THE USE OF BARRIER BAGS WITH RADON DETECTORS

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Abstract

Radon detectors are widely used for research and for monitoring indoor and outdoor radon. During some applications, detectors need to be enclosed in barrier bags which are completely transparent to radon. In other applications, radon detectors need to be enclosed in barrier bags that are opaque to radon. In certain applications, barrier bags may provide resistance to human manipulation. Tyvek® bags appear to meet most requirements for being transparent to radon, while providing some protection from water in harsh environments and from human manipulation. Aluminized Mylar® bags and Mylar® bags with or without activated carbon (AC) bags appear to meet the requirement of being opaque to radon. The current work includes examining the performances of these barrier bags at both low and high radon concentrations and over extended periods of time.

Introduction

Radon detectors are widely used for research and for monitoring indoor and outdoor radon. During some applications, detectors need to be enclosed in barrier bags which are completely transparent to radon. In other applications, radon detectors need to be enclosed in barrier bags that are opaque to radon. In certain applications, barrier bags may provide resistance to human manipulation. Tyvek® bags appear to meet most requirements for being transparent to radon, while providing some protection from water in harsh environments and from human tampering. Manila paper envelopes also appear to be transparent to radon, but may not withstand moisture or direct water. Freezer Ziploc® bags do not serve as a transparent barrier or as an opaque barrier to radon. However, when an activated carbon (AC) bag is placed inside Ziploc® bags, these provide a limited radon free environment. Aluminized Mylar® bags and Mylar® bags with or without activated carbon (AC) bags meet the requirement of being opaque to radon. The current work includes examining the performances of these barrier bags at both low and high radon concentrations and over extended periods of time.

Materials and methods

Radon Detectors

The current work requires integrating types of radon detectors, radon test chambers, and different types of barrier materials to be tested. Short term and long term electret ion chambers manufactured by Rad Elec Inc. (E-PERM®s) were considered as appropriate detectors (ref 1). These detectors are known to be true integrating radon detectors and meet the needed range and sensitivities for the current study.

Radon Test Chambers and Radon Testing Areas

For testing at low radon concentrations, the basement area of a typical residence was chosen. The radon concentration in the basement of this home typically ranges from 1.5-8 pCi/L. Rad Elec's flow-through type radon test chamber (ref 2) was used for radon concentrations from 15-20 pCi/L. This radon test chamber is certified by NRSB as an accredited radon test chamber (NRSB TRC 6002 valid through 04/30/13). An accumulating type of radon chamber (ref 3 and ref 4) was used for higher concentrations ranging from 30-200 pCi/L.

Barrier Materials

Commercially available Tyvek® bags and commercially available manila paper envelopes (Appendix A) were chosen to test the radon diffusion characteristics for "transparent" barriers. Commercially available aluminized Mylar® bags and "regular" Mylar® bags were used for testing opaque barriers to radon. Hybrid arrangements such as freezer Ziploc® bags with and without activated carbon (AC) bags were tested to serve as opaque barriers to radon. Appendix A lists the materials used in this study, all of which are commercially available. Specifications and the name of the suppliers are also given in the Appendix. A special heat sealer (impulse sealer) was used for sealing Mylar® bags, aluminized Mylar® bags, and one Ziploc® freezer bag. The specifications of the sealer are given in Appendix A.

Methodology Used

The methodology used was fairly simple and straight forward. For example, if a Tyvek® barrier was to be tested, the "experimental" detectors were enclosed inside the Tyvek® bag, the bag was sealed, and then placed into the radon test chamber. In addition, a similar number of "control" radon detectors were also introduced into the radon test chamber and placed adjacent to the bags. These were "termed" control electrets because they provided the "undisturbed" radon concentration inside the chamber which provided the target value of the radon concentration inside the radon chamber. The target value was derived by averaging the "control" detectors, and this control target value was compared to the radon concentrations found from E-PERM®s enclosed inside the bags. Both the "experimental" set of detectors and the "control" set of detectors were exposed for the same amount of time. At the end of the testing period, both "sets" of detectors were taken out and analyzed to determine the radon concentration over that period. The data was analyzed and the results assessed based on the objective of the experiment.

