REPORT #5 IN A SERIES OF REPORTS ON RADON IN BC HOMES

Statistical Analysis of Radon Concentration, Home Characteristics, and Homeowner Intent in 486 Prince George Homes

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THE LUNG ASSOCIATION™ British Columbia

AS PART OF ITS

RADON AWARE THE LUNG ASSOCIATION™ PROGRAM

THE BC LUNG ASSOCIATION

The British Columbia Lung Association (BCLA) is one of the province's oldest not-for-profit health advocacy and service organizations. BCLA began operations in 1904, first focusing its efforts to eradicate the spread of tuberculosis. Over the last hundred years BCLA has widened its efforts to address many other lung related diseases such as asthma, Chronic Obstructive Pulmonary Disease, flu, and lung cancer. Although a significant funder of medical research, BCLA works primarily in the public health area of prevention and control.

RADONAWARE

RadonAware is a branded public education and advocacy program established by the BCLA. The program is focused on providing research, information, education and public advocacy on issues related to reducing the lung cancer risk caused by radon. For more information please visit www.radonaware.ca

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1. EXECUTIVE SUMMARY

Radon gas is a serious public health risk in British Columbia (BC) and the leading cause of lung cancer after smoking. Most people are exposed to radon in their homes, schools, and workplaces. It is when radon gets 'trapped' in a building and accumulates to high levels, that the risk of lung cancer rises to actionable levels.

In 2014, the BC Lung Association (BCLA) completed the largest single-community radon testing effort performed in Canada to date in the community of Prince George, BC. Not only were home radon concentrations tested, but homeowners were guided through a building survey. The survey was designed with months of communication between stakeholders from the private and public sectors across BC, and internationally. The main purpose of the survey was to determine any association between high or low indoor radon concentrations and building characteristics such as age of construction, heating type, number of storeys, etc.

This report provides the main findings from the statistical analysis of 486 indoor radon test results where homeowners also completed the building survey. All participants were within the Canada Post Forward Service Area (FSA) of V2M in the City of Prince George . All results are reported utilizing the Health Canada guidance level of 200 Becquerels per cubic metre (Bq/m^3).

Key Conclusions of this Study

Characteristics found to be associated with higher radon concentrations include[1]:

- Homes constructed between 1964 and 1977.
- Homes with 2 or 3 storeys.
- Homes with a drain in the basement.
- Homes with plumbing in the basement.

Analysis also found the following associations:

- Higher radon levels in basements versus upper storeys.
- Homes with no basements and lower radon concentrations.

These associations highlight areas where further research and investigation into causation would be useful.

The survey results also provided insights into homeowner intentions and motivations which include:

- People were motivated to test by the BCLA Radon Study, radon articles, concern for children's health, a friend's suggestion, and public information sessions.
- If a high radon level is detected, most people plan to mitigate.
- Cost is the most significant barrier to completing radon mitigation.

1. An association between a building characteristic and a high radon result should never assume causation. Further study is advised.

2. BACKGROUND

Radon is an invisible and odourless gas that is found in soil, rock and water. As a gas, radon moves freely through the soil. When it reaches the atmosphere it is diluted to low levels and does not pose a significant health risk. However, when radon is 'trapped' within a building and can't escape it can be a serious health risk to occupants. A high concentration of radon in a home, and exposure over many years, increases the health risk from radon. Radon has been identified as the leading cause of lung cancer death in Canada after smoking. Radon awareness is a core focus for the BCLA's programs of prevention and control of lung disease.

Many homeowners want to know what the radon level is in their home. In January 2014, the BCLA launched Canada's largest community-wide radon testing project in Prince George, British Columbia (BC). Radon concentrations in homes were tested, and homeowners were guided by an outreach worker through a detailed building survey. This report provides the results-to-date from the analysis of 486 completed wintertime radon tests and building survey pairs within the Canada Post FSA of V2M in the City of Prince George[2].

2. a. Purpose of Analysis

The main purpose of analyzing radon test results and home characteristics is to:

- Identify building characteristics associated with higher or lower radon concentrations to target further research into causal relationships.
- Target more effective intervention and education outreach work.
- Inform Building Code development to reduce radon risk for new homes.

2. b. Review of Radon Exposure Guidelines

Radon exposure guidelines exist to guide personal and regulatory decision making and are based on the estimated risk to public health based on a specific exposure level. In Canada, Health Canada published a radon exposure guideline in 2007 of 200 Bq/m^3, above which, they recommend action be taken to reduce radon exposure levels. In the United States, the Environmental Protection Agency set a radon exposure guideline of 148 Bq/m^3 and the World Health Organization sets its radon 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 to as low as reasonably practicable.

