STUDY #1 IN A SERIES OF REPORTS ON RADON IN BC HOMES

A Comparison of Three Radon Systems in British Columbia Homes:

CONCLUSIONS AND RECOMMENDATIONS FOR THE BRITISH COLUMBIA BUILDING CODE

PUBLISHED BY

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RADON AWARE
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PROGRAM

RADONAWARE

RadonAware is a branded public education and advocacy program established by the BC Lung Association. The program is focused on providing research, information, education and public advocacy on issues related to reducing the public health risk of radon. For more information see www.radonaware.ca

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Study Overview

Radon gas is a serious public health risk, and the second leading cause of lung cancer in Canada. Most people are exposed to this risk in their homes. A key aspect of protecting residents is to ensure that new homes are built to reduce this risk for all future occupants. In effect, "future proofing" new homes from radon exposure is an important public health objective fully supported by the BC Lung Association. The focus of this study is on identifying options and recommendations on how future proofing can be achieved.

Radon Exposure Guidelines

It is important to note that exposure guidelines exist to guide both personal and regulatory decision making on which combination of building techniques, materials and technologies can best achieve the goal of minimizing radon exposure versus the guideline. In Canada, Health Canada published a radon exposure guideline of 200 Bq/m^3, above which action should be taken to reduce radon levels. In the United States the guideline is 150 Bq/m^3 and the World Health Organization sets its guideline for action at 100 Bq/m^3. This suggests strong international scientific consensus within a narrow guideline range that action should be taken to reduce radon levels below this range.

Factors Affecting Future Proofing

There are several aspects to achieving the future proofing goal. These include:

- Identifying and assessing which combination of building techniques, materials and technologies (the "measures") can best ensure that radon levels in new housing are well below radon exposure guidelines.
- The role of the BC Building Code to ensure the best protective measures are installed in new housing.
- The role of the building industry and code compliance authorities in ensuring that radon mitigation measures are installed correctly.

BC Building Code – a Key Role in Delivering Public Health Protection

The BC Building Code recognizes the importance of the radon issue. Measures were first incorporated in the 2006 version of the Code to address this public health issue. In the 2006 Code the most important radon measure was the requirement to place an impermeable barrier underneath concrete foundation floors in an attempt to seal the structure from the entry of radon gas. A further step was required in both the 2006 and 2012 version of the Code in which a vertical pipe is inserted into the concrete floor extending above the floor and capped. This measure has come to be known as the radon "Rough-in" Capped System.

The purpose of this Rough-in Capped System is to enable a complete pipe system extending from the rough-in through the roof of the home to be installed. This would have the effect of allowing radon from below the concrete floor to be drawn away via the "stack effect" and vented through the roof. This completed pipe installation is known as a Passive Radon Reduction System. Where a fan is added to the Passive System to actively depressurize the area below the slab is known as an Active Radon Reduction System.

There are many challenges and assumptions with the rough-in measure, including:

- That an occupant (and future occupants) understands what the pipe is for,
- That an occupant conducts radon testing to determine whether the Health Canada guideline of 200 Bq/m^3 is being exceeded,
- That an occupant has the expertise (or can access it) to assess the mitigation measures needed, and
- That an occupant understands a more complete system should be installed, and if so, agrees to pay for the additional costs.

Due to these factors, industry consensus is even in a situation where an occupant determined their home had high radon, there is low probability that the needed radon mitigation measures would be applied. Industry also recognizes to install a full Passive Radon Reduction System at the time of new home construction would be substantially easier and considerably lower in cost.

Closing the Data Gap

Limited data exists in the Province of BC to inform the effectiveness of different radon measures installed under the 2006 and 2012 BC Building Code versus more complete Passive or Active Systems. Given the important need to ensure that new homes are future proofed to reduce the public health risk of radon the BC Lung Association commissioned a detailed in-the-field study of three variants of a typical radon reduction system, namely:

1. Rough-in Capped System
2. Passive Radon Reduction System
3. Active Radon Reduction System

Study Approach

Two Canadian-National Radon Proficiency Program (C-NRPP) Certified Mitigation Providers were contracted to inspect, test and mitigate 16 homes for each of the measures which had been built under either the 2006 or 2012 BC Building Code. Of the 16 homes, 8 were located in northern BC (Prince George), and 8 homes in the southern Interior of the Province (Castlegar and Nelson). The project was carried out between January and June 2014.

The research methodology provided a unique opportunity to test each of the 16 homes with the 3 different radon measures. All of the homes selected already had a fully installed Passive Radon Reduction System. This enabled the Certified Radon Mitigators to cap the Passive System to emulate the rough-in measure, and add a fan to achieve an Active Radon Reduction System.

