EXPERIMENTAL DETERMINATION OF THE EFFECTIVENESS OF RADON BARRIERS

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Abstract

Several types of membrane materials (radon retarders) are available for placement under concrete slabs as barriers to the upward movement of soil gas into buildings. Selection of barrier material is seldom based on its resistance to air permeation, as such information is not readily available. For the current study, the permeability of several membrane materials, which may be used as radon barriers, were tested in the laboratory using three methods. All membrane materials were found to significantly reduce radon permeation, but the efficacy of resistance varied considerably amongst the membranes.

Introduction

Convective flow and diffusion are the primary driving forces behind radon entry into buildings, with the former often being the dominant force due to reduced pressure in a building relative to the outdoor environment. A barrier, such as polyethylene sheeting, is frequently placed under the concrete slab during building construction as membrane material and vapor barrier to reduce radon transport into the building as a result of both convective flow and diffusion. The purpose of the membrane material is to retard gases and aerosols (e.g., radon, methane, water vapor) that emanate through the soil from being transported into the living area of the home. The membrane is typically laid over the layer of gravel placed under the foundation. The effectiveness of a membrane for reducing the movement of radon (or soil gas) into the building is dependent upon the material composition, material thickness, and sealing of the membrane seams.

There have been several studies of the efficacy of barrier membranes for reducing radon penetration. Chen et al. (2009) examined 10 membranes commonly used in Canada, and concluded that membranes of higher density are better barriers of radon permeability. Similarly, Daoud and Renken (2001) determine that several membrane materials are sufficiently impermeable to be used under a concrete slab for radon reduction. The methodologies utilized were somewhat different than the approach used in the present study.

Materials and Methods

For this study, several potential membrane materials were examined. In addition to the membranes available from distributors of radon mitigation supplies, various thicknesses of polyethylene sheeting were included in the study. Table 1 provides a listing and description of the membranes that were studied. The thicknesses of the membranes varied from about 1 mil (0.001 inch; 0.0254 mm) to 16 mil; colors included blue, black, clear, and white; and, as shown in Fig. 1, thickness was well correlated ($r^2 = 0.97$) with area density (i.e., unit weight).

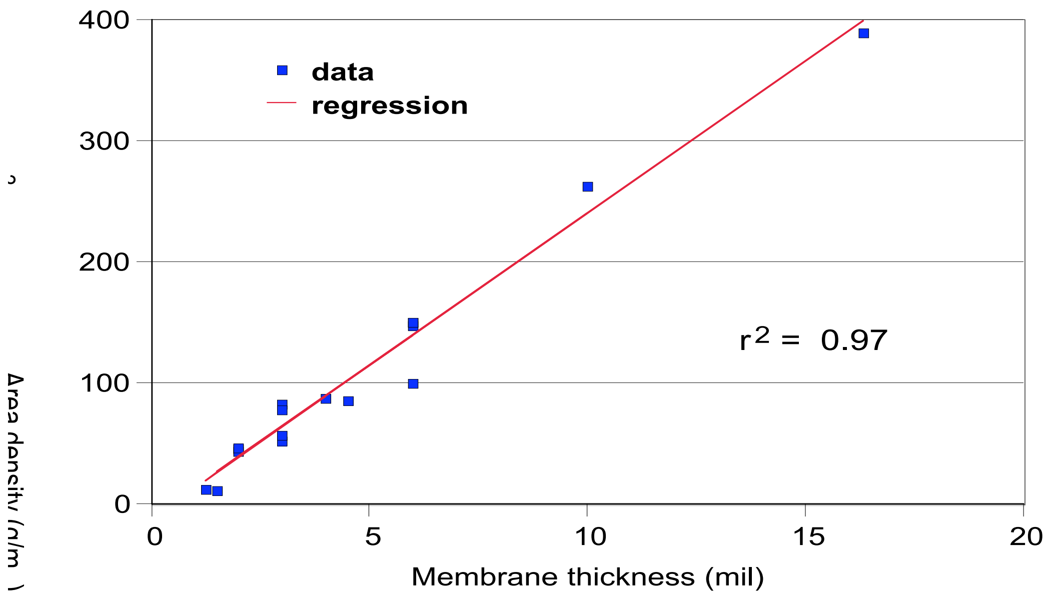

Fig. 1. Membrane thickness is strongly correlated with area density for the materials studied.

