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ELECTRET ION CHAMBERS (EIC) TO MEASURE RADON EXHALATION RATES FROM BUILDING MATERIALS

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ABSTRACT

Electret ion chambers (EIC) have been used for measuring radon in water. This method uses a four liter jar with rubber seals as radon leak tight accumulator. In view of increased interest in measuring radon exhalation rates from building materials, the method is now extended for this purpose. Required equations are derived to compute the exhalation rates for granite samples. As an illustration, a set of granite slabs are characterized by using different accumulation times. Fluxes measured on typical commercially available granites range from 20 to 30 Bq m^{-2} d^{-1}. These are similar to the published results for granite samples. This is an additional useful application for users of EIC.

INTRODUCTION

Four liter jars with rubber seals have been used as radon leak tight accumulators. These have been successfully used for measuring radon in water and also for characterizing NIST (National Institute of Standards and Technology) emanation standards. In view of increased interest in measuring radon exhalation rates from building materials, the method is now adapted for this purpose. Required equations are derived to compute the exhalation rates by measuring average radon concentration for a given accumulation period. As an illustration, a set of granite slabs are characterized by using different accumulation times.

(1) The authors are developers of, and have a commercial interest in the electret ion chamber featured in this paper.

MATERIALS AND METHODS

An accumulator is simply a container of known volume that can be sealed radon leak tight. The sample and the detectors are enclosed inside the container that serves as an accumulator. Integrating radon detectors such as EIC (electret ion chamber) are used for measuring integrated averages over the accumulation time. See Figure-1.

Typical accumulator successfully used for several applications is simply a glass jar with a nominal volume of 4 liters, with a sealable rubber collar (Kotrappa, 1993; Kotrappa, 1994).

Radon concentration (Aldenkamp, 1992) at any time T is given by a well known equation (1):

$$C(Rn) = \frac{(FxA)}{Vx0.1814}(1 - e^{-0.1814T}) \qquad \text{Equation (1)}$$

When $C(Rn)$ in equation (1) is integrated and divided by the total time, it leads to time averaged radon concentration (Kotrappa, 1994) after accumulation time of *T* days. This leads to equation (2)

$$C(Rn)Av = \frac{(F \times A\ )}{V \times 0.1814}\left[1 - \left(\frac{1 - e^{-0.1814T}}{0.1814T}\right)\right] \qquad \text{Equation (2)}$$

F is the radon flux in Bq m^{-2} d^{-1}
A is the area in m^2
(F x A) is the exhalation rate in Bq d^{-1}
0.1814 is the decay constant of radon in d^{-1}
C(Rn) is the radon concentration at any accumulation time of T (days) in Bq m^{-3}
C(Rn) Av is the integrated average radon concentration in Bq m^{-3}
T is the accumulation time in days
V is the air volume of the accumulator in m^3

If we call K as the constant inside the bigger bracket in equation (2), equation (2) can be rewritten as equation (3) and equation (4).

Note K depends only on time of exposure in day units. For those who do not have access to spread sheet, a table can be built to provide K values for different T values. Such table in conjunction with equation (4) is used for hand computation.

$$C(Rn)Av = \frac{(F \times A\ )}{V \times 0.1814} \times K \qquad \text{Equation (3)}$$

$$(F\ x\ A) = C(Rn)Av\ \ x\ V\ x\ 0.1814\ /\ K \qquad \text{Equation (4)}$$

All parameters on right hand side of equation (4) are either measurable or computable. Exhalation rate *(FxA)* is calculated using equation (4). Further dividing exhalation rate by the area of the sample leads to the flux.

Table-1 gives average radon concentration for different accumulation times for exhalation rate (*F x A)* of 1 Bq d^{-1}. Figure 2 gives a graphical representation of the build up of time averaged concentration for stated accumulation time.

PROTOCOLS

Accumulator and sample size

This protocol describes the method of using sealable jars and EIC radon monitors for measuring radon emanation rates from granite slabs. Sample size of 7.8 cm long, 8.9 cm wide and 3.1 cm thick, or of any other suitable sizes are usable in this method.

Sealable glass jars have been used successfully used for measuring radon in water (Kotrappa, 1993) and in using NIST (National Institute of Standards and Technology) sources (Kotrappa, 1994) for calibrating passive detectors. These are of nominal volume of 4 L, with arrangement to seal and suspend an electret ion chamber. Sample is introduced inside the jar, held by small adhesive pivots at the bottom of the jar. Figure 2 gives a sketch of the arrangement.

