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STUDY OF THE RADON RELEASED FROM OPEN DRILL HOLES

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ABSTRACT

The radon emanating from three open drill holes was measured at a site of known uranium mineralization in the Red Desert of south central Wyoming. The radon flux from the soil and drill holes was measured by the accumulator method with activated charcoal cartridges. The surface soil was found to release radon at an average rate of $0.41 \text{ atoms/cm}^2/\text{sec}$; the radon emanating from the holes was more variable than that from the soil. The three holes studied released an average of $47 \text{ atoms/cm}^2/\text{sec}$ of radon. This average is equivalent to the radon released to the atmosphere by 14.5 ft^2 of soil. The data indicate that the radon emanated from an open drill hole is not as significant as other possible activities at a drill site (i.e. digging a trench or drilling a hole) or from household activities involving the usage of water.

INTRODUCTION

While numerous studies of atmospheric radon concentrations and the radon flux from the earth have been reported (Rubin, 1980; Tanner, 1980; Turekian et al., 1977; Wilkening et al., 1972; George, 1972; Wilkening and Hand, 1960), the amount of radon released to the atmosphere from open holes drilled by the energy and mineral industry has not been addressed. The U.S. Department of Energy, therefore, directed their prime contractor at the Grand Junction Office, Bendix Field Engineering Corporation, to measure the radon released by open drill holes. From the resulting data, the environmental impact of radon released by exploration drill holes may be ascertained.

The study was performed at the ENQ uranium deposit in the Red Desert area of Wyoming. Drill holes at a known uranium deposit were studied so that the radon (a decay product of uranium) released would be maximized. In other words, this is an extreme case study of the radon released by open drill holes.

SITE DESCRIPTION

The research site lies within the Great Divide Basin of south central Wyoming (Figure 1). The topography consists of broad depressions, low hills, bluffs, and flats with a total relief of about 60 feet. Drainage is internal, and all streams are intermittent in the area of the research site. There is a gentle northwest stratigraphic dip of about 1° at the site. The soil is essentially sandy and contains primarily quartz and feldspar grains derived from the underlying Battle Spring Formation. Locally, zones of clay-rich overburden produce regions of hardpan.

The economic uranium mineralization in the Red Desert area occurs in coarse-grained arkosic sandstones of the Battle Spring Formation which interfinger with the carbonaceous mudstones of the Wasatch Formation.

The ENQ ore deposit lies principally within an arkosic sand, called the "ENQ trend" (Sherborne et al., 1979), at a depth of 420 to 460 feet. The ore-bearing arkose is capped and underlain by uranium-bearing carbonaceous mudstones. The water table is at about 160 feet. Three drill holes within 200 feet of each other penetrated the deposit and were monitored for their radon release. The site plan is illustrated in Figure 2. The holes, which are 5 inches in diameter, had been drilled 7 years ago and were unplugged for this experiment. Two of the holes (105-13 and 105-16) were closed off at 310 feet, while the third (105-3) was closed off at 200 feet. The interpreted gamma-spectral uranium, neutron-neutron, and resistance logs obtained for these holes are shown in Figures 3 through 5. The neutron-neutron and resistance logs indicate that the site is underlain by sandstone with intercalated mudstone units. The gamma-spectral uranium logs indicate that the sandstone contains 10 ppm uranium while the mudstones typically contain 19 ppm uranium.

FIGURE 1. Location of research site at Red Desert, Wyoming.

FIGURE 2. Measurement locations at the study site.

FIGURE 3. Uranium by spectral gamma, neutron-neutron, and resistance logs for drill hole 105-3.

FIGURE 4. Uranium by spectral gamma, neutron-neutron, and resistance logs for drill hole 105-13.

FIGURE 5. Uranium by spectral gamma, neutron-neutron, and resistance logs for drill hole 105-16.

