ATTENUATION OF THORON (Rn^{220}) IN TYVEK$^{(®}$ MEMBRANES

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Abstract

Tyvek is a popular membrane used as a building wrap during construction due to a unique property which allows water vapor to permeate without wetting the membrane itself. Radon (Rn^{222}) and thoron (Rn^{220}) both diffuse equally through a Tyvek membrane, but radon is not attenuated due to its relatively long half-life of 3.8 days. Thoron, with a half-life of 55.6 seconds, will partially decay while diffusing and therefore, it becomes attenuated. The current work determines the attenuation of thoron for varying thicknesses of Tyvek. A thorium-loaded gas mantle is used as the source of thoron. The 960-milliliter thoron EIC monitor is used to measure thoron concentration, while different thicknesses of Tyvek membranes were introduced in the path of the thoron.

A 1-mm-thick and a 4-mm-thick Tyvek membrane attenuated thoron approximately by 50% and 95% respectively; radon is not attenuated in either case. The results are useful to choose the thickness of the Tyvek membrane needed to attenuate thoron by a desired factor.

Introduction

Radon gas monitors of different varieties, both active and passive types, are used for measuring radon concentration in air. One of the radon isotopes (Rn^{222}) ,usually referred to as **radon,** has a half-life of 3.8 days. Another isotope of radon (Rn^{220}), referred to as **thoron,** has a half-life of 55.6 seconds). In many cases both radon and thoron are present in the environment to be sampled. These two gases have not only different half-lives, but also have different biological properties, with different action limits. While measuring indoor radon, thoron is an interference and should be stopped from entering the sensitive volume of true radon monitors. The methods used for stopping thoron usually take advantage of the differences in half lives of radon and thoron. Any such method should not stop radon, but only thoron. Recently a study (Leung, 2007) used a thin layer (5 to 6 µm) of polyethylene (PE) in front of the passive entry of gas into the sensitive volume of the passive radon monitors. This stopped 92% of thoron, but allowed more than 98% of radon to go *(1)*

The authors are the developers of the E-PERM$^{(®}$ electret ion chambers used for measuring thoron in this study and have no commercial interest on the Tyvek$^{®}$ membranes studied in this work.

through to the sensitive volume. This is considered as adequate for most passive radon monitors. It is easy to explain the performance of PE, based on the differences in the half lives between radon and thoron. The time taken to diffuse through PE is the same for both radon and thoron, but that diffusion time is very small relative to the half life of radon leading to insignificant decay of radon during the passage, whereas it is significant relative to the half life of thoron leading to the significant decay of thoron. Smaller or larger thicknesses of PE will not function satisfactorily. Leung optimized and demonstrated that 5 to 6 µm thick PE works satisfactorily. There are other methods of achieving the same results. In electret ion chambers (Kotrappa, 1990) radon enters through a small opening. By controlling the ratio of the diffusion area to the sensitive volume, it is possible to control the diffusion entry time, thus stopping or minimizing thoron interference. The E-PERM® EIC responds only to 3% of thoron while fully responding to radon. Another method used in flow-through radon monitors is to have a long loop of tube to allow the decay of thoron before entry into the sensitive volume. Even though PE works, it has some practical limitations. The membrane is very thin and electrostatic. It is difficult to position this on the inlet of the radon progeny filter in a stretched condition, and sealing the edges with an adhesive can be quite challenging. This may introduce uncertainty in the performance.

Tyvek Membranes of standard thicknesses, well defined properties and complete transparency to radon, are available commercially. (Stieff, 2012). These are antistatic and have relatively larger thicknesses for handling and sealing. In the current work, different layers of Tyvek membranes are introduced between the thoron source and the thoron detector, and thoron attenuation is measured, leading to attenuation of thoron for different thicknesses of Tyvek. The results can be used to control the thoron attenuation factors.

Materials and methods

Figure 1 gives the schematic of the experimental arrangement for measuring the attenuation of thoron for different layers of Tyvek membranes. A 960 ml EIC thoron monitor (Kotrappa, 2010) is positioned above a thorium loaded gas mantle. A carbon-coated Tyvek membrane forms part of the 960 ml EIC thoron monitor. Additional Tyvek membranes are introduced and the thoron concentrations are measured by standard procedure, fully described in the referenced publication (Kotrappa, 2010).