2. c. Relationship Between Building Characteristics and Radon Levels

It is generally accepted there are five core factors that influence a home's radon level. These are:

1. The strength of the radon source.
2. The forces that draw radon gas into a home such as pressure differentials between the house and the sub-grade.
3. Pathways for radon gas to be drawn into a home such as permeable soils and drainage systems.
4. Openings in a home where the foundation contacts the soil and radon can infiltrate.
5. The ventilation rate (exchange of indoor air with outdoor air).

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2. At the time of testing, none of the 486 homes had active or passive systems installed.

Less understood is the relationship between high and low indoor radon levels and individual building characteristics. Canadian research has yet to determine if specific characteristics impact radon exposure levels. For example:

- Does the construction year of a home or its design type have any association with indoor radon levels?
- Does plumbing in a basement impact a home's indoor radon level?
- Do homes with basements versus crawlspaces or slab-on-grade, consistently have higher radon levels?

To date, these types of building science questions have largely gone unanswered and are often left to speculation. The concern is, assumptions by homeowners about a home's potential radon level based on its age, foundation type or size, can lead to guessing whether or not a home is deemed 'at-risk.' For example, it is not uncommon to hear anecdotal comments such as the following:

- "My home is old and drafty so it is not a radon risk."
- "My home is new and really 'tight' so it may be a radon risk."
- "My home has no basement so it is not a radon risk."

This study explores these and other ideas about a home's potential to have a higher or lower radon level based on certain building characteristics.

2. d. Assessing Radon Concentrations and Dwelling Characteristics

Typically, it would be difficult to assess the association of radon concentration and measurable building characteristics such as year of construction, heating systems, building size, etc. This is because geographic radon potential can vary greatly from one location to another; meaning, that a home in a low radon risk area will tend to have lower indoor radon levels regardless of a home's construction characteristics. The high indoor radon exposure result of a home in a high radon risk area is likely due primarily to location and the strength of the source, obscuring any other associations that can affect a home's radon level. Gathering results from across communities in order to have a sufficient sample size for analysis is prone to this challenge.

2. e. Learning Through the Prince George Radon Study

The BCLA Prince George Indoor Radon Study presents a unique opportunity to examine the relationship between indoor radon levels and home characteristics. There were 486 surveys with radon tests completed for homes in an area of approximately 5 square kilometers. These homes are all located within the Prince George Canada Post Forward Service Area (FSA) of V2M. FSA is commonly known as the first half of the postal code, and V2M contains roughly the higher population density, "downtown" area of the City of Prince George. This study attempts to reduce the obscuring effect of geographic location by reviewing a large number of homes in a small area.

2. f. Building Survey

The building survey used in the study included a variety of sections where the homeowner or renter was asked to input contact information, test deployment dates, motivation and intention, and information about the home's building characteristics (Appendix 1). Filling out the survey took roughly ten minutes to complete and was voluntary. However, it was necessary for the participants to provide contact information and deployment dates for lab analysis and returning of test results. No confidential information included in the survey was shared outside of the BCLA or used in any way that might identify participants and the specific location of each home tested.

3. DATA ANALYSIS

The following provides some details on how question responses were organized on the survey:

- Most questions were a check-box format. A check meaning 'Yes', and a blank meaning, 'No.'
- In a few cases, 'Yes', 'No' and 'Other,' were included.
- As needed, other appropriate response options were provided.

3.a. Use of a t-Test method for data analysis:

This study calculated mean radon concentrations linked to the various responses to each survey question. Then comparison of those means was completed using a t-Test. A t-Test is a statistical tool which helps determine whether two groups have different averages. That is, it tells us whether the difference in means is likely to be a result of random chance. The results from the t-Tests then tell us if there is any association between each characteristic from the survey and radon concentration.

Technical note: All t-Tests were a two-tailed test assuming unequal variances, using alpha of 0.01, and the null hypothesis that the means are equal.

3.b. Sample Size

There were 486 completed matching home radon tests and surveys within the Canada Post FSA of V2M in the City of Prince George.

4. RESULTS

It is important to remember that association does not always mean causation.

That is, finding that a specific building characteristic is associated with higher radon concentrations does not guarantee that characteristic caused the effect on radon concentrations. For example, finding that homes of a particular age have higher radon concentrations may indicate that home construction techniques at that time led to higher radon concentrations (causation), or it may simply be that the homes at that time were predominantly built in areas with higher radon potential (not caused by building construction).

However, finding an association, or one which could likely be confirmed with more data, is a crucial step toward targeting additional data collection and analysis to confirm any causal relationship between radon level and construction characteristics.

Home characteristics associated with HIGHER radon concentrations (confirmed by t-Test):

- Home was constructed between 1964 and 1977.
- Home is 2 or 3 levels.
- Home has a drain in the basement.
- Home has plumbing in the basement or crawl space.