RADON FLUX MEASUREMENT METHOD

Radon flux measurements were performed using activated charcoal cartridges in inverted 15-gallon tubs. The method is based on the radon accumulation method used by Kraner et al., 1964 and Wilkening et al., 1972, and the radon adsorption techniques used by Megumi and Mamuro, 1972; Thomas, 1975; and Countess, 1976. An inverted tub 22 inches in diameter at its mouth, 18 inches at its base, and 11 inches in height was installed in the ground (see Figure 6). Soil was packed around the outer edge of the tub to ensure that the device was sealed with the ground. There is an orifice 0.25 inches in diameter in the base of the tub for pressure equalization. An activated charcoal cartridge was secured to the inside base of the tub (see Figures 7 and 8). The activated charcoal cartridges, marketed for uranium exploration, were ROAC cartridges from Inter-Science Research and Development Services (Pty) Ltd. of Bramley, Republic of South Africa. They were exposed for several days and returned to Grand Junction where the gamma activity was measured twice. By applying decay correction factors and calibration factors determined with the Bendix radon calibration unit, the final radon concentrations in the collectors were obtained.

RESULTS OF RADON FLUX MEASUREMENTS

The radon flux measurement devices were placed over the three drill holes and five surface measurement locations. The surface measurements indicated the amount of radon released to the atmosphere by the top layers of soil at the site; the measurements were performed for two exposure periods. The first exposure was from August 24 to August 28, 1980; the second exposure was from August 30 to September 1, 1980. The exposures were initiated and terminated at approximately 10 a.m. of the stated dates.

Tables 1 and 2 list the radon concentrations obtained in the collectors. The standard deviation listed with each measurement is due to the uncertainty from counting statistics, replicate counting, and calibration. Kraner et al., 1964, observed that for a similar radon accumulation device, the radon concentration buildup was linear until the concentration within the container reached approximately 10 percent of the radon concentration at a 5-inch depth. Table 3 lists the daily radon concentrations in the ground at a depth of 18 inches obtained with a RE-350 radon emanometer produced by TSA Systems, Inc., of Boulder, Colorado.

These data indicate that the final radon concentration obtained in the collectors was slightly higher than that recommended by Kraner et al., 1964. It is felt that these final radon concentrations were not great enough to have been increasing nonlinearly. Table 3 indicates that location B has a significantly lower radon concentration in the ground than the other locations. The final radon concentration in the collector at this location is not significantly different than the other sampling locations for the first sampling period. This indicates that for this sampling period the final radon concentration in a collector was not dependent on the local variation of the radon concentration in the ground and the radon buildup in the collector should be linear. For the second sampling period, the collector at location B contained the lowest radon concentration, but the radon flux as shown in Table 1 is approximately the same for both samplings at this location. Since

FIGURE 6. Radon collector device deployed at site.

FIGURE 7. A ROAC activated charcoal cartridge.

FIGURE 8. Inside of radon collector with ROAC cartridge attached.

TABLE 1. RADON RELEASED FROM SURFACE SOIL

<u>Location</u>	<u>Final Radon Concentration in Collector</u> <u>(pCi/l) $\pm 1\sigma$</u>		<u>Radon Flux</u> <u>(atoms/cm²/sec) $\pm 1\sigma$</u>	
	<u>Sampling 1</u>	<u>Sampling 2</u>	<u>Sampling 1</u>	<u>Sampling 2</u>
A	251 $\pm$ 30	191 $\pm$ 11	0.29 $\pm$ 0.04	0.46 $\pm$ 0.03
B	221 $\pm$ 13	134 $\pm$ 12	0.26 $\pm$ 0.02	0.32 $\pm$ 0.03
C	221 $\pm$ 20	250 $\pm$ 29	0.26 $\pm$ 0.02	0.60 $\pm$ 0.07
D	229 $\pm$ 17	198 $\pm$ 11	0.27 $\pm$ 0.02	0.48 $\pm$ 0.03
E	389 $\pm$ 21	298 $\pm$ 35	0.46 $\pm$ 0.02	0.72 $\pm$ 0.08
Average	262 $\pm$ 68	214 $\pm$ 59	0.31 $\pm$ 0.08	0.52 $\pm$ 0.14
Overall average = 0.41 $\pm$ 0.16				