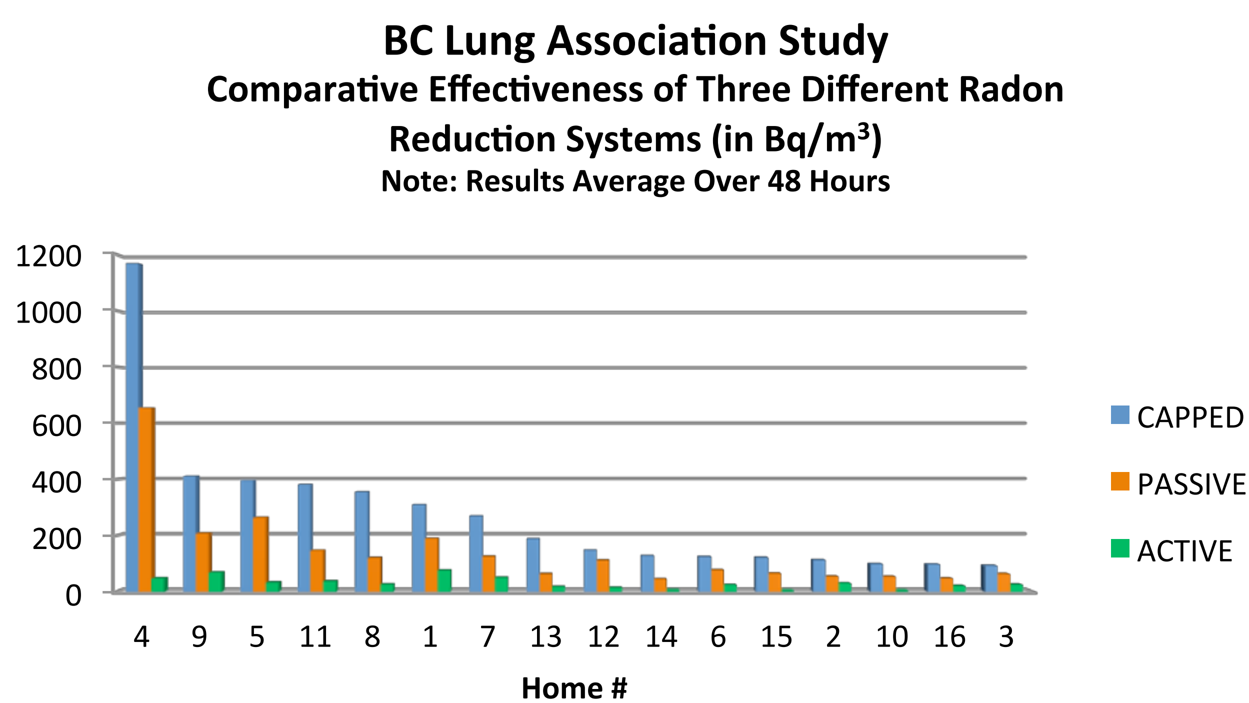
As part of the field study the researchers also noted the degree to which home builders had fully satisfied the requirements of the BC Building Code with regard to aspects that are radon related.

Results – Comparative Effectiveness of Different Radon Reduction Systems

The test results showed that (see Chart 1):

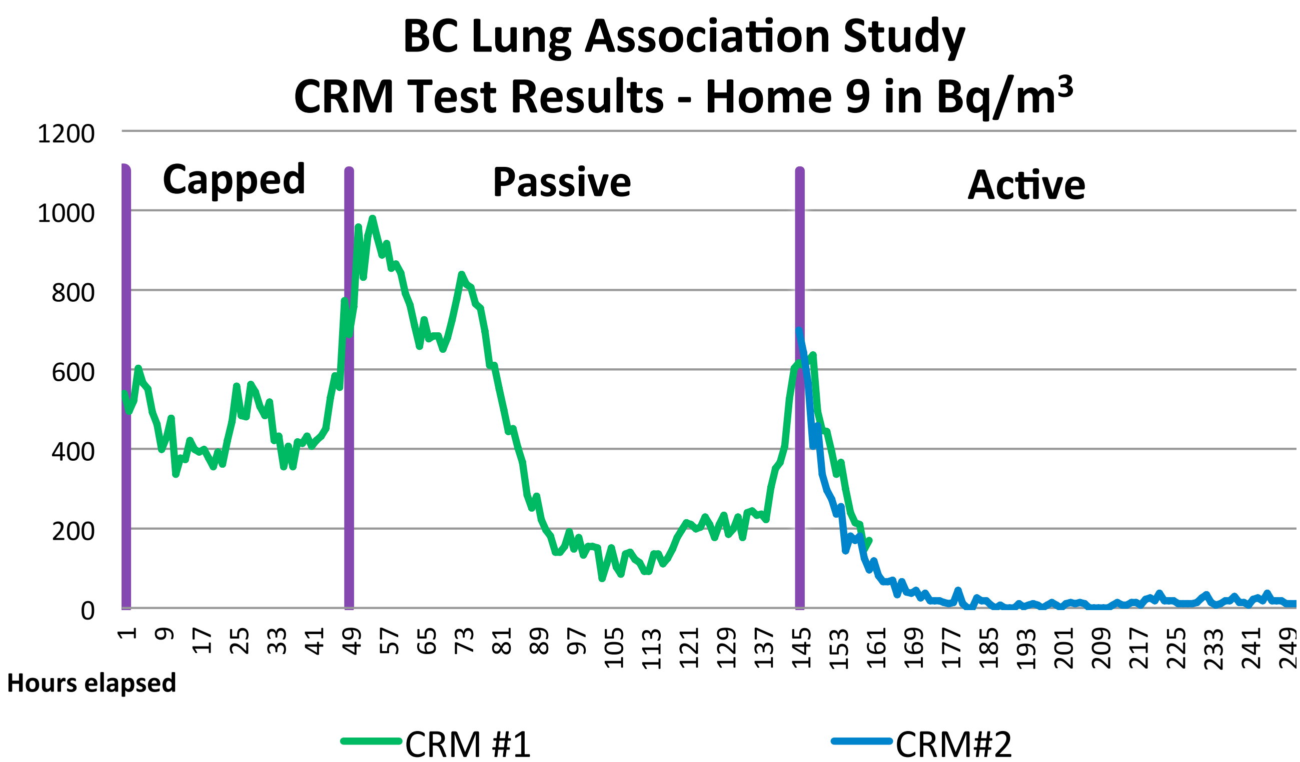
- The Rough-in Capped Systems did not reduce radon levels in homes below the Heath Canada Guideline of 200 Bq/m³ in just over half of the homes tested.
- Passive Radon Reduction Systems were consistently more effective in all cases in reducing radon levels versus the Rough-in Capped Systems.
- Passive Radon Reduction Systems were not 100% effective in reducing radon levels below the Heath Canada Guideline of 200 Bq/m³.
- Active Radon Reduction Systems were significantly the most effective in all cases, and reduced radon levels below the maximum exposure radon guidelines from Health Canada (200 Bq/m³), the US Environmental Protection Agency (150 Bq/m³) and the World Health Organization (100 Bq/m³).

