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# Comparison of Field-Measured Radon Diffusion Coefficients with Laboratory-Measured Coefficients

Prepared by E. A. Lepel, W. B. Silker, V. W. Thomas, D. R. Kalkwarf

**Pacific Northwest Laboratory**
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**Prepared for**
**Division of Health, Siting and Waste Management**
**Office of Nuclear Regulatory Research**
**U.S. Nuclear Regulatory Commission**
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## ABSTRACT

Experiments were conducted to compare radon diffusion coefficients determined for 0.1-m depths of soils by a steady-state method in the laboratory and diffusion coefficients evaluated from radon fluxes through several-fold greater depths of the same soils covering uranium-mill tailings. The coefficients referred to diffusion in the total pore volume of the soils and are equivalent to values for the quantity, D/P, in the Generic Environmental Impact Statement on Uranium Milling prepared by the U.S. Nuclear Regulatory Commission. Two soils were tested: a well-graded sand and an inorganic clay of low plasticity. For the flux evaluations, radon was collected by adsorption on charcoal following passive diffusion from the soil surface and also from air recirculating through an aluminum tent over the soil surface. An analysis of variance in the flux evaluations showed no significant difference between these two collection methods. Radon diffusion coefficients evaluated from field data were statistically indistinguishable, at the 95% confidence level, from those measured in the laboratory; however, the low precision of the field data prevented a sensitive validation of the laboratory measurements. From the field data, the coefficients were calculated to be 0.03 ± 0.03 $cm^2/s$ for the sand cover and 0.003 ± 0.002 $cm^2/s$ for the clay cover. From the laboratory data, the coefficients were calculated to be 0.021 ± 0.002 $cm^2/s$ for the sand cover and 0.0036 ± 0.0004 $cm^2/s$ for the clay cover. The low precision in the coefficients evaluated from field data was attributed to high variation in radon flux with time and surface location at the field site.

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## EXECUTIVE SUMMARY


The purpose of this study was to compare radon diffusion coefficients evaluated for 0.1-m depths of soils under laboratory conditions with diffusion coefficients evaluated for several-fold greater depths of the same soils when used to cover uranium-mill tailings. These coefficients referred to diffusion in the total pore space of the soils and are equivalent to values for the quantity, D/P, in the diffusion equations presented in the Generic Environmental Impact Statement on Uranium Milling prepared by the U.S. Nuclear Regulatory Commission[1]. Two soils were tested: a well-graded sand with a dry porosity of 0.38 and containing 0.07 moisture by volume; and an inorganic clay of low plasticity with a dry porosity of 0.49 and containing 0.20 moisture by volume. Both were considered by the mill operators as candidate cover soils for attenuating radon emission from tailings at the field test site.

In the field, radon diffusion coefficient were evaluated from the radon fluxes emitted by bare and covered tailings and from the porosities, and depths of the soil covers as well as the $^{226}$Ra content and radon emanation coefficient of the underlying mill tailings. The sand cover was 1.14 m in depth and covered an area of 1.31 $m^2$. The clay cover was applied over an equal-sized area but to a depth of only 0.44 m. Radon fluxes were measured by two independent methods, one based upon the passive diffusion of radon into an open canister of charcoal and the other utilizing recirculated air to sweep the radon flux collected by an aluminum tent into a charcoal trap. Analysis of variance in the flux measurements showed no significant difference in the measurement methods. The diffusion coefficient evaluated for the sand cover was $0.03 \pm 0.03$ $cm^2/s$ at the 95% confidence level, whereas that for the clay cover was $0.003 \pm 0.002$ $cm^2/s$.

In the laboratory, diffusion coefficients were evaluated by a steady-state diffusion method applied to soil samples, 0.02 $m^2$ in area and 0.10 m in depth, with the same porosity and moisture content as in the field experiments. The diffusion coefficient measured for radon in the sand cover was $0.021 \pm 0.002$ $cm^2/s$ at the 95% confidence level, whereas that for the clay was $0.0036 \pm 0.0004$ $cm^2/s$ at the 95% confidence level. Both values were within the uncertainty ranges for the field-evaluated coefficients, and the best estimates for coefficients obtained by the two methods agreed within a factor of two. However, the 95% confidence intervals for the field-determined values were too broad to provide a sensitive check on the validity of the laboratory-measured values. The low precision of the field-determined coefficients was attributed to the high variation of radon flux with time and surface location at the field site, a phenomenon reported by other investigators.

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## INTRODUCTION

Uranium-mill tailings continually release $^{222}Rn$, a gaseous, radioactive decay product of $^{226}Ra$, which enters the air-filled voids of the tailings and diffuses into the atmosphere. This gaseous radon transport or flux can be reduced by covering the tailings with soil. The soil increases the diffusion path of radon to the atmosphere and provides time for radioactive decay of $^{222}Rn$ ($T_{1/2}$ = 3.82d) within the cover. The soil depths required to keep the flux or atmospheric concentration of radon below prescribed limits will be determined by calculation. These calculations require knowledge of the radon diffusion coefficient through the soil and its variation with moisture content and compaction.

The purpose of this study was to compare the diffusion coefficients of radon in soils measured under field conditions with those measured in the laboratory under identical conditions of soil-moisture content and porosity. The latter measurements can be made rapidly and conveniently with a cylinderical column of soil, 0.1 m in height, 0.02 $m^2$ in area, and weighing 3 to 4 kg(2,3). The method involves sealing a prepared column of soil in a chamber containing a $^{226}Ra$ source, which continually generates $^{222}Rn$. The radon diffusion coefficient is evaluated from the steady-state radon concentration in the bottom chamber, the predetermined radon flux escaping the source with no soil in place, and the depth of soil in the test column. Because of the small height and amount of soil used, however, the validity of these coefficients in calculating required cover depths for mill tailings was uncertain. As a result, it was considered prudent to evaluate some diffusion coefficients for larger-scale soil samples in the field and to compare them with laboratory-measured coefficients.

Field experiments were conducted at a mill-tailings disposal site and both a well-graded sand and an inorganic clay were tested as barriers to radon diffusion. The well-graded sand covered a 1.31-$m^2$ area of tailings to a depth of 114 cm and weighed 2.68 Mg. The inorganic clay covered another 1.31-$m^2$ area of tailings to a depth of 44 cm and weighed 0.91 Mg. Radon diffusion coefficients were evaluated from the radon fluxes emitted from bare and covered tailings and from the properties and depths of the soil covers. Radon fluxes were measured by two independent methods, one based upon the passive diffusion of radon into an open canister of charcoal and the other utilizing recirculating air to sweep the radon flux collected by an aluminum tent into a charcoal trap. Diffusion coefficients were evaluated from both types of flux measurements, and the results were compared with those obtained by the laboratory method on samples of the same soils under identical conditions of soil-moisture content and porosity.

## EXPERIMENTAL

### Field Test Site Preparation

Field tests were conducted on an inactive section of the tailings disposal site at the Dawn Mining Company's mill at Ford, Washington. The test facility consisted of six aluminum caissons, each 1.29 m in diameter and about 3 m high, placed vertically in a trench that was excavated in the tailings. The trench was then backfilled with tailings and compacted to replicate the surrounding landscape. Two meters of tailings material were then added in 20-cm lifts to the caissons and compacted to again replicate the undisturbed tailings. After sufficient time had elapsed to permit the radon to attain steady-state equilibrium, measurements were made to determine the radon flux from the bare tailings in each caisson. A cover of inorganic clay with low plasticity and weighing 911 kg was then applied in caisson No. 3 to a depth of 44 cm, using 8- to 10-cm lifts with compaction following each lift. A cover of well-graded sand weighing 2680 kg was applied in caisson No. 2 to a depth of 114 cm, utilizing the same compaction technique. After the field test, samples of the soils and tailings were packed in moisture-proof containers and taken to the laboratory for analysis. Physical properties of the tailings and each applied cover were determined by methods recommended by the American Society for Testing and Materials (ASTM).[4] The moisture content and specific gravity were determined by ASTM methods D2216 and D-854, respectively. The particle-size distributions of the soils were evaluated by ASTM methods D-422 and D-1140, and the soils were given engineering classifications according to ASTM method D-2487. The dry packing density was determined by taking a core of known volume and determining its dry mass.

