention device under conditions of actual use.

(4) One μμcurie equals 2.2 disintegrations per minute.

(5) These radon values are the results of grab samples made at the time of dust collection as reported by D. E. Rushing in a note of June 28. The values corresponding to samples 2 and 3 are the average of duplicates. The values corresponding to 1 and 4 are the results on single samples.

(6) These results are the values of (4) divided by (5) and multiplied by 100.

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