Chart 1: Comparative Effectiveness of Three Different Radon Reduction Systems (in Bq/m³)



The effectiveness of an Active Radon Reduction System versus a Passive Radon Reduction System can be seen in Chart 2. Project researchers used real time radon monitoring in the same home in Prince George BC. Two separate Continuous Radon Monitors (CRMs) were used with a time overlap in the middle of the testing process. Two monitors were necessary because each CRM has a maximum usage limit of 10 days. CRM monitoring was required for 12 days to capture the entire testing process from start to finish. This provided confirmation that readings between the CRMs were consistent during that overlap.

Chart 2. Continuous Radon Monitoring of a home in Prince George: Passive vs. Active System Results (Bq/m³)



In addition to the radon test results the field researchers noted discrepancies between radon related requirements in the BC Building Code and practises in the field within the sixteen houses evaluated. See Appendix for more information on this issue.

Study Conclusions

The test results lead the BC Lung Association to conclude that:

- The Rough-in Capped System required in the 2006 and 2012 Code (for Area 1 communities referenced in the 2012 Code) provides limited protection from the cancer health risk posed by radon.
- The addition of a Passive Radon Reduction System consistently reduced radon levels but in some cases the reduction levels were close to or above the Health Canada maximum radon exposure guideline of 200 Bq/m^3.
- Active Radon Reduction Systems reduced indoor radon levels to the most health protective level possible. In one case, radon levels were undetectable with the Active System.

In some cases home builders have not followed the requirements of the radon related requirements in the BC Building Code; these deficiencies have not been identified or enforced by local Code compliance authorities.

Key Recommendations

The BC Lung Association recommends:

1. The BC Building Code amend the 2012 Code to include a requirement that Passive Radon Reduction Systems be installed in all new housing built in BC communities where radon is known or suspected to be a health risk.

2. As Passive Radon Reduction Systems may not guarantee homes are within the Health Canada radon maximum exposure guidelines that either the Building Code, or local building code authorities in areas with known high radon risk, require mandatory radon testing as a condition of building permit occupancy; and where the radon test results exceed the Health Canada standard the home builder be required to install an Active Radon Reduction System for the health protection of the occupants.

3. As some home builders and their construction trades have not fully followed the radon related requirements in the BC Building Code it is recommended that the BC Home Owner Protection Office, which works closely with the home building industry to ensure compliance with the Code, take the lead role in communicating and educating builders on radon related requirements in the BC Building Code.

4. As it appears radon related deficiencies with regard to the Building Code have not been identified or enforced by local Code compliance authorities, it is recommended that these authorities apply enhanced diligence via Code compliance inspections and especially prior to the issuance of occupancy permits.

In addition to these key recommendations a detailed list of specific recommendations may be found in Appendix 1.

APPENDICES

APPENDIX 1 – Detailed Recommendations

During the course of the field research numerous observations were made that result in recommendations that if implemented will result in more effect radon reduction measures being applied. These recommendations relate to responsibilities of home builders, compliance authorities and the BC Building Code.