Air Volume of the accumulator

One of the parameter needed is the air volume inside the jar. This is obtained by subtracting air volume occupied by the sample and the detector from the volume of the jar. Precisely measured air volume of the jar with one EIC is 3.843 L 9Kotrappa, 1994). The volume of the sample is 0.215 L. Therefore, the net air volume is 3.628L.

Time averaged radon concentration

Most suitable EIC is the SST E-PERM® (Kotrappa, 1990). Stick two small adhesive clay (3 mm thick) pieces at the bottom of the sample. This keeps the sample above the bottom of the jar, allowing radon to escape from the bottom part of the sample. Position the sample at the bottom of the jar, suspend a pre-measured EIC, and close the jar and tighten the seal. The measurement has started. At the end of the desired exposure period, remove the EIC, calculate the radon concentration $C(Rn)Av$. Set up a similar arrangement without a sample to obtain background radon concentration $C(Rn)Av$. The net radon concentration is obtained by subtracting the background concentration from the concentration measured with the sample.

Calculation of the exhalation rate and flux

Use equation (4) to calculate the exhalation rate from the sample. Divide the exhalation rate by the area of the sample (0.0243 m^2) to calculate flux.

Error associated with measurement is simply the errors expected in radon measurements. Other errors are negligible. Methods of calculating errors are given in reference (Kotrappa, 1990).

ILLUSTRATIVE MEASUREMENTS AND DISCUSSIONS

Total of five samples are obtained from commercial granite Supply Company, cut to the required sample size. Results of the measurements done for accumulation time of 2, 3, 5 and 7 days, are given in Table 2. Fluxes measured are in the range of 20 - 30 Bq m^{-2} d^{-1}.

DISCUSSION AND CONCLUSIONS

Fluxes measured are in the range of 20 to 30 Bq m^{-2} d^{-1}. These are similar to the published results for granite samples. Reference [5] gives values from 7 to 29 Bq m^{-2} d^{-1} and reference (Hazal-ur-Rehman, 2003) gives an average of 32.4 Bq m^{-2} d^{-1}. Reproducibility of measurements done on the same sample at different accumulation times, are with in the expected range.

Large number of EIC users with E-PERM® system (Kotrappa, 1990) can easily use this method for measuring the required parameters. Being a small accumulator, it is not possible to use larger samples. However the equations given in this note can be used for any other sealable accumulator and other integrating passive or active radon monitors. If sample is likely to leave debris inside the accumulator, it is advisable to enclose the sample in radon transparent bags such as Tyvek bags. Standard EICs do not have significant sensitivity to thoron as such the results are truly for radon.