Field Measurements of Radon Surface Flux

Surface fluxes of radon in the field were measured by two independent methods. These were 1) a passive charcoal-canister adsorption method, and 2) a tent method in which radon was removed from a recirculating air stream by adsorption on granular, activated charcoal.

The charcoal-canister method has been employed by several other investigators[5-8] and was reported to measure radon flux with a precision of ±15%[7]. A commercial charcoal-filled gas mask canister (Mine Safety Applicance Company, Number GMA-459315) was used in this study. The larger end of the canister was covered with Tedlar® film, which is impervious to radon; the smaller end was pressed into a 7.5-cm diameter, 5-cm length of Lucite® cylinder and sealed with pressure-sensitive tape as seen in Figure 1. The assembled samplers were then placed on the soil surface and forced into the ground to a depth of from 1 to 2 cm to insure good contact. Each unit sampled an area of $4.42 \times 10^{-3} m^2$. Several samplers were exposed simultaneously in each caisson for periods ranging from several hours to about 1 day. After exposure, the samplers were disassembled; and the charcoal canisters were removed, sealed in aluminum cans, and returned to the laboratory for radon analysis by gamma-ray spectrometry.

The tent method was developed at Pacific Northwest Laboratory,[8,9] and sampled a soil-surface area of 0.225 $m^2$. A pressure-balanced flow system recirculated air through an aluminum tent placed on the soil surface. Radon emitted from the soil under the tent was swept to an in-line trap of activated charcoal where it was adsorbed. The system is shown schematically in Figure 2. The U-shaped aluminum collection tent was sealed onto the soil surface, the pressure drop across the collection tent was balanced, and the system was flushed for a time to bring radon concentration within the tent to its steady-state value. Flow was then routed through the charcoal trap, and