Testing TYVEK® bags as transparent barriers

Tyvek® is a durable substance with a unique property that permits water vapor to pass through the material with nearly 100% efficiency, but it does not permit water droplets to penetrate. It is because of this property that Tyvek® is used as a "building wrap" during home construction and is also used to make resilient shipping bags. The material properties of being transparent to vapors, light weight, and durable should make it an ideal "transparent barrier" inside of which radon detectors could be deployed. Experiments were conducted to confirm that Tyvek® bags were transparent to radon gas of various radon concentrations and tests ranging from 1-7 days. Table 1 details the results for experiments conducted using Tyvek® bags. Columns 2 and 3 provide the measured radon concentration of radon detectors inside the Tyvek® bags. Column 4 provides the radon concentration as measured by similar control detectors located adjacent to the bags being tested. Column 5 gives the exposure period in days. Column 6 shows the control averages and the standard deviation of those averages. The results of these experiments indicate that there is practically no difference in the radon concentration given by controls compared to the radon concentrations provided by the detectors inside the Tyvek® bags. The radon concentrations ranged from 1.5-33.9 pCi/L, and the test periods ranged from 1 day to 7 days. This data confirms that Tyvek® bags provide an ideal "transparent barrier" to radon detectors in all the tests conducted.

Testing manila envelopes as transparent barriers

Manila envelopes are inexpensive and easily obtainable from commercial suppliers. Questions have been raised whether these bags provide transparency regarding the diffusion of radon into radon detectors enclosed inside the manila envelopes. In attempting to answer this question, an experiment was conducted similar to the experiment that was conducted using Tyvek® bags. Table 2 gives the results of the experiment. Columns 2 and 3 provide the measured radon concentration of radon detectors inside the manila envelopes. Column 4 provides the radon concentration as measured by similar control detectors located adjacent to the envelopes being tested. Column 5 gives the exposure period in days. Column 6 shows the control averages and the standard deviation of those averages. Once again, the results of these experiments indicate that there is practically no difference in the radon concentration given by controls compared to the radon concentrations provided by the detectors deployed inside the manila envelopes. The radon concentrations ranged from 1.6-95.5 pCi/L, and the test periods ranged from 1 day to 5 days. This data confirms that manila envelopes are a "transparent barrier" to radon detectors in all the tests conducted, and provide a viable and less expensive alternative to Tyvek® bags for radon testing.

Testing of Mylar® and aluminized Mylar® bags

Table 3 gives the test results. The column headings are self explanatory. Column 2 reflects that Mylar® bags permit an extremely small amount of radon (about 1%) to diffuse into the bags. Similarly, columns 3 and 4 show that virtually no radon diffuses into the aluminized Mylar® bags. It should be noted that these tests involved relatively high radon concentrations for a period of 5 days to 14 days. Of special note, column 4 gives the results of a Ziploc® aluminized Mylar® bag containing an AC bag that was sealed by using only the "zip lock" feature, but without being heat sealed. This experiment was conducted to demonstrate whether the radon that "leaks" into the bag gets absorbed by the AC bag, thus providing a radon free environment to the radon detectors inside the Ziploc® aluminized Mylar® bag. The shaded areas reflect the percent transmission which is defined as the ratio of the average measured radon concentration in target bags to that of the average radon concentration of the controls, multiplied by 100. Table 3 confirms both Mylar® and aluminized Mylar® bags provide a near opaque barrier for radon detectors enclosed in such bags. The specifications of the bags tested are listed in Appendix A.

Testing of Ziploc® freezer bags

It was of interest to conduct studies to determine whether a Ziploc® freezer bag or a "zipped and heat-sealed freezer bag" would provide a radon barrier to the radon detectors deployed inside the bags. The data in Table 4 clearly shows that the transmission or diffusion is almost 70 to 80%, irrespective of the radon concentrations (both higher and lower radon concentrations) and irrespective of the testing periods (both longer and shorter testing periods). These experiments demonstrate that radon easily diffuses through the polyethylene, while some portion of radon appears to be absorbed in the medium.