BC Lung Detailed Recommendations:

1. Home Builders/Compliance Authority Enforcement of 2012 Code

- Ensure use of sub-slab granular layer [100 mm].
- Ensure use of appropriate sub-slab granular material [no clay, crushed rock, or sand].
- Ensure slab and penetration sealing in basement.
- Ensure no penetrations of the rough-in pipe above the slab floor.
- Ensure proper capping of rough-in pipe in basement.
- Ensure proper labelling of the radon pipe with a warning label.

2. Future Code Requirements for Passive Radon Reduction Systems

- Radon piping up the slab and through the house remains as straight as possible (must be vertical at point of fan installation).
- Radon pipe supports and bracing.
- Labelling of the radon pipe at every 1.8 meters and at every change in direction.
- Insulation of radon pipe in all unconditioned spaces.
- Electrical source near point of roof penetration.
- Radon pipe to be vented out the roof.
- Screen attached to radon pipe end point.

3. Other Future Code Issues

- Only allow side-venting from a basement with a radon fan attached.
- Only fans designed for radon mitigation systems should be permitted for use.
- Radon fan should be installed within 2 metres of roof discharge point to prevent icing/condensation.
- Radon pipe after the radon fan (in a roof vented system) must be vertical.

APPENDIX 2 – Selection Criteria for Homes Participating in the Study

The research project needed to identify enough homes that would allow for a large enough sample of homes to be evaluated to provide certainty in terms of the conclusions and recommendations that would emerge from the study. A decision was made to conduct the research and use the same methodology in two different areas of the province: Prince George and the Castlegar/Nelson area.

The main challenges during the home identification process included:

1. Finding interested participants with homes built under either the 2006 or 2012 Building Code.
2. Finding homes with adequate sub-slab conditions to allow for an effective "draw" from under the slab.
3. Finding homes with existing Passive Radon Reduction Systems.

Homes with Passive Radon Reduction Systems in place were given priority in the screening process as this selection criterion provided several project benefits:

- Reduced in the field research time,
- Reduced research costs, and
- Provided more in-depth information on current 'in-the-field' applications of Passive Radon Reduction Systems vs. requirements of the BC Building Code that would assist in informing future changes to the Code if such systems are mandated.

The sample was evenly split geographically with 8 homes from Prince George in Northern BC and 8 homes from Castlegar and Nelson located in the south-east part of the province. It should be noted that these areas were selected in part as past radon testing has indicated radon is present in these areas of the Province. An example of a home that was evaluated but not selected is revealed in the photo below.

While this home was identified as meeting the year of construction criteria it clearly was not compliant with the 2012 Code in several ways:

- The rough-in pipe had not been capped by the home builder and simply left on the floor, and this situation was not observed during final inspection by the Code compliance authority.
- The radon pipe was perforated. Even if the cap had been placed the perforations in the pipe allowed radon entry into the home.
- The cost of fixing this issue and then making extensive internal alterations to install a passive pipe system through finished space to the roof would have been prohibitive.

APPENDIX 3 – Profile of Homes Participating in the Study

A variety of common building types were evaluated. The overall sample was fairly evenly divided between homes with a crawlspace, full basement or slab-on-grade. Several duplexes were included from both the North Region and Interior Region. The table below provides the high-level construction details of each home.

Note: For privacy reasons neither street addresses nor exterior photos of any of the homes that participated in the study are published in this study.

HOME #	BUILDING TYPE
1	Single family dwelling, one level, fully finished walk-out basement
2	Single family dwelling, two levels, partially finished basement. Basement is part underground and opens onto a large deck above parking area
3	Single family dwelling, two levels, with basement. Basement is fully finished and part underground. Basement opens onto a large deck above a parking area
4	Single family dwelling, one level, 3' high crawlspace*
5	Single family dwelling, duplex, one level, 3' crawlspace
6	Single family dwelling, duplex, one level, 3' crawlspace
7	Single family dwelling, duplex, one level, 3' crawlspace
8	Single family dwelling, duplex, one level, 3' crawlspace
9	Single family dwelling, grade level, plus one story, walkout basement
10	Single family dwelling, duplex, grade level (main floor), plus one story
11	Single family dwelling, duplex, grade level (main floor), plus one story
12	Single family dwelling, duplex, grade level (main floor), plus one story
13	Single family dwelling, duplex, grade level (main floor), plus one story
14	Single family dwelling, one level, basement 4' in ground
15	Single family dwelling, one level, basement 4' in ground
16	Single family dwelling, two levels, grade level basement

* 3' denotes 3 feet

APPENDIX 4 – Radon Testing Methodology

The study used a standardized testing methodology and sequence for each of the 16 homes. The information provided below lists the various steps in the testing process undertaken by the Certified Radon Professionals.

Testing Procedures:

1. Visit home to prep for test and ensure "closed house conditions".
2. Determine electrical requirements for the fan and schedule electrician if required.
3. Wait 48hrs.
4. Take baseline 48hr test as Passive.
5. Install cap.
6. Wait 48hrs.
7. Take 48hr test as Capped.
8. Install certified fan, remove cap, and energize.
9. Wait 48hrs.
10. Take 48hr test as Active.
11. Leave long term test kit and instructions with owner.