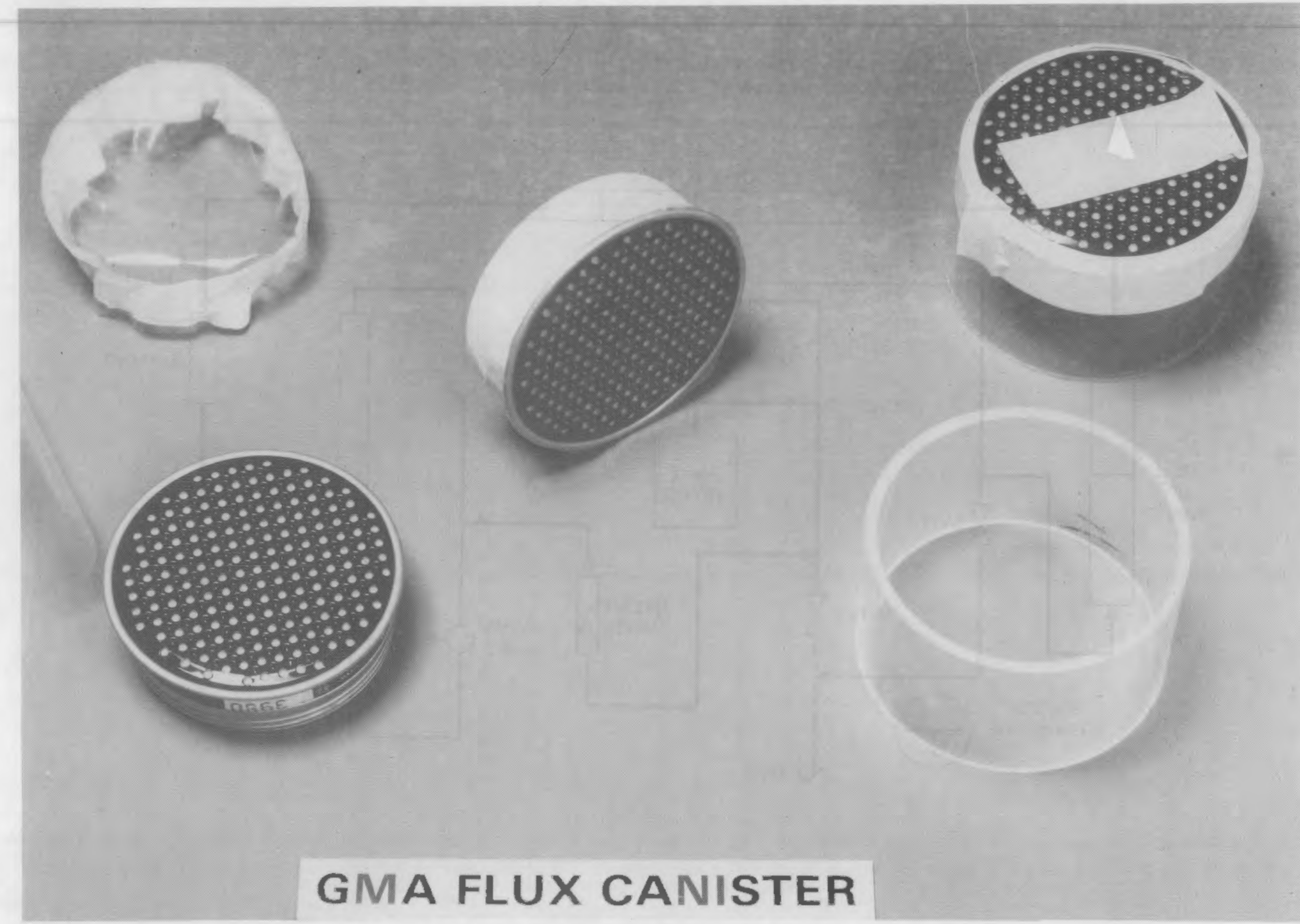


Figure 1. Steps in the Assembly of the GMA Radon Flux Canister

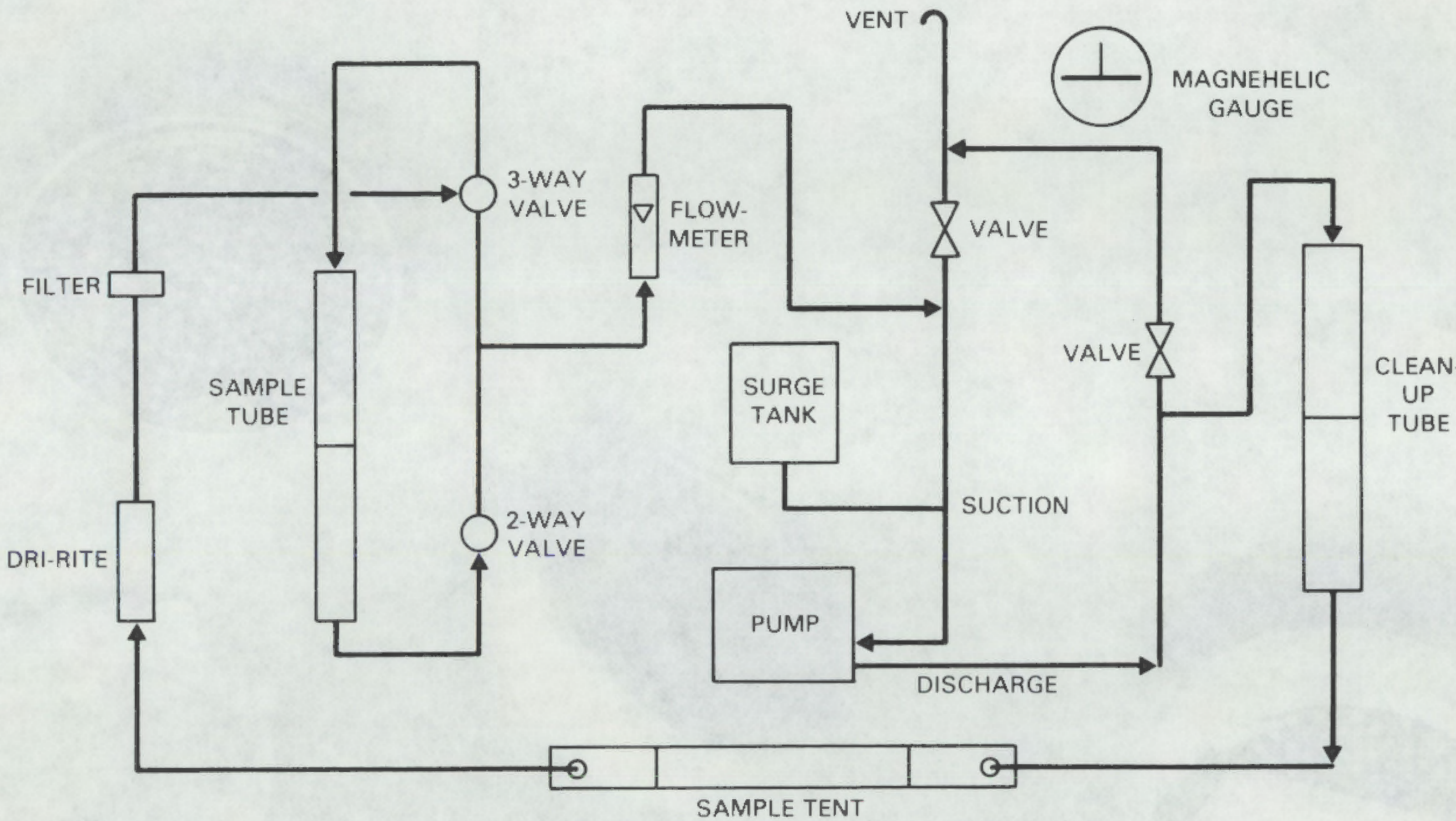


Figure 2. Schematic of Tent System Used to Measure Radon by a Pressure-balanced, Recirculating Pump System

radon was collected for 1/2 to 2 hours. Upon termination of sampling, the charcoal in the radon trap was transferred to a 2.5 x 15.2 cm diameter,plastic petri dish, which was then sealed with pressure-sensitive tape and returned to the laboratory for radon analysis.

The activity of $^{222}Rn$ in each sealed sample of activated charcoal was measured by counting its $^{214}Pb$ and $^{214}Bi$ daughters with which it was in equilibrium. The counting rates were measured with multidimensional gamma-ray spectrometers that used NaI (Tl) detectors.[10] These spectrometers were calibrated with $^{226}Ra$ standards that could be traced to NBS reference material and were contained in identical geometry as the samples to obtain a counter efficiency expressed as counts per disintegration.
Radon fluxes were then calculated by the following equation:

$$J = \frac{C\lambda}{(2.22)\ EA(e^{-\lambda t_2})\ (1-e^{-\lambda t_1})} \qquad \text{(Equation 1)}$$

where: $J$ = radon flux (pCi/$m^2$s)
$C$ = net count rate (cpm)
$\lambda$ = radon decay constant ($s^{-1}$)
$E$ = counter efficiency (counts/disintegration)
$A$ = area sampled ($m^2$)
$t_1$ = sampling period(s)
$t_2$ = time lapse between end of sampling and start of count(s).

Data were averaged for common collection periods from each caisson.

Evaluation of Radon Diffusion Coefficients by the Laboratory Method

Laboratory measurement of the diffusion coefficients for radon in tailings and the two cover soils was conducted with the Radon Attenuation Test Facility (RATF) described previously[2]. The facility employed columns of soil 0.1 m in depth and 1.54 x $10^{-2}m^2$ in area. Each sample was prepared to closely duplicate the moistures and compactions used for the field tests. The prepared soil columns were sealed over a constant source of $^{222}Rn$ and allowed to equilibrate for 3 days to permit radon to attain its steady-state distribution throughout the bottom chambers and soil columns. The gas in the bottom chamber was then sampled and adsorbed onto activated charcoal, which was analysed for radon determination of the $^{214}Bi$ daughter, using gamma-ray spectrometry.

Calculation of diffusion coefficients was accomplished using the following equation:

$$\frac{C_o}{J_o} = \frac{k\ (1-e^{-2kx})}{\lambda\ (1+e^{-2kx})} = \frac{k}{\lambda} \tanh\ (kx) \qquad \text{(Equation 2)}$$

where: $C_o$ = radon concentration in soil at the bottom of the column (pCi/$cm^3$)
$J_o$ = radon flux with no soil in the facility (pCi/$cm^2$s)
$x$ = depth of soil (cm)
$k = (\lambda/D)^{1/2}$

$\lambda$ = $^{222}$Rn decay constant ($s^{-1}$)
D = diffusion coefficient for radon in the total pore space of bulk soil ($cm^2/s$).

The quantity, $C_o$ was evaluated from the radon gas concentration in the bottom chamber, $C_g$, by means of the equation[11]:

$$C_o = (P - 0.74\Theta)C_g \qquad \text{(Equation 3)}$$

where: P = dry porosity of the soil (dimensionless)
$\Theta$ = volume fraction moisture in the soil (dimensionless).

The diffusion coefficient, D, was then evaluated by iteration of Equation (2), using measured values for the other parameters. It is equivalent to the quantity "D/P" used in the equations presented in the Generic Environmental Impact Statement on Uranium Milling[1] prepared by the U.S. Nuclear Regulatory Commission.

Evaluation of Radon Diffusion Coefficients from Field Measurements

Radon diffusion coefficients for cover materials (as applied in the field test) were evaluated from the measured radon fluxes escaping the bare and covered tailings, using the following equation that describes flux attenuation as a function of the porosities of the tailings and cover soils and the diffusion coefficients for radon in these materials.[1].

$$J_c = \frac{2J_o \exp(-k_c x)}{\left[1 + \frac{P_t}{P_c}\left(\frac{D_t}{D_c}\right)^{1/2}\right] + \left[1 - \frac{P_t}{P_c}\left(\frac{D_t}{D_c}\right)^{1/2}\right]\exp(-2k_c x)} \qquad \text{(Equation 4)}$$

where: $J_c$ = radon flux across the cover surface ($pCi/m^2 s$)
$J_o$ = radon flux across the bare tailings surface ($pCi/m^2 s$)
$D_t$ = diffusion coefficient for radon in the total pore space of bulk tailings ($cm^2/s$)
$D_c$ = diffusion coefficient for radon in the total pore space of bulk cover material ($cm^2/s$)
$P_t$ = dry porosity of tailings (dimensionless)
$P_c$ = dry porosity of cover material (dimensionless)
x = cover depth (cm)
$k_c$ = $(\lambda/D_c)^{1/2}$
$\lambda$ = radon decay constant ($s^{-1}$).

