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SOLVING THE CONFLICT BETWEEN BASEMENT WATERPROOFING BEST PRACTICE AND RADON MANAGEMENT IN THE UNITED KINGDOM

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Abstract

Cellar conversion and new basement creation is widespread in the UK where basement living and working is frequent. All basements are at risk of elevated radon levels regardless of geographic location. In 1999, a landmark court ruling altered the approach to waterproofing, steering designers and contractors towards the use of internally fitted drained cavity drain membrane systems. Based on air-gap technology, these membrane systems are not appropriate for gas proofing; in part of continental Europe their use is specifically discouraged for that purpose. The author set about resolving the conflict between good waterproofing practice and radon gas management in basements, producing a successful solution.

The paper explores the background of UK basement use, the key points of the landmark judgment and subsequent code of practice for below ground waterproofing. This code of practice now requires radon to be considered in waterproofing design and implementation, but overlooks how this might be achieved. The paper describes the process that was developed to solve the dilemma and illustrates with case studies.

Although construction practices and basement usage differ across the globe, the principles involved may have relevant applications internationally.

Introduction

In this paper, a basement is defined as being “a usable part of a building that is situated partly or entirely below ground level” and a cellar is defined as a “basement used for storage, heating plant and for purposes other than habitation”.

Where radon (radon-222) measurements are referred to, they are given in Becquerels per cubic metre of air (Bq/m$^3$) with approximate conversions into Picocuries per litre of air (pCi/L) shown beside. Measurements referred to in this paper were obtained using passive detectors and track etch technology. Passive detectors were supplied and analysis undertaken by Track Analysis Systems Limited, a UK laboratory validated by Public Health England.

Basement living and working are frequent in the UK. Basement and ‘Garden’ flats are a regular feature of most towns and cities; similarly basement offices are plentiful, office

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(1) The author is the inventor of the process described in this paper and is a director and shareholder of a company that, among other things, installs this process.
blocks usually have basements and a significant number of town centre stores and restaurants utilise basements.

Property (and land) is expensive in the UK and particularly in cities basement creation or cellar conversion is routinely undertaken to maximise accommodation. For similar reasons, many new builds include basements to get the most out of site development.

**Radon in Basements in the UK**

Radon is responsible for some 2000 lung cancer deaths in the UK each year.²

Maps indicating the geographic areas where elevated levels of radon are more likely to be found (known in the UK as Affected Areas) have been published by the Health Protection Agency (HPA, now absorbed into Public Health England (PHE)). Figure (1) below shows the indicative radon map for England and Wales. Separate maps are available for Scotland and Northern Ireland.

![Figure (1): Overall map of radon Affected Areas in England and Wales, HPA 2007](image)

In 2007 the Health Protection Agency stated in its Environmental Radon Newsletter “high radon concentrations can be found in basements anywhere in the country, regardless of Affected Area status” (Gooding, 2007).³

Workplace regulations regarding radon risk assessments and radon management specifically apply to all basement workplaces in the UK. The regulations have been in force since 1999 and state that “Risk assessment for radon should be carried out in relation to all below ground workplaces in the UK and all workplaces located in radon Affected Areas. For occupied below ground workplaces (for example occupied greater than an average of an hour per week/ 52 hours per year)…the risk assessment should include radon measurements. This

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²Maps indicating the geographic areas where elevated levels of radon are more likely to be found (known in the UK as Affected Areas) have been published by the Health Protection Agency (HPA, now absorbed into Public Health England (PHE)). Figure (1) below shows the indicative radon map for England and Wales. Separate maps are available for Scotland and Northern Ireland.

³In 2007 the Health Protection Agency stated in its Environmental Radon Newsletter “high radon concentrations can be found in basements anywhere in the country, regardless of Affected Area status” (Gooding, 2007).
applies to all below ground workplaces in the UK, irrespective of the above ground Affected Areas status.”

Thus it can be seen that basements have long been recognised as areas at risk of elevated radon levels. This is hardly surprising since radon is a soil gas and a basement may have up to five surfaces in communication with the soil, as opposed to a single surface for a building constructed on the ground.

Radon sump systems (known as sub-slab depressurisation systems or SSDs in the USA) are recognised as an effective method of radon management by providing a void with low pressure under the building where radon can be collected and subsequently managed away from the building.

A basement is, in effect, a large sump (or SSD) that people live or work in.

**History of UK Waterproofing.**

Until the 1990s waterproofing was undertaken by the damp proofing industry, many of whom did not understand the distinction between ‘damp proofing’ (action against capillary-held moisture) and ‘waterproofing’ (action against intrusion of free water) or by general building contractors. Techniques involved bitumen emulsions, mastic asphalt, or dense cement based render systems. New build basements were increasingly provided with externally fixed self-adhesive sheet membranes typically made from rubber/bitumen and polyethylene.

When basement waterproofing fails it is evident and it can cause great upset to the building user. Figures (2) and (3) show failure of a bitumen and newbuild waterproofing system respectively.

![Figure (2) Failure of bitumen waterproofing system in basement](image)
Growing numbers of failures caused major appraisal in the 1990s. Increasingly, internally fitted drained cavity drain membrane systems were adopted. These consist of studded high density polyethylene sheet membrane, supplied typically in 40 m$^2$ or 20 m$^2$ rolls. Stud heights principally used for below ground waterproofing are 8mm for walls (Figure (4)) and 20mm for floors and in severe cases of water incursion (Figure (5)).

The membranes are installed to the walls and floors of the basement with the stud-side in communication with the building fabric, creating a cavity behind the membrane.

The membrane is fixed to the wall using pre-drilled plugs driven into the masonry by a process that compresses butyl or neoprene on the shank beneath the head as a waterproof seal (Figure 6 below). Membrane sheets are jointed using butyl rope or overtape (Figure 7 below)
The membranes are linked with a drainage channel bedded in the floor perimeters at the wall/floor margins. Typically these are formed of 75mm x 50mm plastic installed on 20mm clean stone in a rebate channel at the floor edge. Figure (8) below shows a typical perimeter drainage channel.

Many drain profiles will have lugs on the face of the upstand, as can be seen in Figure (8) above. This is to account for condensation that might occur; beads of condensate will trickle down the accommodation side of the membrane and will percolate through the gap formed by the lugs into the perimeter drainage channel.

The drain profile is in reality not an actual drain but is formwork to stop the flooring material filling the channel when the embedded perimeter channel is covered with the floor topping. The profile is set level or to a slight fall to ensure that water in the drainage channel (which may be within the drain profile or beside it) discharges either to a sump pump system or to an open discharge, for example if the site is on a hillside or incline.

The membrane installations are generally finished with standard floor finishes and there are various options for wall finishes, which may be plastering on meshed membranes, batten and plasterboard, ‘dot & dab’ with plasterboard or independent stud systems.
Rising numbers of basement waterproofing failures involving traditional methods and the regular use of drained cavity drain membrane systems saw the development in the late 1990s of a more clearly defined body of waterproofing specialists.

The Outwing Case

In 1999 a landmark judgment was made in respect of basement waterproofing that had a profound and lasting effect.

Outwing Construction Ltd v Thomas Weatherald Ltd concerned a dispute and claim for damages in respect of failed below ground waterproofing in a new construction where an external self-adhesive sheet membrane system had been used. The salient points relating to waterproofing designers and installers were the reinforcement that

1. Less than perfect workmanship was foreseeable so:
2. A system should be designed to take account of less than perfect workmanship and
3. The ease with which repair could be undertaken should be considered in the choice & design of system

Further, Mr Phil Hewitt, Expert Witness for Outwing Construction, argued that there was a significant fault with the design, for the following reasons:

1. Clause 3.3 of BS 8102, Code of Practice for the Protection of Structures Against Water from the Ground, states that the designer should i) Consider the consequence of less than adequate workmanship, ii) Consider the consequence of leaks and iii) Consider the form and feasibility of remedial work.

2. By installing the land drain in the position shown, the designers created a head of water that would bear against the membrane. In these circumstances, any defect would constitute less than adequate workmanship, as the consequence of those defects would be flooding through the membrane into the basement.
3. It is not realistic or reasonable to expect a bonded sheet membrane to be applied without any defects at all.

4. Clause 3.1.1 of BS 8102, Pre-Design Considerations, recommends that basements should include provision for resisting a pressure equivalent of 1m head of water at least.

5. The interpretation of the above was that a design team must anticipate that defects will occur in a membrane, and so must design a system in such a way that water pressure is removed before it comes to bear against the membrane. If they are unable to achieve this, it is implied that an alternative form of waterproofing must be used.

6. Furthermore, a bonded sheet membrane is only one element within an overall waterproofing system. The membrane, together with the drainage and the structure, all form part of the system and must be considered together. No one element should be considered in isolation.

In his judgment, Recorder Colin Reese QC agreed with this evidence without reservation.

The rulings in this landmark case set legal precedents.

After the Outwing case, there was a major swing towards the use of drained cavity drain membrane systems as primary waterproofing systems and as secondary systems to integral waterproofing and sheet membrane installations.

This shift and the key points of the Outwing case Judgment were recognised and formally embodied in a revision of the relevant Code of Practice, BS8102:2009 Code of practice for protection of below ground structures from water from the ground.\(^8\)

**2009 Revision of BS8102 Code of Practice**

The Code of Practice not only led waterproofers towards drained cavity drain membrane systems (referred to in the Code as Type C systems) but – crucially – for the first time recognised a duty by designers and installers to take account of radon
- It is essential for any project involving below ground structures that strategies for dealing with groundwater, soil gases and contaminants are considered from the very earliest stages of the planning and design processes. (Section 4.1)
- The advice of a geotechnical specialist should be sought on the geology and hydrogeology... (Section 4.2)
- A desk study should be carried out to assess the geology and hydrogeology, including soil permeabilities, flood risk, radon and other ground gases and contaminants (Section 5.1.1a)
- A risk assessment should be carried out......and should consider the effects of ......radon and other gases. (Section 5.1.2a)
- The insertion of a ground barrier for the prevention of radon and other ground gases from entering a structure should be considered in the design, choice of the materials and installation of any waterproofing system. (Section 6.5)
- It might be necessary [to ventilate the voids created behind the membrane] in certain circumstances, such as where there is a potential for radon or other ground gases to be present. In these circumstances, specialist advice should be sought during the design phase. (Section 10.2.3)

Figure (10): Extracts from BS8102:2009 relating to requirement to take address radon

Figure (11) Design flowchart from BS8102:2009
At this time, the waterproofing industry was made aware of an important published statement from Professor William Angell, Chair of the World Health Organisation Radon Project Prevention and Mitigation Group:

“WHO Radon Handbook emphasizes that indoors, radon is largely caused by the way homes are designed and built, and clarifies the long-term misconception that indoor radon is naturally occurring. Outdoor radon concentrations are naturally occurring but indoors, radon concentrations are profoundly influenced by the way homes are designed and built. The implications of this clarification are that it places clear responsibility for radon control on:

- Architects and designers
- Builders
- Building Code Officials
- Real Estate Agents etc” (Angell, 2009)

The Conflict Between Type C Waterproofing and Radon Management

By 2009, drained cavity drain membrane systems had become recognised as the ‘best practice’ form of waterproofing and the first choice of designers and installers. For good radon management this presented a problem. The very nature of the dimpled membranes is based upon what manufacturers describe as ‘air gap technology’. An air gap is created between the raised studs or dimples on the rear side of the membrane so that water can depressurise after passage through the wall and is guided by the membrane to fall to the drainage channel at the base. Typically an 8mm stud height membrane will have an air space of 4 litres/m² and a 20mm stud will have an air space of 14 litres/m². Volumes will vary slightly between manufacturers and membrane types according to stud diameter, shape and density.

Type C waterproofing lines the walls, floors and, in vaulted situations ceilings, to form in effect a ‘room within a room’ which has a cavity between the lining and the soil that provides a pathway for radon. Within the basement, indoor pressure can be expected to be lower than soil air pressure and outside air pressure (McHugh et al, 2006). Cavity drain membrane systems are water management systems. They are not designed to behave as perfect waterproof membrane/barriers. They are favoured positively because they do not require perfection. The basement when put into use will generate a significant ‘stack effect’ (Crump et al, 2005).

In consequence, basements waterproofed with a drained cavity drain membrane system are effectively large radon collection sumps which serve at worst as living or work spaces, or at least as collection points from which radon can be despatched into accommodation above the basement.

Cavity drain membranes are not intended to be airtight and it would be difficult to make them so due to their weight relative to the size and population density of fixings, thermal movement in the membrane sheets as well as movements in the various substrates. These factors can cause installations to ‘relax’ over time. Such relaxation will not normally have any adverse effect on the waterproofing performance but render it impractical to convert these systems into gas barriers. In parts of Europe their use for this purpose is
discouraged. For example, “According to the Czech technical standard ČSN 73 0601 it is not allowed to use plastic membranes with dimples for radon barriers, because it is nearly impossible to provide airtight joints between membranes” (Jiranek, 2006).

The Solution

The conflict between good waterproofing and poor radon management was resolved by addressing and managing the pressure relationships.

A standard Type C system is installed but with an attempt to seal joints as far as possible including sealing the condensate trickle gap on the drain profile upstand. These actions will reduce the demand on subsequent positive air pressure that is introduced and which will also have the incidental benefit of mitigating condensation. Sealing the head of membranes that are wall mounted with a flat soffit at the top will avoid radon from behind the membrane being displaced to the accommodation above.

A positive pressure unit is installed within the accommodation with ducting drawing air from outside the building. The positive pressure unit should incorporate a heater facility to pre-warm the air to an ambient indoor level during the colder months. The purpose of the positive pressure unit is to create a higher pressure within the accommodation relative to the pressure behind the membrane and in the surrounding soil. This means that even if there are imperfections in the membrane, advection of radon should not occur into the habitable accommodation.

The area behind the membrane acts as a radon collection sump. At the time of installation of the system, provision should be made for the installation of an inline exhaust fan to draw radon from this area and evacuate it outside the building. Pipework leading from the air gap behind the membrane should be taken to a convenient location outside the building and capped off. Its purpose should be clearly labelled.

After the basement has been completed, radon testing should be carried out, both within the basement and the ground floor accommodation to ascertain whether an inline fan should be added to ‘activate’ the exhaust system. Where the air gap behind the membrane is not continuous, additional exhaust points will be required.
Case Study 1: Domestic Property in Oxfordshire, UK

The property is a Georgian three storey townhouse with two brick-vaulted basements. Initial radon testing carried out by NRPB (predecessor of the Health Protection Agency) showed radon concentrations of 2200 Bq/m$^3$ (≈59.5 pCi/L) in one of the basements and 29 Bq/m$^3$ (≈0.8 pCi/L) in the living room at ground floor level.

The system described above was installed within the basement vaults. Repeat radon testing was carried out after completion of the installation. The radon level within the basement had fallen to 8 Bq/m$^3$ (≈0.2 pCi/L) and the radon level in the living room above was 44 Bq/m$^3$ (≈1.2 pCi/L). Radon monitoring has continued, and some five years later the most recent testing has shown that the radon level in the basement is 21 Bq/m$^3$ (≈0.6 pCi/L) and 29 Bq/m$^3$ (≈0.8 pCi/L) in the living room above.

Case Study 2: Commercial Property, Kent, UK

The property is located in a “lower risk” area according to the indicative maps published by Health Protection Agency. As the workplace recreation area for employees is located within a basement, radon testing was carried out by the employer as part of their risk assessment obligation. The radon level in the basement was discovered to be 3001 Bq/m$^3$ (≈81.1 pCi/L). After installation of the components described in the methodology above, repeat radon testing was carried out and the radon level within the basement had fallen to 81 Bq/m$^3$ (≈2.2 pCi/L).
Case Study 3: Domestic Property, Somerset, UK

The property is a three storey Edwardian villa with a basement beneath part of the ground floor footprint. Upon purchasing the property, the owners carried out a radon test which revealed radon levels of 412 Bq/m$^3$ ($\approx$11.1 pCi/L) within the basement. After installation of the components described in the methodology above, repeat radon testing was carried out and the radon level within the basement had fallen to 104 Bq/m$^3$ ($\approx$2.8 pCi/L).

Conclusions

Basement usage in the UK is common as living and work space. Basements are susceptible to the accumulation of elevated levels of radon which presents a serious health risk. The Code of Practice for basement waterproofing requires designers and installers to take account of radon. Those who fail to do so may find themselves adjudged at fault and responsible for any consequences.

The process of combined waterproofing and radon gas management described in this paper has been shown to be effective and takes account of the crucial principles in that perfect workmanship in membrane installation is not essential and that all elements of the process can be accessed for repair and maintenance.

Best practice waterproofing in the UK can be successfully combined with effective radon management. There are more than 300 specialist waterproofing contractors in the UK, few of whom have knowledge of or competence in radon management or who offer radon management as part of their waterproofing. The recently formed UK Radon Association has created a category of membership together with suitable training to overcome this important gap in knowledge and skill.
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THE EFFECT OF RAIN AND HVAC SETTING ON RADON LEVELS IN A HOME

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Abstract

This study sought to determine the effect of environmental conditions on radon levels in a home. The two independent variables in the experiment were (1) whether or not it was raining and (2) whether the HVAC system on the main level of the home was set to “ON” for continuous ventilation or “AUTO” for forced air only to maintain temperature. A recently calibrated Radalink AirCat® radon detector was placed in an unfinished basement of a three story house that had recently recorded concentrations at 4.0 pCi/l, the action threshold level. Based on the results it was concluded that an active ventilation system successfully reduces radon. For this particular house, it was also concluded that the presence of rain increases radon concentration levels. The absence of requirements for engineered ventilation in our residential building codes misses the opportunity to achieve safer levels. Accordingly, regulatory measures are recommended for new residential construction.

Introduction

Radon penetrates homes through walls, floors, foundations, and pipes. Radon is the second leading cause of lung cancer, causing 21,000 deaths per year in the United States and many professionals estimate that a reduction of levels to below 2.0 pCi/L nationwide would likely reduce the annual lung cancer deaths attributed to radon by 50% (EPA, 2013). Therefore, even though radon concentrations below 4.0pCi/l are acceptable, for health considerations, lower radon exposure levels would be even safer.

Background

Many factors influence the laws governing radon levels in residential structures. Ensuring public safety is balanced with various financial considerations. For example, in home re-sale situations, the presence of high levels of radon during the inspection could either cost the seller significant radon mitigation costs or perhaps cancel the contractual offer. For new home sales, builders who expect testing below the 4.0 pCi/l threshold in a new neighborhood will unlikely employ mitigation techniques which could reduce radon levels even more. This misses the opportunity to make our homes even safer at a time during new construction when it is much less expensive to implement and less invasive to the homeowner.

One of the most fundamental factors affecting radon levels is the negative pressure differential of the air on the ground floor of a home relative to that of the underlying soil. Higher differentials result in more radon being pulled to the surface and into the home via the so-called “stack effect.” Various factors can influence this pressure differential and overall detected radon levels. Even within a given testing period, large fluctuations typically occur and are even expected.
During the course of a 24-hour cycle, homes often exhibit a characteristic signature of rising and lowering radon levels due to the diurnal environmental changes (Cohen, 1992). A minimum 48 hour testing period is required to produce certified results by averaging across at least two of these cycles. Uncontrollable environmental factors such as rain can impact the measurements (Gundersen, 1991). This study shows that the HVAC setting, which can be controlled by the homeowner, also impacts the measurements.

**Material and Procedures**

A three-story house in metropolitan Atlanta which had recently tested at the 4.0 pCi/l action level was identified and served as the subject for this study. Hovering directly on this threshold, changes in the environment could lead to the difference between passing and failing a radon test.

A recently calibrated, professional grade, Radalink AirCat® monitor was placed on a tripod and located in the unfinished basement of the three-story home as shown in Figure 1. This represents standard testing procedures since the lowest story of a home typically has the highest concentrations of radon.

![Figure (1): Experimental setup of Radalink AirCat® monitor located in basement of a three story house which had recently tested at the 4.0 pCi/l action level.](Photo by Pascal Acree)

The instructions and guidelines provided by Radalink were carefully followed to ensure proper technical usage of the AirCat® monitor. Each test was conducted for a minimum of 52 hours duration (4 hour equalization period + minimum of 2 full days of measurement) with results averaged over the full time period. For each testing period, the HVAC was either set to “ON” for continuous ventilation or “AUTO” for forced air only to maintain the temperature set on the thermostat. The weather conditions, HVAC settings, and other variables were logged from the beginning to the end of each test. The monitor automatically tracked time, radon concentration,
barometric pressure, temperature, and humidity. Normal house conditions were followed to test realistic living conditions, however door openings were kept to a minimum and windows were closed.

Results

A total of ten experiments were conducted under different conditions from mid-November 2013 until early January 2014. It was an unusually rainy autumn in the Atlanta area which helped populate a complete matrix of testing conditions. The HVAC setting and environmental factors observed throughout the testing period are noted in Table 1. Also shown are the average radon concentrations and atmospheric pressures measured over the full testing period of each experiment.