APPENDIX 5 – Radon Testing Technology

Researchers utilized E-perm technology for all short term testing. Duplicate E-perms were placed in the lower level of each home occupied on a frequent basis. E-perms are known for high accuracy and precision in radon measurement. Radon decay in a home creates a change in charge on the enclosed Teflon disk of each E-perm which can then be measured via a special voltage reader and the radon level calculated. Figure 1 below on the left shows the E-perm devices in the sealed or off position (Image 1 - left) and in the on position (Image 2 - right).

Image 1 – E-perm radon test devices

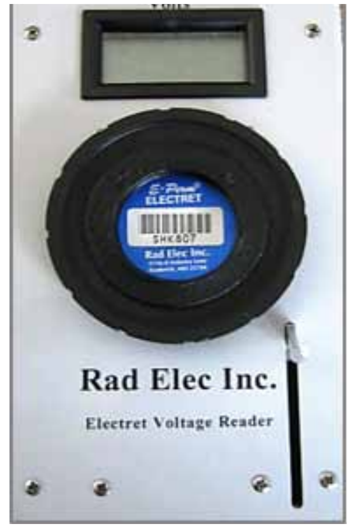


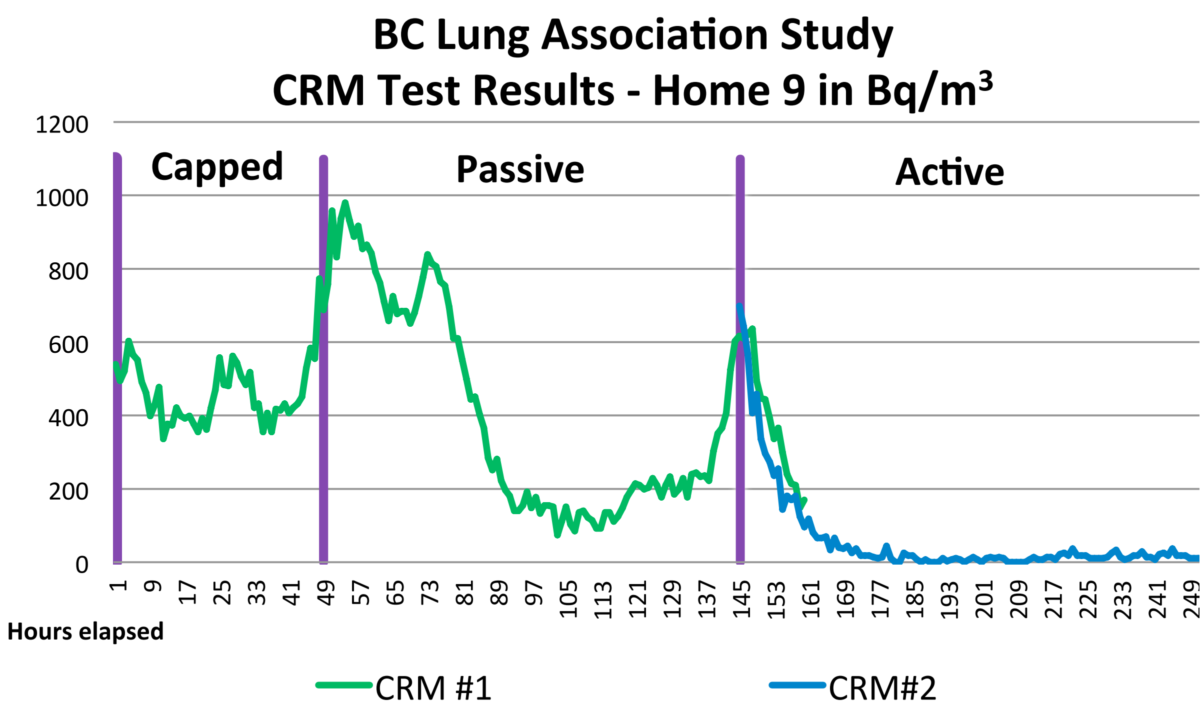
Image 2 – E-perm electret voltage reader