TABLE 2. RADON RELEASED FROM DRILL HOLES

<u>Hole</u>	<u>Final Radon Concentration in Collector</u> <u>(pCi/l) $\pm 1\sigma$</u>		<u>Radon Flux</u> <u>(atoms/cm²/sec) $\pm 1\sigma$</u>	
	<u>Sampling 1</u>	<u>Sampling 2</u>	<u>Sampling 1</u>	<u>Sampling 2</u>
105-03	1187 $\pm$ 82	823 $\pm$ 46	21.1 $\pm$ 2.4	28.3 $\pm$ 3.3
105-13	1037 $\pm$ 58	952 $\pm$ 60	17.7 $\pm$ 2.0	34.2 $\pm$ 3.8
105-16	1497 $\pm$ 81	3509 $\pm$ 191	28.1 $\pm$ 2.3	152 $\pm$ 9.2
Average	1240 $\pm$ 206	1761 $\pm$ 1241	22.3 $\pm$ 4.9	71.5 $\pm$ 57.4
Overall average = 46.9 $\pm$ 47.5				

TABLE 3. DAILY RADON CONCENTRATIONS IN THE GROUND
DETERMINED WITH TSA RADON EMANOMETER

	Radon Concentration (pCi/l)					
	Date					
<u>Location</u>	<u>8/25</u>	<u>8/26</u>	<u>8/27</u>	<u>8/30</u>	<u>8/31</u>	<u>Average</u>
A	1804	310	2499	1708	3108	1886
B	443	986	328	468	431	531
C	1464	1378	1431	1796	1641	1542
D	1517	1545	1466	458	994	1196
E	1532	1346	1343	551	978	1150
105-03	376	1812	1613	1953	2121	1575
105-13	1170	1172	1638	1152	461	1119
105-16	3196	1249	3218	3173	2753	2718
overall average =						1465

the radon concentration in these collectors increased linearly for the collection times used, the radon flux can be calculated directly knowing the final radon concentration, the collector volume, the sampling period, and the area sampled.

The radon released to the atmosphere from the surface rock during the two exposure periods is summarized in Table 1. At all five locations, more radon was released during the second sampling period. This may be the result of a decrease in barometric pressure during this period as shown in Figure 9.

None of the other meteorologic parameters monitored during the study was significantly different for the two measurement periods. This inverse relation between radon flux and barometric pressure has also been observed by Wilkening et al., 1972, and has been explained by Kramer et al., 1964, to be the result of air low in radon being forced onto the ground during times of high barometric pressure and radon-rich soil gas being withdrawn during low pressure periods.

Table 4 lists the radioelement concentrations determined with a Scintrex GAD-6 spectrometer for the five surface sampling locations and near hole 105-16. These data suggest that the variation in radon released between the five surface sampling locations is not a function of the radioelement concentration of the surface soil. Location E, which released the greatest amount of radon during both sampling periods, does not have the greatest surface radioelement concentrations. The radon variation by location may be due to a deeper source since the gamma measurements only investigate the top foot of soil.

The average radon flux from surface soil measured for the Red Desert site is 0.41 ± 0.16 atoms/cm²/sec (Table 2). Wilkening et al. (1972) reviewed radon flux measurements performed by numerous investigators and found that worldwide for a total of 994 measurements the overall radon mean flux is 0.75 atoms/cm²/sec with a range from 0.01 to 2.5 atoms/cm²/sec. The overall mean for New Mexico locations is 1.14 ± 0.34 atoms/cm²/sec compared with 0.49 ± 0.15 atoms/cm²/sec for Texas, 0.33 ± 0.10 for Alaska, and 0.53 ± 0.16 for Hawaii. It was emphasized that without a knowledge of the areal distribution of the soil groups involved, these values could not be considered representative of the total areas of these states. Thus, it appears that the radon flux we determined for the Red Desert site in Wyoming was as expected from literature. It is believed that the radon flux obtained for this site is below the worldwide mean flux stated by Wilkening et al. (1972) because of the clay present in the Red Desert soil. The data presented by Wilkening et al. (1972) indicate that the radon flux is low when clay is mentioned in the soil description.