Table (1): HVAC settings and environmental conditions observed during the ten tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Start Date</th>
<th>End Date</th>
<th>Radon Level</th>
<th>HVAC Fan</th>
<th>Environment</th>
<th>% RH</th>
<th>Avg % RH</th>
<th>Pressure Range (InHg)</th>
<th>Avg Press (InHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/14/13</td>
<td>11/16/13</td>
<td>4.3</td>
<td>On</td>
<td>Intermittent rain both days</td>
<td>37-44</td>
<td>39</td>
<td>30.1-30.2</td>
<td>30.1</td>
</tr>
<tr>
<td>2</td>
<td>12/07/13</td>
<td>12/9/13</td>
<td>3.6</td>
<td>On</td>
<td>Rained throughout</td>
<td>43-47</td>
<td>46</td>
<td>30.0-30.2</td>
<td>30.1</td>
</tr>
<tr>
<td>3</td>
<td>12/09/13</td>
<td>12/12/13</td>
<td>4.0</td>
<td>Auto</td>
<td>Rain during first half of testing</td>
<td>40-47</td>
<td>43</td>
<td>29.9-30.3</td>
<td>30.2</td>
</tr>
<tr>
<td>4</td>
<td>12/12/13</td>
<td>12/15/13</td>
<td>4.7</td>
<td>Auto</td>
<td>Rain all 1st day / morning 2nd day</td>
<td>37-44</td>
<td>40</td>
<td>29.8-30.2</td>
<td>30.0</td>
</tr>
<tr>
<td>5</td>
<td>12/15/13</td>
<td>12/18/13</td>
<td>4.5</td>
<td>Auto</td>
<td>Sunny</td>
<td>37-40</td>
<td>40</td>
<td>30.0-30.2</td>
<td>30.1</td>
</tr>
<tr>
<td>6</td>
<td>12/18/13</td>
<td>12/20/13</td>
<td>3.6</td>
<td>On</td>
<td>Sunny/party cloudy both days</td>
<td>37-40</td>
<td>38</td>
<td>30.1-30.2</td>
<td>30.1</td>
</tr>
<tr>
<td>7</td>
<td>12/20/13</td>
<td>12/23/13</td>
<td>6.9</td>
<td>On</td>
<td>Heavy Rain throughout test</td>
<td>40-47</td>
<td>44</td>
<td>29.9-30.1</td>
<td>30.0</td>
</tr>
<tr>
<td>8</td>
<td>12/24/13</td>
<td>12/27/13</td>
<td>4.1</td>
<td>Auto</td>
<td>Sunny, test began after a big rain</td>
<td>37-40</td>
<td>38</td>
<td>30.1-30.3</td>
<td>30.2</td>
</tr>
<tr>
<td>9</td>
<td>12/27/13</td>
<td>12/29/13</td>
<td>3.7</td>
<td>On</td>
<td>Rained second half of testing</td>
<td>37-40</td>
<td>38</td>
<td>29.8-30.3</td>
<td>30.1</td>
</tr>
<tr>
<td>10</td>
<td>12/29/13</td>
<td>1/2/14</td>
<td>3.6</td>
<td>On</td>
<td>Cloudy - rain only last few hours</td>
<td>37-44</td>
<td>40</td>
<td>29.8-30.1</td>
<td>30.1</td>
</tr>
</tbody>
</table>

Figure 2 shows an example of the graphical output for Test #10. Even though the detected radon level often rose above the action level of 4.0 pCi/l (red line), the average across the entire testing period was only 3.6 pCi/l (green line) resulting in an overall passing score. Also, the general tendency was for the radon levels to be lower during the time period in the middle of the graph when the barometric pressure (bottom plot) was higher.
Figure (2): Graphics provided by Radalink for Test #10 showing a passing score of 3.6 pCi/l

Figure 3 shows the opposite extreme for a radon test conducted on the same house which failed. Heavy rain storms were noted during the full testing period and only one data point was collected below the 4.0 pCi/l level (red line). The barometric pressure in the basement dropped after the beginning of the test and this corresponded to a rise in radon later in the test. The average of 6.9 pCi/l level (green line) is well above the 3.6 pCi/l level for the testing shown in Figure 2. The HVAC setting was “ON” for continuous operation during both of these tests, so the large variance is attributed to the extreme difference in weather conditions.

Figure (3): Graphics provided by Radalink for Test #7 showing a failing score of 6.9 pCi/l

Table 2 summarizes the official results certified by Radalink. The tests are categorized by the HVAC setting (“AUTO” or “ON”) and weather (“Rain” or “No Rain”) for direct data analysis and interpretation. Tests which had rain for only a small fraction of the testing period were designated as “No Rain.” To further facilitate interpretation, the results are sub-categorized into “PASS” and “FAIL” by comparing the average radon level of each test to the 4.0 pCi/l action
level. The average barometric pressure recorded for each test (in inches of mercury, InHg) is also included so that its influence and general correlation toward overall results can be deduced.

Table (2): Summary of test results

<table>
<thead>
<tr>
<th>HVAC &quot;AUTO&quot; (pCi/l, InHg)</th>
<th>HVAC &quot;ON&quot; (pCi/l, InHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PASS</strong></td>
<td><strong>FAIL</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>No Rain</td>
<td>Test #5: (4.5/30.1)</td>
</tr>
<tr>
<td></td>
<td>Test #8: (4.1/30.2)</td>
</tr>
<tr>
<td>Rain</td>
<td>Test #6: (3.6/30.1)</td>
</tr>
<tr>
<td></td>
<td>Test #10: (3.6/30.1)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain</td>
<td>Test #3: (4.0/30.2)</td>
</tr>
<tr>
<td></td>
<td>Test #4: (4.7/30.0)</td>
</tr>
<tr>
<td></td>
<td>Test #2: (3.6/30.1)</td>
</tr>
<tr>
<td></td>
<td>Test #9: (3.7/30.1)</td>
</tr>
<tr>
<td></td>
<td>Test #1: (4.3/30.1)</td>
</tr>
<tr>
<td></td>
<td>Test #7: (6.9/30.0)</td>
</tr>
</tbody>
</table>

Analyzing the data in the convenient format of this table provides direct interpretation. For this house, which had initially measured at the borderline 4.0pCi/l action level:

- with the HVAC set to “AUTO” the radon test was always a “FAIL”
- with the HVAC set to “ON” and “No Rain” the radon test always a “PASS”
- with the HVAC set to “ON” and “Rain” the radon test passed half the time
- within each category, lower barometric pressures tended toward higher radon levels

**Conclusions**

Rainier days resulted in higher radon levels, as they were accompanied by lower barometric pressure as measured in the basement. The higher pressure in the ground relative to the lower pressure in the basement caused the radon gas to seep upward from the soil and into the house through the concrete slab of the basement. On clearer days, however, the higher pressure in the basement resulted in less radon infiltrating the house as evidenced by the lower detected levels.

When the HVAC system was turned to the “ON” position, the detected radon levels were noticeably lower than the “AUTO” position since there was more air ventilation and circulation between the basement and the other stories of the house as well as its exterior.

It has been shown that severe weather conditions can result in testing results almost double those observed during other tests. While a single test needs to be averaged over a minimum of 48 hours to count as an official result, any random two-day period is not representative of the radon levels in the home during all weather and ventilation conditions. Therefore, a more conservative government standard should be set if it is serve as the litmus test that a single result is to be compared against.
Recommendations

The absence of requirements for engineered ventilation in our residential building codes misses the opportunity to reduce radon levels in new homes. This study shows that even the most standard ventilation provided by an HVAC system can reduce levels. The impact of radon is statistical and improvements can continue to be gained at levels below the current 4.0 pCi/l action level. For example, values of 2.0 pCi/l will likely reduce the yearly lung cancer deaths attributed to radon by 50%. Thus, the lower the level the better. Even the World Health Organization (WHO) recommends action levels at 2.7 pCi/l (100Bq/m3 in their units) (Zeeb, 2009). Rather than failing to meet this recommendation, the United States should exceed these standards and lead by example to improve overall air quality and reduce health risks.

Additionally, with radon recognized as the second leading cause of lung cancer, regulatory measures are recommended to include engineered ventilation for new residential construction to reduce levels even further. During construction, mitigation techniques are easier to implement, more cost effective, and less invasive to future homeowners.

Acknowledgements

Many thanks to Mr. Terry Howell and his staff at Radalink for donating an AirCat® monitor, product training, and certified processed data reporting, to support this research.
References


PUBLIC HEALTH POLICY FOR TESTING OF RADON IN MONTANA SCHOOLS

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Abstract

Radon as a human carcinogen has been clearly documented and children are an especially vulnerable population due to biophysical characteristics and duration of exposure. An investigation was necessary to determine if health policies exist to protect school children from radon exposure. This study inventoried the states with regulations regarding school radon testing. Nine states, eight with high geographic risk, have school testing policies. The implication of the policy inventory is that 28 high-radon states do not have policies in place to protect school children from radon. The need for well written policy is evident and as states consider public health initiatives, radon testing in schools should be included in that discussion. The authors drafted a public health policy governing testing of radon in Montana schools based on the best practices included in the nine states. The study authors recommend working with the state attorneys general and nursing organizations to adopt the policy.

Introduction

Based on a nationwide survey, the Environmental Protection Agency (EPA) estimated that children in more than 70,000 classrooms nationwide are at risk for radon exposure with one in five classrooms in use above the recommended action level (2010). Next to smoking, radon exposure is the leading cause of lung cancer (NCI, 2011) and is a known human carcinogen (NTP, 2011; NCI, 2011; ATSDR, 2013; EPA, 2013). Dr. Bill Field, one of the foremost experts on radon, stated that of all the environmental exposures, radon is the one that causes the most deaths (Rossen Reports, 2012). Field compared a student’s exposure to radon, even at the EPA’s action level, 4 pCi/L, as equivalent to smoking half a pack of cigarettes per day (Rossen Reports, 2012). Children are a vulnerable population that are at increased risk for negative effects of radon exposure because of their increased respiratory rate, increased contact with the ground and greater cell division with growth (Hill, Butterfield, & Larsson, 2006; Dunn, Burns, & Sattler, 2003; Schneider & Freeman, 2000).

Radon is dangerous when it seeps into enclosed buildings and is inhaled by human occupants. Prolonged radon exposure is harmful to the lungs and may cause cancer. The mechanism of radon exposure and subsequent “cellular damage is not from radon gas itself, which is removed from the lungs by exhalation, but from radon's short-lived decay products” (University of Minnesota, 2013, “Specific genetic damage caused by radon”). Once inhaled, the alpha particles from radon decay products are deposited in the airways and lungs and continue to emit more alpha particles as the decay progeny are broken down further. Alpha particles are massive and highly charged, ultimately lodging
themselves into the airways. Over time, the alpha particles break down the nucleus of the healthy lung tissue causing transformations, mutations, and displacements of cellular growth (University of Minnesota, 2013).

Cancer is a consequence of long term, low dose indoor exposure (EPA, 2013). The effects of radon are cumulative; therefore assessing lifetime radon exposures in the places where we live, work, and study is indicated. Because school children spend the majority of their time in a school building, the primary aim of this research was to determine if there are protective health policies in place to ensure safe school buildings that are free from long term radon exposure.

During an interview with Mr. Darrick Turner of the Montana Department of Environmental Quality, Mr. Turner explained that Montana does not have a school radon testing policy. He stated, “There is little oversight of institutions” and that “if schools do test, the results stay internal.” Turner also stated that it is a “foregone conclusion that school children are exposed” but he hopes that schools are “well vented because of all the doors opening and closing” (personal communication, December 2012).

Mr. Kevin Barre, the maintenance manager of the Bozeman School District stated he did test for radon in the school. During an interview, Mr. Barre stated “it was a personal decision in response to Montana State University recently receiving grants for radon education” that influenced his decision to test. “[He] figured people would be asking if they [Bozeman public schools] tested, and rather than not know, [he] decided to test. There was no policy that mandated the testing” and Mr. Barre felt that it was the “individual school policy to provide safe facilities for kids”, although nothing specific about radon is written in the policy (personal communication, December 2012).

**Statement of the Problem**

Radon has been clearly documented as a human carcinogen (NTP, 2011; NCI, 2011; ATSDR, 2013; EPA, 2013). Radon is the second leading cause of lung cancer after smoking (NCI, 2011) and is found in every state in the U.S. (DEQ, 2013). As Hill, Butterfield, and Larsson (2006) have stated, children are a vulnerable population with consideration to radon exposure due to biophysical characteristics and duration and levels of exposure over time. As a nation responsible for its vulnerable youth, further investigation is necessary to determine if health policies exist to protect school children from this known carcinogen.

**Purpose of the Study**

The purposes of this study were three-fold: 1) to inventory and analyze the regulatory policies addressing indoor radon exposure in public buildings, 2) to compare and contrast existing policies for protecting school children from radon exposure, and 3) to prepare a best practice policy for presentation to the Montana State Attorney General and to state nursing organizations.
Research Questions

1. What are the current policies for administrative, constitutional, and statutory laws for testing radon in public schools in the U.S?
2. What is the best practice for testing radon in public schools based on current policies?

Radon in Montana

Few (12.5%) of Montana’s counties are considered zone two as indicated by yellow on Figure (1), meaning they have a predicted average indoor radon screening level between 2 and 4 pCi/L. The remaining (87.5%) Montana counties are zone one (indicated by red on Figure 1), indicating that they have a predicted average indoor radon screening level greater than 4 pCi/L (DEQ, 2013). None of Montana counties are in zone three.

Mike Vogel, Montana State University Extension housing specialist, conducted a study for the Montana Department of Environmental Quality, in cooperation with the American Lung Association of Montana, which found that, “virtually all Montana counties with over 150 tests had between 28 and 65 percent of those tests show more radon than the EPA action level” (1997). The national average indoor radon level is 1.3 pCi/L, but in Montana the average is 5.9 pCi/L (Vogel, 2013). These findings support the EPA zone designations.

Per a review of the literature using Lexis Nexis database, Montana does not have a federal, state, or local mandate that regulates the testing of radon in public school buildings. Assessment of the absence of a school radon policy in combination with the current radon risk environment in Montana indicates a need for protective policy.

Figure (1): Montana County Radon Map. Image retrieved from EPA (2012).

Montana Schools

Based on the review of literature, it can be concluded that there are geographical risks of living in Montana in terms of lung cancer related to radon exposure (Vogel, 1997; Vogel,
Additionally, numerous studies correlate duration, level of radon and risk of lung cancer (EPA, 1993; Field, 2001; Field et al., 2000). Hill, Butterfield, and Larsson (2006, p.392-392) documented that “children possess different physiologic, behavioral, and biologic capacities than adults; health risks resulting from exposure may be more severe (Dunn, Burns, & Sattler, 2003). Although children share the same routes of exposure with adults, children are at a distinct disadvantage for health consequences from environmental exposures (Schneider & Freeman, 2000). When adjusted for size, children have a greater body surface area, breathe more air, consume more food and fluids, and metabolize toxins differently than adults”. Based on this information, one can posit that Montana children who sit in classrooms above the EPA recommended action level for an average of thirteen years are at an increased risk of developing radon exposure related lung cancer.

**Current Recommendations for Radon Testing and Mitigation in Schools**

The Environmental Protection Agency has developed recommendations for radon testing and mitigation in schools (1993). The EPA (1993, p.4) stated that for “most school children and staff, the second largest contributor to their radon exposure is likely to be their school. As a result, EPA recommends that school buildings as well as homes be tested for radon. EPA recommends reducing the concentration of radon in the air within a school building to below EPA's radon action level of 4 pCi/L. EPA believes that any radon exposure carries some risk - no level of radon is safe. Even radon levels below 4 pCi/L pose some risk, and the risk of lung cancer can be reduced by lowering radon levels. This action level is based largely on the ability of current technologies to reduce elevated radon levels below 4 pCi/L.”

Testing with certified devices is the only way to determine whether or not the radon concentration is below the action level. Measuring levels of radon gas in schools is a relatively easy and inexpensive process compared to many other important building upkeep activities (EPA, 1993). Because radon levels in schools have been found to vary significantly from room to room, schools should test all frequently occupied rooms in contact with the ground such as cafeterias, gymnasiums, staff lounge, and classrooms.

Testing should be completed at a time when the air handling system is at normal school-hour settings to prevent false positive results. If a room is found to have a level of 4 pCi/L or greater, this measurement result should be confirmed with another test. If the second test is also at or above 4 pCi/L, schools should take action to reduce the radon level to below 4 pCi/L (EPA, 1993).

**Public Health Policy**

Public health policies influence entire populations rather than individuals in terms of health prevention and promotion interventions as defined by the Association of Schools of Public Health (2013). The University of Kansas has created a Community Tool Box (2013) to guide in the creation of public health policies. The Community Tool Box
(University of Kansas, 2013) consists of thirteen steps for effective policy development, of which the most appropriate were utilized in the proposed policy recommendations. In addition to The Community Tool Box (University of Kansas, 2013), the Multiple Exposures Multiple Effects (MEME) model (World Health Organization, 2013) was influential as a theoretical framework in the best practices recommendation for policy development based on its components of contextual conditions such as social, political, economic or demographic factors.

**Advocacy Methods**

Successful implementation of public health policy is best achieved through the use of advocacy methods. One advocacy method that is an “unrecognized political force” is the state attorneys general (Rutkow & Teret, 2010). State attorneys general are frequently called upon to give advice to the governor and administrative agencies and give an “issuance of opinions”, which can impact policy and promote change (Rutkow & Teret, 2010, p.8). State attorneys generals utilize “press releases, interviews, and press conferences” to engage in advocacy. State attorneys generals can also “raise awareness about topics by using his or her ability to convene individuals (Rutkow & Teret, 2010, p.9). Rutkow and Teret (2010) documented the increasing support over the past two decades that state attorneys general have provided to health care through policy reform work. An example of their supportive role is the 1998 Master Settlement Agreement against the tobacco industry (Rutkow & Teret, 2010).

Another advocacy method is the grassroots method. Grassroots advocacy encourages the public to advocate for themselves and the “value of this form of advocacy is that it is driven by the people” (Hall, 2010, p.1). Hall (2010) stated that grassroots advocacy is “grounded in the belief that people matter and that their collective voices are powerful in shaping policy” (p.1).

**Methods**

The purpose of this research was three-fold: 1) to inventory and analyze the regulatory policies addressing indoor radon exposure in public buildings, 2) to compare and contrast the policies for protecting school children from radon exposure, and 3) to recommend a best practice policy for presentation to the Montana State Attorney General and state nursing organizations. Keeping the purposes in mind, the specific aims of this project were:
1. Inventory the current policies for administrative, constitutional, and statutory laws for testing radon in public schools in the U.S.
2. Identify the best practice for testing radon in public schools based on current policies.

**Theoretical Framework**

The World Health Organization Multiple Exposures Multiple Effects (MEME) model was used as the theoretical framework for this research. This model is very useful to guide the conceptual framework for this project because it is based on the collection and
use of children’s environmental health indicators. The MEME model as shown in Figure (2), provided a concise and research-based framework to justify the policy inventory of radon testing in schools and subsequent policy recommendations (action) for school children’s (context) exposure to radon (exposure) and the subsequent potential for lung cancer development (health outcome).

![Figure (2): MEME Model. (World Health Organization, 2013).](image)

**Design**

This research served to describe the current policy environment in the United States in terms of radon testing in public schools. A policy inventory was conducted using LexisNexis Academic of each state in the U.S. for statutory, administrative, or constitutional statutes, codes, and regulations concerning radon. A search criterion was that the policy had to have at least five occurrences of the word radon to filter out policies where radon was incidental. Results were organized into categories separating policies governing radon professionals from those that directly addressed indoor air quality for vulnerable populations—in this case school children.
Procedure

Those states that had a policy in place in relation to school children were then reviewed in detail further utilizing the LexisNexis Academic database. Each of the statutes, codes, or regulations was examined in detail and a comparison chart was developed for analysis of best practices. Additionally, a data analysis plan was created by organizing each state by the presence or absence of a policy for radon testing in schools and by degree of risk based on the EPA’s zone designation. These categories were then used to determine a best practices policy proposal for testing radon in Montana schools.

Results

The results of the policy inventory utilizing LexisNexis Academic were that states ranged from zero to 53 radon policies across 10 categories. Results were sorted for those specific to children and schools which revealed nine states that had state laws mandating radon testing in public schools. No federal mandates or local policies that required radon testing in schools were found. See Table (1) for a concise summary of the findings detailed below. The analysis demonstrated that 36 states had greater than 50% of counties in zones one and two (moderate to high risk for radon exposure) but only eight of those states had health policies for testing radon in schools.

Details of Inventory Findings

Colorado

Colorado (6 CCR 10-102 1991) mandates that each school should have completed radon tests per EPA guidelines by March 1, 1991. Mitigation and retesting are per EPA guidelines as stated in the EPA’s Radon Measurements in Schools, Revised Edition (1993). Any schools constructed after 1991 should have the radon tests completed within 19 months of the date of occupancy. Colorado schools that were remodeled after 1991 shall notify the state department of the remodeling so that the department can assess for the need for any additional radon testing. The results of the radon testing should be on file at each school and available for review.

Connecticut

Connecticut has a General Statute 10-220d Duties of boards of education (2004) that requires radon testing prior to January 1, 2008 and every five years thereafter for every school building that is or has been constructed, extended, renovated, or replaced after January 1, 2003. The statute asks that the local or regional board of education determines their own inspection and evaluation program of indoor air quality and gives the EPA’s Indoor Air Quality Tools for Schools Program (EPA, 2010) as an example. The Connecticut rules not only mandate the testing of radon levels but also other indoor air quality potential hazards. The statute mandates that the boards of education make the results available for the public to review at a board of education meeting or on the school’s web site. Connecticut also mandates regulating the testing of radon in child day care centers or group day care homes unless the facility is subject to the regulations of
General Statute 10-220 Duties of boards of education (2004). Connecticut State agency policy 19a-79-7a Child day care centers and group day care homes (2008) states that if the center uses the basement level or first floor of the building, a minimum of one radon test should be conducted by a services listed by the National Radon Proficiency Program and approved by the department. The test should be completed during the months of November to April and the results posted with the license. The Department of Public Health should be notified of results. If the samples of radon gas in the air are equal or greater than 4.0 pCi/L, mitigation should follow by a qualified residential mitigation service provider.

**Florida**

Per Florida Statute 64E-5.1208 Measurement requirements and procedures (1996) rules, the Department of Health mandates radon testing of all public and private school buildings, all state owned, state operated, state regulated, or state licensed 24-hour care facilities, and all state licensed day care centers for minors which are located in counties designed within the Department of Business and Professional Regulation’s Florida Radon Protection Map Categories as “intermediate” or “elevated radon potential”. The statute dictates that all initial measurements be conducted in twenty percent of the habitable first floor spaces and reported within one year of license approval. A second follow up test must be completed in five percent of habitable first floor space within five years of occupancy and all results reported by the sixth year of occupancy. No further testing is necessary unless significant structural changes occur. The Mandatory Radon Measurement Protocols provided by the Florida Department of Health (2010), is utilized to guide testing, mitigation, and retesting.

**Iowa**

Iowa requires by State Statute 109.11 Child care centers (2013) that facilities provide sufficient ventilation to maintain adequate indoor air quality. Adequate indoor air quality is assessed by radon testing performed as prescribed by the Iowa Department of Public Health (2014) at 641--Chapter 43. The testing should be completed within one year of being issued an initial or renewal license for centers that operate in facilities that are at ground level, use a basement area as program space, or have a basement beneath the program area. The statute states that testing shall be required if test kits are available from the local health department or the Iowa Radon Coalition. If the test demonstrates elevated radon levels above 4pCi/L, a plan using radon mitigation procedures established by the state department of public health shall be developed with and approved prior to a full license being issued.