Table 1. Description of membranes tested.

Membrane	ID	Thickness (mil)	Area density (g/m2)	Description
Supplier 1	1	6	100	clear; white fibers
2-mil poly	2	2	46	clear
4-mil poly	3	4	88	clear
1.2-mil polyolefin	4	1.2	13	clear
Low-density poly	5	2	44	clear
PVC film	6	1.5	12	clear
6-mil poly	7	6	148	clear
Polypropylene	8	2	47	clear
Supplier 2	9	16.3	390	white and blue
Supplier 3	10	6	151	blue
Black B	11	3	53	black
Supplier 4	12	3	84	white
Supplier 5	13	10	263	white
Supplier 6	14	4.5	86	black
Supplier 3A	15	6	151	blue
3-mil poly	16	3	58	clear
Black A	17	3	78	black

Three methods were applied to determine the effectiveness of the membrane materials. Not all membranes were tested by each method. Initial measurements were conducted with the membrane material placed between a continuous radon monitor (CRM; Pylon AB-5 with passive radon detector) and a radium-lined crock (i.e., Revigator) filled with water (Fig. 2A). The second approach utilized a ^{226}Ra source (0.9 nCi) that was place inside a hemisphere, and allowed the radon to pass through the membrane material and into the CRM (Fig. 2B). Since the membrane was not affixed to the source or detector, there was the possibility of radon leakage around the membrane for setup 2A and 2B. The third approach used to examine the membranes involved placement of the ^{226}Ra source inside a 4-L glass container that was covered with the membrane material. This setup was sealed inside a 50-L airtight chamber with a CRM (Fig. 2C). Though the membranes were sealed onto the opening of the glass jar, some membranes were too rigid to produce a tight fit. A large hose clamp was affixed to minimize leakage, but radon loss was possible for the rigid membranes. For all three approaches, counts were typically accumulated for at least one day for each membrane.

Fig. 2. Experimental setups that were used to examine the permeability of membrane materials: continuous radon monitor mounted over water-filled Revigator (A); ^{226}Ra capsule and continuous radon monitor (B); and covered glass jar containing ^{226}Ra capsule in airtight chamber (C).

Results and Discussion

Two similar, but separate, experiments were conducted with the membranes covering the top of the revigator. The count rates determined near the end of the measurements (i.e., equilibrium) using the initial experimental setup showed that a large fraction of the radon was blocked by even the thinnest membrane (Fig. 3). The 2-mil polyethylene membrane reduced the measured radon levels by nearly 83%. The reduction increased to 91% for the 3-mil polyethylene membrane, and even greater reduction for the other membranes. The membrane commercially sold by Supplier 2 reduced the radon concentration to near the background level.