The value for $D_t$ could not be evaluated with Radon Attenuation Test Facility since the tailings themselves produced radon, and so did not meet the requirements of the measurement method. However, the diffusion coefficient for tailings was evaluated from other measured values by means of the equation[12]:

$$J_t = R_t E_t \rho_t (\lambda D_t)^{1/2} (10^4) \tanh(x^2 \lambda / D_t)^{1/2} \qquad \text{(Equation 5)}$$

where: $J_t$ = radon flux from the tailings ($pCi/m^2 s$)
$R_t$ = specific activity of $^{226}Ra$ in the tailings (pCi/g)
$E_t$ = radon emanation coefficient of the tailings (dimensionless)
$\rho_t$ = dry packing density of the tailings ($g/cm^3$)
$D_t$ = diffusion coefficient for radon in the tailings ($cm^2/s$)
$\lambda$ = radon decay constant ($s^{-1}$)
x = depth of tailings (cm)

In the field test, x > 300 cm, $D_t < 0.06\ cm^2/s$ and $\lambda = 2.1 \times 10^{-6} s^{-1}$ so that the quantity, tanh $(x^2\lambda/D_t) \approx 1.00$. Hence, Equation 5 reduces to:

$$J_t = R_t E_t \rho_t (\lambda D_t)^{1/2} (10^4) \qquad \text{(Equation 6)}$$

or

$$D_t = \frac{1}{\lambda} \left( \frac{10^{-4} J_t}{R_t E_t \rho_t} \right)^2 \qquad \text{(Equation 7)}$$

The values for $D_t$ were calculated from field measurements of $J_t$ and $\rho_t$, gamma-ray spectrometric measurements of $R_t$ [10], and the value, $E_t$ = 0.28, estimated for uranium mill tailings containing a volume fraction moisture of 0.24 [13].

## RESULTS AND DISCUSSION

### Physical Properties of Tailings and Applied Cover Soils

Properties of the mill tailings and cover soils used in this investigation are listed in Table 1. They show that the two cover soils differed widely in type, moisture and compaction. Since soil-moisture content was only evaluated at the end of the field experiments, the values for weight fraction moisture and volume fraction moisture only apply with certainty at that time.

TABLE 1. Physical Properties of Tailings and Applied Covers

| | Field Samples | | | Laboratory Samples | |
|---|---|---|---|---|---|
| | Sand | Tailings | Clay | Sand | Clay |
| Packing density, $\rho$, ($g/cm^3$) | 1.73 | 1.34 | 1.39 | 1.73 | 1.40 |
| Soil-particle density, d, ($g/cm^3$) | 2.77 | 2.70 | 2.74 | 2.77 | 2.74 |
| Dry porosity, $P = 1 - \rho/d$ | 0.38 | 0.50 | 0.49 | 0.38 | 0.49 |
| Weight fraction moisture, $\omega$ | 0.04 | 0.18 | 0.14 | 0.04 | 0.14 |
| Volume fraction moisture, $\Theta = \rho\omega$ | 0.07 | 0.24 | 0.20 | 0.07 | 0.20 |

## Radon Flux Values from Field Measurements

Radon fluxes measured by the two methods are summarized in Table 2 and presented in detail in Appendices A and B. The values shown in Table 2 for fluxes obtained by the charcoal-canister method are averages of the several values measured simultaneously in each designated caisson. The individual measurements differed by factors of up to 3 during the same sampling period in the same caisson. Still larger variations in flux, ranging up to factors of 35, were found at the same caisson on different days. Radon fluxes measured by the tent method varied by factors of up to 15. This lack of precision was attributed to possible differences in meteorological conditions, changes in soil moisture and variations in the collection efficiencies of the two measurements.

TABLE 2. Radon Fluxes Evaluated by the Charcoal-Canister (C) and the Tent (T) Methods in the Field (All Values in pCi/$m^2$s)

| Date (m/d/y) | Caisson 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | T | C | T | C | T | C | T | C | T | C | T |
| 5/11/81 | 465 | 90 | 435 | 750 | 280 | 350 | 410 | 720 | 200 | -- | 160 | -- |
| 5/12/81 | 320 | 100 | 330 | 280 | 450 | 270 | 360 | 330 | 130 | 200 | 185 | 135 |
| 5/12-5/13/81 | 200 | -- | 390 | -- | 220 | -- | 380 | -- | 110 | -- | 280 | -- |
| 5/13/81 | 270 | 90 | 770 | 700 | 230 | 200 | 330 | 450 | 120 | 310 | 860 | 530 |
| 6/16/81 | 2750 | 790 | 680 | 1660 | 1110 | 160 | 650 | 890 | 840 | 750 | 4300 | 410 |
| 6/16-6/17/81 | 500 | -- | 820 | -- | 410 | -- | 420 | -- | 340 | -- | 240 | -- |
| 6/17/81* | 80 | 60 | 90 | 200 | 350 | 350 | 150 | 380 | 60 | 50 | 60 | 90 |
| 8/5/81 | 160 | 110 | 30 | 20 | 155 | 150 | 270 | 220 | 120 | 110 | 90 | 170 |
| 9/2/81 | 160 | 140 | 65 | 4 | 200 | 120 | 290 | 340 | 135 | 170 | 80 | 100 |
| 9/3/81 | 320 | -- | 60 | -- | 180 | -- | 290 | -- | 110 | -- | 190 | -- |
| 11/9/81 | -- | 280 | 70 | 80 | 30 | 150 | -- | 340 | -- | 310 | -- | 560 |
| 11/9-11/10/81 | 250 | -- | 97 | -- | 43 | -- | 210 | -- | 190 | -- | 500 | -- |
| 11/10/81 | -- | 230 | 270 | 140 | 60 | 150 | 400 | 420 | -- | 490 | -- | 1120 |
| 11/10-11/11/81 | 400 | -- | 230 | -- | 70 | -- | 315 | -- | 450 | -- | 1420 | -- |
| 11/11/81 | 810 | -- | 380 | -- | 110 | -- | 620 | -- | 1240 | -- | 1690 | -- |

* After the measurements on this date, a 114-cm cover of well-graded sand was applied in caisson No. 2 and a 44-cm cover of inorganic clay was applied in caisson No. 3.

The data can be logically divided into two subsets, those measured on or before June 17, 1981 and those measured after that date when the cover of sand was in place in caisson No. 2 and the cover of clay was in place in caisson No. 3. An analysis of variance among the flux measurements made before June 17, 1981 showed no significant difference between caissons or between flux-measurement methods. However, there was a highly significant difference in flux between dates of sampling. Similarly, an analysis of variance among the flux measurements after June 17, 1981 showed no significant difference between the uncovered caissons or between flux-measurement methods, but highly significant differences in flux between dates of sampling and between covered versus uncovered caissons. It was concluded that the diffusion coefficients for radon in the cover soils should be evaluated from Equation 4 using measurements of flux from bare and covered tailings for the same dates.

## Values for Radon Diffusion Coefficients

Since soil moisture is an important factor in determining the diffusion coefficient of radon in a soil, only data taken under conditions of known moisture content were used in the evaluations. This limited the evaluation of diffusion coefficients from field measurements of radon flux to data collected during the period from November 9 to 11, 1981. These data and the computed diffusion coefficients are listed in Table 3.