**Illinois**

The Illinois Statute 105 ILCS 5/10-20.48 Radon testing (2010) recommends that every occupied school building be tested every five years for radon based on the rules established by the Illinois Emergency Management Agency (IEMA). Any new schools should be built using radon resistant new construction techniques as described by the
EPA document, Radon Prevention in the Design and Construction of Schools and Other Large Building (EPA, 1994). Illinois states that each school district may maintain, make available for review, and notify parents and faculty of test results. The school district shall also report radon results to the State Board of Education, which shall then prepare a report every two years from all the schools to be submitted to the General Assembly and the Governor. The IEMA regulates who can be exempt from being required to be a license radon professional for the testing, but dictates that the school district can have specified employees attend an IEMA approved Internet based training course on school radon testing. Any test kit can be used as long as it is provided by a laboratory licensed in accordance with the Radon Industry Licensing Act. If results of the radon testing are at or above 4 pCi/L the school district should hire a licensed radon professional to repeat the measurements before any mitigation decisions are made. If the levels are still 4 pCi/L or above after retest, mitigation should be performed by a licensed radon mitigation professional as designated by IEMA.

Illinois also regulates the radon testing of licensed day care centers, license day care homes, and licensed group day care homes by 225 ILCS 10/5.8. This statute states that these buildings must test once every three years after January 1, 2013 per rules established by the Illinois Emergency Management Agency and that effective January 1, 2014 testing will be required as part of the initial licensing and renewal licensing. The report of the most recent testing shall be posted in the facility next to the license and copies provided to parents upon request. The facility must also include with the report the following statement: “Every parent or guardian is notified that this facility has performed radon measurements to ensure the health and safety of the occupants. The Illinois Emergency Management Agency (IEMA) recommends that all residential homes be tested and that corrective actions be taken at levels equal to or greater than 4.0 pCi/L. Radon is a Class A human carcinogen, the leading cause of lung cancer in non-smokers, and the second leading cause of lung cancer overall” (105 ILCS 5/10-20.48, 2010).

**New Jersey**

New Jersey State Statute 18A:20-40 Testing for radon in public school building (2000) states that every public school building should be tested for radon at least once every five years. The Commissioner of Education, in consultation with the Department of Environmental Protection, shall determine the extent of testing and the locations for the testing. The superintendent of each school district, in consultation with the Department of Environmental Protection and the principal of each school, shall determine based on guidelines found in the New Jersey Department of Environmental Protection School Radon Testing Program (2004) to determine the buildings tested, the locations within each building, the method of testing, and the procedures concerning notification and circulation of testing results.

New Jersey also states that buildings in which child care centers are located must be tested at least once every five years and within 30 days of the completion of the testing procedures must post the results of the test and any measures taken or proposed to
mitigate the presence of radon gas at a location within the building that is readily visible to persons having responsibility for any child that attends the child care center.

**Rhode Island**

Rhode Island State Statute CRIR 14-000-011 School health programs (2009) mandates that all schools be tested for radon based on the Rules and Regulations for Radon Control (State of Rhode Island and Providence Plantations Department of Health, 2007). Measurements should be taken by a certified radon measurement consultant and with acceptable measurement devices and analyzed by certified laboratories. Short term testing should be taken during the months of October through March for a minimum of 48 hours in closed building conditions. Results of initial short term testing should be reported to the Department of Health within 30 days. Follow up measurements shall be required when short term measurements are greater than or equal to 4 pCi/L. Mitigation systems shall be installed in buildings that have radon levels of pCi/L or greater on annual average and shall only be installed by individual licensed as radon mitigation specialists. Post mitigation measurements shall be taken by a certified measurement consultant to ensure the effectiveness of the mitigation system. It is the responsibility of each local fire chief, local building inspector, the Director of the state Department of Health and the Director of the state Labor and Training Department to notify each school superintendent by August 1 of each year as to whether the school buildings conform to state and federal laws and regulations.

Rhode Island CRIR 03-000-018 Family child care home regulations for licensure (2009) implemented in 2013 that any family child care home provider is required to provide documentation that the home has been tested for radon and found safe for the renewal of license. Retesting shall be done every three years in accordance with the Rules and Regulations for Radon Control issued by the Rhode Island Department of Health.

**Virginia**

Virginia State Statute 22.1-138 Minimum standards for public school buildings (1993) mandates that by July 1, 1994 all school buildings in the Commonwealth should be tested for radon per procedures established by the EPA (1993) for radon measurement in schools. Each school should maintain files of the results and make these files available for review. The superintendent should report radon test results to the Department of Health.

**West Virginia**

West Virginia State Statute 18-9E-3 Air quality in new schools (1998) states that radon testing should be performed by the division of health on every new public school building within the first year after occupancy and at least every five years thereafter. The testing should include all major student occupied areas at or below ground level and if radon is present in amounts greater than the amount determined acceptable by the rules of the
School Building Authority, any industry accepted mitigation technique shall be used to mitigate as determined by the School Building Authority.

<table>
<thead>
<tr>
<th>State</th>
<th>Policy</th>
<th>Testing and Retesting</th>
<th>Mitigation Protocol</th>
<th>Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>CCR 10-102</td>
<td>Within 19 mo.; if remodeled</td>
<td>Per EPA (1993)</td>
<td>OF</td>
</tr>
<tr>
<td>Connecticut</td>
<td>10-220</td>
<td>Every 5 yrs; if remodeled</td>
<td>Per EPA (2010)</td>
<td>Present results at board of education meeting or school’s website</td>
</tr>
<tr>
<td>Florida</td>
<td>64E-5.1208</td>
<td>Within 1yr; Every 5yrs and if remodeled</td>
<td>Per Mandatory Radon Measurement Protocols</td>
<td>SHD</td>
</tr>
<tr>
<td>Iowa</td>
<td>109.11</td>
<td>Within 1yr; Every 2 yrs.</td>
<td>SHD</td>
<td>State licensing regulatory agency</td>
</tr>
<tr>
<td>Illinois</td>
<td>105 ILCS 5/10-20.48</td>
<td>Every 5 yrs</td>
<td>ILEMA</td>
<td>OF, LH, LF, SBOE</td>
</tr>
<tr>
<td>New Jersey</td>
<td>18A:20-40</td>
<td>Every 5 yrs</td>
<td>SD, DEP and principal shall determine testing and circulation plan</td>
<td></td>
</tr>
<tr>
<td>Rhode Island</td>
<td>CRIR 14-000-011</td>
<td>SHD Oct through March for 48 hrs; retest after mitigation</td>
<td>SHD</td>
<td>SHD</td>
</tr>
<tr>
<td>West Virginia</td>
<td>18-9E-3</td>
<td>Within 1 yr; Every 5 yrs</td>
<td>Per School Building Authority</td>
<td>SD, HD</td>
</tr>
</tbody>
</table>

Mo. = month, OF = on file at school, OD = on display, SD = copy to school district, HD = copy to health department, LH = letter home, LF = letter to faculty, DEP = Department of Environmental Protection, ILEMA = Illinois Emergency Management Agency, SHD = State Health Department, SBOE = State Board of Education

Table (1): Summary of State Mandated Policies to Prevent School Children’s Exposure to Indoor Radon Gas.
To summarize, the primary purpose of this research study was to inventory and analyze the regulatory policies addressing indoor radon exposure in public buildings. Table (2) provides a list of each state and the percentage of counties within each state categorized by EPA zone designation. The figure documents risk in terms of *more or less* in order to emphasize risk for radon exposure potential. The comparative analysis demonstrated that 36 states had greater than 50% of counties in zones one and two (moderate to high risk for radon exposure) but only eight (indicated by italics) of those states had health policies for testing radon in schools. The most important result is that 28 states with more than 50% of their counties designated as zone one by the EPA have no state policy in place to test the indoor air of public schools for radon.

<table>
<thead>
<tr>
<th>State</th>
<th>% Zone 1</th>
<th>% Zone 2</th>
<th>% Zone 3</th>
<th>Law Present/Absent</th>
<th>Risk</th>
<th>Sum of Zone 1 &amp; 2</th>
</tr>
</thead>
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<tr>
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<tr>
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<tr>
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<tr>
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</tbody>
</table>
The art of crafting a well written policy is underscored in the findings from this research where the inventoried policies shared few elements in common. There are currently very few states with a comprehensive set of public health policies to protect school children from radon exposure. The MEME model utilized to guide this project indicated the need for action based on identified environmental exposures and subsequent health outcomes (World Health Organization, 2013). A discussion of policy gaps for the highest risk students as well as recommendations for a policy for the state of Montana are included in this section.

**Discussion**

<table>
<thead>
<tr>
<th>State</th>
<th>% Zone 1</th>
<th>% Zone 2</th>
<th>% Zone 3</th>
<th>Law Present/Absent</th>
<th>Risk</th>
<th>Sum of Zone 1 &amp; 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>KS</td>
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<td>38.1</td>
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<td>More</td>
<td>100</td>
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<tr>
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<td>1</td>
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<td>ME</td>
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<td>0</td>
<td>0</td>
<td>More</td>
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</tr>
<tr>
<td>MN</td>
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<td>21.8</td>
<td>0</td>
<td>0</td>
<td>More</td>
<td>100</td>
</tr>
</tbody>
</table>

*Note: Italics indicates policy.*

Table (2): EPA Radon Risk Designation.
Regulatory Policies

The first two purposes of this project focused on inventorying the regulatory policies that addressed indoor radon exposure, specifically those for school children and then comparing and contrasting those policies. All of the states mandated testing initially after passage of the policy. Four of the policies stated to retest within five years and one state mandated retesting within two years, indicating that the majority of existing policies found value in retesting at frequent intervals although there was not a specific interval that was consistent to all of the policies. All of the policies mandated retesting post remodel which is indicative of a best practice.

Eight of the states had specific documents to guide radon testing in schools, in addition to the regulations found within the statute. EPA (1993; 2010) documents were cited as specific reference guides in three state policies and the other states had drafted their own document that provided concise rules and direction for testing and mitigation. It can be concluded based on review of existing policies that a separate document detailing the specifics of testing regulations would be a best practice to include in future policy making.

Eight of the nine states mandated reporting of the radon test results to an agency outside of the school itself including departments of health, boards of education, and state licensing agencies. All of the policies required keeping results of testing on file at the school and one policy required notifying parents of test results. It would be best practice for a future policy proposal to include reporting guidelines, including reporting to a state agency such as the State Board of Education or State Department of Health. Reporting to a state agency would allow for compilation of state testing results and regulation of future testing recommendations and policy adjustments based on specific state results.

A finding that would not be a best practice to implement in future policies would be New Jersey’s protocol in which the statute deems testing, retesting, and mitigation to be determined by a coordinated effort of the Commissioner of Education, Department of Environmental Protection, district superintendent, and the principal. Utilizing this practice of relying on a coordinated decision from four different groups could lead to inconsistency in testing and failure of prompt mitigation. It would not be recommended to follow New Jersey’s model for a radon policy.

An interesting finding of this project is that of the nine states that have policies, eight were designated high geographical risk by the EPA (2012) as shown in Appendix B. Florida was the exceptional case in which the EPA did not consider it a high geographical risk state but there is a state policy for testing radon in schools. A hypothesis generating statement could be made about the exceptional case of Florida that high geographical risk is not a perfect predictor of policy.
Recommendations for APRN Involvement

Based on the review of literature and results of this project policy inventory, the clinical implications for the APRN is that policy makers need to be made aware of the cumulative lifetime risks from radon as do parents and caregivers. The third purpose of this project was to prepare a policy for testing radon in Montana schools based on the best practices of existing policies. The policy proposal was written keeping in mind the advocacy methods discussed in the review of literature: utilizing state attorneys general and grassroots methods.

Rationale for targeting Montana State versus a local or federal approach is the ease of implementation and the widespread effect of the initiative. A federal policy is too large of a scale for the purposes of this study. In contrast, a local policy would not effectively achieve the goals of the study of proposing a public health policy that would protect Montana’s school children and teachers from the effects of radon exposure.

History supports the success of environmental health advocates in getting indoor smoking out of public buildings (Rutkow & Teret, 2010); therefore it is hopeful that the science implicating radon as a carcinogen makes a public health policy directing radon testing in schools plausible to policy makers. Health professionals such as APRN’s have the opportunity to improve environmental health and address the issue of radon exposure through strategic interactions with formal and informal community leaders (Milstead, 1999). This project identified the Montana State Attorney General as a formal community leader with a unique position at the crossroads between the state’s legislative, executive, and judicial branches (Rutkow & Teret, 2010; LeGreco & Canary, 2011) that would be a key stakeholder in the adoption of policy governing radon testing in Montana schools.

Rutkow and Teret (2010) suggested that a relationship between state attorney generals and the public health community could be mutually beneficial and that by sharing their own research and summarizing relevant work of others, APRN’s can “provide an evidence base that will drive state attorney generals to take action”. Rutkow and Teret (2010) recommended attending the National Association of Attorneys General meetings as a method to educate states attorneys about public health issues. State attorneys generals share information about their official efforts through a public information officer who is the liaison with the media. The public information officer “promotes the state attorney general advocacy efforts” (Rutkow & Teret, 2010) which could be helpful in pursuing the adoption of a state radon policy. “Additionally, public information officers disseminate pamphlets, reports, or other materials that a state attorney general creates for the public. In doing so, they promote a dynamic relationship between the state attorney general’s office and the individuals the state attorney general serves” (Rutkow & Teret, 2010) and can communicate information about radon health risks and testing recommendations to the public. Ultimately, the Montana State Attorney General could politically benefit from taking a public stance for protecting school children from a known carcinogen by advocating for a public health policy such as the one this project proposes.
The authors also recommend targeting a state audience utilizing the grassroots method. This is perhaps best accomplished by approaching specific boards that would be interested in public health policy and lobbying support at the legislative level. The Montana Association of School Nurses (MASN) and the Public Health Nurses Association of Montana are two boards that would be particularly interested in supporting this public health initiative. The purpose of the MASN is to "maintain, promote, and advance quality school health services and health education throughout the state" (Nursing Network, 2013). The Public Health Nurses Association of Montana stated purpose is to "promote united and dynamic public health nursing leadership, discover innovative solutions, and influence public health policy" (Montana Public Health Association, 2010). Spenceley et.al. (2006) regards advocacy at the policy level as an extension of the advocacy role that nurses provide for individual patients, which further implicates APRN and nurse involvement. Nurses are trained to make "decisions about the allocation of resources. It is only at the level of policy that problem definition, policy implementation, and resource allocation can be examined" (Coveney, 2008, p. 516). Spenceley et.al. (2006) supports that nurses have well developed professional organization infrastructure to support policy advocacy through dialogue and participation and challenges nurses to leverage that opportunity.

**Proposal to State Attorney General**

Analysis of the results indicates that 100% of Montana counties are in zones one or two, indicating a high and moderate risk potential for exposure to radon. Based on the policy inventory conducted, Montana currently does not have a law that regulates the testing of radon in Montana schools. Knowing that the risk for the development of lung cancer due to radon exposure increases over time (EPA, 1993; Field, 2001; Field et al., 2000) it reasonable to conclude that a public health policy for the testing and mitigation of radon be implemented for Montana schools.

Based on a review of the established state policies and the recommendations by the Environmental Protection Agency (1993), the recommendation is for Montana to adopt a public health policy utilizing best practices. Utilizing guidelines from The Community Toolbox (Kansas State University, 2013) and the MEME model (World Health Organization, 2013) as framework, the policy should include these components:

**Who:** All public schools in the state of Montana, including state licensed day cares and group homes. Testing should be completed by a professional with training on radon testing.

**Where:** Test all frequently used rooms on or below ground level.

**When to test:** Test all rooms simultaneously initially for at least 48 hours after the building has been closed for twelve hours, while the normal HVAC systems are running, in closed conditions, and during the months between October and March. If this initial test is at or above 4 pCi/L, follow up testing is necessary. If the level is significantly above action level, repeat a 48 hour test. If the radon level is at 4 pCi/L or only slightly
above action level, repeat test with a 90 day testing kit for a more inclusive average. Perform complete retesting of the building every five years or with any significant structural change.

Mitigation: For schools with test results 4 pCi/L or higher after the second follow up testing, consult a mitigation professional that is endorsed by the Department of Environmental Quality for assistance in mitigation decision making. Repeat 48 hour testing method after mitigation is complete to ensure effective intervention.

Reporting: Keep results on file at school for viewing. Additionally, send the results to the district and state superintendent for compilation in a summative report. Send letter home with child to parents with testing results and action plan. Include information in the letter about home radon testing.

**Limitations**

A limitation to this study is that policies may have been missed that were being written during this current legislative session. Another limitation to this study is that some schools may test for radon in the absence of a state policy, such as the Bozeman school district.

**Implications for the Future**

Implementation of a public health policy governing radon testing in schools has a strong potential for intervention in the community. In order to support the development of public policy for the testing and mitigation of radon in schools, it would be beneficial to understand the influence of the policy implementation on parent knowledge about radon exposure and subsequent home testing. Utilizing the practices as stated in the Illinois public policy (225 ILCS 10/5.8), Montana schools could send the results of radon testing and mitigation home to parents via the school children in the form of a letter that would include the following statement: “Every parent or guardian is notified that this facility has performed radon measurements to ensure the health and safety of the occupants. The Montana Department of Environmental Protection recommends that all residential homes be tested and that corrective actions be taken at levels equal to or greater than 4.0 pCi/L. Radon is a Class A human carcinogen, the leading cause of lung cancer in non-smokers, and the second leading cause of lung cancer overall”.

The letter should also include where home radon testing kits could be found and where additional information about radon could be obtained. The impact of this type of communication distribution has been noted in Rhode Island’s statute that the provision requiring results of school radon testing to be reported to parents was associated with an increase from 40% to 87% of mitigation in high level homes (State of Rhode Island Department of Health, 2013, “2012 Accomplishments and Milestones”).
References


RADON RISK AWARENESS AMONG UNIVERSITY EMPLOYEES OF OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE,

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Abstract

Radon is considered a significant contaminant that affects indoor air quality. However radon is only known to few people, and there is limited documented research on its health hazards in Nigeria. We therefore assessed the awareness of radon and its health risk among employees of Obafemi Awolowo University Ile-Ife, Nigeria. Academic and non-academic staff members from all the 13 faculties were recruited for the study. Based on the requisite sample size, a semi-structured questionnaire was administered to the staff of these faculties. Only 42% of respondents are aware of radon, among which 43.8% knew about radon health risk. There was a statistically significant association between level of knowledge and academic background (p=0.02) with 41% of staff with core science background having good knowledge compared to 19% and 12% of respondents from health science and social science background respectively. Poor awareness of radon and its health risk exists among University employee of OAU.

Introduction

Globally, radon is the second most important cause of lung cancer after smoking (WHO, 2009). The proportion of lung cancers attributable to radon is estimated to range from 3% to 14%. Although not always publicized as a tremendous public health concern, cancer caused by radon exposure ranks very high among other preventable causes of death. Radon is responsible for the majority of the public exposure to ionizing radiation. It is often the single largest contributor to an individual's background radiation dose, and is the most variable from location to location. In the U.S, the average person gets more radiation dose from exposure to indoor radon than from any other source of natural or man-made radiation (Raymond, 1997).

Radon is a naturally occurring radioactive gas that emanates from rocks and soils and tends to concentrate in enclosed spaces like underground mines or houses (WHO,2009). It is formed as part of the normal radioactive decay chain of uranium-238 which is present in small amounts in most rocks and soil. It slowly breaks down to other products such as radium, which breaks down to radon. Some of the radon moves to the soil surface and enters the air, while some remains below the soil surface and enters the groundwater. Uranium has been around since the earth was formed and has a very long half-life (4.5 billion years), which is the amount of time required for one-half of uranium to break down. Uranium, radium, and thus radon, will continue to exist indefinitely at about the same levels as they do now (Tawfiq et al 2012).
Radon has a half-life of 3.8 days. Unlike radon, the decay products are metal and easily attach to dust and other particles in the air. Radon’s primary hazard arises from inhalation of its highly radioactive heavy metallic decay products (polonium, lead and bismuth) which tend to collect on dust in the air. Two of these radioactive elements, polonium-218 and polonium-214, emit alpha particles, which are highly effective in damaging lung tissues (Darby, Hill and Doll; 2001). These alpha-emitting radon decay products have been implicated in a causal relationship with lung cancer in humans.

If inhaled, radon decay products (polonium-218 and polonium-214, solid form), unattached or attached to the surface of aerosols, dusts, and smoke particles, become deeply lodged or trapped in the lungs, where they can radiate and penetrate the cells of mucous membranes, bronchi, and other pulmonary tissues. The ionizing radiation energy affecting the bronchial epithelial cells is believed to initiate the process of carcinogenesis. Although radon-related lung cancers are mainly seen in the upper airways, radon increases the incidence of all histological types of lung cancer, including small cell carcinoma, adenocarcinoma, and squamous cell carcinoma (USEPA 1993).

Radon exposure in homes may arise from certain subsurface rock formations and also from certain building (e.g. granites); greatest risk of radon exposure is from tight, insufficiently ventilated buildings and buildings that have leaks that let in soil air from the ground into the basement and upper dwelling rooms. High indoor radon concentration poses a serious health problem that can be addressed by individual actions and unless people become aware of the dangers radon poses, they will not act (USEPA 2011). Radon poses a serious health problem to a substantial portion of the population. According to the office of the United States Surgeon General, “Indoor radon gas is a serious health problem in our nation that can be addressed by individual action. Millions of homes are estimated to have elevated radon levels. Like the hazards from smoking, the health risk of radon can be reduced (USEPA 2011). Understanding the population's knowledge about radon can provide insights for policy makers and public health practitioners in developing and testing promotion campaigns. This study therefore assessed awareness of Radon and its health risk among University employees of Obafemi Awolowo University, Ile-Ife, Nigeria.