Testing Ziploc® bags with activated carbon (AC) bags

It was also of interest to determine whether a "zipped" Ziploc® freezer bag containing activated carbon bags could be used to absorb the "transmitted" radon and thereby provide a "radon free" atmosphere to the radon detector enclosed inside these bags. It is well known that activated carbon bags have a high capacity to absorb radon. To verify this hypothesis, studies listed in Table 5 were conducted. The results in columns 2 and 3 are with Ziploc® bags containing one AC bag, while the results in columns 4 and 5 are with Ziploc® bags containing two AC bags. The highlighted rows reflect the percent transmission or radon into the Ziploc® bags with AC bags. In interpreting the data, the results show that one bag of carbon brings down the transmission from nearly 80% to about 6%. An additional AC bag (total of 2) produced results that reduced the transmission even further to about 4.6%. The radon environment inside the bags containing AC bags was quite low, and it may be acceptable to use this type of arrangement as a simple opaque radon barrier in some cases.

Discussion

Applications

One of the applications for transparent barriers, which is in current use, is to enclose electronic continuous radon monitors, such as Alpha Guard units, in Tyvek® bags when used for extended periods in harsh or dusty environments such as monitoring inside of mines. Without a "transparent enclosure", the sensitive electronic components used by these CRMs can become contaminated by dust or damaged by dripping water resulting in costly repairs. Enclosing these monitors in large Tyvek® bags has solved this problem. Tyvek® bags are also routinely used for enclosing E-PERM® electret ion chambers when used in the outside environment for measuring ambient radon concentrations, as well as in harsh environments such as saw mills, fish hatcheries, and in post offices (that may be laden with paper dust). When conducting radon tests in such conditions, detectors may become covered with dust, including the stem and spring of the detector which can transfer dust into the chamber, unless they have been enclosed in a transparent barrier such as Tyvek®. When testing radon levels in mines or fish hatcheries where water dripping onto the detectors may present a problem, the use of Tyvek® bags has been beneficial. When conducting long-term radon measurements, the use of manila envelopes or Tyvek® bags secured to permanent fixtures can be used to discourage human manipulation and prevent physical movement of the detectors. The use of very simple "transparent" enclosures can often solve these problems.

The use of opaque barriers, such as heat sealed Mylar® bags, can be useful in situations where one is trying to eliminate the influence of radon gas upon the measurement. Opaque barriers may be useful when transporting radon detectors, such as AT detectors, back to the laboratory for analysis; or for trying to determine the instrument background for CRMs in the absence of radon. Another application is when E-PERM® detectors are used to measure background gamma radiation, and in this case, opaque barriers can be used to eliminate the "signal" produced from radon gas.

Conclusions

Tyvek® bags provide the best barriers allowing nearly 100% transmission of radon when used in harsh environments where protection from water is needed. In less harsh environments, manila paper envelopes also provide nearly 100% transmission of radon and provide a low cost method to reduce human tampering. The zipped freezer bags transmit 70 to 80% of radon and therefore are not suitable either as a transparent barrier or as an opaque barrier; however, if 1 or 2 AC bags are introduced inside these bags, the transmission decreases from 70 or 80% down to approximately 4 to 7%. This arrangement may be used as an opaque enclosure in specialized cases. Heat sealed Mylar® and aluminized Mylar® bags provide near opaque barriers with the transmission rate for radon of approximately 1%.

Appendix A - List of Materials Used in Experiments

Material	Thickness	Length & Width	Company	Comment
Aluminized Mylar ®	5 mil (0.127 mm)	16 in x 10 in	Im Pak	
Ziploc Aluminized Mylar®	4 mil (0.102 mm)	12 in x 8 in	Im Pak	
Large Mylar ®	3 mil (0.076 mm)	15 in x 13 in	Packateers Inc.	
Medium Mylar ®	3 mil (0.076 mm)	11 in x 10 in	Packateers Inc.	
Small Mylar ®	3 mil (0.076 mm)	8 in x 7 in	Packateers Inc.	
Large Tyvek ®*	3 mil (0.076 mm)	15 in x 10 in	Western States Envelopes	
Small Tyvek ®*	3 mil (0.076 mm)	9 in x 6 in	Western States Envelopes	
Ziploc® Bag	2 mil (0.051 mm)	12 in x 10 in	Ziploc	Double Zipper, Heavy Duty, Freezer Gallon Bag
Manila Envelope	4.5 mil (0.114 mm)	12 in x 9 in	Staples	Staples 9 x 12 Clasp Envelopes
Impulse Wide Area Heat Sealer			American Int'nl Electric	
Activated Carbon Bags			Süd-Chemie	Getter Pak ® 30 Grams of Activated Carbon, Belen, NM 87002, www.s-cpp.com