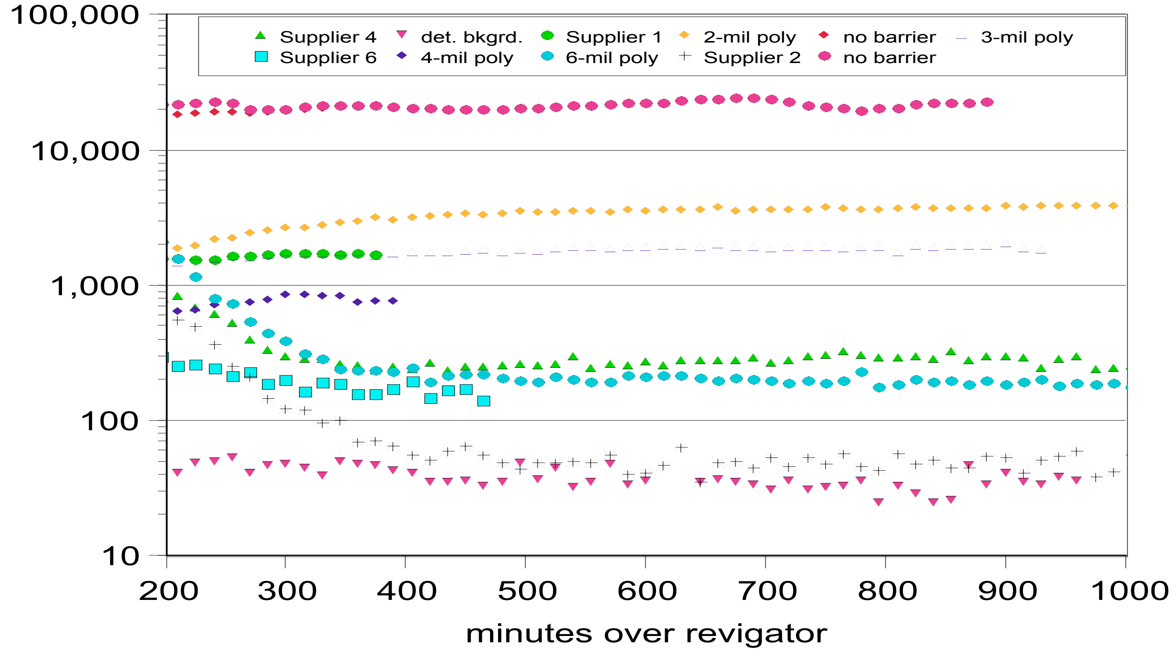

Fig. 3. Count rates measured with membranes separating continuous radon monitor and revigator (initial setup 2A).

A summary of results (Fig. 4) of the follow-up experiment using the same configuration showed a similar pattern, but with somewhat greater reductions. All membranes provided at least a 90% reduction in radon compared to the count rate measured without any membrane.

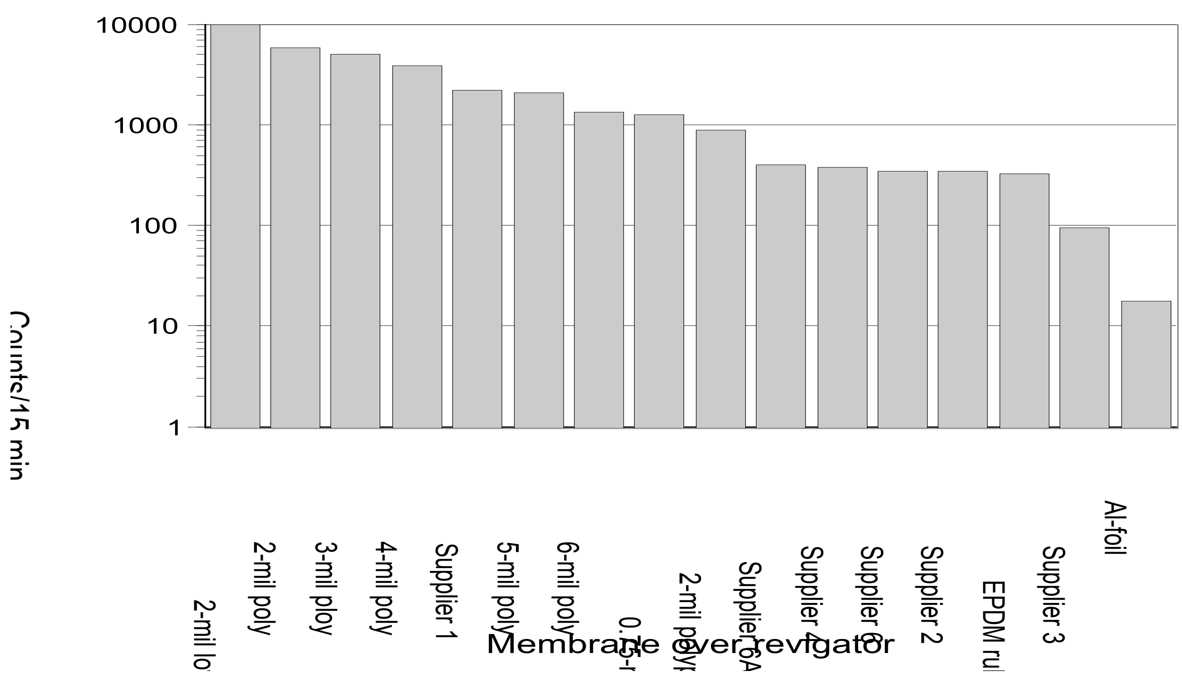

Fig. 4. Count rates measured with membranes separating continuous radon monitor and revigator (repeated setup 2A).