Material and Methods

The study was conducted in various office buildings of the Obafemi Awolowo University, Ife, Osun State. Obafemi Awolowo University (O.A.U) is a comprehensive public institution established in 1962 as the University of Ife. The landscape is marked by many steeply inclining hills of granite rock formation- the inselbergs- whose slopes are covered with dense vegetation, forming a natural green back drop to the campus. Its topography is hilly and there are many steep slopes, ranging from a 6-12% incline. The University campus is divided into 3 major zones; academic, student residential area and staff quarters. The academic zone consisting of the main core and its extensions contains the 13 faculties and Departmental buildings, including lecture rooms, seminar rooms, libraries, laboratories, auditorium and offices. This area is located on a gently sloping area in the centre of the campus designed as foreground to the nearby hills and planned as the heart of the entire university complex. Most of these buildings were built and landscaped according to terrain which suggests a possibility of radon emanation through these ground into the living spaces/ offices in the environment.
This study employed a cross-sectional study design and the offices in the academic area and their occupants were the study population. A sample size of 87 was calculated using the Fisher’s formula with level of confidence set at 95%; a precision of 0.05 and prevalence of attribute at 6% which represented the proportion of households with radon levels exceeding 4 pCi/l in the U.S (USEPA 1990).

The buildings were stratified based on the classification by Adepelumi et al, 2005 into granite gneiss; grey gneiss and mica schist with most of the buildings in the academic area falling within the grey gneiss zone. The buildings were sampled randomly in each unit with a total of 8 buildings selected and these were further stratified into floor levels (basement, first and second) with equal sampling from the floor levels. Therefore, in each building, an average of 11 offices was selected distributed equally by floor. In each office, if there was only an occupant, the occupant of the office was automatically selected but if there was more than one occupant, then the respondent was selected by simple balloting. A total of 76 respondents participated in the study yielding a non-response rate of 13%.

The respondents were given explanation about the study and their consent sought and obtained. Thereafter, a pre-tested semi-structured questionnaire was administered. The questionnaire was in three sections with section A containing the socio-demographic characteristics of respondents; section B contained questions to assess respondents’ awareness of radon and its health risk and section C contained questions on ventilation preferences of the respondents. To assess the knowledge of staff about Radon, a scoring system was developed based on 7 questions which were then made into a composite score of 9; poor knowledge was graded 0-2, fair knowledge 3-5 and good knowledge 6-9.

Data was entered using Epidata and then exported to SPSS version 16 where analysis was done at univariate and bivariate levels. Data were presented as tables and charts with significant p value set at <0.05.

Ethical clearance was obtained from the ethical review board of the Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife.

**Results**

Table (1) below reveals the socio-demographic characteristics of occupants of sampled offices. The mean age of the sampled respondents was 43years, the mean number of years spent in the office was 6 years and the mean length/hours of stay per day was 7.3hours. Respondents were academics and non-academic staff with Lecturer I and below accounting for 51%, Senior lecturers16%, Reader 2%, Professor 4%, Technologists (12%) and Administrative staffs (14%).
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<th>Percent (%)</th>
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<td><strong>Mean age (S.D)</strong></td>
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</table>

**Designation/Cadre**

<table>
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<th>Percent (%)</th>
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<tr>
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</tr>
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<tr>
<td>Reader</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Professor</td>
<td>3</td>
<td>3.9</td>
</tr>
</tbody>
</table>

**Number of years of occupancy of the office**

<table>
<thead>
<tr>
<th>Years of occupancy</th>
<th>Frequency (76)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>11</td>
<td>14.5</td>
</tr>
<tr>
<td>Between 1-9</td>
<td>48</td>
<td>63.2</td>
</tr>
<tr>
<td>Between 10-20</td>
<td>14</td>
<td>18.4</td>
</tr>
<tr>
<td>&gt;20</td>
<td>3</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Mean year (S.D)</strong></td>
<td>5.9(5.4)years</td>
<td></td>
</tr>
</tbody>
</table>

**Average length of stay in the office/day**

<table>
<thead>
<tr>
<th>Average length of stay</th>
<th>Mean (S.D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum stay</td>
<td>7.3 (2.5)hours</td>
</tr>
<tr>
<td>Maximum stay</td>
<td>12 hours</td>
</tr>
</tbody>
</table>

Table (1): Socio-demographic characteristics of occupants of sampled offices

Table (2) shows the various faculties from which respondents were recruited. About 18% of respondents were from faculty of Arts and Humanities, Sciences- 21%, 9% from Environmental design and management. Other faculties included Engineering and Technology (11%), Health Sciences (30%), and pharmacy accounted for 11%.

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Frequency (76)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arts and Humanities</td>
<td>14</td>
<td>18.4</td>
</tr>
<tr>
<td>Environmental design and</td>
<td>7</td>
<td>9.2</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering and Technology</td>
<td>8</td>
<td>10.5</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>23</td>
<td>30.3</td>
</tr>
<tr>
<td>Sciences</td>
<td>16</td>
<td>21.1</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>8</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Table (2): Faculties of Respondents of sampled offices
Table (3) compares the awareness of respondents about radon and its health risk. Only 42% of the respondents had ever heard about radon. Of those who had heard about radon, 14(43.8%) were aware of its health risk.

<table>
<thead>
<tr>
<th>Proportion of respondents who had heard about radon (N=76)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>32(42.1)</td>
</tr>
<tr>
<td>No</td>
<td>44(57.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aware of health risk of radon (N=32)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>14(43.8)</td>
</tr>
<tr>
<td>No</td>
<td>18(56.3)</td>
</tr>
</tbody>
</table>

Table (3): Awareness of respondents on radon and its health risks

In the study, 71% of the respondents who were aware of the health risk reported cancer as a health risk of radon. Other health risks reported includes eye defects (7%), radioactive effects (7%), fetal disorder (7%) and acute and chronic conditions (7%). See Figure (1) above.

Result of respondent's knowledge of radon is presented in Table (4) below. 91% of those who are aware of radon knew that radon is a gas; 71% identified open air as the source of radon and 84% of respondents knew radon can be detected.
<table>
<thead>
<tr>
<th>Item</th>
<th>Frequency (N=32)</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which best describes Radon?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon is a gas</td>
<td>29</td>
<td>91</td>
</tr>
<tr>
<td>Radon is a solid</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Can it be seen with naked eyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Where can Radon be found? {multiple answers allowed}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open air</td>
<td>22</td>
<td>71</td>
</tr>
<tr>
<td>Ground</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Water</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>Don’t know</td>
<td>1</td>
<td>3.8</td>
</tr>
<tr>
<td>Can Radon be detected?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>27</td>
<td>84</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>3.1</td>
</tr>
<tr>
<td>Not sure</td>
<td>4</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Table (4): Respondent’s knowledge of radon

In this study, higher percentage of respondents read about radon from books (62.5%); internet accounted for 18.8%, newspapers (3.1%), television (9.4%) while 29.6% of the respondents stated other sources, which include training, lectures, classroom and journal articles.
More than half (57.9%) of respondents had a poor knowledge of radon, 15.8% had a fair knowledge while only about 26% of the respondent had a good knowledge of radon. See Figure (3) above.

Comparison of knowledge of respondents by academic background, Table (5), revealed that there was a statistically significant relationship (p=0.02) with 41% of respondents with core science background (e.g. Geology, Physics, Chemistry, etc.) having good knowledge about radon compared to 19.4% of respondents with health background (e.g. Doctors, Pharmacist, physiotherapists, etc.) and 12.5% of respondents with social science background (Dramatic arts, Music, African language and linguistics, etc.).

<table>
<thead>
<tr>
<th>Background</th>
<th>Poor knowledge</th>
<th>Fair knowledge</th>
<th>Good knowledge</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health background</td>
<td>16(51.6%)</td>
<td>9(29.0%)</td>
<td>6(19.4%)</td>
<td>31(100%)</td>
</tr>
<tr>
<td>Social background</td>
<td>13(81.3%)</td>
<td>1(6.25%)</td>
<td>2(12.5%)</td>
<td>16(100%)</td>
</tr>
<tr>
<td>Core Science background</td>
<td>15(51.72%)</td>
<td>2(6.90%)</td>
<td>12(41.38%)</td>
<td>29(100%)</td>
</tr>
<tr>
<td>Total</td>
<td>44(57.89%)</td>
<td>12(15.79%)</td>
<td>20(26.32%)</td>
<td>76(100%)</td>
</tr>
</tbody>
</table>

Pearson Chi-square = 11.96,  P= 0.02

Table 5: Determinant of knowledge of radon

Discussion

This study has shown a lack of knowledge on the part of the employees of Obafemi Awolowo University (OAU) about radon, with only 26% of respondents having good knowledge while a larger proportion (about 58%) of respondents had poor knowledge. Only 42% of the respondents had heard about radon among the sampled population and just about 44% of those who had heard knew about the health risk of radon. This reveals that awareness of radon and its health risk in this area is still very low. The result obtained in this study is lower than that of a study conducted
in Boston University, Boston, where 55% of respondents were aware of radon prior to the survey (Peterson and Howland 1996). This, in turn, is much higher than the study done by Home Owner Protection Agency among Canadian citizens which revealed a lack of awareness of radon with just 8% of the surveyed home owners being aware (Homeowner Protection Centre 2012). This could be attributed to the fact that our study was conducted in an academic environment compared to general public in the Canadian study. Also, in a study done by Pramod V. et al in India, it was reported that poor awareness and knowledge of Indoor Air Pollution (radon as an example) exists among its citizens.

This study showed the significant relationship between knowledge and educational background with 41% of staff with technical/science background having good knowledge. The reason for this is understandable when looked at in relation to the source of information, with respondents from core science background possibly coming across it as part of their course content. Also, early works, including the discovery of radioactivity were done by physicists and geologists.

High indoor radon concentration poses a serious health problem that can be addressed by individual actions and, unless people become aware of the danger radon poses, they will not act (USEPA 2011). Radon poses a serious health problem to a substantial portion of the population. The result from this study reveals a poor knowledge about radon among staff of OAU. This further emphasizes the urgent needs for increase in awareness raising activities and this could be achieved through mass media, campaigns, public lectures, and door to door campaigns for the general population. As part of National Action Month held on 15th of January, 2012, the U.S Environmental Protection Agency, Department of Housing and Urban Development and the American Lung Association jointly held a conference in order to publicize the health threat from radon and steps people can take to protect themselves and their families. This program can also be adopted in Nigeria.

**Conclusion and recommendation**

This study established that the knowledge of staff of Obafemi Awolowo University about radon is very poor. There is an urgent need by the management to increase awareness and sensitize the entire OAU community about the hazard of radon.
References


WHY CHARCOAL DEVICES MUST BE ANALYZED SOON AFTER MEASUREMENT: UNCERTAINTY AND MINIMUM DETECTABLE CONCENTRATION

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pjenkins@bowser-morner.com

Abstract

The value of a radon measurement is meaningless unless one knows two additional pieces of information about the measurement; the total uncertainty and the Minimum Detectable Concentration (MDC). These statistics are particularly important when making measurements with devices that capture radon and then are analyzed later; such as grab scintillation cells and charcoal devices. During the delay between sampling and analysis, the quantity of radon in the device constantly decreases due to its decay with a half-life of about 3.8 days. Using 4-inch charcoal canisters as an example, and using typical values of analysis parameters, it is shown that the total uncertainty and the MDC for the measurement both increase with time after the sampling period and can become unacceptable, thus rendering the measurement useless. This illustrates the importance of analyzing these devices as quickly as possible after sampling.

Introduction

Most people realize that charcoal devices capture radon which then decays with a half-life of about 3.8 days, and therefore the device must be analyzed soon after the measurement is made. However, many do not understand the full implications; specifically, the effect of delay time on measurement uncertainty and the Minimum Detectable Concentration (MDC). It would be helpful to realize that the measurement uncertainty is related to the ratio of the “signal” from the charcoal to the “noise” which is the background of the analysis system. With decreasing radon activity in the charcoal, this signal-to-noise ratio becomes smaller, and it becomes difficult to discern the difference between signal and noise. The signal-to-noise ratio is highest immediately following the exposure of the charcoal. Examples are given here, using typical values of pertinent parameters for 4-inch open-face charcoal canisters, to demonstrate the counting uncertainty at the 2-sigma level and the MDC as a function of delay time.

Method

The equation originally published by George (1984) has been used by many for calculating the radon concentration from charcoal canisters. That equation is as follows:

\[ C = \frac{NCR}{(CF \times t_e \times \varepsilon \times DF)} \]  

(1)

where

- \( C \) = Rn concentration (pCi/L)
- \( NCR \) = net count rate (cpm)
- \( CF \) = calibration factor (L/min)
- \( t_e \) = exposure time (min)
\[ \varepsilon = \text{counting efficiency (cpm/pCi)} \]
\[ \text{DF} = \text{decay factor (unitless)} \]

The decay factor, DF, corrects for the decay of radon from the midpoint of the measurement duration to the beginning of the analysis. The counting efficiency, \( \varepsilon \), is determined by counting a standard canister of the same geometry containing radon in equilibrium with a known activity of radium-226.

**Minimum Detectable Concentration**

The Lower Limit of Detection (LLD) is the lowest net count rate (cpm) that is statistically greater than background. The LLD is a function of the background count rate of the analysis system and the counting times for the sample and for the background. The LLD at the 95% confidence level is calculated using the following equation (Currie, 1968):

\[ \text{LLD} = 2.71/t_s + 3.29 \left( \frac{R_b}{t_b} + \frac{R_b}{t_s} \right)^{1/2} \]  

where
- \( \text{LLD} = \) lower limit of detection (cpm)
- \( R_b = \) background count rate (cpm)
- \( t_b = \) background counting time (min)
- \( t_s = \) sample counting time (min)

The MDC (pCi/L) is calculated by dividing the LLD by the same calibration factor, or combination of factors, that is used to convert the sample net count rate to radon concentration. For these examples, the LLD is substituted for NCR in equation (1):

\[ \text{MDC} = \frac{\text{LLD}}{\text{CF} \times t_e \times \varepsilon \times \text{DF}} \]  

**Counting Uncertainty**

The total uncertainty of the measured radon concentration is a function of the individual uncertainties of all the terms on the right-hand side of equation 1. Only the uncertainty associated with the net count rate (NCR), hereafter called the “counting uncertainty,” is addressed in this paper, because NCR is the only term in equation (1) whose uncertainty increases with delay time. However, it should be realized that this is only one component, and perhaps not the largest component, of the total uncertainty.

The counting uncertainty \( S_{CT} \) at the 95% confidence level expressed as a percentage of the net count rate is calculated using the following equation:

\[ S_{CT} = 200 \times \frac{\left( \frac{R_s}{t_s} + \frac{R_b}{t_b} \right)^{1/2}}{\text{NCR}} \]  

where
- \( S_{CT} = \) counting uncertainty at 95% confidence level (%)
- \( R_s = \) sample gross count rate (cpm)
- 200 = factor consisting of 2 for the 95% confidence level and 100 to convert from fraction to percentage
All other terms are as defined above.

This equation is based on Poisson “counting statistics,” which is described in numerous texts on radiological sciences or health physics (for example, Cember & Johnson, 2008).

A value of NCR can be calculated for any assumed value of radon concentration using equation (1) rearranged as follows:

\[
NCR = C \times CF \times t_e \times \varepsilon \times DF
\]  

(5)

The sample gross count rate, \( R_s \), can be calculated by adding NCR and \( R_b \). Using typical values for the various parameters for 4-inch open-face charcoal canisters, and typical values for the measurement system, a value of \( S_{CT} \) can be calculated for any assumed value of radon concentration, \( C \), using equations 4 & 5.

**Results and Discussion**

*Effect of Background Count Rate*

The values listed in Table 1 for several parameters for 4-inch open-face charcoal canisters were used with equations 2 & 3 to calculate the MDC for values of 0 to 6 days for the delay from the end of the exposure period to the analysis. Three values of background count rate were used to demonstrate how the MDC changes with that parameter. The value for the calibration factor, CF, is typical for a two-day exposure and a relative humidity of about 50%. The results of the calculations are shown in Figure 1.

**Table 1. Parameter values used for demonstrating effect of background count rate on the MDC**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure time, ( t_e )</td>
<td>48 hours</td>
</tr>
<tr>
<td>Counting efficiency, ( \varepsilon )</td>
<td>0.39 cpm/pCi</td>
</tr>
<tr>
<td>Calibration factor, CF</td>
<td>0.096 L/min</td>
</tr>
<tr>
<td>Sample counting time, ( t_s )</td>
<td>10 min</td>
</tr>
<tr>
<td>Background counting time, ( t_b )</td>
<td>10 min</td>
</tr>
<tr>
<td>Background count rate, cpm</td>
<td>100, 200 &amp; 300 cpm</td>
</tr>
</tbody>
</table>
The LLD calculated using equation 2 does not change with delay time, but because of the factors used to convert LLD to MDC in equation 3, the MDC increases with delay time. The values of background count rate are in the range that is typical of sodium iodide gamma spectroscopy systems used to analyze charcoal canisters.

The values in Table 1 were also used to calculate the counting uncertainty, $S_{CT}$, using equations 4 & 5. Unlike the MDC, $S_{CT}$ is a function of the radon concentration. A value of 4 pCi/L was assumed for the radon concentration for this example. The results are shown in Figure 2.

Figure 1. Effect of background count rate on MDC
After just one day of delay, $S_{CT}$ ranges from 4.7% to 6.3% and increases rapidly after that. The counting uncertainty alone can equal or exceed 8% after about 2.5 to 5 days depending on the background count rate and with the assumed values in Table 1. $S_{CT}$ can be a significant fraction of the total uncertainty, and with long delay times it can be the largest contributor to the total.

*Effect of Relative Humidity*

The values listed in Table 2 for several parameters were used to calculate the MDC for different values of calibration factor (CF) typical of a two-day exposure and for values of relative humidity of approximately 20%, 50% and 70%. The results are shown in Figure 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure time, $t_e$</td>
<td>48 hours</td>
</tr>
<tr>
<td>Counting efficiency, $\varepsilon$</td>
<td>0.39 cpm/pCi</td>
</tr>
<tr>
<td>Calibration factor, CF</td>
<td>0.12, 0.096 &amp; 0.088 L/min</td>
</tr>
<tr>
<td>Sample counting time, $t_s$</td>
<td>10 min</td>
</tr>
<tr>
<td>Background counting time, $t_b$</td>
<td>10 min</td>
</tr>
<tr>
<td>Background count rate, cpm</td>
<td>200 cpm</td>
</tr>
</tbody>
</table>
Again, the MDC increases with delay time. Note that the MDC increases with increasing relative humidity, because the value of CF decreases. The values of MDC were calculated using a background count rate of 200 cpm. If the background count rate were larger, then the MDC would be even greater.

The values in Table 2 were also used to calculate the counting uncertainty, $S_{CT}$. As was done above for the results shown in Figure 2, a value of 4 pCi/L was assumed for the radon concentration for these calculations. The results are shown in Figure 4.
As was true for MDC, $S_{CT}$ increases as the relative humidity increases, because less radon is adsorbed onto the charcoal at higher humidity.

**Effect of Radon Concentration**

The MDC is not a function of the radon concentration, but is a function of the “noise” or background. It is determined in the laboratory by counting a blank charcoal canister and depends on the specific analysis equipment and the times spent determining the background count rate and the sample gross count rate. However, $S_{CT}$ is a function also of the “signal,” which in this case is the gamma rays observed from the radon adsorbed on the charcoal and which in turn varies with the radon concentration. To demonstrate how $S_{CT}$ changes with values of radon concentration, the parameter values in Table 1 were used to calculate $S_{CT}$ for values of radon concentration of 2, 4, 6, 8 and 10 pCi/L. These results are shown in Figure 5.
A background count rate of 200 cpm was used in the calculations; therefore, the curve corresponding to a relative humidity of approximately 50% in Figure 4 (the green curve) and the curve for 4 pCi/L in Figure 5 (the red curve) are identical. As expected, $S_{CT}$ increases as the radon concentration decreases. Note from Figure 5, however, that below approximately 6 pCi/L, $S_{CT}$ increases rapidly with decreasing radon concentration.

All analysis laboratories should have established control values for the MDC and $S_{CT}$ for their measurements. For example, the laboratory may have a control value of MDC of 0.5 pCi/L and a value of 15% for $S_{CT}$. From the figures one can see that these values can be exceeded after just a few days of delay from the exposure period. Longer counting times would improve the signal-to-noise ratio, but a counting time of 10 minutes is typical. Combinations of factors such as high background and high humidity would make the situation even worse than shown in the figures.

Further, $S_{CT}$ is only one component of the total uncertainty. The uncertainty associated with CF may be the largest contributor to the total uncertainty. As an example, assume that $S_{CT}$ is 10% and that the uncertainty of CF is 15% and the uncertainties of all the other parameters are trivial. The total uncertainty from these causes alone would then be $(10\%^2 + 15\%^2)^{1/2}$ or 18%.

Some laboratories that analyze charcoal devices by gamma-ray spectroscopy use an equation that differs from equation (1) assumed here. However, similar results would be found regardless of the equation or model used; in other words, that MDC and $S_{CT}$ both increase with delay time.

It is not possible to consider here all possible combinations of values of the various parameters for measurements using 4-inch open-face charcoal canisters or other charcoal devices. But a laboratory may apply the approach shown here to its measurements for charcoal devices that are
analyzed using gamma-ray spectroscopy. The underlying assumptions that make counting statistics valid are violated for several methods of measuring radon, but it has been shown (Jenkins, et al. 2006) that counting statistics may be applied to the analysis of charcoal devices using gamma-ray spectroscopy for the short counting times that are typically used. However, this is not true for analyses based on liquid scintillation spectroscopy. In order to calculate a valid $S_{CT}$, a correction must be applied to adjust counting statistics for these devices due to the detection of a significant number of correlated counts (Jenkins et al. 2006). Note that this reference contains a formula (equation 82) for calculating the counting uncertainty in cases where one or more of the assumptions that underlie counting statistics have been violated; however, there is an error in the equation as published. The following modification to equation (4) in this paper can be used for all charcoal devices or grab scintillation cells:

$$S_{CT} = 200 \times \left\{ \frac{[J \times R_s + (1 - J) \times R_b]}{t_s + R_b/t_b} \right\}^{1/2} / NCR$$

where $J$ is a unitless term known as the “coefficient of dispersion.” If $J = 1$, as it is for a Poisson distribution, then equation 6 reduces to equation 4.