*Tyvek® Spunbonded Olefin Sheets
Manufactured by: E.I. Du Pont de Nemours & Company
Barley Mill Plaza
Reeves Mill Building

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Table 1 - Testing Tyvek® Bags

E-PERM® Radon Detector	Tyvek® bags- RnC & Error	Tyvek® bags- RnC & Error	(Control) RnC & Error	Exposure Period	(Control) Average RnC and STD
1	32.7 ± 1.8		35.4 ± 1.9	1 Day	**33.9 pCi/L & 1.3**
2	33.7 ± 1.8		32.9 ± 1.8		
3	34.6 ± 1.9		33.4 ± 1.8		
Avg RnC & STD	**33.7 & 1.0**		**33.9 & 1.3**		
4	16.3 ± 0.9	16.5 ± 0.9	17.4 ± 0.9	2 Days	**16.5 pCi/L & 1.1**
5	14.8 ± 0.8	15.8 ± 0.9	16.7 ± 0.9		
6	15.3 ± 0.8	16.5 ± 0.9	15.1 ± 0.8		
7	17.5 ± 0.9	15.8 ± 0.9	15.6 ± 0.8		
8	17.0 ± 0.9	16.1 ± 0.9	17.5 ± 0.9		
Avg RnC & STD	**16.2 & 1.1**	**16.1 & 0.4**	**16.5 & 1.1**		
9	1.5 ± 0.3		1.5 ± 0.3	2 Days	**1.6 pCi/L & 0.1**
10	1.5 ± 0.3		1.7 ± 0.3		
11	1.4 ± 0.3		1.7 ± 0.3		
12	1.4 ± 0.3		1.7 ± 0.3		
13	1.5 ± 0.3		1.4 ± 0.3		
14	1.7 ± 0.3				
15	1.7 ± 0.3				
16	1.5 ± 0.3				
17	1.5 ± 0.3				
18	1.7 ± 0.3				
Avg RnC & STD	**1.5 & 0.1**		**1.6 & 0.1**		
19	1.5 ± 0.2		1.8 ± 0.2	2.5 Days	**1.8 pCi/L & 0.1**
20	1.9 ± 0.3		1.7 ± 0.3		
21	1.5 ± 0.3		1.8 ± 0.2		
Avg RnC & STD	**1.6 & 0.2**		**1.8 & 0.1**		
22	4.7 ± 0.3	4.9 ± 0.3	4.7 ± 0.3	3 Days	**4.7 pCi/L & 0.3**
23	3.8 ± 0.3	4.5 ± 0.3	4.8 ± 0.3		
24	4.3 ± 0.3	4.3 ± 0.3	4.1 ± 0.3		
25	4.3 ± 0.3	4.7 ± 0.3	4.8 ± 0.3		
26	4.5 ± 0.3	4.3 ± 0.3	4.9 ± 0.3		
Avg RnC & STD	**4.3 & 0.3**	**4.5 & 0.3**	**4.7 & 0.3**		
27	1.5 ± 0.2		1.3 ± 0.2	5 Days	**1.5 pCi/L & 0.2**
28	1.6 ± 0.2		1.6 ± 0.2		
29	1.6 ± 0.2		1.5 ± 0.2		
30	1.4 ± 0.2		1.7 ± 0.2		
31	1.6 ± 0.2		1.6 ± 0.2		
32	1.5 ± 0.2				
33	1.5 ± 0.2				
34	1.6 ± 0.2				
35	1.4 ± 0.2				
36	1.4 ± 0.2				
Avg RnC & STD	**1.5 & 0.1**		**1.5 & 0.2**		
37	4.6 ± 0.3	4.6 ± 0.3	4.9 ± 0.3	7 Days	**4.6 pCi/L & 0.3**
38	3.8 ± 0.2	4.3 ± 0.3	4.6 ± 0.3		
39	4.3 ± 0.3	4.8 ± 0.3	4.2 ± 0.3		
40	4.4 ± 0.3	4.6 ± 0.3	4.5 ± 0.3		
41	4.6 ± 0.3	4.3 ± 0.3	4.7 ± 0.3		
Avg RnC & STD	**4.3 & 0.3**	**4.5 & 0.2**	**4.6 & 0.3**		