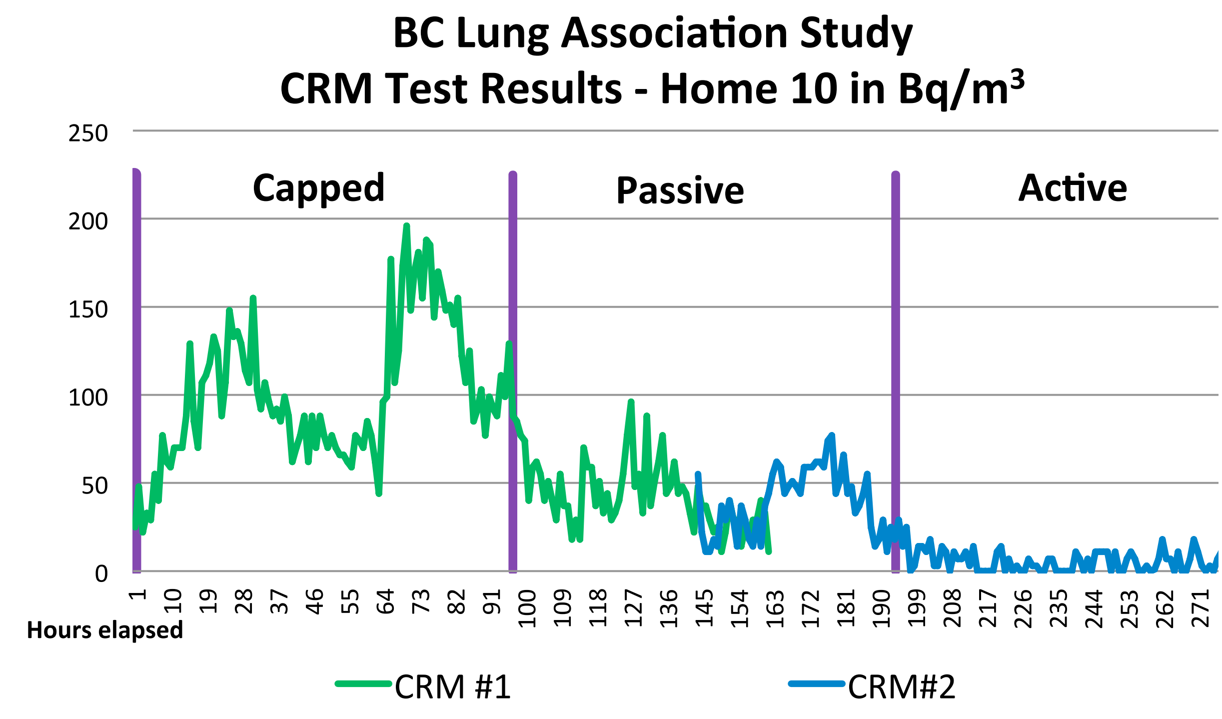
As a cross check of the results from the E-perm testing researchers selected a small sample of three of the participating homes in which Continuous Radon Monitors (CRM) were used. A CRM accurately measures radon levels on an hourly basis over short term periods. To observe the full range of radon level fluctuations, each of the 3 homes had the CRM installed for the complete process of E-perm testing (capped rough-in, passive and active). The benefits of using CRM technology include its high degree of sensitivity, use in a range of temperatures and relative humidity, and its ability to indicate any possible tampering. For this Study, the RadStar RS300 CRM was used as shown on the right.