**Conclusion**

The effects of background count rate and relative humidity on the MDC and $S_{CT}$ with delay times ranging from 0 to 6 days were demonstrated through a few examples using typical values of several parameters for 4-inch open-face charcoal canisters. The effect of radon concentration on the values of $S_{CT}$ was also demonstrated with the same range of delay time and typical values for parameters. The results demonstrated that both MDC and $S_{CT}$ increase quickly with delay time, and can exceed acceptable levels in terms of control values or requirements of standards. Therefore it is important to analyze the sample as quickly as possible after the exposure, before the “signal” from the charcoal becomes indistinguishable from the “noise” of the background.
References


ALERT BUT DON’T ALARM: RADON RISK COMMUNICATION STRATEGIES OF A UK MITIGATOR

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Abstract

Some 2000 people die from radon related lung cancer in the UK every year. Despite this, awareness of radon amongst the general public and understanding of the risks amongst property professionals remains low. Communication from official sources has failed to impact significantly upon awareness levels in the past. It has therefore fallen to commercial organisations to take action to raise awareness and understanding in a proactive manner. A number of approaches have been tailored to target specific audience sectors, including technical seminars for property professionals and creation of easy-to-understand cartoons for those searching for information on the internet. Care is taken in the language used to communicate risk to avoid accusations of scaremongering. The underlying philosophy that has been taken when developing risk communication campaigns is the need to alert individuals to the risks of radon but not to alarm them. This paper explores the channels used and discusses methods found to be most and least effective.

Introduction

The UK radon industry has been established for over 25 years, however awareness of radon gas amongst building professionals and particularly members of the public remains relatively low. This is despite the existence of several Government departments and advisory bodies, robust legislation for workplace risk assessments, mapping of risk areas and building codes for radon protection in new buildings.

Public Health England (PHE) is ‘the UK’s Primary authority on radiation protection’ and is an executive agency of the Department of Health. Between 2005 and 2013, this role was carried out by the Health Protection Agency (HPA) however in 2013 PHE was formed when a number of existing organisations, including HPA, were brought together. HPA had itself absorbed the National Radiological Protection Board (NRPB) in 2005.

The NRPB first issued formal advice on radon in 1987 and the UK Government subsequently initiated a programme to determine the means of reducing high exposure in existing homes and reducing it in future ones (NRPB, 1987). In 1990 the NRPB adopted the concept of the ‘Affected Area’ where 1% or more of homes were above the Action Level (a reference level where remedial action is advised when exceeded), which was set at 200 Bq/m³, and in 1996 NRPB released an indicative map of radon Affected Areas in England and Wales. This map was based upon test results obtained from measurements in almost 250,000 homes over 20 years (NRPB, 1996).

[1] The Author is a Director and shareholder of propertECO Ltd
As more data has become available, these maps have been updated. The most recent map was published in 2007 and is based upon the results of measurements taken in 460,000 homes. Each set of maps is divided into colour-coded bands showing the estimated probability that a home in that location will contain radon levels in excess of the Action Level. Figure (1) below shows the 1996 map and Figure (2) shows the 2007 map.

The Health and Safety Executive (HSE) is the official independent watchdog and regulator acting in the public interest to reduce work-related death across Great Britain’s workplaces. HSE works under a framework agreement with the UK Government’s Department for Work and Pensions (DWP) and is represented in Parliament by a DWP Minister.
Under the Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Act 1999, all UK employers are required to carry out a radon risk assessment for their premises. The risk assessment should include radon monitoring if the workplace is located in an Affected Area or if it has a basement or below-ground workspace (regardless of geographic location).

The Building Research Establishment (BRE) was a Government-funded research laboratory before being privatised in 1997. Now operating as an ‘independent and impartial research-based consultancy, testing and training organisation’ BRE has written several guidance documents about radon protection for new buildings and extensions, principally document BR211: Radon - Guidance on protective measures for new buildings and extensions. The current UK Building Regulations refer to the guidance contained in BR211, which includes a set of maps indicating areas of the country where various levels of radon protection (none, ‘basic’ and ‘full’) are required.

propertECO is an independent radon testing provider and mitigation contractor covering the whole of the UK. As a commercial organisation, propertECO operates to generate a return on the shareholders’ investment however the company’s directors have a strong personal interest in radon and recognise that by engaging with stakeholders, change can be affected that will simultaneously save lives and grow the market.

**Lack of radon awareness amongst UK general public**

Following an extensive household measurement campaign by NRPB in the early 1990s, a study of the public responses was carried out (Lee et al 1994). The study found that many householders did not even read the information pamphlets that were sent. Of those that applied for a measurement to be taken and were subsequently informed that the radon concentration was above the action level, only 3-5% carried out effective remediation. Lee et al concludes by stating “It is vital to continue to educate the general public in an attempt to improve the remediation rate”.

Some 20 years later many would argue that public awareness has moved on very little. Anecdotal evidence received conversationally certainly indicates that, unless somebody has had specific cause to be alerted to the issue (e.g. a property transaction), they are unaware of radon or its risks.

**Lack of radon awareness & understanding amongst UK property professionals**

Whilst most building professionals (e.g. surveyors, architects, engineers, solicitors, facilities managers and estate agents) in the UK have at least heard of radon, many do not appreciate a) how widespread the issue is and b) the risk to human health associated with radon exposure.

Many building professionals believe that radon is limited to certain geographic areas, a misconception that stems from historical data and reports focusing only on the South West of England, and which to a certain extent has been perpetuated by the existence of indicative radon maps.
Many large cities that lie outside of designated Affected Areas contain a high proportion of properties with occupied basements. Guidance from HPA states that “...high radon concentrations can be found in properties with basements anywhere in the country, regardless of Affected Area status” (Gooding, 2007). There is very little recognition of this fact.

Anecdotal evidence of the lack of awareness and understanding of radon amongst professionals was collected as part of a research paper (Burt, 2014). Responses from Local Authority Building Control Managers to an invitation to attend a free seminar about radon gas included “I don’t think it is a very good topic for a seminar... Can’t you do something more relevant?” and “No, it is unlikely that anyone would attend. It’s not really of interest”. Worryingly, these Building Control Managers were operating in an area where basements are almost omnipresent and which is densely populated. Their colleagues in the Environmental Health department of the same Authority have delegated workplace compliance duties from HSE. Further, Burt’s research included an interview with representatives of the Royal Institute of Chartered Surveyors (RICS). RICS is an international professional body with over 100,000 members which describes itself as being a body to “represent everything professional and ethical in land, property and construction”. The interviewee was asked about RICS’ guidance on radon and responded “We looked up the guidance notes on hazards on our database but there are no guidance notes on radon. Radon is only really mentioned as a side note. RICS is a chartered body which has the public interest at heart. There is a guidance note for Japanese knotweed for example. RICS is a source for members or for industry, for anything we can help them with. For instance anything hazardous or relating to flooding or subsidence or trees is of concern to us. I think the flooding risk is more important than radon.”

**Raising awareness amongst professionals**

Several years ago, one of the best ways of communicating a message to a specific group of professionals was via editorial in a professional journal. propertECO have supplied detailed technical editorial to several of these journals, including Building Engineer, RICS Building Control and Safety & Health Practitioner.

Following the publication of these articles, a number of enquiries were usually received from readers requesting further information, however the true reach and impact cannot be ascertained. In line with other print media, it would not be unreasonable to expect that overall readership of such journals is in decline with increasing numbers of people looking to online resources and social media for access to information relevant to their professions.

In the UK, many professional bodies require members to undertake Continuing Professional Development (CPD) throughout their membership and there is normally a minimum number of hours’ worth of formal learning required each year. This creates a demand for technical seminars which propertECO has been able to capture.

A seminar entitled “Radon Gas: Risks, Regulations & Remediation” lasting one hour has been written and developed over the last few years to provide information in an easy to understand and engaging format. The seminar uses PowerPoint slides that have minimal bullet points, lots of illustrations and several videos. Video content includes several clips from public service announcements created in other countries to highlight the risk of radon, such as those produced by the United States Environmental Protection Agency.
Attendees are told at the start of the seminar that an electronic copy of the slides will be distributed after the event; it has been found that this provides a good compromise between ensuring audience members do not miss information as they are too busy writing everything down and preventing them from being distracted from the seminar by flipping through a printed handout.

It is important that the content of the seminar is of a technical and informative nature and that any commercial references are kept to a minimum to ensure that it is not viewed as a ‘sales pitch’, as this would detract from the message of the seminar.

Equally important is to avoid accusations of scaremongering. Scaremongering can lead to disbelief and apathy and can taint a company’s reputation. When discussing the risks associated with radon exposure, including number of lung cancer deaths per year, the information is presented in a way intended to alert attendees to the risks but not alarm them.

Interestingly, at the start of seminars it can be observed from their demeanour that many attendees are probably attending simply to gain the necessary number of CPD credits and have no particular interest in the subject matter, however as the seminar progresses and more information about the widespread risks of radon is disseminated, a noticeable shift in attendees’ interest and engagement can be observed. This is often demonstrated by the number of questions asked and level of discussion generated at the end of the seminar.

Educational seminars to property professionals are an effective way of raising radon awareness not only amongst those who have attended the seminar but to a much wider audience. As an example, propertECO were invited to deliver a seminar to a regional group of the Royal Institute of British Architects (RIBA). One attendee, from a FTSE100 company contacted propertECO shortly after the event to request an ‘in-house’ seminar for her colleagues in the company’s new build department as she felt that the company needed to review its building policies urgently. The seminar was repeated to the 10 architects & designers in-house, and a manager from the company’s repair and maintenance division also attended. The repair and maintenance manager subsequently requested further information about the company’s responsibilities as an employer for carrying out radon risk assessments and requested that the seminar be repeated to his team of 18 regional maintenance managers. Following this, the company has decided to embark on a programme of radon risk assessments throughout its premises, which include over 1000 workplaces with over 55,000 employees. Information about radon will be disseminated from the company’s head office to employees to explain why and how radon monitoring will be taking place. Advice will also be given about home radon testing, which could lead to a large number of residential premises being tested as a result.

Another useful way of engaging with other professionals is via the use of social media, and in particular, Twitter. Many non-users of Twitter wrongly believe it is simply a platform for sharing inane details about day-to-day life, however an article on technology news website TechCrunch sums up that “Yes, we can share what we’re having for breakfast or what we watch on TV. But at its best, Twitter is a tool for distilling understanding of the world into the most digestible format possible. (Constine, 2013). Twitter can be used to engage directly with other professionals or professional bodies by ‘mentioning’ them in that Tweet. This is a useful way of responding to a question that may
have been asked. It can be used as a tool for initiating contact with stakeholders, which can then be followed up and developed by other channels.

Other social networks, such as Facebook and LinkedIn can be used to connect with other professionals and share content such as news articles and research papers.

Raising awareness amongst general public

A new European Commission Directive, the Basic Safety Standards (BSS) Directive (2013/59/Euratom)\textsuperscript{16} was adopted across European member states in December 2013 and incorporates the latest recommendations from the International Commission on Radiological Protection (ICRP) published in 2007.\textsuperscript{17} The BSS requires that all member states create a ‘national action plan’ for dealing with radon, which should include a ‘strategy for communication to increase public awareness… of the risks of radon’.

McLaughlin (2014)\textsuperscript{18} suggests that ‘The most important objectives of such a communication strategy should be:

1) Raising public awareness of radon and its associated health risks
2) Persuading the public to measure radon in their homes and
3) Persuading householders to take action to reduce elevated indoor radon concentrations.’

If item 1) above is carried out effectively, items 2) and 3) should naturally follow, as “people are motivated to seek health and avoid illness” (Rothman \textit{et al}, 1997).\textsuperscript{19} Rothman \textit{et al} (1997) hypothesises that “health-relevant communications can be framed in terms of the benefits (gains) or costs (losses) associated with a particular behaviour”.

A radon risk communication message could be framed in terms of the benefits or costs, for example “Test your home for radon so that action can be taken to avoid your family being exposed to harmful levels of radiation if high levels are found” (benefit) or “If you don’t test your home for radon, your family are at risk of lung cancer” (cost).

propertECO has found that when communicating with the general public, many of whom will not have had any previous knowledge about radon, it is most effective to frame the message in terms of benefits. If the message is framed in terms of costs, people may view this as scaremongering. This is particularly important to avoid when the message is being sent from a commercial organisation, as it could lead to the organisation being branded an ‘ambulance chaser’.

The information must also be communicated in a way that is clear and readily understandable by the intended audience, whilst also being factually and scientifically accurate. For many years, information aimed at the general public in the UK has mentioned the national reference levels in Becquerel per cubic meter (Bq/m\textsuperscript{3}) and occasionally an exposure dosage in millisieverts (mSv). These scientific measurements are not helpful in increasing members of the public’s understanding of the risks, as the effect on the individual’s health is not readily understandable by a layperson.

propertECO found that other countries were explaining the radiation doses and health impacts of radon exposure by calculating equivalences that are more commonly recognised. For example, the US Environmental Protection Agency (EPA) convert lung damage received from exposure to a given radon concentration into lung damage that would be received from
smoking an equivalent number of cigarettes in the same time period\textsuperscript{20} and the Radiological Protection Institute of Ireland (RPII) converts the radiation dose from radon exposure into the equivalent number of chest x-rays.\textsuperscript{21}

propertECO have adopted this method when communicating radon risk and have found that the engagement of members of the public increases significantly after they understand what the radiation dose from radon could be doing to their body. Anecdotal evidence has shown that remedial action is more likely after homeowners have discovered that the radon concentration in their homes means that each member of their family is receiving the equivalent radiation does to a number of chest x-rays each year. Non-smokers are also often horrified that they could unknowingly be causing lung damage equivalent to smoking a pack of cigarettes every day just by inhaling the air in their home and subsequently decide to perform a test.

The format that any information is presented is important so that people can quickly find the information that is relevant to them. Webpages with information specifically aimed at people in different scenarios (e.g. information for homebuyers and sellers, information for landlords and tenants etc.) is beneficial as people are immediately presented with information that is relevant to them. Webpages listing Frequently Asked Questions (FAQs) and answers have been found to be some of the most highly visited pages on propertECO’s website, indicating that presentation of information in this format is preferable to those seeking advice.

propertECO also looked to use other media for communicating the radon risk. Research from Cisco (2013) predicts that video will account for 79\% of all consumer internet traffic in 2018, up from 66\% in 2013.\textsuperscript{22}

Taking advice from a specialist video marketing company, propertECO created four separate videos about radon (“What is Radon and Why Should I Care?”, “How to Test for Radon Gas”, “How to Reduce High Radon Levels” and “Reducing Radon Levels in Basements”). Creating four separate videos enabled each video to be kept short (under 90 seconds) yet distil key pieces of information. Cartoon animation with voiceover was used for the videos as it allowed different scenarios to be quickly and easily shown without needing to find ‘real life’ examples. Animated videos including characters allow the information to be told as a story from the audiences’ point of view and create empathy with the viewer. Animation also allows the video to be more entertaining, which increases engagement and memorability.

Figures (3) – (6) below show screenshots from each of the videos.

Figure (3): Screenshot from video entitled What is Radon and Why Should I Care?
These videos have been uploaded to YouTube and also appear on propertECO’s webpage, and positive feedback has been received from the public and other radon professionals. After publication of these, similar videos have since been produced by the German Federal Office for Radiation Protection (BFS)\textsuperscript{23} and Radiological Protection Institute of Ireland (RPII).\textsuperscript{24} These are shown in Figures (7) and (8) below.
Figure (7): Screenshot from BFS video entitled What is Radon and How Does it Reach Buildings?

Figure (8): Screenshot from RPII video entitled How to Test Your Home for Radon Gas

**UK Radon Association – A professional body**

Having attended the International Radon Symposium in 2013 in Springfield, Illinois and witnessed how the energy and enthusiasm of radon professionals can be collectively harnessed and used to promote the industry by a body such as the American Association of Radon Scientists & Technologists (AARST), propertECO recognised that this was sadly lacking in the UK. propertECO had been involved in the instigation of the European Radon Association (ERA) in 2012-2013, and so discussed the idea of creating a similar UK body with several other industry colleagues.

The UK Radon Association was registered as a not-for-profit company with a group of industry members and, in addition to providing a professional body for those involved in radon testing, radon mitigation and radon protection, will work to raise awareness of radon and provide ‘consumer-friendly’ information on the subject.25

The members recognise that, although working alongside competitors, a collective voice is more likely to be heard than an individual one. Greater awareness leads to an increased market from which everyone will benefit.
Following the lead of AARST and CARST (Canadian Association of Radon Scientists & Technologists), the UK Radon Association will engage with health professionals and cancer charities, as this link has not currently been utilised in the UK. It is hoped that successful partnerships with such bodies can be made, enabling joint activities to raise radon awareness to be undertaken.

The UK Radon Association also plans to arrange a Radon Awareness Week, again following the lead of other nations. By focusing efforts into a single targeted period of time, it is expected that a better response by the media will be received rather than a ‘scattergun approach’ of random communication throughout the year.

Conclusions

Several methods of communication have been identified, and propertECO have demonstrated that different channels can be used to raise awareness amongst different stakeholder groups.

Property professionals should be targeted, as they have the ability to diffuse the information not only amongst their profession but to clients (who may include employers of large numbers of people and the general public). Such professionals also have the ability to implement change in the work they do, by specifying radon testing and/or remediation where relevant. Where possible, face-to-face communication such as educational seminars can be used as there is a danger that unless they are specifically told otherwise, professionals may skip over information regarding radon presented in written format as they wrongly believe it is not relevant to them.

Messages should focus on the benefits of becoming radon-aware, presenting the information in a positive light and in a manner that will ‘alert not alarm’ the audience. Risks should be communicated in an easy-to-understand manner using non-scientific language. Converting the effects of radon into other more readily recognised risks, such as radiation from x-rays or lung damage from smoking has been shown to be particularly effective.

Alternative media, such as videos can be used to capture internet users’ attention. These can be used as an introduction to the subject to complement more in-depth information that may be in written format. Targeting written information to specific user groups, such as homebuyers or employers, allows the relevant messages to be communicated clearly and concisely to the user.

Social media can be used to reach a wide audience and also to target specific individuals or groups.

This has been the experience of one mitigator operating in the UK market. It follows that if a healthy and active radon industry exists, and other mitigators are encouraged to carry out similar activities, the message about radon will be spread further and quicker.
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ATTENUATION OF THORON (Rn\textsuperscript{220}) IN TYVEK\textsuperscript{®} 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\textsuperscript{222}) and thoron (Rn\textsuperscript{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\textsuperscript{222}), usually referred to as radon, has a half-life of 3.8 days. Another isotope of radon (Rn\textsuperscript{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\textsuperscript{®} electret ion chambers used for measuring thoron in this study and have no commercial interest on the Tyvek\textsuperscript{®} 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 cm²) 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/cm². This further divided by the physical thickness (0.01296 cm) leads to the density of the membrane in conventional units as 0.517 gm/cm³.

The source of thoron

Some older versions of gas lantern mantles (made between 1912-1941) 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 a 5 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 through 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.

\[ P = 109.3092 - 30.6801 \times \ln(M) \]  — (1)

where 0.9881 was 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.
References

EXPERIMENTAL ARRANGEMENT SCHEMATIC
MEASURING THE ATTENUATION OF THORON THROUGH TYVEK MEMBRANES OF VARIOUS THICKNESS

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

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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

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

Figure (3): Radon Concentration for stated number of Tyvek membranes
INDIVIDUAL INITIATIVES IMPROVE HEALTHY HOUSING THROUGH PUBLIC POLICY

Gloria Linnertz, Founder & President, Citizens for Radioactive Radon Reduction
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Abstract

EPA estimates a death rate of 21,000 yearly due to radioactive radon gas; the need for state and federal legislation is paramount. Because of individuals advocating for radon awareness and legislation, homeowners in Illinois testing their home at the point of sale have increased from 8% to 45% according to Illinois Emergency Management Agency. Stemming from the radon awareness of the legislators, numerous bills have been enacted including radon reducing features for all new residential construction in Illinois. Kansas and Minnesota have modeled their own Radon Awareness Acton the Illinois law; other states are attempting the same legislation. Advocates give a personal and heartfelt account of the tragic effect of radioactive radon gas exposure and have effectively spoken in front of and submitted written testimony to the U.S. House Interior and Environment Appropriations Subcommittee for the continued support of the State Indoor Radon Grants by EPA. Radon Leaders share a booth at the NCSL to educate legislators throughout the nation about the danger of radon, the existing laws, and model legislation. Since 2006, numerous radon bills and resolutions have been passed in the U.S. Conclusion: individual and personal connections are what change our world for healthier environments.

Introduction

Radon is invisible, odorless, and tasteless; the most effective way to protect homeowners, renters, students, school and other employees is through public policy. Because the presence of radon cannot be detected with human senses, most people are completely unaware if they are living, working, or attending school in environments with elevated levels of radioactive gas or not. This paper shows how changes needed for public policy can be effected through individual initiative.

Objective

This paper has four objectives: first, to prove the effectiveness of individual commitment in changing public policy; second, to show verifiable evidence of public policy changes thus effected; third, to show some proven methods behind, such changes; and fourth, to advocate for more individuals to engage in public policy changes concerning radon awareness and public health and safety.

Method

Approaches to effect changes in public policy on the local, state, and national levels are similar, but not always identical: speaking before local school and community groups; using the press in local, state and national advocacy; knowing your political representatives and communicating via
mail, email, and personal visits; recruiting like-minded adherents; assisting and using organizations.

**Motivation and Strategy**

No one should purchase a house with elevated levels of radioactive radon gas. In December 2005, an oncologist informed the author’s husband, Joe, and the author that radon is a known cause of lung cancer as he gave the diagnosis of Stage IV lung cancer to the author’s husband. Six weeks after his diagnosis, Joe died. We had been living with over four times the EPA action level of radon for 18 years.

Determination overtook grief, devastation, and anger as the author gathered statistics, data, and scientific studies to present to the Illinois (IL) representative, Dan Reitz, with a proposal for mandated radon testing at the point of sale and— if the level was 4.0 or higher— required mitigation before occupancy\(^1\) (Linnertz, 2006). The author also sent this document to thousands of newspapers across the country. Immediately, Representative Reitz filed HR 1288\(^2\) (Reitz, 2006), a resolution to urge everyone to test for radon, test schools, and financial institutions to offer low interest loans for mitigation—which was adopted two days after the filing. Throughout the summer, fall, winter of 2006, and spring of 2007, the author continued to communicate with all of the Illinois legislators by personal visits, emails, faxes, and correspondence through the U.S. Postal Service, informing them of the danger of living with high levels of radioactive radon gas and sent them a proposal and fact sheet along with the 2006 Illinois Radon Status Report issued by the Illinois Emergency Management Agency Radon Program in the Nuclear Safety Division which stated that 42 percent of Illinois homes tested with elevated levels of radon\(^3\) (IEMA, 2006). The strong state radon program in Illinois was a great asset in providing radon data and facts.