Table 2 - Testing Manila Envelopes

E-PERM® Radon Detector	E-PERM®s in Manila Envelopes- RnC & Error	(Control) RnC & Error	Exposure Period	(Control) Average RnC and STD
1	1.4 ± 0.3	1.5 ± 0.3	2 Days	**1.6 pCi/L & 0.1**
2	1.2 ± 0.3	1.7 ± 0.3		
3	1.4 ± 0.3	1.7 ± 0.3		
4	1.6 ± 0.3	1.7 ± 0.3		
5	2.0 ± 0.3	1.4 ± 0.3		
6	1.7 ± 0.3			
7	1.4 ± 0.3			
8	1.5 ± 0.3			
9	1.5 ± 0.3			
10	1.2 ± 0.3			
Avg RnC & STD	**1.5 & 0.2**	**1.6 & 0.1**		
11	101.9 ± 5.9	88.8 ± 5.2	3 Days	**96.5 pCi/L & 6.1**
12	91.8 ± 5.3	100.0 ± 5.7		
13	97.5 ± 5.7	100.2 ± 5.7		
14	89.5 ± 5.2	96.0 ± 5.6		
15	92.4 ± 5.4	89.9 ± 5.3		
16	103.8 ± 5.9	103.9 ± 6.0		
Avg RnC & STD	**96.2 & 5.8**	**96.5 & 6.1**		
17	1.7 ± 0.2	1.3 ± 0.2	5 Days	**1.5 pCi/L & 0.2**
18	1.4 ± 0.2	1.6 ± 0.2		
19	1.6 ± 0.2	1.5 ± 0.2		
20	1.6 ± 0.2	1.7 ± 0.2		
21	1.5 ± 0.2	1.6 ± 0.2		
22	1.5 ± 0.2			
23	1.7 ± 0.2			
24	1.8 ± 0.2			
25	1.7 ± 0.2			
26	1.8 ± 0.2			
Avg RnC & STD	**1.5 & 0.1**	**1.5 & 0.2**		

Table 3 - Testing Mylar® & Aluminumized Mylar® Bags

E-PERM® Radon Detector	E-PERM®s in Sealed Mylar® Bags-RnC & Error	E-PERM®s in Sealed Alum. Mylar® Bags-RnC & Error	E-PERM® w/ AC bag in Ziplocked Alum. Mylar® bag-RnC & Error	(Control) RnC & Error	Exposure Period	(Control) Average RnC and STD
1	1.7 ± 0.2	1.5 ± 0.2		166.0 ± 8.5	5 Days	**168.5 pCi/L & 7.4**
2	1.7 ± 0.2	1.5 ± 0.2		162.8 ± 8.3		
3	1.5 ± 0.2			179.4 ± 9.1		
4	1.8 ± 0.2			165.8 ± 8.5		
Avg RnC & STD	**1.7 & 0.1**	**1.5 & 0.0**		**168.5 & 7.4**		
% Transmission	**1.0%**	**0.9%**				
5			0.6 ± 0.1	16.7 ± 0.9	6 Days	**16.6 pCi/L & 0.6**
6			0.2 ± 0.1	16.1 ± 0.8		
7				17.6 ± 0.9		
8				16.0 ± 0.8		
Avg RnC & STD			**0.4 & 0.3**	**16.6 & 0.6**		
% Transmission			**2.4%**			
9	3.5 ± 0.5	1.0 ± 0.3		227.4 ± 11.4	14 Days	**229.6 pCi/L & 2.0**
10	3.5 ± 0.2	2.1 ± 0.1		231.1 ± 11.6		
11	3.7 ± 0.2	2.3 ± 0.2		>230.4 ± 11.5		
12	1.0 ± 0.3	2.2 ± 0.4				
13	0.9 ± 0.1	1.7 ± 0.1				
14	1.0 ± 0.1	0.8 ± 0.1				
Avg RnC & STD	**2.3 & 1.4**	**1.7 & 0.6**		**229.6 & 2.0**		
% Transmission	**1.0%**	**0.7%**				