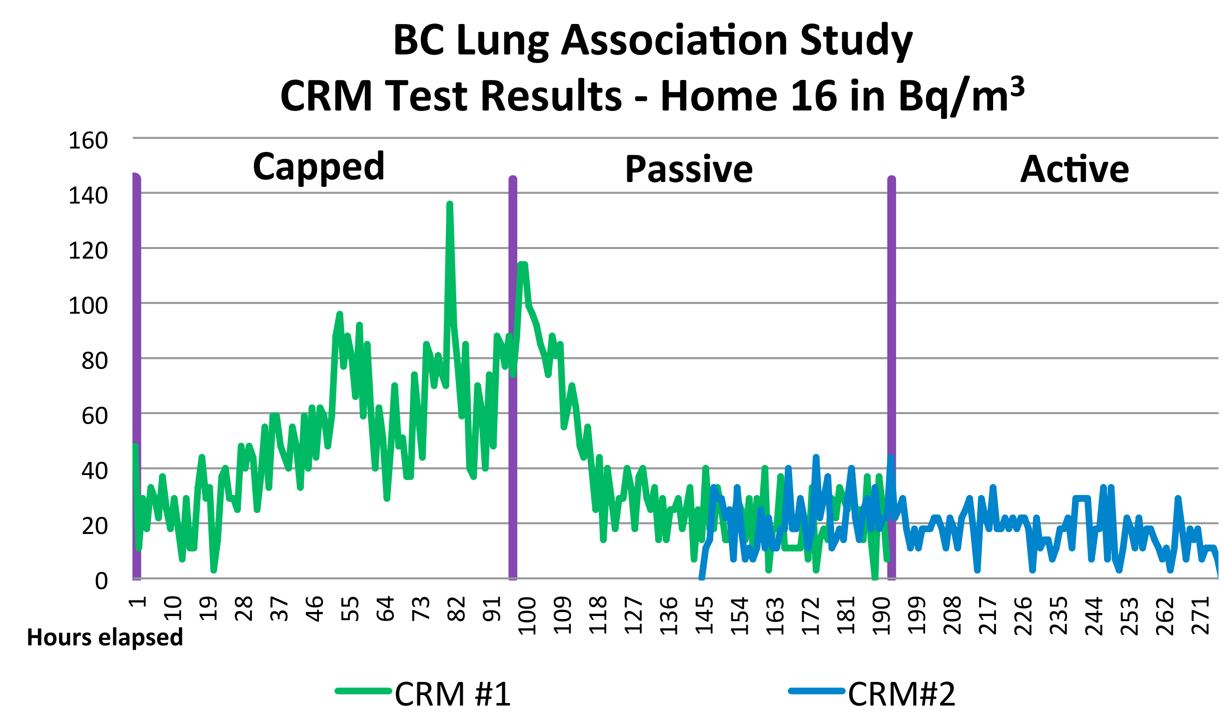
APPENDIX 6 – Radon Test Results

The purpose of the study was to assess the effectiveness of different radon mitigation measures via short term testing that compares radon test results between mitigation measures – not to determine what the average longer term exposure of a home to radon might be. The first test results were completed using the E-perm technology to establish an average of the radon levels in each house over a 48 hour period under each of the three radon mitigation measures. The results of this testing is in the chart below which shows that a Rough-in Capped System is the poorest performing system vs. Passive Radon Reduction Systems and Active Radon Reduction Systems.

The charts below show the hourly results of CRM testing on 3 homes over a maximum period of 12 days including the overlap between test #1 and test #2. The obvious variability over the short term underscores the importance of using long-term testing techniques where feasible to determine average concentration. Note the fluctuation of the home's radon level during Passive System operation. This is not surprising as Passive System effectiveness relies on the natural "stack effect" of a home which, as the charts show, has a large degree of variability compared to an Active System in reducing radon concentrations.




BC Lung Association Study
CRM Test Results - Home 10 in Bq/m³
Capped
Passive
Active
Hours elapsed
CRM #1
CRM#2


BC Lung Association Study
CRM Test Results - Home 16 in Bq/m³
Capped
Passive
Active
Hours elapsed
CRM #1
CRM#2

APPENDIX 7 – Field Work Observations of Homes Constructed Under 2006 and 2012 Building Code

The table below identifies the specific observations, and in some cases, deviations from the 2006 and 2012 BC Building Code (for radon related issues) in each of the 16 homes included in the sample. These observations provide important feedback to the building industry and compliance authorities on radon related aspects of new housing which should be improved under both the current Code as well as possible future changes to it.

HOME #	YEAR BUILT	OBSERVATIONS	LOCATION
1	2012	• Radon Pipe not labelled • Exhaust pipe in attic area uninsulated	Castlegar
2	2011	• Radon Pipe not labelled • Exhaust pipe in attic area uninsulated • Radon Pipe exhausts into attic area	Nelson
3	2011	• Radon Pipe not labelled • Exhaust pipe in attic area uninsulated • Radon Pipe exhausts into attic area	Nelson
4	2011	• Radon Pipe not labelled • Exhaust pipe in attic area uninsulated	Castlegar
5	2013	• Mechanical air exchange timer not set • Radon Pipe not labelled • Penetrations not sealed • Floor slab / footing joint poorly sealed, large gaps visible • Exhaust pipe in attic area uninsulated • Plastic poly from under slab continued up and over interior footings • poly was not sealed to footing; many cuts, tears, and abrasions visible	Castlegar
6	2013	• Mechanical air exchange timer not set • Radon Pipe not labelled • Penetrations not sealed • Floor slab / footing joint poorly sealed, large gaps visible • Radon pipe in attic area uninsulated • Plastic poly from under slab continued up and over interior footings • Poly was not sealed to footing; many cuts, tears, and abrasions visible	Castlegar
7	2013	• Mechanical air exchange timer not set • Radon Pipe not labelled • Penetrations not sealed • Floor slab / footing joint poorly sealed, large gaps visible • Radon Pipe in attic area uninsulated • Plastic poly from under slab continued up and over interior footings • Poly was not sealed to footing; many cuts, tears, and abrasions visible	Castlegar
8	2013	• Mechanical air exchange timer not set • Radon Pipe not labelled • Penetrations not sealed • Floor slab / footing joint poorly sealed, large gaps visible • Exhaust pipe in attic area uninsulated • Plastic poly from under slab continued up and over interior footings • Poly was not sealed to footing; many cuts, tears, and abrasions visible	Castlegar
9	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George

HOME #	YEAR BUILT	OBSERVATIONS	LOCATION
10	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George
11	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George
12	2013	• Exhaust pipe in attic area uninsulated • Pipe not labelled	Prince George
13	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George
14	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George
15	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George
16	2013	• Exhaust pipe in attic area uninsulated • Radon Pipe not labelled	Prince George

APPENDIX 8 – Visual Record of Radon Related Issues

The following record was generated from in-field inspections of participant homes and during mitigation of each home. Each finding presents an issue and offers a solution along with a visual example. Please note: Not each finding's before and after image is from the same home.

FINDING #1:

In 15 of 16 homes the radon pipe was not clearly labelled (Figure 1).

Issue - Residents may not identify the radon pipe's function. This could lead to improper use.

Solution - Apply a Radon Pipe Warning label (Figure 2).

Figure 1. Example of Pipe Not Labeled

Figure 2. Example of Pipe Labeled

FINDING #2

In all homes the radon pipe was not insulated in unconditioned spaces (Figure 3).