Networking and communication were essential to the success of my crusade. Sharing the facts of the danger of radioactive radon exposure through presentations to local, community, and state groups and organizations was vital and rewarding in increasing awareness and radon testing in homes. The author secured letters from Joe’s oncologists and other physicians to send to the legislators requesting support for a passage of radon legislation to protect our citizens. With the assistance of Dallas Jones, Chairman of the American Radon Policy Coalition of American Association of Radon Scientists and Technologists (AARST), who drafted the bill which would become known as the Radon Awareness Act or Public Act 095-0210; the physical presence, testimony, and support of John Dunn, President of the Illinois Home Inspectors Association along with the moral support of Cal Murphy, AARST member, and Peter Hendrick AARST Executive Director, a momentum was building.

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Results

SB3200 (Claybourne, 2006) was introduced on November 16, 2006, by Senator James F. Clayborne, Jr. The bill amended the Residential Real Property Disclosure Act and stated that prior to the sale of a residential property, the seller must have the property tested for radon and radon progeny by a licensed radon contractor and furnish a prospective buyer with the test results and provided that if the test revealed that radon is present at a level in excess of 4.0 picocuries per liter of air (pCi/L) in the indoor atmosphere of the residential real property, the seller must mitigate, repair, or alter the premises to reduce the radon level to below 4.0 (pCi/L) or give the prospective buyer notice of the right to terminate the sale agreement without loss of any earnest money or down payment effective July 1, 2007.

However, Representative Reitz felt SB3200 would encounter too much opposition to pass, and he desperately wanted to have a bill pass, as a bill can only stay in the legislature for two years. Dallas Jones, an AARST board member, formulated the language of HB1425 (Reitz, 2006) that became known as the Radon Awareness Act modeled after the lead base paint disclosure act. This bill provided that the seller of the home supply the buyer with a pamphlet entitled “Radon Testing Guidelines for Real Estate Transactions” and the Illinois Disclosure of Information on Radon Hazards stating that the property may present the potential for exposure to radon before the buyer is obligated under any contract to purchase the residential real property.

A meeting was held with Representative Reitz, John Dunn, and Greg St. Albans, the legislative liaison for the Illinois Realtors Association, to work through an agreement of the wording of the bill. The bill was introduced on February 21, 2007; the House Rules Committee assigned the bill to the Environmental Health Committee. On March 6, 2007, the author testified at the public hearing at which time the bill passed the Environmental Health Committee with a slight amendment. The bill passed the second and third reading on March 13 and March 22, and on March 27 it arrived in the Senate with Senator Donnie Trotter as chief sponsor. The author had met previously with Senator Trotter in his office in the capitol building and on March 30 testified in front of the Senate Housing and Community Affairs Committee where the bill had been assigned. On May 22, 2007, the Radon Awareness Act passed the third reading in the Senate. Coincidently on August 16, 2007, the Illinois governor signed the bill into law—The author’s thirty-first wedding anniversary.

Although this law is not a mandate for testing, according to Patrick Daniels of Illinois Emergency Management Agency the percent of homeowners testing their home at the point of

sale has increased from eight percent to almost 50 percent. Stemming from the radon awareness of the Illinois legislators, numerous bills have been enacted since 2006 in Illinois including mandated radon reducing features for all new residential construction, mandated testing for licensed day care centers, recommended radon testing for schools, required disclosure of unsafe environmental conditions including unsafe levels of radon by sellers of a multifamily unit (4 or more units), and a declaration of a misdemeanor to misrepresent the capabilities of a radon or radon progeny testing and measuring device.\textsuperscript{8}(ELI, 2014) The education of the legislators concerning the danger of radon was the backbone for the ease of the passage of these bills. Other states are modeling Illinois’ radon legislation. Minnesota\textsuperscript{9} (Marty, 2013) and Kansas\textsuperscript{10} legislatures have adopted the Radon Awareness Act to their states.

\textsuperscript{8}http://www.eli.org/research-report/state-indoor-air-quality-laws-database-excerpt-radon-laws
\textsuperscript{9}https://www.revisor.mn.gov/statutes/?id=144.496
Advocates give a personal and heartfelt account of the tragic effect of radioactive radon gas exposure and have effectively spoken in front of and submitted written testimony to the U.S. House Interior and Environment Appropriations Subcommittee for the continued support of the State Indoor Radon Grants by EPA. Since 2007, the author has participated in the Radon Leaders Saving Lives booth at the annual Summit of the National Conference of State Legislatures to educate legislators throughout the nation about the danger of radon, the existing laws, and model legislation.
Conclusion

Individual and personal connection is what changes public policy in our world for improved healthy housing which has been evident in this abstract. However, in order to achieve the desired outcome of increased awareness of the danger of radioactive radon gas exposure, increased radon testing, and increased radon mitigation protection, more involvement on a personal level is needed by our citizens. By educating ourselves on radon and its potential harmful effects--lung cancer--and then sharing that knowledge with citizens and political leaders in cities, states, and congress, we can really begin to take action to protect our citizens against this silent killer, the second leading cause of lung cancer.11

COMBINING TOBACCO CESSATION AND RADON TESTING: A MULTIAGENCY COLLABORATION TO PROMOTE THE HEALTH OF MONTANANS

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Abstract

Exposure to indoor radon and tobacco smoke have a synergistic effect, meaning that the combined risk for lung cancer is more than additive. In a rural, high-radon geographic state, this concern led to a coalition approach to encourage radon testing for Montana residents. A one-page radon background and risk document was included in the orientation packets for “Quit Line” enrollees attempting to quit smoking cigarettes. Free radon kits were sent to interested individuals. Data collection began January 1, 2014 and ended May 15, 2014. Six hundred individuals were invited and fourteen (2.3%) accepted the invitation. Two of the fourteen (14.3%) completed the test kit they requested. This rate is well below the approximately 65% test kit return rate reported from state radon programs. Indoor radon concentrations were less than the recommended action level for both participants. Members of the six agencies involved in the coalition agreed to try an alternative outreach approach for Quit Line participants in January 2015. The results of this pilot-test provide important information for other high-radon states wishing to launch a similar collaboration.

Introduction

Persons who smoke and are exposed to radon decay products are at a “substantially greater” risk for lung cancer than smokers who have not been exposed to indoor radon (National Research Council, 1999; U.S. Department of Health and Human Services, 1999). The Environmental Protection Agency estimated a nearly ten-fold increase in lung-cancer risk for smokers (2012). Unfortunately, this synergistic health effect has not led to increased rates of radon testing among smokers. In the Montana Radon Study (Larsson, 2014), most county radon program participants were neither current (n = 291; 91.2%) nor former smokers (n = 235; 72.3%). Low radon testing rates by smokers coupled with limited public health funding led Lantz, Mendez, and Philbert (2013) to their published opinion that “residential radon control policy would be most effective and efficient if it combined forces with tobacco prevention and control efforts.” Lantz and colleagues also noted that no state radon programs had any explicit screening activities directed to smokers. Finding this a compelling conclusion, the author organized a coalition of representatives from the Montana Tobacco Use Prevention Program (MTUPP), the Montana Department of Environmental Quality (MDEQ), the Montana Cancer Coalition, Gallatin and Ravalli County Tobacco Prevention Specialists and Gallatin and Ravalli County Health Officers to discuss the Lantz, Mendez, and Philbert article and identify actions that could be taken in Montana to integrate tobacco cessation with the radon awareness and testing. The purpose of this research brief is to 1) report on the formation and activities of this coalition, and 2) report the results of a pilot-research project to invite Montanans initiating a tobacco cessation attempt to receive a free radon test kit.
Background

This group of eight stakeholders met via teleconference in August, September, and October of 2013. The group agreed with Lantz, Mendez, and Philbert (2013); the work of each agency would be improved through a complementary approach that emphasized the importance of both tobacco cessation and radon awareness. Group members recognized current and former smokers as the highest priority audience and pursued the following three action items to demonstrate their commitment to inter-agency efforts to promote health. First, Mr. John Podolinsky of MDEQ and Mr. Jeremy Brokaw of MTUPP collaborated to include literature from the Montana Tobacco Quit Line in the DEQ radon booth. This educational booth is displayed at health fairs and home shows around Montana. Second, Ms. Bonnie Rouse of MDEQ and Ms. Jennifer Ullman of MTUPP cross-linked information on each of their agency’s websites to underscore the health effects of radon and tobacco smoke exposure (Montana Department of Environmental Quality, 2014; Montana Department of Public Health and Human Services, 2014). Third, coalition members designed and incorporated a pilot research study into the Montana Tobacco Quit Line program to learn if offering a radon screening opportunity to individuals initiating a tobacco cessation attempt would be an effective approach to increase home-radon testing among smokers.

Methods

Coalition members agreed that the ideal way to recruit persons initiating a tobacco cessation attempt to test their home for radon would be to include an invitation to participate in the script used by the telephone operators who coach “Quit Line” participants. MTUPP leaders decided this approach was not possible as the script in use by the Quit Line coaches already included content from other health promotion projects (e.g., childhood asthma, chronic obstructive pulmonary disease, etc.) and the addition of radon information would make the calls too long. Instead they suggested we send a one-page radon information sheet in the packet of materials sent to each person attempting a smoking cessation attempt. One advantage of this approach was the ability to target only smokers rather than those attempting to quit chewing tobacco.

Montana State University Institutional Review Board assigned an exempt status (LL1004-13EX) to the protocol titled, “MTUPP MTDEQ Collaboration: Radon Testing during Smoking Cessation Attempt” on October 4, 2013. The National Jewish Hospital in Denver, Colorado administers the Quit Line programs for several states including Montana. Through a cooperative agreement with their fulfillment center, a graphically rich (see Figure 1) information sheet was included in the initiation packets for 600 individuals attempting to quit smoking from January 1 – May 15, 2014. Quit Line participants were invited to contact the author if they wanted to receive a free radon test kit.
Figure 1 One page information sheet included in the orientation packets of 600 Montanans who initiated a smoking cessation attempt through the Montana Quit Line from January 1, 2014 - May 15, 2014.

Results

Fourteen individuals (2.3%) responded to the invitation; six by ground mail, four by electronic mail, and four by telephone. Only two of the fourteen (14.3%) returned their radon test kit to the laboratory for analysis. Both results (1.6 pCi/L and 2.7 pCi/L) were below the EPA recommended 4 pCi/L action level (Environmental Protection Agency, 2012).
Discussion

Coalition members were impressed at the volume of cessation attempts initiated through the Quit Line as 600 mailed invitations is a somewhat large sample size for a pilot research project. This is a promising avenue through which to reach the priority population and provide information to people at highest risk for lung cancer about the role of residential radon exposure in increasing their lung cancer risk. On the other hand, including the written invitation in a packet of information was not an effective way to increase radon testing as only 14 out of 600 (2.3%) accepted the invitation for a free radon test kit. Further, a 14.3% test-kit return rate is very low compared to the 65.6% return rates documented for county radon programs in Ravalli, Gallatin, and Flathead counties (Larsson, 2014).

Coalition members will next have the opportunity to work with MTUPP agency leaders to consider if radon testing should have equal standing with other high priority health topics and be rotated into the Quit Line script on some reasonable basis. For example, due to the severity of winters in Montana indoor radon concentrations are likely to be highest from January through March. Radon could be the highlighted health topic Quit Line callers receive during those months. A simple question inserted into the script could be, "Perhaps one of the reasons you have decided to quit smoking is concern about lung cancer. Since Montana is a high-radon state and radon also causes lung cancer, we have radon test-kits available for our participants. Would you like us to send you a kit so you can test your home?" If the participant answers in the affirmative then the Quit Line operator at National Jewish Hospital would forward the participant’s mailing address to the research team. A packet including the radon test kit and the EPA pamphlet “A Citizen’s Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon” would be sent to the participant. Follow up contact with the participant to answer questions about how to complete their test kit could be elements of that research method. A one-season pilot-study would provide data to help coalition members understand if the low response rate in this study was related to only having a one-page information sheet included in a packet of paperwork or if alternatively, individuals attempting a smoking cessation attempt are too overwhelmed or preoccupied to adopt residential radon testing.

Conclusion

A multi-agency coalition was formed in Montana to address the problem of low radon knowledge and testing among individuals at highest risk for lung cancer. In addition to integrating information across agencies and committing to address the problem of radon exposure among individuals who smoke cigarettes, we completed a pilot study to measure participation and the rate of completed residential radon testing in a sample of Montanans who had voluntarily initiated a smoking cessation attempt. While this pilot study yielded poor results, the coalition is committed to finding another way to work with the Quit Line participants to better assess their dual exposure to radon and tobacco smoke.
References


NATIONAL AND LOCAL PERSPECTIVES ON RADON RESISTANT NEW CONSTRUCTION POLICIES

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Abstract

The primary study aims were to conduct a national inventory of radon resistant new construction (RRNC) policies, test the association between geographic risk and policy adoption, and survey local building industry members to learn their perspectives on RRNC policy. Comparison and contrast of existing policies revealed a heterogeneous approach to RRNC. An odds ratio analysis was conducted to test if RRNC adoption was associated with high EPA zone designation. States with more radon risk were five times more likely to have implemented RRNC ($\chi^2 = 2.34$, OR = 5.00, 95% CI 1.2 - 19.3, $p < .05$). Local industry members reported 100% of projects included radon system installation at least occasionally despite the lack of RRNC policy in Montana. Given the heterogeneous nature of RRNC policies, the authors recommend including building industry members’ perspectives as partners in drafting future policy.

Introduction

Radon, a known carcinogen, is the second leading cause of lung cancer in the U.S. after smoking (Environmental Protection Agency, 2008). Epidemiological studies have provided convincing evidence of an association between indoor radon exposure and lung cancer, even at the relatively low radon levels commonly found in residential buildings (Lubin & Boice, 1997). Radon, a natural air pollutant comes from radioactive decay of Uranium-238 present throughout the earth’s crust. Indoor levels of radon are higher than the naturally occurring outdoor levels, significantly in homes and other small buildings. Radiobiological research suggests bronchial epithelium exposed to radon progeny is damaged at the cellular level proportionate to number of cells exposed. For most of the population, exposure to this radiation is determined mainly by the concentration of radon in the home (Gray, Read, McGale & Darby, 2008).

Approximately 2.1 million of the 76.1 million existing single-family homes in the United States in 2005 had radon reducing features in place (Environmental Protection Agency, 2008). Socioeconomically stressed populations are at a higher risk for radon related lung cancer. This population is not only exposed to higher rates of cigarette smoking, but additionally reside in homes built without radon resistant construction or mitigation systems. Addressing this health disparity poses several different approaches.
**Background**

In 2005, the World Health Organization established the International Radon Project to identify effective strategies for reducing the health impact of radon and to raise public and political awareness about the consequences of long term exposure to radon. International Radon Project members published their recommendations for reducing the radon health risk including an evaluation of six radon control options for the construction industry and building professionals (World Health Organization, 2009). The radon prevention strategies for new construction focused on “sealing radon entry routes and on reversing the air pressure differences between the indoor occupied space and the outdoor soil through different soil depressurization techniques” (World Health Organization, 2009). Often it is a combination of strategies that provides the most effective reduction of radon concentrations where active radon levels are compared with mitigation needs and policy.

At the national level, the Environmental Protection Agency (EPA) (2011), the Department of Health and Human Services (2010a), and the President’s Cancer Panel (2009) have all established a public health agenda in response to the radon threat that include adoption of radon resistant construction practices. Noteworthy, however, is that the recommended approaches to RRNC policies vary from wholesale adoption of the International Building Code to limited implementation in high radon areas. The members of the President’s Cancer Panel recommended sweeping “building code changes” to reduce indoor radon concentrations. This recommendation called for venting in all new construction whereas the architects of the Healthy People 2020 advocated for a more selective approach. Their recommendation proposes 100% of the homes in high-radon geographic areas to be built using RRNC in Objective EH–15 (U.S. Department of Health and Human Services, 2011). Suggested methods for RRNC practice defer to maintaining consistency with national programs, regulations, policies, and laws, such as the International Residential Building Code (Appendix F) which provides building instruction and layout of systems.

Montana has 56 counties, 49 of which are designated by the EPA as Zone 1. This is the highest-geographic risk designation and means that the average indoor radon level is above the EPA’s designated action level of 4.0 pCi/L (Environmental Protection Agency, 2013). Montana is well placed to introduce radon policy due to its radon risk, lack of state wide policy and rural demographic suggesting increased health disparity among housing and access to services. All new buildings constructed in Montana both residential and commercial must comply with the Montana energy code as of 2010 (Montana Department of Environmental Quality, 2012). This precedent of introducing statewide building code policy ensures the people of Montana have comfortable, energy efficient, cost effective homes and commercial buildings. The state of Montana is primed to receive equal treatment in their comfort and knowledge of safe indoor air quality in their homes and public buildings. Additionally, there are currently no disclosure laws for rental properties regarding indoor radon levels. As a result, rental properties are less likely to have been tested for radon or to have been remediated if levels are known to be high. Low-income homeowners may find remediation cost prohibitive as well. By addressing new construction policies, radon can be controlled at the onset of building thereby reducing some of this health disparity burden.
Locally, only one county in Montana has preempted Montana state law and adopted a building code addressing RRNC. Building industry members in Billings, the seat of Yellowstone County, recently adopted RRNC into their local practices. As awareness of radon health effects continues to grow within the housing communities, Montana may continue its course in affecting RRNC policy setting trends for other like-minded Western states with similar radon risk.

Because of the high risk for radon in the state of Montana and uncertainty about the national regulatory framework, a study with the following three aims was crafted. These three aims were to: 1) conduct a national inventory of radon resistant new construction (RRNC) policies in state or county-level laws, 2) test for an association between geographic risk and existing policies, and 3) administer a survey to building industry members to learn their perspectives on RRNC.

Method

A literature review of municipal, state, and national radon-related policies was conducted in each of the 50 states. A query of statutory, administrative or constitutional statutes was performed using LexisNexis Academic; a searchable electronic database of legal documents, for any statute that had contained the term “radon” at least five times. Results were cross-referenced with the EPA’s database of states and jurisdictions with RRNC code. See results of the query in Appendix 1. Additionally, results were compared to articles in the Radon Reporter (Barber, 2010), the popular media (McCanna, 2012), and the Environmental Law Institute (Environmental Law Institute, 2013) for confirmation. For example, articles announcing the adoption of new laws in Maine confirmed findings using the LexisNexis search engine. Alternatively, discrepancies were noted in the case of Washington state where the EPA lists six Zone 1 counties but identifies seven on their map (Environmental Protection Agency, 2013). This however did not negate the overall findings of radon policy enactment in that state.

Next we created categories describing each state according to the presence or absence of state or local-level statutes (see figure 1). The categories were 0 = no statewide or local policies related to radon resistant new construction, 1 = no statewide statutes but instances of local jurisdictions (i.e., city or county) adopting RRNC; 2 = statewide adoption of RRNC with local jurisdictions allowed local control over whether to adopt RRNC; and 3 = statewide adoption of RRNC with designations for which local jurisdictions must conform. All states fit into this organizational framework except California where the radon policy is not governed through the building code, but rather through the public health department. As this divergence does not fit with any other state’s RRNC procedures, they were not included in this analysis.

A Chi-square analysis was performed to test for an association between EPA risk designation and RRNC. States were dichotomized into high and low risk groups. A low-risk state was defined as having more than 50% of the counties designated by the EPA as moderate (Zone 2) to low risk (Zone 3). A high-risk state was defined as having more than 50% of the counties designated as moderate (Zone 2) to high risk (Zone 1). States were then further sorted on the presence or absence of any existing RRNC policy (see Appendix 1).

After analysis of trends in state and local level RRNC policy, qualitative interviews were conducted with affected building industry members and officials to gain a better understanding
of the issues and concerns experienced in their state when an RRNC policy was added to the building code. Subjective data from the telephone interviews were assessed for common themes using qualitative descriptions. From these interview themes a survey was crafted to gather the opinions of local tradesman in a region with high radon risk and no current RRNC policy. This survey was then administered to local tradesmen through the Southwest Montana Building Industry Association (SWMBIA) and through the Building Division office in Bozeman, Montana. Completion of this anonymous survey was voluntary.

The 20-item survey was a combination of multiple choice, Likert type scale and open-ended questions. Participation was voluntary and no identifying information was collected. Four questions were created to establish demographic information. Five of the survey items were used to establish level of trade and market affiliation of the participant. Five survey questions were used to ascertain current RRNC practice. The remaining six questions were crafted to explore local opinion related to RRNC policy and practices. The questionnaire data were then entered into an excel spreadsheet for descriptive statistical analysis.

Results

The first aim of this study was to conduct a national inventory of RRNC policies in state or county-level statutes, laws or ordinances (see Figure 1). States colored in blue (category 0) indicated states where no policies had been adopted either at the state or local level (n = 21). Orange (category 1) indicated states where local policies in one or more counties or jurisdictions were adopted even though no state law had been adopted (n = 19). Red states (category 2) indicated adoption of RRNC at the state level with the provision that each jurisdiction/county had to vote to adopt the regulation at the local level (n = 5). In these cases, the state law was not a mandate. Finally, states colored green (category 3) indicated a state law that required high-risk counties to adopt RRNC. In these cases, local adoption was not optional for the high-risk counties or jurisdictions. California did not fit into any of these four categories as their state law requires the health department, rather than the building division, to implement RRNC. In this state, health department radon testing requirements must be met before a building permit may be granted. At the time of this writing, the California state law had not been operationalized.