TABLE 3. Evaluations of Radon Diffusion Coefficients from Field Data

| Date | Average Flux($pCi/m^2s$) | | | Diffusion Coefficients ($cm^2/s$) | | |
|---|---|---|---|---|---|---|
| (m/d/y) | Bare Tailings | Sand Cover | Clay Cover | Bare Tailings | Sand Cover | Clay Cover |
| 11/9/81 | 372 | 75 | 90 | 0.018 | 0.011 | 0.0037 |
| 11/9-11/10/81 | 288 | 97 | 43 | 0.011 | 0.017 | 0.0019 |
| 11/10/81 | 532 | 205 | 105 | 0.038 | 0.028 | 0.0038 |
| 11/10-11/11/81 | 646 | 230 | 70 | 0.056 | 0.029 | 0.0024 |
| 11/11/81 | 1090 | 380 | 110 | 0.158 | 0.040 | 0.0034 |

The values for the radon fluxes from bare tailings are the averages of all flux measurements in the four uncovered caissons, on the specified date. The diffusion coefficients for radon in bare tailings were calculated from Equation 7, the data shown in Tables 1 and 3 and the measured specific activity, $R_t$ = 504 pCi/g, for radium in the tailings. The diffusion coefficient in tailings measured for November 11, 1981 is clearly too high as it exceeds the coefficient in air, 0.11 $cm^2/s$[14] Nevertheless, it was used to evaluate the diffusion coefficients of radon in the cover soils on that date since all flux values were observed to be high at that time. Available meteorological data at the test site during this time period are shown in Table 4. They did not

TABLE 4. Meteorological Parameters at the Test Site From November 9 to 11, 1981

| Date | Air Temperature | | Air Pressure | Precipitation | Max. Wind Velocity |
|---|---|---|---|---|---|
| (m/d/y) | Max. °C | Min. °C | (mm mercury) | (mm.) | (km/hr, direction) |
| 11/9/81 | 9 | -8 | 772.7 | 0.6 | 0, ESE |
| 11/10/81 | 4 | -3 | 771.4 | 0.2 | 4, N |
| 11/11/81 | 3 | -3 | 768.2 | 0.4 | 2, WNW |

suggest reasons for the variations in radon flux but may overlook short-term changes in air-temperature, atmospheric pressure or wind velocity during a day.

The diffusion coefficients evaluated from field data and those measured in the laboratory are compared in Table 5.

TABLE 5. Comparison of Field-Measured Radon Diffusion Coefficients with Laboratory-Measured Coefficients (95% Confidence Limits)

| Method | D (Sand Cover) | D (Clay Cover) |
|---|---|---|
| Laboratory | 0.021 ± 0.002 | 0.0036 ± 0.0004 |
| Field | 0.03 ± 0.03 | 0.003 ± 0.002 |

The values are presented as 95% confidence limits based on the data shown in Table 3, and on a relative standard deviation of ±5% for the laboratory method[10]. The best estimates of the diffusion coefficients evaluated by the two methods agreed to within a factor of two for both soil covers. This may be fortuitous, however, in view of the large 95% confidence intervals for the coefficients evaluated from field data. In any case, the diffusion coefficients evaluated by the two methods for each soil are indistinguishable at the 95% confidence level.

The low precision in the diffusion coefficients evaluated from field data were attributed to high variation in the radon flux with time and surface location at the field site. These variations occurred over relatively short time intervals and with only small differences in surface location of the radon collectors. Their exact cause is unknown, but variations of similar magnitude have been reported by other investigators for other tailings sites[5,15]. The higher precision of the laboratory-measured coefficients is attributed to the ability to better control influential parameters such as soil-moisture content and compaction as well as being relatively free from changes in meteorological conditions.

## CONCLUSIONS

Laboratory-measured diffusion coefficients for radon in relatively small quantities of two widely different types of soils were indistinguishable, at the 95% confidence level, from coefficients evaluated from field measurements on much larger quantities of the same soils covering uranium mill tailings. The best estimates for coefficients obtained by the two methods agreed within a factor of two; however, the 95% confidence intervals for the field-determined values were too broad to provide a sensitive check on the validity of the laboratory-measured values. The low precision of the field-determined values was attributed to high variation in radon flux with time and surface location at the field site.

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# APPENDIX A

Data Obtained With GMA Radon Flux Canisters

Area sampled was $4.42 \times 10^{-3} m^2$

## GMA Radon Flux Canisters

### Caisson 1

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* / Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 5/11/81 | 1309 | 5/11/81 | 1810 | 301 | 5/14/81 | 1348 | 45320±500 | 260 |
| 1B | 5/11/81 | 1309 | 5/11/81 | 1810 | 301 | 5/14/81 | 1348 | 115610±1200 | 670 |
| 1C | 5/12/81 | 0728 | 5/12/81 | 1248 | 320 | 5/14/81 | 1410 | 74841±830 | 400 |
| 1D | 5/12/81 | 1248 | 5/12/81 | 1800 | 312 | 5/14/81 | 1423 | 42726±435 | 240 |
| 1E | 5/12/81 | 1802 | 5/13/81 | 0747 | 825 | 5/14/81 | 1457 | 92810±1200 | 200 |
| 1F | 5/13/81 | 0747 | 5/13/81 | 1418 | 391 | 5/14/81 | 1445 | 61162±710 | 270 |
| 1A | 6/16/81 | 1117 | 6/16/81 | 1710 | 353 | 6/18/81 | 1521 | 558000±4400 | 2750 |
| 1B | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1536 | 240700±2100 | 500 |
| 1C | 6/17/81 | 0735 | 6/17/81 | 1542 | 487 | 6/18/81 | 1549 | 22460±250 | 80 |
| 1A | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1443 | 37100±160 | 160 |
| 1A | 9/2/81 | 0756 | 9/3/81 | 0822 | 1466 | 9/4/81 | 1136 | 125560±1420 | 160 |
| 1B | 9/3/81 | 0823 | 9/3/81 | 1140 | 197 | 9/4/81 | 1048 | 35782±600 | 320 |
| 1A | 11/9/81 | 0906 | 11/10/81 | 1251 | 1665 | 11/14/81 | 0657 | 220317±1260 | 250 |
| 1B | 11/10/81 | 1252 | 11/11/81 | 1014 | 1282 | 11/14/81 | 1511 | 275870±2220 | 400 |
| 1C | 11/11/81 | 1014 | 11/11/81 | 1427 | 253 | 11/14/81 | 1513 | 118490±940 | 810 |

* Decay corrected to end of sampling.

GMA Radon Flux Canisters

Caisson 2

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 2A | 5/11/81 | 1310 | 5/11/81 | 1810 | 300 | 5/14/81 | 1348 | 65690±690 | 380 |
| 2B | 5/11/81 | 1310 | 5/11/81 | 1810 | 300 | 5/14/81 | 1354 | 84198±1030 | 490 |
| 2C | 5/12/81 | 0728 | 5/12/81 | 1250 | 322 | 5/14/81 | 1411 | 61233±710 | 330 |
| 2D | 5/12/81 | 1250 | 5/12/81 | 1800 | 310 | 5/14/81 | 1430 | 59314±780 | 330 |
| 2E | 5/12/81 | 1802 | 5/13/81 | 0747 | 825 | 5/14/81 | 1459 | 178500±1900 | 390 |
| 2F | 5/13/81 | 0747 | 5/13/81 | 1418 | 391 | 5/14/81 | 1447 | 172070±1660 | 770 |
| 2A | 6/16/81 | 1118 | 6/16/81 | 1710 | 352 | 6/18/81 | 1524 | 137500±1300 | 680 |
| 2B | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1538 | 398100±3100 | 820 |
| 2C | 6/17/81 | 0735 | 6/17/81 | 0932 | 117 | 6/18/81 | 1551 | 6433±120 | 90 |
| 2A | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1436 | 6390±40 | 30 |
| 2A | 9/2/81 | 0754 | 9/2/81 | 2035 | 761 | 9/4/81 | 1034 | 2598±68 | 6 |
| 2B | 9/2/81 | 0754 | 9/2/81 | 2035 | 761 | 9/4/81 | 1053 | 2802±69 | 7 |
| 2C | 9/3/81 | 0749 | 9/3/81 | 1122 | 213 | 9/4/81 | 1034 | 7892±169 | 60 |
| 2A | 11/9/81 | 0910 | 11/9/81 | 1655 | 465 | 11/14/81 | 0707 | 17220±230 | 70 |
| 2B | 11/9/81 | 0910 | 11/10/81 | 1235 | 1645 | 11/14/81 | 0700 | 84070±770 | 90 |
| 2C | 11/9/81 | 0910 | 11/10/81 | 1235 | 1645 | 11/14/81 | 0700 | 90460±730 | 100 |
| 2D | 11/9/81 | 1655 | 11/10/81 | 1235 | 1180 | 11/14/81 | 0708 | 67212±798 | 100 |
| 2E | 11/10/81 | 1236 | 11/10/81 | 1714 | 278 | 11/14/81 | 0710 | 42617±610 | 270 |
| 2F | 11/10/81 | 1236 | 11/11/81 | 1017 | 1301 | 11/14/81 | 1514 | 170240±1080 | 240 |
| 2G | 11/10/81 | 1236 | 11/11/81 | 1017 | 1301 | 11/14/81 | 0716 | 127380±1310 | 180 |
| 2H | 11/10/81 | 1713 | 11/11/81 | 1017 | 1024 | 11/14/81 | 0717 | 151690±1310 | 270 |
| 2I | 11/11/81 | 1017 | 11/11/81 | 1424 | 247 | 11/14/81 | 0721 | 50510±410 | 350 |
| 2J | 11/11/81 | 1017 | 11/11/81 | 1424 | 247 | 11/14/81 | 0723 | 52540±410 | 370 |
| 2K | 11/11/81 | 1017 | 11/11/81 | 1424 | 247 | 11/14/81 | 0725 | 59797±590 | 420 |