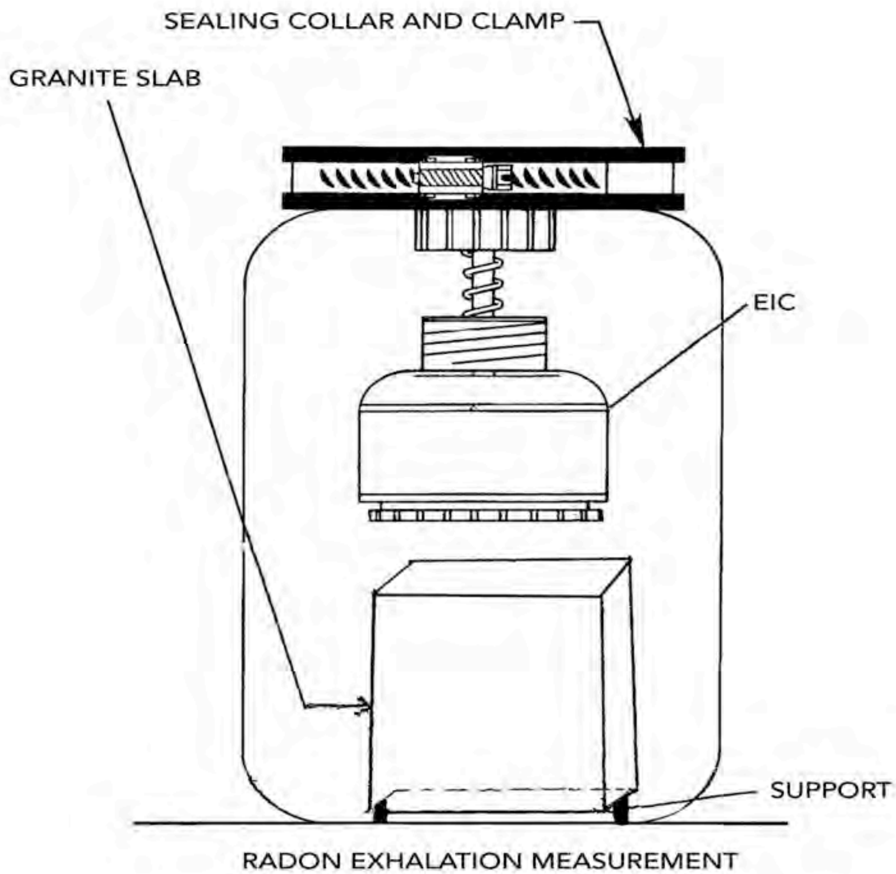

Figure -1 Radon Exhalation Measurement

Table-1 Average radon concentration for stated accumulation time for exhalation rate of 1 Bq/day

(F X A) Bq d^{-1}	Acc time Days	K	Vol m^3	Rn Av. Bq m^{-3}
1	1	0.08545563	0.00363	129.8
1	2	0.16131633	0.00363	245.1
1	3	0.22878692	0.00363	347.6
1	4	0.28891133	0.00363	439.0
1	5	0.34259494	0.00363	520.5
1	6	0.39062373	0.00363	593.5
1	7	0.43368073	0.00363	658.9
1	8	0.4723601	0.00363	717.7
1	9	0.50717923	0.00363	770.6
1	10	0.53858921	0.00363	818.3

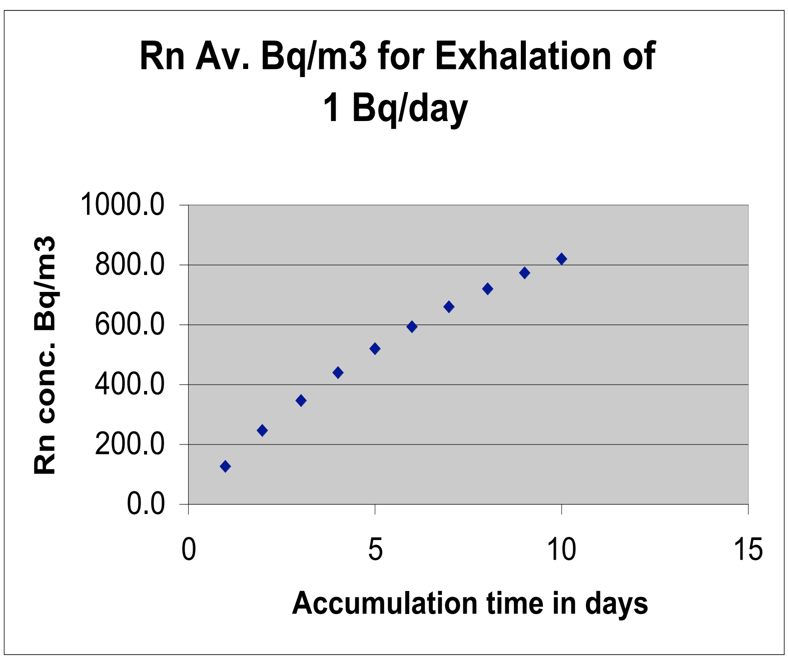

Figure 2 Build up of time averaged radon concentration for stated accumulation time

Table-2 Results of measurements

Acc Time days	Sample #	Rn Conc. pCi L^{-1}	F x A pCi d^{-1}	FxA Bq d^{-1}	F Bq m^{-2} d^{-1}	F Bqd^{-1} Kg^{-1}
3	#1	7.61	21.89	0.81	33.33	1.47
3	#2	6.58	18.93	0.70	28.82	1.27
3	#3	5.23	15.04	0.56	22.91	1.01
5.88	#1	13.06	22.32	0.83	33.98	1.50
5.88	#2	12.97	22.16	0.82	33.75	1.49
5.88	#3	9.86	16.85	0.62	25.65	1.13

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