The second aim was to test for an association of policy with high radon-potential areas as set forth as a goal in the HP2020 objective EH-15 (U.S. Department of Health and Human Services, 2010b). In order to complete an odds ratio (OR) analysis the states were separated into high and low risk groups. The states were defined as low risk when more than 50% of the counties were designated by the EPA as moderate (Zone 2) to low risk (Zone 3). They were defined as high risk when more than 50% of the counties were designated as moderate (Zone 2) to high risk (Zone 1). States were then further sorted on the presence or absence of any existing RRNC policy. The odds were five times greater that states with more radon risk had adopted at least some level of RRNC compared to states with less radon risk ($\chi^2 = 2.34$, OR = 5.00, 95% CI 1.2 - 19.3, $p < .05$). While this is a descriptive analysis and includes states where only one or two counties have adopted RRNC in an overall high-risk state, the results indicate that the policy initiatives are directionally positive and associated with geographic risk.
The third aim was to survey local industry tradesmen in order to provide feedback as to current local practices and opinions on implementation of RRNC. Twenty-two individuals, all males, completed the project survey and reported their specialty in the following areas: general/sub-contractor (n = 11), plumbing contractors (n = 5), electrical contractors (n = 2), and one HVAC contractor. Participants documented a wide range of years in the construction industry with an average of 10-20 years (range from <5 to > 20 years). Participants recorded the types of projects they typically worked on as single family homes (n = 19), custom homes (n = 19), speculation “spec” homes (n = 12), townhome/condominium projects (n = 11), multiple family homes (n = 8), subdivision/tract housing (n = 6), and commercial (n = 1). The average range for the market prices of the respondents’ projects was $200,000 - $400,000 with some projects costing more than $600,000 and none less than $200,000. Respondents identified themselves as extremely (13.6%, n = 3), very (46%, n = 10), or somewhat (41 %, n = 9) knowledgeable on the subject of radon in building structures. No one reported having no knowledge at all. Respondents documented their educational preparation in the following range: high school/GED equivalent (n = 2), some college or trade (n = 8), completed 2-year degree (n = 3) to completed 4-year degree (n = 9). The majority of respondents were white non-Hispanic with two respondents not reporting ethnicity and one not reporting race. One participant identified himself as Hispanic and one as Native American.

Participants next answered questions regarding RRNC in their work. Participants reported that their projects had radon systems installed always (n = 6), most of the time (n = 10), or occasionally (n = 6). The average cost of including a radon system to the project was estimated by six participants with a noteworthy range of responses ($300, $300 – $800, $800, $1200, $1500, $2000, $2000, $1500 - $2000, $1500 - $2500, and $10,000). When installing radon systems, 18 reported using PVC pipes, 15 reported using a vapor barrier, and 14 reported installing exhaust fans. The terminology “PVC pipe” was used in the survey. Perforated PVC pipe is the more descriptive term to explain the piping used in RRNC. Two of the 22 respondents indicated “perforated” in their responses as an “other” method. These responses were incorporated into the total of 18 respondents reporting use of “PVC”.

When participants were asked their reason for installing RRNC, 10 reported client preference, five stated local building practice, 11 reported builder preference, three stated local policy, 10 stated health and safety and three reported real estate value. When participants were asked, “How often do your clients express interest in having radon systems installed in their homes,” participants responded always (n = 1), often (n = 11), sometimes (n = 5), rarely (n = 3), and never (n = 1). Range of costs varied but could have been a function of interpreting the project costs as just to the particular specialist. Also, the high cost estimate was correlated to an individual who built very high-end homes.

The final section of the survey included questions for participants about their opinions on future RRNC policies. Responses to the question, “Should radon systems be included in the building code” were split with nine in agreement and 13 against. If RRNC were adopted into the building code, three participants chose to adopt Appendix F, while five felt an alternative approach should be used. Most (n = 17, 77.3%) participants did not want to have a certified radon contractor for system installation. Participants indicated if radon systems were adopted into the building code a local building inspector should be used for system inspection (n = 11) or a state certified
inspector \((n = 3)\) should be used. Most participants \((n = 14, 63.6\%)\) did not think an exhaust fan should be mandatory equipment in RRNC. (The installation of an exhaust fan is the difference between an active and passive radon mitigation system.)

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<tr>
<th>Construction Specialty</th>
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<th>Approach Used</th>
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<td>$200 – 400</td>
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*Passive system without fan.

Table 1. Participant estimate of current RRNC approach by method and market price of project \((n=10)\).

**Discussion**

The first aim of this study was to conduct a national inventory of radon resistant new construction (RRNC) policies by state and county. We learned that the regulatory framework is diverse with at least five approaches to adopting policy. The least structured approach is a non-regulatory position, found in 25 states, with no state or local policy regarding radon reduction in
new construction. Of the remaining states, 20 provide limited regulation with some local jurisdictions taking the lead and implementing their own policies when their states had not, while other states have adopted a state wide policy that local counties and jurisdiction must vote on to be utilized locally. The most selective approach to RRNC was established in four states where a statewide policy was used to regulate only the Zone 1 counties—those with average indoor radon levels at or above the EPA designated action level.

Not all states fit into the framework norm or fit into expected patterns of regulation. A unique approach to RRNC can be found in California. This state has partnered with public health in its bid to address indoor air quality. California does not have statewide or local jurisdictions with RRNC building codes. However radon testing and necessary mitigation plans based on test results must be submitted through the public health department and building permits are not issued until compliance is met. The state of California has also reserved the authority to adopt any future Environmental Protection Agency RRNC standards prospectively unless the Department of Housing and Community Development adopts standards, in which case only the latter standards may be adopted (Environmental Law Institute, 2013).

Another standout in the policy framework is Florida. Florida implemented statewide RRNC into their building code despite the fact that the entire state is designated as EPA Zone 3. Recall that Zone 3 designation indicates low geographic risk for radon. While eight of the nine states with some level of RRNC adoption are high-risk states, the case of Florida suggests that perhaps factors apart from high-geographic risk lead some communities to adopt RRNC. Perhaps Floridians have high smoking rates and RRNC is one solution to improving indoor air quality and reducing lung cancer deaths.

The second aim of this study was to test for an association between geographic risk and existing policies. An odds ratio analysis of the differences in existing policies compared with geographic radon risk level revealed critical distinctions for future policy framework. The odds were five times greater that states with more radon risk had implemented at least some level of RRNC compared to states with less radon risk. It is important to recognize this is a descriptive analysis and includes states where only one or two counties have implemented RRNC in an overall high-risk state. However, the results indicated that the policy initiatives are directionally positive and associated with geographic risk. This demonstrates an increasing awareness in states where radon is prevalent.

Increased awareness however does not address health disparity in many cases. For instance in Idaho, a high radon risk state with 40.9 percent and 47.7 percent of counties in EPA Zones 1 and 2 respectively, RRNC policy has been passed only in high income pockets around ski resort towns. The majority of its rural counties have not enacted nor can they generally afford the infrastructure required for increased code requirements. This is a cause for discussion of risk-based or statewide policy in efforts to avoid increasing health disparity predicated on socioeconomic status.

The third aim of this study was to administer a survey to building industry members to attain their perspectives on a local RRNC policy. In order to make the most promising attempt at a state
response to the HP 2020 objectives and the reported trend, it is important to hear the voices of those Montanans who would adopt an RRNC policy and bear the weight of its costs in this state.

Analyses of interviews with industry members in other states that have adopted statewide RRNC reveal differing themes on the success of the program. Themes varied depending on industry member role. Building officials reported the program a success while industry members in the field find the new codes ineffective and prohibitive. Additionally industry tradesmen reported fewer construction projects with RRNC in place than before the policy adoption due to “loopholes.” These opinions are anecdotal but attest to the difficulty of adopting useful and effective policy without engaging appropriate industry members who would bear the weight of implementation.

While survey results were limited in number, generalized implications toward local viewpoints can be drawn from the data. Almost two dozen local industry members (n=22) reported that their projects included installation of radon systems at least occasionally with 72.7% (n=16) stating that most or all projects included a radon system. The common practice of installing radon systems in new homes is indicative of both industry awareness and client preference. Survey results showed respondents identified themselves as extremely (13.6%, n = 3), very (46%, n = 10), or somewhat (41%, n = 9) knowledgeable on the subject of radon in building structures. No one reported having no knowledge at all. When asked the reason for installing radon systems a majority of respondents indicated client and/or builder preference as well as health and safety concerns. Additionally 52% of survey participants indicated clients often expressed interest in having radon systems installed in their homes. Despite the common practice of installing radon systems, respondents were divided on the issue of incorporating an RRNC policy into the Montana Building Code.

In the next phase of research the variety of approaches implemented by states where RRNC has been adopted need to be shared with stakeholders in Montana. This information is important to share as it may facilitate next efforts toward an ultimate goal of utilizing members of the building industry as public health partners in adopting an RRNC policy. It would be ideal to collaborate with all of the partners—public health officials, tradesmen, building inspectors, and regulators to adopt a policy that has buy-in from all of the vested parties.

Limitations

A limitation of this study was the limited location and sample size for specific aim 3. The locality of this study is a microcosm of higher income and housing market price that does not necessarily convey to the state as a whole. While Southwest Montana maintains a rural designation, it is surrounded by two ski resorts and a university which has created an area with high real estate and housing costs. In terms of the small sample size, the lack of survey results may indicate a methodological error or a lack of interest in RRNC within the membership of the local building industry. A small incentive for survey-based research is a typical way to engage participants that was not employed in this study due to budgetary constraints. Despite these limitations, this study is one of only a few to examine local industry perceptions and current practices in RRNC as it relates to Healthy People 2020 objectives.
Conclusions

Residential radon exposure presents a significant health risk. Health care and environmental health have similar professional values such as disease prevention and social justice. Nurses are responsible for addressing the environmental hazards that present a risk for their patients and community. As the population continues to age, adverse health effects from radon will continue to increase without a successful program to reduce exposures. Several cost/benefit analyses have clearly indicated mitigation of existing homes along with adopting RRNC systems can be justified on a national level. High-risk states can and are setting precedent by addressing some of these issues through building code and policy. It is imperative as we move forward to create a policy that is evidence-based and informed by local industry members in order to create the changes that will result in improved indoor air quality and improved health.
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nvironmental+Health

single family homes (SFH) constructed with radon-reducing features, especially in high-
radon-potential areas.* Retrieved from 

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Figure 1. United States map of existing RRNC policy

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Appendix 1. Existing RRNC policy versus Environmental Protection Agency zone designation with odds ratio.

*0 = no state or local RRNC policy; 1 = no state but some local RRNC policy; 2 = state RRNC policy with local choice of adoption; 3 = state RRNC policy that selects for specific high risk areas
ENGAGING ONCOLOGY NURSES IN A PRIMARY PREVENTION PROJECT RELATED TO RADON EXPOSURE: OUTCOME ANALYSIS AND IMPLICATIONS FOR PRACTICE

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Abstract

The position statement of the Oncology Nursing Society supports the role of oncology nursing to educate and facilitate integration of cancer prevention in clinical practice (ONS, 2007). The Radon Education Project (REP) had two aims. First, to increase oncology nurses knowledge of the association between radon exposure and lung cancer through an educational program as evaluated by an online survey. Second, to identify how primary prevention strategies related to radon exposure can be incorporated into clinical practice as recommended by participants in follow up focus groups. The final output was the development of a white paper as a guide for oncology nurses in clinical practice. This is the first documented initiative where oncology nurses have partnered with a state department of health in a formalized, programmatic approach to radon education. Oncology nurses were able to identify programmatic and prescriptive strategies for incorporating primary prevention education on radon into clinical practice.

Project Partnerships

Oncology Nurses

Although oncology nurses typically work in a variety of roles in tertiary care, most are aware of risk factors that lead to the development of cancer and the importance of early detection to improve outcomes. For instance, knowing the association between smoking and the development of lung cancer, oncology nurse often assess patients for a smoking history during clinic visits and can advocate for patients and family members to participate in smoking cessation programs. This general understanding of the principles of risk reduction through primary and secondary prevention for cancer could guide behaviors; like radon testing and mitigation, applicable to themselves and to patients and their families.

The Oncology Nursing Society (ONS) is a national organization of oncology nurses whose mission is dedicated to promoting excellence in oncology nursing and quality cancer care (ONS, 2011). The national organization was founded in 1975 and has grown to over 35,000 members, 231 chapters and 27 special interest groups (ONS, 2011). It has four local chapters in
Minnesota. The largest chapter, Metro MN ONS, draws its membership from the Minneapolis/St. Paul area.

In addition, ONS supports oncology nurses work in the area of primary prevention. In their organizational position statement it acknowledges that oncology nurses can develop, implement and evaluate measures to ensure that individuals and families have access to education about cancer prevention and appropriate cancer screening (ONS, 2007). The position statement supports primary prevention strategies in general, but is not specific in the area of radon and does not provide specific education or support to prepare practitioners to educate patients and their families on radon and lung cancer.

**Minnesota Department of Health and Minnesota Cancer Alliance**

Organizations that focus on radon in Minnesota collaborated with Metro MN ONS in implementing the REP. The MDH received the State Indoor Radon Grant from the federal government for the purpose of protecting the health of the public from the risks of radon related lung cancer (MDH, 2010). The Minnesota Cancer Alliance (MCA) is a broad coalition of organizations and leaders from diverse backgrounds and disciplines dedicated to reducing the burden of cancer across the continuum from prevention to end-of-life care (MCA, 2013). In response to this charge, they developed a five year plan. Cancer Plan Minnesota 2011-2016 is a framework for action created by the partners of the MCA (2011) to address the burden of cancer in Minnesota. One area for intervention identified in the framework is to educate stakeholders about radon safety. The medical community has been one partner targeted for education on the health risks of radon and how to effectively communicate these facts to patients (MDH, 2010).

**Radon Education Project Overview**

The purpose of the Radon Education Project (REP) was to evaluate knowledge and perception of the relationship between lung cancer and radon exposure among the nurses who belonged to the Metro MN Chapter of ONS and to identify how oncology nurses might incorporate radon safety education into clinical practice. If successful, this project could serve as a model for organizing other alliances in these efforts locally and nationally. The focus group recommendations for integrating primary prevention into practice have the potential to advance the role of the oncology nurse in the area of radon exposure and risk reduction.

The purpose of the REP was to educate and develop recommendations for a primary prevention strategies related to radon for oncology nurses in the Metro MN Chapter of ONS. This was accomplished through an educational program for oncology nurses focused on increasing knowledge of the association of radon and lung cancer. This program was evaluated by an online survey. Several months after attending the educational program, participants were invited to follow up focus groups to identify how primary prevention strategies related to radon exposure might be incorporated into oncology clinical practice.
The scientific evidence to support the causal relationship between radon and lung cancer has been well described. Therefore, the REP was not designed to add to the scientific knowledge, but sought to explore perceptions and knowledge related to radon and lung cancer.

**Literature Review**

Given the overwhelming scientific evidence of the association of radon to lung cancer, the literature surprisingly lacks research focused on knowledge and perception related to radon exposure risk. Despite this limitation, the literature review did yield some important findings that focus on education, radon risk perception and correlates that may guide nursing radon education. Radon perception and sociodemographic correlates demonstrate that a knowledge deficit exists related to radon health risk and that there is a common perception that personal risk associated with radon is low. Knowledge about radon is often superficial and can lead to misconceptions and incorrect conclusions about risk. Demographic data analysis also yielded interesting but inconsistent findings. Although education and household income may lead to greater testing, there is no data to suggest that there is an association with mitigation in homes with high levels of radon. There was no specific published data on knowledge and perception of radon risk by oncology nurses or other health care professionals. Since health care providers are the primary source of health information, education is clearly needed to help achieve a greater understanding of radon health risks by health care professionals and the general public.

**Project Design and Methodology**

The REP was a mixed methods design to explore knowledge and perceptions of oncology nurses about radon exposure and lung cancer. The ultimate goal was to identify and recommend strategies for incorporating primary prevention education into clinical practice. The study participants were recruited from members of the Metro MN Chapter of the ONS who attended an in-service at a monthly meeting. The project had three phases. In Phase I, an educational program was developed and presented that met the standards for certified CE programming from the ONS national organization. All attendees were offered free radon test kits. Some of the attendees at the educational program signed a consent form indicating interest in participating in the next phase of the REP. These individuals completed a post in-service online survey. In Phase II, focus groups were designed and offered to individuals who attended the Phase I educational program. Phase III included the development of a white paper (Appendix A) on radon and lung cancer which was based on the recommendations gleaned from the focus groups. This paper was presented to the Metro MN ONS Board for adoption and posting on the website.

To safeguard informed consent in this study, an application was submitted for review to the Institutional Review Board (IRB) at St. Catherine University prior to the implementation of both Phase I (education phase) and Phase II (focus groups) for this study.
Phase I: Educational Program

In March 2012, a continuing nursing education activity on radon and lung cancer was approved by ONS, which is an accredited approver through the American Nurses Credentialing Center. The educational activity was presented on April 10, 2012 during the monthly meeting of the Metro MN Chapter of the ONS with a total of 66 members and affiliates in attendance. Of these attendees, 41 Metro MN ONS members signed consent forms for participation in the REP. Of the 41 who signed consent forms, a total of 33 completed the online survey with the questions found in Table 1.

1. What is your practice setting?
2. What is your highest degree you have received in nursing?
3. Number of years you have worked in oncology nursing?
4. Prior to this educational program, have you tested your home for radon?
5. Prior to this educational program, was your home mitigated for radon?
6. Did you test your home with the radon test kit provided at the radon educational program at Metro MN ONS?
7. Did you or are you planning to mitigate your home due to test results?
8. Did you share information about this program on radon and lung cancer with family and friends?
9. Was the educational program relevant to you personally?
10. In what ways do you think you may use the information you learned in the program in your practice?

Table 1: Post radon education electronic survey questions

Phase II: Focus Groups

In the fall of 2012 members of the Metro MN Chapter of ONS who attended the educational program on radon exposure and lung cancer and signed consent forms for participation were invited to attend one of three follow up focus groups. Focus groups were conducted between five to seven months after attending the educational program. Participants included oncology nurses holding various positions (research, management and clinical practice) from five health care institutions within a large metropolitan area.

Each focus group began with a review of relevant information on radon and lung cancer covered in the educational inservice in April as well as a short discussion on the key findings from the online survey. Participants were provided with the ONS definition for primary prevention: Primary cancer prevention refers to the prevention of cancer through health
promotion and risk reduction (ONS, 2013). Open ended questions were utilized to elicit possible ways that radon education might be incorporated into clinical practice (Table 2).

1. Now that we just recapped information on radon and lung cancer, tell us why you attended the program?
2. Tell me how primary cancer prevention compares to your current role in oncology clinical practice? (To clarify also do you utilize health promotion or risk reduction activities currently in your work?)
3. Talk about specific ways that radon and lung cancer education testing and mitigation can be done in clinical practice? (To clarify, how can it be accomplished? Any specific time point in the trajectory of the disease that you feel will be more relevant for primary cancer prevention?)
4. Tell me a little about what may be potential challenges to bringing forth this information to oncology patients and educating cancer patients and their families?
5. What do you feel are the necessary components in developing a position paper or white paper for Metro MN on radon and lung cancer education?
   a. Consider the role of the oncology nurse?
   b. General or specific components?
   c. What should be included?
   d. What steps are required?
   e. The position of the Metro MN ONS on radon and lung cancer education in oncology clinical practice is…..?

Table 2: Focus group questions

Phase III: White Paper

The oncology nurses who participated in the focus groups were informed that their input would be used in the development of a radon education document for clinical practice. This document was envisioned to be either a position paper or white paper. Definitions were provided for both types of documents during the focus group.

Data Analysis

Phase I

Data collection of the Phase I educational program was done via an electronic survey. Survey questions were constructed to assess learning, motivation to complete radon testing and mitigation if indicated, and to assess study participants interest in sharing radon safety information with family, friends or patients.
Summary of the survey revealed that study participants worked primarily in the outpatient setting and represent oncology nurses from five health care institutions within a large metropolitan area. Participants worked in a variety of oncology roles including research, clinical practice, nurse practitioner, clinical nurse specialist, clinical coordinator and hospice nurse (Figure 1). Other demographic data were also collected. The majority of nurses had a Bachelor of Science in Nursing (BSN) degree and worked for more than 20 years in oncology nursing.

![Figure 1](image_url)

Figure 1: Responses to practice setting question.

Responses to content items indicated that 46% tested their home for radon prior to the educational program and that 46% also tested with the radon test kit provided at the Metro MN ONS meeting. In addition, 94% shared the information on radon and lung cancer with family or friends and 100% stated that the information was relevant to them personally and the majority identified applicability to clinical practice. Survey comments were generally positive and demonstrated interest and the importance of radon testing and mitigation.

In addition, a quantitative assessment was completed on actual radon testing done by participants. A number was assigned to the test kit and the laboratory sent the radon test result using the number and not the participant name. Utilization of the radon kits and responses to the survey were summarized (Table 5). Radon test kits offered at the conclusion of the program and laboratory results were tabulated. A total of 49 participants used the radon test kit provided at the program. Six test kits were inevaluable. Radon test levels ranged from 0.7 to 18.3. A total of 12 tests out of 43 evaluable results (28%) exceed the EPA action level of 4Pci/L. These results were better compared to the Minnesota Department of Health data that states that two in five
homes (40%) have radon levels that are rated high radon zones (MDH, 2013). This may be related to the high testing already done by participants prior to the in-service. Survey results showed that 46% of the project participants had tested their homes for radon prior to the program.

<table>
<thead>
<tr>
<th>Test Kits Used</th>
<th>Prior Testing</th>
<th>Inevaluable Tests</th>
<th>Test Level Range</th>
<th>% Above EPA Action Level</th>
<th>% MN Homes Above EPA Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>49 (74%)</td>
<td>46%</td>
<td>6 (12%)</td>
<td>0.7 – 18.3</td>
<td>28%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Table 5: Radon test kit results

In a cross sectional study, Larsson, Hill, Odom-Maryon and Yu (2009), reported the results of radon testing in 1994 and 1998 in National Health Interview Surveys. Of the individuals who had heard of radon, a follow up question was given on whether their household air has been tested for radon. A total of 9.7% and 15.5% answered affirmatively (Larsson et al., 2009). In another study Nissen, Leach, Nessen, Swenson, and Kehn (2006), investigated the testing rate by patients instructed on radon in a primary care practice where patients had a radon testing rate at baseline of 24.7%. The high level of testing by the oncology nurses, prior to the REP, may demonstrate their interest in adopting protective behaviors around radon consistent with primary prevention. This result also aligns well with the hypothesis that oncology nurses will engage in behaviors from which they anticipate deriving personally valued benefits. This appears evident from the high testing rate at baseline and suggests this is a motivated group.

**Phase II: Focus Groups**

In Phase II, three focus groups were conducted and audio taped. Data were captured using a transcript-based analysis. In alignment with an analysis methodology described by Krueger and Casey (2009), a classic analysis strategy guided identification of themes and categorized results. The analytical framework used key concepts. This framework was useful to understand how participants view a topic and identify important ideas, experiences, and preferences that illuminate the results.