The radon released from the three drill holes is listed in Table 2. These values were obtained by subtracting the radon contribution from the soil (average radon flux for a sampling period used) under the radon collectors from the total radon released and assuming a linearly buildup of radon in the collectors. Since the uranium concentration of the soil near hole 105-16 is higher than that of the surface sampling locations, the radon determined to be released by this drill hole may be slightly overestimated. The slightly higher radiometric values at this location may be due to drill cuttings from the hole, although cuttings were not readily observable. Like the surface measurements, more radon was released from the holes during the second

FIGURE 9. Meteorologic data for the testing period at the Red Desert Wyoming site.

TABLE 4. SURFACE RADIOELEMENT CONCENTRATIONS
DETERMINED WITH GAMMA SPECTROMETER

<u>Location</u>	<u>Potassium (%K)</u>	<u>Uranium (ppm eU)</u>	<u>Thorium (ppm eTh)</u>
A	3.17 $\pm$ 0.06	7.1 $\pm$ 0.5	24.7 $\pm$ 0.6
B	3.50 $\pm$ 0.05	6.6 $\pm$ 0.5	25.6 $\pm$ 0.6
C	3.03 $\pm$ 0.05	7.2 $\pm$ 0.5	25.6 $\pm$ 0.6
D	3.37 $\pm$ 0.05	5.9 $\pm$ 0.4	21.4 $\pm$ 0.6
E	3.06 $\pm$ 0.05	6.6 $\pm$ 0.4	22.6 $\pm$ 0.5
105-16	3.13 $\pm$ 0.06	8.8 $\pm$ 0.5	30.6 $\pm$ 0.6

sampling period. The radon flux determined for hole 105-16 during the second sampling period is a factor of five times greater than the other two holes. This did not occur for the first sampling period. The agreement between replicate measurements of the charcoal cartridge used at hole 105-16 was better than 1 percent. Since this agreement is dependent on the gamma activity measured and the half-life of radon, it is felt that this measurement is valid. The average radon flux for the three drill holes studied is 46.9 atoms/cm²/sec.

DISCUSSION

The radon determined to be released by open drill holes can be compared to other activities related to a drilling program in order to evaluate the impact on atmospheric radon.

The radon released by the open drill holes can be normalized with the radon released by the soil at the site. Since the radon released varied with sampling period, measurements for each sampling period were handled separately. As an example, the radon flux for hole 105-03 was 21.1 atoms/cm²/sec during the first sampling period, and the average radon flux for surface soil was 0.31 atoms/cm²/sec. Since the area of the hole was 127cm², the hole released 2670 atoms/sec of radon which was the amount of radon released by 8620 cm² or 9.28 ft² of surface soil. Table 5 indicates that the holes emanated radon equivalent to that emanated by an average of 14.3 ft² of soil surface. This amount of additional surface rock was exposed when a trench, 1 foot wide, 1 foot deep, and 6 feet long was dug. These data also suggest that the increase in atmospheric radon from open drill holes on 50-foot centers is 0.58 percent while drill holes on 1-mile centers increase the radon in the atmosphere by 0.000052 percent.

This normalized radon flux can be compared to the total radon production in a hole. The rock surface area in one of these 5-inch holes which contributes radon to the airspace is 208 ft² since only the rock surface above the water need be considered. It is assumed that the water in the hole will contribute an insignificant amount of radon to the airspace in a hole because of its small surface area (0.14 ft²) and the small diffusion coefficient (10⁻⁵cm²/sec) for radon in water (Tanner, 1964). If the radon emanating from the wall rock of the hole is the same as the surface soil at the site, then only 7 percent of the radon released into a hole escapes to the atmosphere.