Physical properties of Tyvek membranes

The properties of Tyvek membranes are fully described in the manufacturer's handbook (DuPont, 2012). The unique ability to resist air and water penetration, while still allowing moisture vapor to pass through, makes this a unique product extremely popular for providing protection, comfort and energy efficiency when used in residential and commercial construction as a building wrap. This property makes it fully transparent to radon (Stieff 2012) and other gases. Tyvek is made by pressing the very fine 0.5 to 10 µm spun bonded Olefin (a form of polyethylene) fibers. Commercially available #14A (antistatic) Tyvek membrane is used in this study. The thickness and the density of the membrane are measured experimentally in this work. The thickness of a stack of 50 membranes is measured using a digital caliper and is found to be 6.48 mm. This calculates the thickness of each membrane to be 0.1296 mm (0.01296 cm or 5.1 mil). A stack of 50 membranes (each with a diameter of 176 cm^2) is weighed and found to be 59.0 gm. The thicknesses of each membrane can be calculated. This leads the thickness of each membrane to be 0.006704 gm/cm^2. This further divided by the physical thickness (0.01296 cm) leads to the density of the membrane in conventional units as 0.517 gm/cm^3.

The source of thoron

Some older versions of gas lantern mantles (made between1912-1941) contain thorium to produce incandescence when lantern fuel is burned on the mantle. Newer versions of mantles do not contain thorium. The older version of the mantle that was used in this study showed a gamma radiation level of 10 µrem/h at a distance of 4 cm from the source when measured with a Bicron micro rem meter. The gamma background in the area measured by the same instrument was 5 µrem/h. This means the net radiation level was 5 µrem/h, at a 4 cm distance from the source.

Experimental procedure

Several sets of EIC thoron monitors were prepared with the openings covered with different layers of Tyvek membranes. The first one was prepared with 1 membrane; the second one was prepared with 2 membranes, etc.

The initial reading of the electret (I) is taken and loaded into the EIC. The cover on the mantle is removed and the monitor is lowered into position (see Figure 1). This is the start of the exposure. The experiment is continued for 3 hours. The final reading (J) of the electret is taken at the end of the exposure. This completes one measurement. A background measurement is also needed and for this purpose, an EIC thoron monitor with no additional membrane is used. The thoron source is covered with a5 mm thick polycarbonate sheet. The initial and final electret voltages (K and L) are taken for this set for 3 hour exposure. This completes background measurement. For subsequent sets of EIC thoron monitors, background is the same and is not measured. Thoron concentration is calculated as described in (Kotrappa 2010). The data collected is entered in Table 1. Table 1 gets completed after completing measurements for all the EIC thoron monitor sets.

Results and discussions

Table 1 gives the experimental results. Column 1 gives the number of membranes in the respective EIC thoron monitors. Column 10 gives the transmitted thoron concentrations. Column 11 gives the percentage of thoron transmitted though the respective membranes (Column 1). This is calculated assuming the concentration of thoron as 100% corresponding to 2 membranes. Also note that the last two sets had 24 and 31 membranes because the resolution would have been poor, otherwise, for performing experiments one membrane at a time. Results are plotted in Figure 2. Smaller cubes are the experimental results taken from the Table 1. The curve appears to fit an exponential curve. Linear regression fit was carried out between natural logarithm of the number of the membranes (M) and the percent transmitted (P) through the stated number of membranes using Microsoft Excel program. Equation (1) gives the regression equation led to a very good fit.

$$P = 109.3092 - 30.6801\ X\ Ln(M)\ ----(1)$$

where 0.9881was the multiple regression coefficient, and,

where P is the percent thoron transmitted and M is the number of membranes, Ln is the natural logarithmic function.

The calculated points resulting from the regression equation are also plotted in Figure 2 as indicated by larger cubes. Excellent agreement between the experimental results and the results calculated by Equation (1) concludes that Equation (1) can be used to determine the number of membranes needed to reduce the required thoron concentration by a specific percent attenuation. For example, a stack of 7 membranes reduces thoron by 50%, and a stack of 31 membranes reduces thoron by 95%. Table 2 and Figure 3 give the performance of the EIC monitors for radon in a standard radon test chamber (Kotrappa, 2007). Table 2 shows that there is virtually no decay of radon for the Tyvek membranes even with 31 membranes whereas a stack of 31 membranes reduced the thoron concentration by 95%.

Applications

A stack of Tyvek membranes can easily be built to be used as a thoron attenuator without attenuating radon. Such a stack can be inserted at the passive entry of any passive radon monitors such as SSNTD monitors or other similar radon monitors. One of the important applications is in uranium exploration projects. 960 ml electret ion chambers are widely used in uranium exploration projects in Canada (Charlton, 2006) and elsewhere. The procedure results in mapping of radon concentrations on the ground to indentify radon anomalies (ups and down) to locate where to look for uranium. It is also important to make sure that such anomalies are not caused by thoron. Using EIC radon monitors with a thoron attenuating stack of Tyvek in parallel with a regular radon monitor will prove whether the signal is due to thoron or not. Any uncertainty in uranium exploration work is solved.