The oncology nurses, within the Metro MN chapter of ONS, are a homogeneous population as compared to nurses that may choose to work in a primary care. Oncology nurses within ONS are voluntary members of this organization. Nurses who join ONS tend to be committed to oncology practice and to this specialized work. In addition, ONS has standards for patient care related to chemotherapy administration and side effect management. Therefore, this commitment to a specialized practice that has national standards of care may create a group of
Evaluation of Phase II involved data analysis of the tapes transcribed from the focus groups. Content was analyzed for emerging themes related to participant recommendations for incorporating radon safety education into clinical practice. These recommendations for practice are important to advance the field in the area of primary prevention and the role of the oncology nurse. Five themes were identified.

**Theme one: Education.** The first theme related to education. Several focus group participants stated that they did not know much about radon prior to the educational in-service. They identified education of oncology nurses and physicians as important so health care professionals could be knowledgeable on the topic of radon and lung cancer when speaking with patients. This was identified as a challenge and described in this way: “Feeling that you can’t give a proper answer. Who wants to give an answer if they don’t know about it?” Another nurse engaged her colleagues on the topic of radon and, based on their responses, expressed concern about their knowledge level stating the first priority should address the “need to educate nurses and doctors first.” Another nurse stated that the data are “what impresses people.” There was interest in understanding the data. One nurse describe it this way: “The recommended level [is] less than 4. Well what does it mean if it is 5? What does it mean if it is 7? What does it mean if it is 10? You might say well recommend level is 4, but mine is 5.4? Well that isn’t much higher than 4 so I don’t need to do anything about that. Is it logarithmic? Is 5.4 really extreme? Is 50 really extreme? People won’t be able to really know.”

**Theme two: Access.** The second theme identified was access to data and readily available information in the clinical setting. Data on radon and lung cancer should be easily accessible to oncology nurses and have contact information/websites and brochures available to educate patients and families. Nurses expressed that they have access to a library, but what they need are educational material such as brochures and teaching sheets. Other nurses shared that “getting this information out for oncology nurses is great.” and “if you have the brochures in the clinic then you can answer their questions.” The nurses also expressed that they should also have access to easily available information on how to test and mitigate your home. The nurses shared that this information was new to them and that it was important for all nurses to have readily accessible information.

**Theme three: Timing.** Another important theme related to the timing of patient education. Although the importance of educating patients was recognized, it was suggested that the timing of this education should be individualized to the patient. Some patients are open to receiving the information on radon after diagnosis or early on in treatment while others are overwhelmed with the new information. For some patients, education on radon may be best done later in the
trajectory of the disease possibly in a survivorship clinic. One nurse described her patients initially feeling overwhelmed by the teaching on disease and treatment in this way: “There is usually a lot of information overload at first. But later down the line if someone is there for a week or two, which is often the case for some of these intensive treatments, it is a better time to talk to them.”

**Theme four: The role of ONS.** The role of ONS in primary prevention was also clearly stated as another theme. Oncology Nursing Society involvement was recognized as important endorsement for this work. The society is well established with a large national membership. Several nurses agreed with the statement of one participant that “if you have the ONS backing this position then it gives it a little more credibility.” The nurses referred to ONS involvement, or at least endorsement, of educating patients on radon in clinical practice as important. Focus group members stated that ONS approval or involvement in this work was positive, but could also be strengthened by forming partnerships with community, primary care and other organizations. It was described in this way: “maybe partnering with the American Lung Association or the Breathe of Hope Lung Foundation. Those are other key organizations, also, I am sure, would have a similar endorsement of this.”

**Theme five: Barriers.** There were barriers identified to radon education in the clinical setting. The cost of mitigation for homes above the EPA action threshold was a concern. If a patient is unable afford to mitigate their home, it was viewed as a barrier to patients being interested in learning about radon testing and mitigation. One nurse stated that the patient may not want the information as they may be concerned that they have to move and that no one would buy the house. Other barriers to educating in the clinical setting included limited time and lack of knowledge on the topic as well as physician/clinic support.

**Phase III: White Paper**

The oncology nurses who participated in the focus groups were informed that their input would be used in the development of a radon education document for clinical practice. From the comments of the focus group participants, a prescriptive outline of data, information and references was developed. The white paper was adopted, without changes to format or content, by a unanimous vote by the Metro MN ONS board on September 10, 2013 and posted to the website. The membership was updated on the white paper on November 12, 2013 at their regular monthly meeting. Minnesota Department of Health supports radon educational outreach and reviewed the draft white paper with a few recommendations and no changes to the format.
Conclusion

The REP was the first documented collaboration of oncology nurses and the MDH in educating oncology nurses on radon and lung cancer and identifying potential ways to educate patients in clinical practice. The Metro MN oncology nurses embraced the education and found the information to be highly relevant to them personally and professionally. Compared to the literature, the nurses that participated in the educational in-service had a higher percentage of testing their homes at baseline than seen in the general public. This higher than expected level of testing prior to the education program, possibly relates to their understanding of the health hazard related to radon. However, in follow up focus groups, nurses identified a knowledge deficit related to radon in themselves, their colleagues and physicians. So despite their recognition of the hazards of radon, their overall knowledge of radon risk to develop lung cancer is limited and mirrors the general population.

In the era of health care reform, the need to focus on cost of care and prevention of disease is desperately needed. Oncology nurses have a unique perspective on cancer and could be one entry point for a systematic and organized educational process on radon education in clinical practice. The departments of health and clinical practice settings have functioned independently when they clearly have an interdependent function in fostering the health of our nation. The Institute of Medicine clearly defines the initiative to collaborate (IOM, 2012). This greater utilization of combined resources may be what is needed in radon education in the future.
References


Appendix A

Radon and Lung Cancer: Information and Resources for Use in Oncology Clinical Practice

September 10, 2013

Maureen Quick RN, MS, OCN
Doctoral Candidate, St. Catherine University
Metro MN ONS Member

“I don’t know if it is a community or state or federal requirement or if it is just widely considered best practice. The radon thing could be, at least in MN, considered best practice to be addressed by all health care providers.”
Focus Group Participant, Metro MN Member, 2012

“Lung cancer due to radon is a preventable disease. Our mission should be that we disseminate information about that.”
Focus Group Participant, Metro MN Member, 2012

I think it is great that we as a chapter have something specific that we sort of stand for or have a goal for or can present as part of as to why we are in existence
Focus Group Participant, Metro MN Member, 2012
Introduction

The Radon Education Project (REP) included the development of a process to educate, create interest and develop recommendations for primary prevention strategies related to radon for oncology nurses in the Metro MN Chapter of the ONS. This white paper was developed based on input from Metro MN Chapter members who participated in the REP focus groups.

Background

- Radon is a naturally occurring gas produced from the decay of uranium that is found in nearly all soil (MDH, 2010)¹
- Radon flows from the soil into the air. Outside air typically has low concentrations; however, radon gas can also seep into homes where it is unable to disperse. This build up of radon gas within the home can then lead to higher concentrations. (National Research Council, 1999)²
- Radon is chemically inert. However, the radon atoms can spontaneously decay or change into other atoms called radon progeny. The radon progeny are electrically charged and can attach themselves to small dust particles. The dust particles can easily be inhaled into the lung.
- The deposited atoms emit alpha radiation that can disrupt DNA of the lung cells leading to one step in the development of lung cancer (National Research Council, 1999)²
- The map below shows average radon levels in the state

*Environmental Protection Agency (EPA) recommends that all homes with radon levels of 4 pCi/L or more be mitigated.

Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L (picocuries per liter) (red zones) ³*  
Zone 2 counties have a predicted average indoor radon screening level between 2 and 4 pCi/L (orange zones) ³  
Zone 3 counties have a predicted average indoor radon screening level less than 2 pCi/L (yellow zones)³
**Significance**

*Radon gas is the second leading cause of lung cancer in the U.S. with an estimated 21,000 deaths per year*\(^3\)

- Approximately 15% of all lung cancers are attributable to indoor radon.
- Leading cause of lung cancer for non-smokers
- The combined effect of smoking and radon exposure is synergistic; therefore at equivalent exposure to radon, smokers will have a higher risk of developing lung cancer than non-smokers\(^4\)
- Environmental Protection Agency (EPA) recommends that all homes with radon levels of 4 pCi/L or more be mitigated
- Comparable risk at 4 pCi/L is 200 chest x-rays per year\(^3\)
- Death risk to the average person from radon gas at home is 1,000 times higher than the risk from any other carcinogen or toxin regulated by the FDA or EPA\(^3\)

**There is no known safe level of radon**

**Radon in Minnesota**

Since radon gas is clear and odorless, individuals may be unaware of their exposure to this harmful gas.

Nationally elevated radon levels are in approximately one in 15 homes (US Environmental Protection Agency, 2013).

Nearly 80% of counties are rated high radon zones\(^3\)

The Minnesota Department of Health (MDH) recommends that all Minnesota homeowners test their home for radon\(^2\)

The radon test kit costs between $5-$25 and radon mitigation costs approximately $800-$2500\(^2\)

*Due to the geology and how homes are built and operate in Minnesota, two in five homes have radon levels above the EPA action level of 4 pCi/L (MDH, 2010).*
How can Oncology Nurses and other Health Care Professionals Help?

1. **Education of oncology nurses and physicians:** This document contains basic information on the health hazard associated with radon. Resources below also provide additional information for use in educating professionals so they feel confident in teaching patients/family members.

2. **Patient Assessment Form/Intake:** Patients complete a personal health assessment questionnaire/intake form. Consider asking them if they have ever tested their home for radon or do they know what the radon level of their home. If added to the form, it may provide an avenue for them to ask questions.

3. **Access to data and information for patients:** Information should be available to educate patients and families
   a. Add radon brochures from MDH to the clinic information center, patient resource center or patient library.
   b. Provide an information board in the lobby. Consider picking a topic for the board for a month. This may generate patient questions. January is radon action month and November is lung cancer awareness month.
   c. Consider the timing of education. Some patients would be open to receiving the information on radon immediately and others would be overwhelmed with the new information. This education should be individualized and education on radon may be best in a survivorship clinic.
   d. Topic of discussion or informational booth at support group, survivorship conference or volunteer activity
   e. Consider ways to enhance community involvement and primary care involvement
   f. MDH also recommends having bookmarks and test kit order forms available and to utilize the Star Tribune portal to provide zip code data to the community
      [www.startribune.com/local/190554621.html](http://www.startribune.com/local/190554621.html)
   g. Consider using one of the MDH radon posters for your information board
      [http://www.health.state.mn.us/divs/eh/indoorair/radon/sirg.html](http://www.health.state.mn.us/divs/eh/indoorair/radon/sirg.html)

**Benefits of Oncology Nursing Society (ONS) Involvement**

- Organization promotes awareness and teaching. Metro MN ONS endorsing and promoting this work would provide credibility
- Information is relevant to health care providers both personally and professionally

**Resources/Websites**

1. Minnesota Department of Health: Radon in MN homes. The primary portal for radon in MN: [www.health.state.mn.us/radon](http://www.health.state.mn.us/radon)


**Test Kits and Brochures**

1. Radon Testing Procedure and information:  [www.health.state.mn.us/radon](http://www.health.state.mn.us/radon) (pick radon testing or radon test kits)

2. Minnesota Department of Health:  Radon Brochure has information on radon testing and mitigation.  available on-line, also as a pdf, and hard copy can be ordered (for free from MDH, as supplies last).  A shorter bookmark is also available for mass distribution:  [www.health.state.mn.us/radon](http://www.health.state.mn.us/radon)

**References**

   Minnesota: Radon Resistant Toolkit
   [www.health.state.mn.us/divs/eh/indoorair/radon/sirg.html](http://www.health.state.mn.us/divs/eh/indoorair/radon/sirg.html)


5. University of Minnesota: Radon Risk Assessment 2011


**Acknowledgement**

Author, MH Quick, would like to thank the Minnesota Department of Health (MDH)  for their contributions to this Systems Change Project on radon and lung cancer.

This is the first work demonstrating oncology nurses partnering with the Minnesota Department of Health in a formalized programmatic approach on radon safety education.
Abstract

Measurement of radon is very important in dwellings because of its radiological impact on public health. Radon contributes more than half of the total ionizing radiation dose. It is known from the recent surveys in many countries that radon is the second cause of lungs cancer after smoking. In this context, we have measured radon ($^{222}$Rn) concentration in different dwellings of Kathmandu valley, Nepal. The time integrated method using LR-115, type II plastic track detectors, was employed for the measurement based on Solid State Nuclear Track Detector (SSNTD). In addition, radon concentrations in the bedroom and kitchen were also measured. The overall concentration of radon in Kathmandu valley varied from 8±2 to 787±134 Bq/m$^3$ with the average value of 80±15 and annual effective dose varied from 0.14 to 13.54 mSv per year. The radon concentration was found more in the dwellings of highly urbanized areas and in the poor ventilated dwellings of Kathmandu Valley.

Introduction

Radon and its progeny constitute the most important natural radiation exposure not only in mining but also in many dwellings. After smoking, radon represents the second most important cause of developing lungs cancer (Szacsavai, 2013; UNSCEAR, 1994; IAEA/AQ/33, 2013). The main sources of radon are soil and rocks, however, it is present in trace amounts almost everywhere because of its parent radioactive element uranium which is commonly found in the earth’s crust. Radon belongs to the noble gas column in the periodic table with a fairly long half-life of 3.8 days. Three natural isotopes of radon occur; Radon ($^{222}$Rn), Thoron ($^{220}$Rn), and Actinon ($^{219}$Rn) emerging from the radioactive decay of Uranium ($^{238}$U), Thorium and the Actinium series respectively (Sathish, 2011).

Radon emanates mainly by diffusion processes from the point of origin following alpha decay of $^{226}$Ra in underground soil and water, building materials used in the construction of floors, walls, ceilings, natural gas used for cooking, etc. The concentration of radon in the atmosphere varies depending upon the place, time, height above the ground and meteorological conditions (Kant, 2004). Generally, all building materials contain certain amount of uranium and radium. So the exhalation of radon from these materials to the inside of the house can be a source of residential radon. Outdoor air can also play a role for the radon entering inside the dwellings through open doors and windows, cracks and fissures in the buildings, etc. (Ahmed, 1994). Also, the concentration of radon and its decay products show large fluctuations in the indoor atmosphere.
due to the variations of temperature, pressure, nature of building materials, wind speed, occupants’ behavior, etc. (Al-Khalifa, 2006).

When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon (\(^{218}\)Po and \(^{214}\)Po) can interact with biological tissue in the lungs and disrupt the DNA of these lung cells. The damaged DNA is potential enough to lead to cancer. This DNA damage, associated with radon, can occur at any level of exposure because a single alpha-particle can genetically damage a cell (Mehra, 2006; BEIR VI 1999; WHO 2009). It has been pointed out that indoor radon exposure is also tentatively linked with the risk of leukemia and certain other cancers, such as melanoma and cancers of the kidney and prostate (Henshaw, 1990).

Keeping the radiation hazards of radon in mind, it is quite important to make a systematic study of the indoor radon concentration. For this purpose, radon measurements have been carried out in a number of dwellings of Kathmandu valley. The nuclear track detector technique a fairly reliable method for the integrated and long term measurement of indoor radon activity (Subba Ramu, 1992). In this work, we have used the SSNTD technique for the assessment of indoor radon (\(^{222}\)Rn) and its progeny concentration.

**Materials and Methods**

**Study Area: Kathmandu Valley at a Glance**

Kathmandu valley is comprised of three different districts; Kathmandu, Bhaktapur and Lalitpur. It lies between the latitudes 27° 32’ 13” and 27° 49’ 10” north and longitudes 85° 11’ 31” and 85° 31’ 38” east. It is located around1, 300 meters above sea level. The climate of Kathmandu valley is sub-tropical cool temperate with maximum of 35.6°C in April and minimum of –3°C in January and 75% annual average humidity. The average rainfall is 1,400mm, most of which falls during June to August (Dangol, 2009).

The Kathmandu valley is surrounded by the high rising mountains such as Shivapuri (2,732 m) in the north and Phulchoki (2,762 m) in the south. The rugged topography of the mountains with steep slopes reflects the geological structure of the valley. The basin is in the middle part of the lesser Himalaya, and bounded by the hill ranges Mahabharatlekh to the south and Shivapurilekh to the north (Upreti, 2001). The surface of Kathmandu valley is generally broad and almost flat except towards the boundaries of the valley, where rivers are deeply incised. Well developed terraces, formed by erosion from rivers, are common in the valley. The Kathmandu valley infilling consists of three million year-old fluvial and lacustrine sediments, consisting mainly of gravel, sand, silt, clay, peat, lignite and diatomaceous earth, etc., delivered mainly from the mountains in northern parts of the basin. Mines and minerals found in Kathmandu Valley are quartzite, dolomite, pegmatite, gneiss, schist, slates, limestones and marbles. The soil of the basin of Kathmandu valley is mainly alluvial soil, residual soil, and alluvial fan deposit (Shrestha, 2004).
**Detector**

A passive method using LR-115 type-II plastic track detectors (1 cm × 1 cm size) developed by Kodak-pathe, France, based on SSNTD technique, was employed for the assessment of radon concentration. The cellulose nitrate LR-115 (12 µm thickness), is a very useful detector for the direct registration of alpha particles in the energy range of 0.17-4.80 MeV. Such alpha particles penetrate through the thin film of LR-115, forming observable tracks (Abd-Elzaher, 2012; Dwivedi, 1997; Gupta, 2012).

**Dwellings**

Altogether 41 dwellings around Kathmandu Valley were selected for the radon study. The choice of the houses was random. LR-115 was kept in both the kitchen and bedroom of each house. The majority of the houses were concrete with plastered walls with proper ventilation system. The detectors were fixed on a thick flat card with both sides taped and exposed in an unfiltered mode by hanging them on the wall of the room with the sensitive side facing the environment such that the detector viewed a hemisphere of radius at least 6.9 cm, the range of $^{214}$Po α-particles in the air. See Figure (1). No surface was closer than this range in order to prevent the surface decay products’s alpha particles from reaching the detector. The detectors were exposed for 100 days inside the dwellings. The height of detectors was kept about 2 m from the floor. Arrangements were made to avoid settling of dust on the detectors, which could possibly effect the radon concentration (Kant, 2004; Kumar, 2010; Kumar, 2000).

**Exposure measurement:**

The exposed detectors were collected and sent to Dosirad laboratory, France, for track reading. The detectors were etched in a solution of 2.5 mol/l NaOH at 60°C for one and half hour. The counting of alpha tracks was done using a binocular optical research microscope with a magnification of 400 ×. The calibration factor of the detector was 2.1 tracks/cm² per kBq·h/m³. For open dosimeter the indoor equilibrium factor for radon (UNSCEAR, 2000) is equal to 0.40.

The average radon concentration ($C_{Rn}$) in terms of Bq/m³ was determined using equation 1 (Kodalalpha, 2014).

$$C_{Rn} = \frac{1000 \times \text{Exposure (kBq·h/m³)}}{\text{Exposure time (h)}} \quad (1)$$

The annual effective dose from radon was calculated using equation 2, given by International Commission on Radiological Protection (ICRP, 1993),
\[
D = \frac{C_{Rn} \times K \times 0.4 \times H}{3700 \text{Bq m}^{-3} \times 170 \text{h}} \tag{2}
\]

where \(D\) is the annual effective dose in mSv/yr; \(C_{Rn}\) is the average radon concentration in Bq/m\(^3\); \(K\) is the ICRP dose conversion factor 3.88 mSv per Working Level Month (WLM) for general public; \(H\) is the annual occupancy at the location (7000 hours for residents), i.e. 80% of the total time; 170 is the exposure hours taken for Working Level Month.

**Results and Discussion**

Radon monitoring was carried out at three different districts of Kathmandu Valley. Table (1) summarizes the average radon concentration and annual effective dose in three different districts of Kathmandu Valley.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of districts</th>
<th>Total number of Dwellings</th>
<th>Radon Concentration in(Bq/m(^3))</th>
<th>Annual Effective dose in(mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bhaktapur</td>
<td>12</td>
<td>36±8</td>
<td>415±71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90±17</td>
</tr>
<tr>
<td>2.</td>
<td>Kathmandu</td>
<td>20</td>
<td>8±2</td>
<td>161±29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56±11</td>
</tr>
<tr>
<td>3.</td>
<td>Lalitpur</td>
<td>9</td>
<td>8±2</td>
<td>787±134</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93±17</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>80±15</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Table (1): Average radon concentration and annual effective dose in Kathmandu Valley

In addition, the variation in radon concentrations both in the bedroom and kitchen of dwellings has been shown in the Figure (2).
The overall concentration of radon in Kathmandu valley varied from 8±2 to 787±134 Bq/m³ with the average value of 80±15 Bq/m³ and annual effective dose varied from 0.14 to 13.54 mSv.

Figure (2): Radon concentrations in dwellings; BTP-Bhaktapur; KTM- Kathmandu; LTP- Lalitpur; B-Bedroom; K-Kitchen

**Conclusion**
The higher radon concentrations are found in the following locations: Kamalbinayak, Kirtipur, Maharajgunj, Sinamangal and Godamchaur of the Kathmandu valley. These places are densely populated and polluted. Many industries are set up in these areas. A large amount of coal is being used as fuel in the brick factories near the Kamalbinayak area of Bhaktapur district and near the Godamchaur area of Lalitpur district. This could be one reason for the elevated levels of radon. In addition, a large marble factory near the Godamchaur area of Lalitpur district may contribute more radon to that area. However, the possibility of higher radon concentrations in the Bhaktapur and Lalitpur districts could be the presence of minerals which have a high abundances of uranium (Kaphle, 1990; Shah, 1999) like granite, gneiss, shale, schist, limestone, dolomite, sand, etc. This fact was also observed in other, previous, studies (Fairbridge, 1972).

We found the radon concentration is higher in the kitchen than in the bedroom in most of the dwellings. Higher concentration of radon in the kitchen could be the result of contribution from radon sources like water, cooking gas, kerosene etc. In addition, the overall concentration of radon and annual the effective dose of radon in Kathmandu valley are well within the reference levels (200-600 Bq/m³ and 3-10 mSvy⁻¹) of International Commission of Radiological Protection (ICRP-103, 2007), except Godam Chaur of Lalitpur district (which needs further investigation).

Acknowledgement

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