* Decay corrected to end of sampling.

GMA Radon Flux Canisters

Caisson 3

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Exposure $\Delta t$ (min.) | Counted Date | Counted Time | (dpm)* / Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 3A | 5/11/81 | 1520 | 5/11/81 | 1826 | 186 | 5/14/81 | 1356 | 30196±350 | 280 |
| 3B | 5/12/81 | 0730 | 5/12/81 | 1252 | 202 | 5/14/81 | 1416 | 59760±780 | 510 |
| 3C | 5/12/81 | 1252 | 5/12/81 | 1804 | 312 | 5/14/81 | 1432 | 69640±780 | 390 |
| 3D | 5/12/81 | 1805 | 5/13/81 | 0745 | 820 | 5/14/81 | 1500 | 98600±600 | 220 |
| 3E | 5/13/81 | 0745 | 5/13/81 | 1417 | 392 | 5/14/81 | 1449 | 51650±620 | 230 |
| 3A | 6/16/81 | 1117 | 6/16/81 | 1710 | 353 | 6/18/81 | 1529 | 226200±2200 | 1110 |
| 3B | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1540 | 199100±2000 | 410 |
| 3C | 6/17/81 | 0735 | 6/17/81 | 1145 | 250 | 6/18/81 | 1555 | 50720±500 | 350 |
| 3A | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1448 | 31380±150 | 140 |
| 3B | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1454 | 40143±165 | 170 |
| 3A | 9/2/81 | 0803 | 9/2/81 | 2035 | 752 | 9/4/81 | 1119 | 80830±870 | 190 |
| 3B | 9/2/81 | 0803 | 9/2/81 | 2035 | 752 | 9/4/81 | 1115 | 88401±1220 | 210 |
| 3C | 9/3/81 | 0820 | 9/3/81 | 1122 | 182 | 9/4/81 | 1140 | 19256±290 | 180 |
| 3A | 11/9/81 | 0912 | 11/9/81 | 1655 | 973 | 11/13/81 | 1325 | 15937±227 | 30 |
| 3B | 11/9/81 | 0912 | 11/10/81 | 1242 | 1650 | 11/13/81 | 1325 | 48698±465 | 50 |
| 3C | 11/9/81 | 0912 | 11/10/81 | 1242 | 1650 | 11/13/81 | 1325 | 63099±690 | 70 |
| 3D | 11/9/81 | 1655 | 11/10/81 | 1242 | 1187 | 11/13/81 | 1336 | 8043±64 | 10 |
| 3E | 11/10/81 | 1241 | 11/10/81 | 1715 | 274 | 11/14/81 | 1521 | 10007±188 | 60 |
| 3F | 11/10/81 | 1241 | 11/11/81 | 1020 | 1299 | 11/14/81 | 1515 | 12644±200 | 20 |
| 3G | 11/10/81 | 1241 | 11/11/81 | 1020 | 1299 | 11/13/81 | 1339 | 43899±152 | 60 |
| 3H | 11/10/81 | 1712 | 11/11/81 | 1020 | 1028 | 11/13/81 | 1341 | 70661±190 | 130 |
| 3I | 11/11/81 | 1022 | 11/11/81 | 1424 | 242 | 11/13/81 | 1501 | 2789±26 | 20 |
| 3J | 11/11/81 | 1022 | 11/11/81 | 1424 | 242 | 11/13/81 | 1504 | 10163±48 | 70 |
| 3K | 11/11/81 | 1022 | 11/11/81 | 1424 | 242 | 11/13/81 | 1505 | 33384±84 | 240 |

* Decay corrected to end of sampling.

## GMA Radon Flux Canisters

### Caisson 4

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | $\Delta t$ (min.) | Counted Date | Counted Time | (dpm)* Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 4A | 5/11/81 | 1523 | 5/11/81 | 1827 | 184 | 5/14/81 | 1358 | 43710±445 | 410 |
| 4B | 5/12/81 | 0730 | 5/12/81 | 1252 | 202 | 5/14/81 | 1417 | 39634±610 | 340 |
| 4C | 5/12/81 | 1252 | 5/12/81 | 1804 | 312 | 5/14/81 | 1433 | 67874±730 | 380 |
| 4D | 5/12/81 | 1805 | 5/13/81 | 0745 | 820 | 5/14/81 | 1436 | 173000±2000 | 380 |
| 4E | 5/13/81 | 0745 | 5/13/81 | 1417 | 392 | 5/14/81 | 1451 | 73878±770 | 330 |
| 4A | 6/16/81 | 1118 | 6/16/81 | 1710 | 352 | 6/18/81 | 1530 | 132200±1340 | 650 |
| 4B | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1541 | 204100±2000 | 420 |
| 4C | 6/17/81 | 0735 | 6/17/81 | 1542 | 487 | 6/18/81 | 1603 | 41070±400 | 150 |
| 4A | 8/5/81 | D827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1438 | 62814±260 | 270 |
| 4A | 9/2/81 | 0801 | 9/3/81 | 0818 | 1457 | 9/4/81 | 1121 | 226751±2470 | 290 |
| 4B | 9/3/81 | 0818 | 9/3/81 | 1122 | 184 | 9/4/81 | 1128 | 31526±360 | 290 |
| 4A | 11/9/81 | 0906 | 11/10/81 | 1248 | 1662 | 11/14/81 | 1458 | 184798±1330 | 210 |
| 4B | 11/10/81 | 1249 | 11/10/81 | 1714 | 265 | 11/14/81 | 1458 | 61200±651 | 400 |
| 4C | 11/10/81 | 1249 | 11/11/81 | 1027 | 1298 | 11/14/81 | 1458 | 222518±1820 | 320 |
| 4D | 11/10/81 | 1713 | 11/11/81 | 1027 | 1024 | 11/14/81 | 1504 | 175404±1193 | 310 |
| 4E | 11/11/81 | 1028 | 11/11/81 | 1426 | 238 | 11/11/81 | 1505 | 71675±777 | 520 |
| 4F | 11/11/81 | 1028 | 11/11/81 | 1426 | 238 | 11/11/81 | 1507 | 98995±905 | 720 |

* Decay corrected to end of sampling.