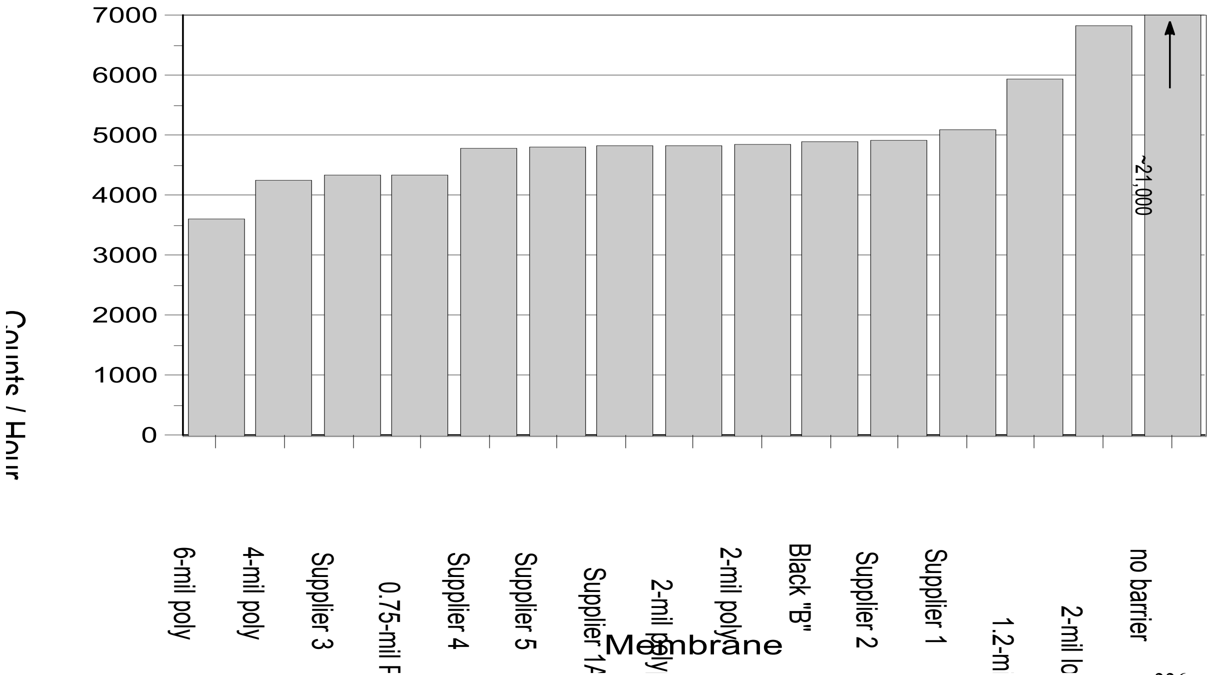

Fig. 5. Count rates measured with membranes separating continuous radon monitor and ^{226}Ra capsule (setup 2B).

Results from the measurement of count rates (Fig. 5) emitted from the ^{226}Ra capsule (setup 2B) are somewhat different than those determined using the revigator (setup 2A). In general, the membrane distributed by Supplier 3 showed the significant radon reduction and thin polyethylene sheeting provided the least resistance to radon permeability. As with the Revigator, no effort was made to seal the setup, so there was the possibility of radon leakage around the edge of the membranes. This possibility is supported by the lower radon reductions (70-84%) that were achieved for the various membranes using this setup.