As indicated in Figures 3 through 5, the average uranium content of the wall rock above the water level of the holes is 13 ppm, with the sandstone averaging 10 ppm eU and the mudstones averaging 19 ppm eU. This is greater than the uranium content of the surface soil as listed in Table 4. The emanating factor for the rock inside the holes is not known but can be assumed to be the same as the soils based on the work of Schutz, 1981. He found core samples taken over the ENQ deposit to have an average emanating factor of 0.57, while soil samples at the site had an emanating factor of 0.55. Thus, the wall rock of the holes has a greater radon source value and a similar emanating factor compared to the surface soil, and the estimated loss of radon from the holes at 7 percent is probably an overestimate.

TABLE 5. RADON RELEASED FROM DRILL HOLES NORMALIZED TO SURFACE SOIL

<u>Hole</u>	<u>Radon Flux</u> <u>(atoms/cm²/sec)</u>		<u>Equivalent Surface Soil</u> <u>(ft²)</u>	
	<u>Sampling 1</u>	<u>Sampling 2</u>	<u>Sampling 1</u>	<u>Sampling 2</u>
105-03	21.1 $\pm$ 2.4	28.3 $\pm$ 3.3	9.28 $\pm$ 2.68	7.42 $\pm$ 2.16
105-13	17.7 $\pm$ 2.0	34.2 $\pm$ 3.8	7.79 $\pm$ 2.25	8.97 $\pm$ 2.58
105-16	28.1 $\pm$ 2.3	152 $\pm$ 9.2	12.4 $\pm$ 3.5	39.9 $\pm$ 10.9
Average	22.3 $\pm$ 4.9	71.5 $\pm$ 57.4	9.82 $\pm$ 3.28	18.8 $\pm$ 15.9
Overall average	46.9 $\pm$ 47.5		14.3 $\pm$ 12.0	

The drilling operation itself brings radon to the surface and releases it. Radon in the rock and pore fluid are mixed with the drilling mud and pumped to the surface. The pumping and agitation of the mud will essentially release most of the radon to the atmosphere. A typical amount of radon released by a drilling operation can be estimated from data acquired with a drilling mud emanometer developed by Bendix (Bell et al., 1981). The unit provides a radon log of a hole by degassing the recirculating drilling mud and measuring the radon present with a flow-through ionization chamber. Two holes, drilled to an average depth of 470 feet, were monitored at the ENQ deposit. Approximately 43,000 gallons of mud were circulated in drilling a hole to this depth. The recirculated mud contained an average radon concentration of 140 pCi/l or 9.4×10^6 atoms/gal. Assuming pumping and agitation will release all the radon from the mud (the radon profile downhole did not show a radon buildup in the mud), the drilling of a hole released 4.0×10^{11} atoms of radon. Considering that the average radon emanating from a hole is 47 atoms/cm²/sec or 6,000 atoms/sec, the hole would need to stay open for 770 days or 2 years for the released radon to be equivalent to that released in drilling a hole. However, exploration holes are usually sealed within hours of being drilled.

Measurements of radon in the ground water at and in the vicinity of the ENQ deposit indicated that the water contained typically 700 pCi/l of radon (Czarnecki et al., 1981). Gesell and Prichard, 1980, showed that a typical household with 1000 pCi/l of radon in their water supply will use 890 liters of water daily for normal uses which will release 459,000 pCi of radon. Since the water at the research site contains 700 pCi/l, then it is expected that normal household use of this water would release 321,000 pCi or 5.7×10^9 atoms of radon daily. Since the average radon emanating from a hole is 47 atoms/cm²/sec (6,000 atoms/sec or 5.2×10^8 atoms/day), then 11 open holes would release radon equivalent to that released by one household using water at this site.

It appears that the radon emanated from an open drill hole is not as significant as other possible activities at a drill site (i.e. digging a trench or drilling a hole) or from household activities involving the usage of water.

CONCLUSIONS

The radon released from open drill holes was investigated at a site of known uranium mineralization in the Red Desert area of Wyoming. The radon released from surface rock at the site and from three drill holes was measured for two sampling periods. The surface soil was found to release radon at a rate of 0.41 atoms/cm²/sec. The radon released by the holes, 47 atoms/cm²/sec, was more variable than that released by the surface soil. An open drill hole in the Red Desert released radon to the atmosphere at a rate equivalent to 14.3 ft² of soil.

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