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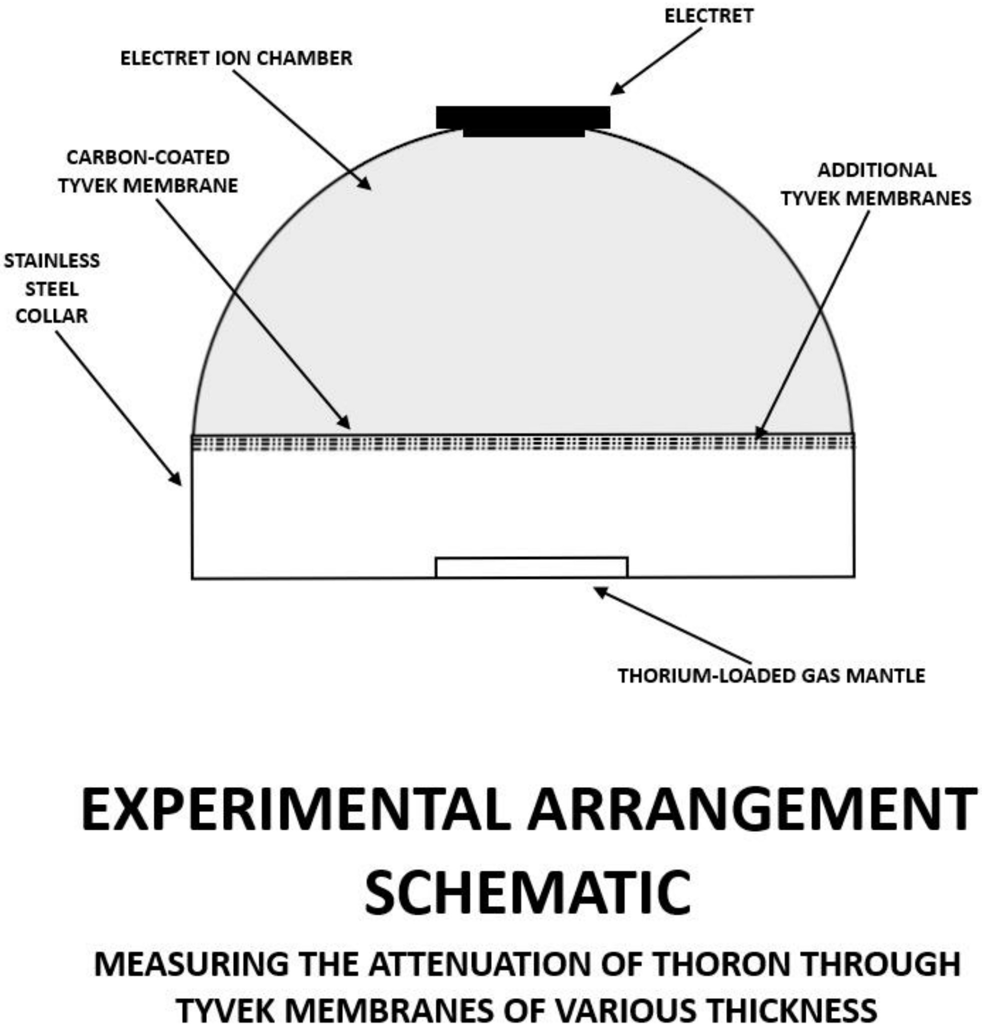

Figure (1): Schematic of Experimental Arrangement

Table (1): Calculation and attenuation of thoron for different thicknesses of Tyvek membranes

H chambers for measurement of thoron

I and J are the initial and final volts for radon thoron chamber

K and L are the initial and final volts for radon chamber

Exposure Days are in day units

Number of membranes	I	J	K	L	Days	CF(I,J) CF(I,J)	CF(K,L) CF(K,L)	kBq/m3 Tn conc.	Exptal % Transmitted
1	643	481	431	412	0.125	90.4736	86.86275	12.57473	100
2	766	604	431	412	0.125	93.6347	86.86275	12.09114	96.1542
3	766	643	431	412	0.125	94.13585	86.86275	8.703091	69.21093
4	693	582	431	412	0.125	92.41395	86.86275	7.859052	62.49875
5	425	324	431	412	0.125	85.65485	86.86275	7.683321	61.10125
6	778	676	431	412	0.125	94.7141	86.86275	6.865514	54.59769
7	251	170	431	412	0.125	81.44005	86.86275	6.206886	49.35998
8	676	593	431	412	0.125	92.33685	86.86275	5.441175	43.27069
9	324	251	431	412	0.125	83.41895	86.86275	5.25092	41.7577
10	581	511	431	412	0.125	90.0624	86.86275	4.468024	35.53176
11	481	415	431	412	0.125	87.5438	86.86275	4.28138	34.04747
12	592	520	431	412	0.125	90.3194	86.86275	4.62748	36.79982
13	604	542	431	412	0.125	90.7563	86.86275	3.715298	29.54574
14	520	458	431	412	0.125	88.5975	86.86275	3.848465	30.60474
15	592	531	431	412	0.125	90.46075	86.86275	3.644718	28.98445
16	388	334	431	412	0.125	85.3079	86.86275	3.314122	26.3554
17	334	283	431	412	0.125	83.95865	86.86275	3.109648	24.72933
18	477	430	431	412	0.125	87.68515	86.86275	2.538182	20.18478
24	581	543	431	412	0.125	90.4736	86.86275	1.610209	12.80511
31	496	469	431	412	0.125	88.43045	86.86275	0.692711	5.508748