Transmission is defined as: (Avg. Measured RnC/Avg. Control RnC) x 100

Table 4 - Testing Ziploc ® Freezer Bags without Activated Carbon (AC) Bags

E-PERM® Radon Detector	Zipped bag-RnC & Error	Heat sealed on all sides-RnC & Error	Aluminum Taped over zipper-RnC & Error	(Control) RnC & Error	Exposure Period	(Control) Average RnC and STD
1	11.1 ± 0.6	12.8 ± 0.7		16.7 ± 0.9	6 Days	**16.6 pCi/L & 0.6**
2				16.1 ± 0.8		
3				17.6 ± 0.9		
4				16.0 ± 0.8		
Avg RnC & STD	**11.1 ± 0.6**	**12.8 ± 0.7**		**16.6 & 0.6**		
% Transmission	**66.9%**	**77.1%**				
5	172.4 ± 8.6		182.4 ± 9.1	227.4 ± 11.4	14 Days	**229.6 pCi/L & 2.0**
6	171.1 ± 8.6		182.5 ± 9.1	231.1 ± 11.6		
7	170.8 ± 8.6		187.0 ± 9.4	>230.4 ± 11.5		
Avg RnC & STD	**171.4 & 0.9**		**184.0 & 2.6**	**229.6 & 2.0**		
% Transmission	**74.7%**		**80.1%**			

Transmission is defined as: (Avg. Measured RnC/Avg. Control RnC) x 100

Table 5 - Testing Ziploc ® Freezer Bags with Activated Carbon (AC) Bags

E-PERM ® Radon Detector	Zipped bag w/ E-PERM®s & 1 AC bag- RnC & Error	Zipped & Alum. Taped bag w/ E-PERM®s & 1 AC bag- RnC & Error	Zipped & Alum. Taped bag w/ E-PERM®s & 2 AC bags- RnC & Error	Zipped bag w/ E-PERM®s & 2 AC bags- RnC & Error	(Control) RnC & Error	Exposure Period	(Control) Average RnC and STD
1	2.3 ± 0.6				34.8 ± 1.9	1 Day	**34.8 pCi/L & 1.9**
Avg RnC & STD	**2.3 & 0.6**				**34.8 & 1.9**		
% Transmission	**6.6%**						
2	2.5 ± 0.4				46.4 ± 2.4	1.5 Days	**46.4 pCi/L & 0.1**
3	2.9 ± 0.4				46.3 ± 2.4		
4	3.5 ± 0.5						
5	1.7 ± 0.4						
Avg RnC & STD	**2.7 & 0.8**				**46.4 & 0.1**		
% Transmission	**5.8%**						
6	0.7 ± 0.1				16.7 ± 0.9	6 Days	**16.6 pCi/L & 0.6**
7	0.7 ± 0.1				16.1 ± 0.8		
8					17.6 ± 0.9		
9					16.0 ± 0.8		
Avg RnC & STD	**0.7 & 0.0**				**16.6 & 0.6**		
% Transmission	**4.2%**						
10	14.9 ± 0.9	16.1 ± 1.0	11.4 ± 0.8	10.1 ± 0.7	227.4 ± 11.4	14 Days	**229.6 pCi/L & 2.0**
11	13.5 ± 0.9	17.2 ± 1.0	11.4 ± 0.8	10.4 ± 0.7	231.1 ± 11.6		
12	15.9 ± 1.0	15.9 ± 1.0	11.0 ± 0.8	9.2 ± 0.7	>230.4 ± 11.5		
Avg RnC & STD	**14.8 & 1.2**	**16.4 & 0.7**	**11.3 & 0.2**	**9.9 & 0.6**	**229.6 & 2.0**		
% Transmission	**6.4%**	**7.1%**	**4.9%**	**4.3%**			

Transmission is defined as: (Avg. Measured RnC/Avg. Control RnC) x 100