Issue - System may not work to maximum efficiency if pipe is not insulated in an unconditioned space and condensation may form in the pipe.

Solution - Insulate the radon pipe all the way through to the roof (Figure 4).

Figure 3. Example of Uninsulated Pipe

Figure 4. Example of Insulated Pipe

FINDING #3:

In 2 of 16 homes the radon pipe was venting into the attic (Figure 5).

Issue - Radon venting into attic increases risk of radon levels in living space, condensation may form on the pipe and affect insulation and water on ceiling, and mold may establish in attic space.

Solution - Ensure radon pipe is vented out the roof (Figure 6).

Figure 5. Example of Pipe Venting Into Attic

Figure 6. Example of Pipe Venting Out Roof

FINDING #4

In 6 of 16 homes horizontal runs of the radon pipe were unsupported (Figure 7).

Issue - Radon pipe could bend, move, or become unattached.

Solution - Provide adequate bracing along the horizontal runs of pipe (Figure 8).

Figure 7. Example of Pipe Run Unsupported

Figure 8. Example of Pipe Run Supported with Bracing

FINDING #5

More than half of homes had inadequate sealing in the slab-floor and edges (Figure 9).

Issue - Slab floor cracks, rough edges, and open gaps can be a point of radon ingress.

Solution - Ensure proper sealing of all edges, cracks and openings in slab floor (Figure 10).

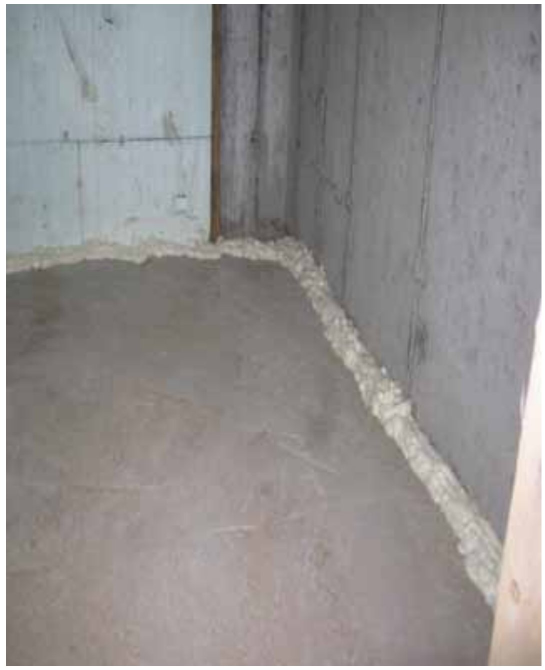


Figure 9. Example of Inadequate Sealing of Slab Edges *Figure 10. Example of Slab Edges Sealed with Spray Foam*

FINDING #6

In 2 of 16 homes the radon pipe was positioned in the attic on an angle (Figure 11).

Issue - A radon fan installed to a radon pipe on an angle may get moisture pooling in the fan casing. This will impact the efficacy of the radon fan.

Solution - Ensure that the radon pipe exiting the attic is completely vertical (Figure 12).

Figure 11. Example of Radon Pipe Positioned on Angle *Figure 12. Example of Radon Pipe Cut and Straightened*

FINDING #7

In all 16 homes the radon pipe exiting the roof was unscreened (Figure 13).

Issue - Debris may fall into the pipe and block the flow.

Solution - Insert a screen onto the end point of the radon pipe (Figure 14).

Figure 13. Example of Radon Pipe End with No Screen

Figure 14. Example of Radon Pipe End with Screen

FINDING #8

More than half of homes required installation of electrical provisions near the radon pipe in the attic (Figure 15).

Issue - Installing an added electrical connection in the attic at the same time as a Passive System install can substantially reduce costs for future application of an Active Radon Reduction System.

Solution - Install an electrical connection during Passive System install (Figure 16).

Figure 15. Example of Passive Pipe with No Electrical Provisions

Figure 16. Example of Pipe with Electrical Provisions Added

APPENDIX 9 - RADON WARNING LABEL

The BC Lung Association, in conjunction with the Canadian Home Builders Association of BC, developed a radon warning label to be applied to radon piping in new and existing homes. The 2012 BC Building Code, Section 9.13.4.3.3.b.iii, states that the rough-in pipe must be clearly labeled near the cap and, if applicable, every 1.8 metres and at every change in direction to indicate that the pipe is intended only for the removal of radon.

Labels may be obtained from the nearest Canadian Home Builders' Association (CHBA) local affiliate office (see below). Local Code compliance authorities may also have labels available.

CHBA – Central Okanagan
212-1884 Spall Road
Kelowna, BC V1Y 4R1
Tel: 250-861-3988/Fax: 250-861-3950
E-mail: sherri@chbaco.com
www.chbaco.com

CHBA – Northern BC
#300 1705 3rd Avenue
Prince George, BC V2L 3G7
Tel: 250-563-3306/Fax: 250-563-3815
E-mail: admin@chbanorthernbc.ca
www.chbanorthernbc.ca

CHBA – Central Vancouver Island
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