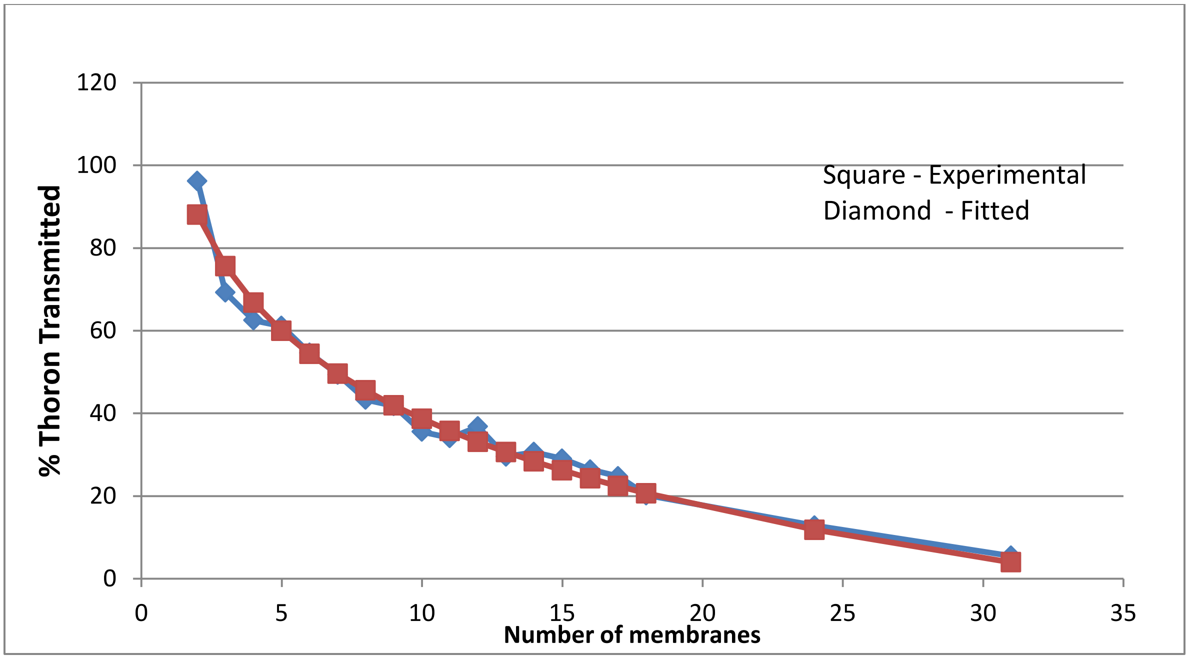

Figure (2): Percent thoron attenuation (experimental and regression fitted) for the stated number of Tyvek membranes

Table (2): Radon concentration for stated number of Tyvek membranes

Number of Membranes	Thickness of Tyvek	Radon Concentration (Bq/m³)
1	0.1296	503
5	0.648	519
10	1.296	492
15	1.944	514
25	3.24	503

*Average thickness of each #14 Tyvek membrane is 0.1296 mm

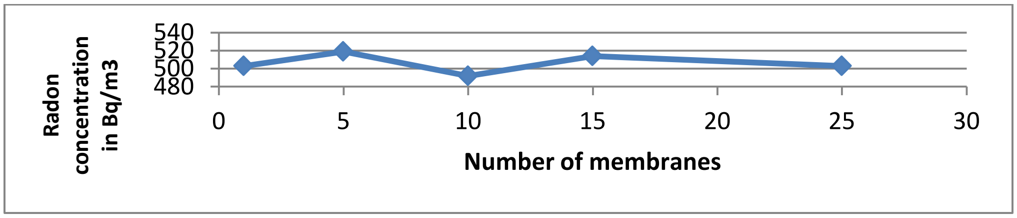

Figure (3): Radon Concentration for stated number of Tyvek membranes