GMA Radon Flux Canisters

Caisson 5

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* / Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 5A | 5/11/81 | 1528 | 5/11/81 | 1830 | 182 | 5/14/81 | 1359 | 21080±300 | 200 |
| 5B | 5/12/81 | 0848 | 5/12/81 | 1253 | 245 | 5/14/81 | 1419 | 15095±240 | 110 |
| 5C | 5/12/81 | 1254 | 5/12/81 | 1806 | 312 | 5/14/81 | 1438 | 27460±470 | 150 |
| 5D | 5/12/81 | 1807 | 5/13/81 | 0747 | 813 | 5/14/81 | 1502 | 51097±430 | 110 |
| 5E | 5/13/81 | 0743 | 5/13/81 | 1416 | 393 | 5/14/81 | 1453 | 48819±350 | 220 |
| 5A | 6/16/81 | 1117 | 6/16/81 | 1710 | 353 | 6/18/81 | 1532 | 170300±1600 | 840 |
| 58 | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1543 | 163900±1200 | 340 |
| 5C | 6/17/81 | 0735 | 6/17/81 | 1542 | 487 | 6/18/81 | 1604 | 18090±260 | 60 |
| 5A | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1429 | 28017±120 | 120 |
| 5A | 9/2/81 | 0751 | 9/3/81 | 0814 | 1463 | 9/4/81 | 1045 | 101192±1240 | 130 |
| 5B | 9/2/81 | 0751 | 9/3/81 | 0814 | 1463 | 9/4/81 | 1048 | 105670±1343 | 140 |
| 5C | 9/3/81 | 0815 | 9/3/81 | 1122 | 187 | 9/4/81 | 1123 | 11511±170 | 110 |
| 5A | 11/9/81 | 0906 | 11/10/81 | 1247 | 1661 | 11/14/81 | 1523 | 171864±2080 | 190 |
| 5B | 11/10/81 | 1247 | 11/11/81 | 1030 | 1303 | 11/14/81 | 1527 | 320419±1013 | 450 |
| 5C | 11/11/81 | 1030 | 11/11/81 | 1426 | 236 | 11/14/81 | 1530 | 169771±2272 | 1240 |

* Decay corrected to end of sampling.

## GMA Radon Flux Canisters

### Caisson 6

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Exposure $\Delta t$ (min.) | Counted Date | Counted Time | (dpm)* Sample | J $\frac{(pCi)}{(m^2\ sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| 6A | 5/11/81 | 1530 | 5/11/81 | 1830 | 180 | 5/14/81 | 1408 | 16350±270 | 160 |
| 6B | 5/12/81 | 0848 | 5/12/81 | 1253 | 245 | 5/14/81 | 1421 | 17830±285 | 130 |
| 6C | 5/12/81 | 1254 | 5/12/81 | 1806 | 312 | 5/14/81 | 1439 | 43073±440 | 240 |
| 6D | 5/12/81 | 1807 | 5/13/81 | 0743 | 816 | 5/14/81 | 1441 | 127500±1000 | 280 |
| 6E | 5/13/81 | 0743 | 5/13/81 | 1416 | 393 | 5/14/81 | 1455 | 192584±1970 | 860 |
| 6A | 6/16/81 | 1118 | 6/16/81 | 1710 | 352 | 6/18/81 | 1535 | 866000±5500 | 4300 |
| 6B | 6/16/81 | 1710 | 6/17/81 | 0735 | 865 | 6/18/81 | 1545 | 118100±950 | 240 |
| 6C | 6/17/81 | 0735 | 6/17/81 | 1542 | 487 | 6/18/81 | 1606 | 17260±220 | 60 |
| 6A | 8/5/81 | 0827 | 8/5/81 | 1515 | 408 | 8/6/81 | 1431 | 21827±100 | 90 |
| 6A | 9/2/81 | 0818 | 9/3/81 | 0813 | 1445 | 9/4/81 | 1115 | 62569±729 | 80 |
| 6B | 9/3/81 | 0814 | 9/3/81 | 1122 | 188 | 9/4/81 | 6.3 | 21093±325 | 190 |
| 6A | 11/9/81 | 0906 | 11/10/81 | 1246 | 1660 | 11/14/81 | 1532 | 439941±4592 | 500 |
| 6B | 11/10/81 | 1245 | 11/11/81 | 1031 | 1306 | 11/14/81 | 1533 | 1009065±6889 | 1420 |
| 6C | 11/11/81 | 1031 | 11/11/81 | 1426 | 235 | 11/14/81 | 1534 | 230393±2427 | 1690 |

* Decay corrected to end of sampling.

# APPENDIX B

## Data Obtained With Radon Collection Tents

Area sampled was 0.225 $m^2$

## Radon Tent Samplers

### Caisson 1

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Exposure $\Delta t$ (min.) | Counted Date | Counted Time | $\frac{(dpm)^*}{Sample}$ | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| C1-1 | 5/11/81 | 1305 | 5/11/81 | 1505 | 120 | 5/14/81 | 1544 | 369900±2800 | 90 |
| C1-2 | 5/12/81 | 1031 | 5/12/81 | 1231 | 120 | 5/14/81 | 1558 | 418300±3400 | 100 |
| C1-3 | 5/13/81 | 1230 | 5/13/81 | 1400 | 90 | 5/14/81 | 1615 | 293100±2400 | 90 |
| C1-1 | 6/16/81 | 1126 | 6/16/81 | 1226 | 60 | 6/18/81 | 1422 | 1610000±7300 | 790 |
| C1-2 | 6/17/81 | 0902 | 6/17/81 | 1002 | 60 | 6/18/81 | 1453 | 123200±1410 | 60 |
| C1-1 | 8/5/81 | 1147 | 8/5/81 | 1247 | 60 | 8/6/81 | 1417 | 227430±500 | 110 |
| C1-1 | 9/2/81 | 1528 | 9/2/81 | 1628 | 60 | 9/4/81 | 1147 | 283370±2580 | 140 |
| C1-1 | 11/9/81 | 1421 | 11/9/81 | 1533 | 72 | 11/16/81 | 1230 | 675150±3260 | 280 |
| C1-2 | 11/10/81 | 1828 | 11/10/81 | 1935 | 67 | 11/16/81 | 1239 | 517180±4020 | 230 |

* Decay corrected to end of sampling.

Radon Tent Samplers

Caisson 2

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* Sample | J (pCi)/(m² · sec) |
|---|---|---|---|---|---|---|---|---|---|
| C2-1 | 5/11/81 | 1305 | 5/11/81 | 1505 | 120 | 5/14/81 | 1546 | 3018000±13000 | 750 |
| C2-2 | 5/12/81 | 1031 | 5/12/81 | 1231 | 120 | 5/14/81 | 1600 | 1135000±6800 | 280 |
| C2-3 | 5/13/81 | 1230 | 5/13/81 | 1400 | 90 | 5/14/81 | 1617 | 2111000±12000 | 700 |
| C2-1 | 6/16/81 | 1126 | 6/16/81 | 1226 | 60 | 6/18/81 | 1428 | 3370000±16000 | 1660 |
| C2-2 | 6/17/81 | 0831 | 6/17/81 | 0902 | 31 | 6/18/81 | 1457 | 205800±2090 | 200 |
| C2-1 | 8/5/81 | 0947 | 8/5/81 | 1047 | 60 | 8/6/81 | 1419 | 42581±140 | 20 |
| C2-1 | 9/2/81 | 0936 | 9/2/81 | 1041 | 65 | 9/4/81 | 1153 | 6977±180 | 4 |
| C2-1 | 11/9/81 | 1125 | 11/9/81 | 1251 | 86 | 11/16/81 | 1232 | 223490±1920 | 80 |
| C2-2 | 11/10/81 | 1828 | 11/10/81 | 1935 | 67 | 11/16/81 | 1240 | 316650±2870 | 140 |

* Decay corrected to end of sampling.