Lastly, the ^{226}Ra source inside the glass jar (setup 2C) produced results that are similar to the other experimental setups. Membranes from Suppliers 2 and 3 provided the greatest resistance to radon permeation (Fig. 6), with a ~95% reduction in the levels measured for the unobstructed (open) source. As with setup 2A, the commercial membrane from Supplier 1 provided the least radon reduction (41%). As explained in the Experimental section, radon leakage around the edge was possible for the thicker membranes that could not be tightly compressed between the threads of the glass jar and the lid.

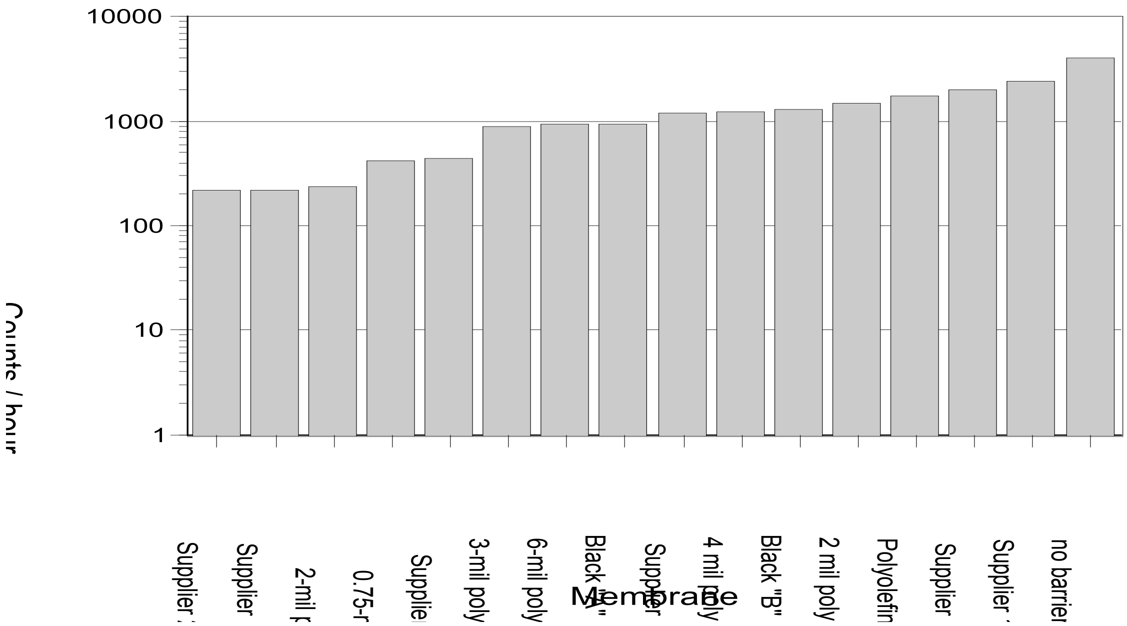

Fig. 6. Count rates measured with membrane separating continuous radon monitor and ^{226}Ra capsule inside airtight chamber (setup 2C).

Most publications regarding membrane permeability by radon express results in terms of gas diffusion coefficients (e.g., 10^{-11} to 10^{-14} m^2 s^{-1}). Daoud and Renken (2001) did provide percent reductions for membranes that range from 71-98% for the various materials that were tested. These reductions are similar to those determined in this study, though the materials tested were somewhat different. There are no known studies of the long-term durability of these membrane materials in a subslab environment.

Based on (unpublished) measurements of various stone aggregates that are often placed under the concrete (basement) slab of a home (2000 ft^2 and 0.5 ft thick), at least 1 μCi of radon is present at equilibrium from the aggregate alone. Assuming a barrier that is 90% effective is used, the radon above the barrier and available for transport into the basement, from the aggregate, is roughly 100,000 pCi. These levels of radon emphasize the importance of selecting a high-performance radon barrier, and sealing of the seams and holes that may occur during placement of the barrier at a building site.

Conclusions

The permeability of thin-film membrane barriers to radon was determined for several different materials that may be placed under concrete slabs to reduce radon transport. Although none of the three setups were airtight for all of the membranes, the results are similar and can be considered qualitative. All of the membrane materials effectively reduced radon transport. Membranes of greater density typically provided an improved resistance to radon movement, and often allowed only 5-10% of the radon to pass through.

References

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