## Radon Tent Samplers

### Caisson 3

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* / Sample | J $\frac{(pCi)}{(m^2 \cdot sec)}$ |
|---|---|---|---|---|---|---|---|---|---|
| C3-1 | 5/11/81 | 1807 | 5/11/81 | 2007 | 120 | 5/14/81 | 1548 | 1397000±7600 | 350 |
| C3-2 | 5/12/81 | 1330 | 5/12/81 | 1530 | 120 | 5/14/81 | 1601 | 1077000±5900 | 270 |
| C3-3 | 5/13/81 | 1025 | 5/13/81 | 1155 | 90 | 5/14/81 | 1611 | 598300±3800 | 200 |
| C3-1 | 6/16/81 | 1330 | 6/16/81 | 1430 | 60 | 6/18/81 | 1433 | 332400±3160 | 160 |
| C3-2 | 6/17/81 | 1044 | 6/17/81 | 1144 | 60 | 6/18/81 | 1506 | 711500±3750 | 350 |
| C3-1 | 8/5/81 | 0947 | 8/5/81 | 1048 | 61 | 8/6/81 | 1245 | 318640±650 | 150 |
| C3-1 | 9/2/81 | 0936 | 9/2/81 | 1041 | 65 | 9/4/81 | 1158 | 258200±3820 | 120 |
| C3-1 | 11/9/81 | 1125 | 11/9/81 | 1251 | 86 | 11/16/81 | 1234 | 442721±2870 | 150 |
| C3-2 | 11/10/81 | 1639 | 11/10/81 | 1739 | 60 | 11/16/81 | 1243 | 313340±3000 | 150 |

* Decay corrected to end of sampling.

## Radon Tent Samplers

## Caisson 4

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Δt (min.) | Counted Date | Counted Time | (dpm)* / Sample | J (pCi) / ($m^2 \cdot sec$) |
|---|---|---|---|---|---|---|---|---|---|
| C4-1 | 5/11/81 | 1807 | 5/11/81 | 2007 | 120 | 5/14/81 | 1550 | 2911000±13000 | 720 |
| C4-2 | 5/12/81 | 1330 | 5/12/81 | 1530 | 120 | 5/14/81 | 1603 | 1320000±7200 | 330 |
| C4-3 | 5/13/81 | 1025 | 5/13/81 | 1155 | 90 | 5/14/81 | 1613 | 1381000±7600 | 450 |
| C4-1 | 6/16/81 | 1330 | 6/16/81 | 1430 | 60 | 6/18/81 | 1441 | 1798000±9100 | 890 |
| C4-2 | 6/17/81 | 1103 | 6/17/81 | 1144 | 41 | 6/18/81 | 1510 | 777700±4500 | 380 |
| C4-1 | 8/5/81 | 1147 | 8/5/81 | 1247 | 60 | 8/6/81 | 1422 | 448400±980 | 220 |
| C4-1 | 9/2/81 | 1528 | 9/2/81 | 1628 | 60 | 9/4/81 | 1200 | 695340±4680 | 340 |
| C4-1 | 11/9/81 | 1421 | 11/9/81 | 1533 | 72 | 11/16/81 | 1251 | 827570±5250 | 340 |
| C4-2 | 11/10/81 | 1639 | 11/10/81 | 1739 | 60 | 11/16/81 | 1245 | 853770±8370 | 420 |

* Decay corrected to end of sampling.

Radon Tent Samplers

Caisson 5

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | Exposure Δt (min.) | Counted Date | Counted Time | (dpm)* / Sample | J (pCi) / ($m^2 \cdot sec$) |
|---|---|---|---|---|---|---|---|---|---|
| C5-1 | 5/12/81 | 0736 | 5/12/81 | 939 | 123 | 5/14/81 | 1553 | 667300±3800 | 170 |
| C5-2 | 5/12/81 | 1615 | 5/12/81 | 1815 | 120 | 5/14/81 | 1605 | 944400±5200 | 230 |
| C5-3 | 5/13/81 | 0820 | 5/13/81 | 0950 | 90 | 5/14/81 | 1608 | 943000±5300 | 310 |
| C5-1 | 6/16/81 | 1523 | 6/16/81 | 1623 | 60 | 6/18/81 | 1443 | 1526400±7600 | 750 |
| C5-2 | 6/17/81 | 1245 | 6/17/81 | 1346 | 61 | 6/18/81 | 1512 | 102100±1240 | 50 |
| C5-1 | 8/5/81 | 1337 | 8/5/81 | 1437 | 60 | 8/6/81 | 1425 | 220840±580 | 110 |
| C5-1 | 9/2/81 | 1738 | 9/2/81 | 1854 | 76 | 9/4/81 | 1202 | 422560±3440 | 170 |
| C5-1 | 11/9/81 | 1619 | 11/9/81 | 1726 | 67 | 11/16/81 | 1254 | 692500±3380 | 310 |
| C5-2 | 11/10/81 | 1445 | 11/10/81 | 1545 | 60 | 11/16/81 | 1247 | 985740±7390 | 490 |

* Decay corrected to end of sampling.

## Radon Tent Samplers

## Caisson 6

| Sample | Exposure On Date | Exposure On Time | Exposure Off Date | Exposure Off Time | $\Delta t$ (min.) | Counted Date | Counted Time | (dpm)* Sample | J (pCi)/($m^2 \cdot sec$) |
|---|---|---|---|---|---|---|---|---|---|
| C6-1 | 5/12/81 | 0736 | 5/12/81 | 0939 | 123 | 5/14/81 | 1553 | 203100±1900 | 50 |
| C6-2 | 5/12/81 | 1615 | 5/12/81 | 1815 | 120 | 5/14/81 | 1607 | 886500±5800 | 220 |
| C6-3 | 5/13/81 | 0820 | 5/13/81 | 0950 | 90 | 5/14/81 | 1610 | 1595000±10000 | 530 |
| C6-1 | 6/16/81 | 1523 | 6/16/81 | 1623 | 60 | 6/18/81 | 1449 | 837400±5400 | 410 |
| C6-2 | 6/17/81 | 1235 | 6/17/81 | 1335 | 60 | 6/18/81 | 1516 | 170500±2000 | 90 |
| C6-1 | 8/5/81 | 1337 | 8/5/81 | 1438 | 61 | 8/6/81 | 1427 | 347710±660 | 170 |
| C6-1 | 9/2/81 | 1738 | 9/2/81 | 1854 | 76 | 9/4/81 | 1204 | 258460±2040 | 100 |
| C6-1' | 11/9/81 | 1619 | 11/9/81 | 1726 | 67 | 11/16/81 | 1256 | 1259980±5310 | 560 |
| C6-2 | 11/10/81 | 1445 | 11/10/81 | 1545 | 60 | 11/16/81 | 1249 | 2259010±12750 | 1120 |

* Decay corrected to end of sampling.

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16. ABSTRACT (200 words or less)

Experiments were conducted to compare radon diffusion coefficients determined for 0.1-m depths of soils by a steady-state method in the laboratory and diffusion coefficients evaluated from radon fluxes through several-fold greater depths of the same soils covering uranium-mill tailings. Two soils were tested: a well-graded sand and an inorganic clay of low plasticity. For the flux evaluations, radon was collected by adsorption on charcoal following passive diffusion from the soil surface and also from air recirculating through an aluminum tent over the soil surface. Radon diffusion coefficients evaluated from field data were statistically indistinguishable, at the 95% confidence level, from those measured in the laboratory; however, the low precision of the field data prevented a sensitive validation of the laboratory measurements. From the field data, the coefficients were calculated to be 0.03 ± 0.03 $cm^2/s$ for the sand cover and 0.003 ± 0.002 $cm^2/s$ for the clay cover. From the laboratory data, the coefficients were calculated to be 0.021 ± 0.002 $cm^2/s$ for the sand cover and 0.0036 ± 0.0004 $cm^2/s$ for the clay cover. The low precision in the coefficients evaluated from field data was attributed to high variation in radon flux with time and surface location in the field site.

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