Analysis also found the following associations:

- Higher radon levels in basements versus upper storeys.
- Homes with no basements and lower radon concentrations.

Recall that any building characteristics found to have an association with higher or lower radon levels should not be assumed to have CAUSED the higher or lower radon levels. Any statistically significant association only highlights an area where more study into the cause is needed.

Although not directly related to a home's radon concentration, noteworthy information was also collected from Section 6 of the Survey, MOTIVATION AND INTENTION. This information is critical to better understanding how to plan for, and address, issues that have a serious public health impact.

The results also identified the following:

- Effective ways to motivate radon testing include this BC Lung radon study, radon articles, concern for children's health, a friend's suggestion, and public information sessions.
- If a high radon level is detected, most people plan to mitigate.
- Cost is the biggest barrier to completing radon mitigation.

This information tells us a great deal in terms of how important targeted community outreach and education is to raise awareness of radon and its health risks. It also tells us that people are genuinely concerned about the health risk of radon exposure and that cost, not interest/engagement, is the number one barrier to public action to reduce home radon exposure levels.

APPENDIX 1:
Building Survey

Participants were provided with the following simple instructions:

- Deploy the indoor air radon test within 48 hours of receipt.
- Place the radon detector in the home per instructions.
- Complete as many of the survey questions as possible.
- Submit the radon test for lab analysis at the end of the minimum 91 day testing period.
- Include the survey with the submitted radon test.

The following list provides further details about the sections included in the survey:

- **Section 1.** DETECTOR ID AND EXPOSURE PERIOD **and 2.** CONTACT AND BUILDING FOR DETECTOR PLACEMENT were mandatory fields for the lab to send accurate test results to each participant.
- **Section 3.** DETECTOR PLACEMENT DETAILS required the participant to provide information on where the test was located in the home and if the test was placed according to directions.
- **Section 4.** BUILDING required the participant to provide information on the type of home, size, age, and heating system/fuel type.
- **Section 5.** GROUND FLOOR CHARACTERISTICS required the participant provide information on the type of basement/foundation, if there are openings/plumbing in the basement, and type of foundation walls.
- **Section 6.** MOTIVATION AND INTENTION required the participant to provide information on what prompted them to test for radon and their intentions upon receiving a result.
- **Section 7.** OCCUPANT INFORMATION required the participant to provide information on how much time is spent in the basement and if the basement windows are kept open.
- **Section 8.** PAST BUILDING CHANGES required the participant to provide information on radon measurement and mitigation work already completed in the home.

THE LUNG ASSOCIATION™ British Columbia

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SURVEY SHEET

VER. 2013-1

1. DETECTOR ID AND EXPOSURE PERIOD

Detector ID Number	Date Detector Placed (e.g. Dec / 15 / 2013)	Date Detector Removed (e.g. Mar / 15 / 2014)

If this is your only detector, please skip to Section 2 and continue with the survey.

If you have received two radon detectors:

- Write the other detector ID number here (**IMPORTANT**): Second (other) Detector ID Number
- You must place BOTH on the same day in the same location (4 inches / 10 cm apart).
- Complete Section 1 of both surveys. Please only complete Sections 2 - 8 on ***one*** survey.
- After testing, return each survey with its own detector in separate zip lock bags.

2. CONTACT AND BUILDING FOR DETECTOR PLACEMENT

Contact First Name	Contact Last Name	Email	Phone

For the Building, do you (check all that apply):
☐ Own ☐ Rent ☐ Work ☐ Live ☐ Rent to Tenants ☐ Other (specify)

Would you like to be contacted regarding radon related outreach or assistance programs? ☐ Yes ☐ No

Building Address	City	Postal Code
Mailing Address of Contact (if different from Building Address)	**City**	**Postal Code**

3. DETECTOR PLACEMENT DETAILS

How many feet above the floor was it placed?

Who placed the detector?
☐ Owner ☐ C-NRPP Certified Measurement Professional ☐ Other (specify):
☐ Program Volunteer ☐ Maintenance Professional

Able to place as per instructions?
☐ Yes ☐ No

If No, specify:

What floor?
☐ Basement ☐ Main ☐ Second ☐ Third ☐ Other (specify):

What room?
☐ Rec Room ☐ Living Room ☐ Den/Study ☐ Basement ☐ Gym ☐ Other (specify):
☐ Storage Room ☐ Bedroom ☐ Office ☐ Dining Room ☐ Attic

Type of space?
☐ Closed ☐ Open Concept ☐ Other (specify):

4. BUILDING

Type of Home

Single Detached	Semi-detached	Other
☐ Bungalow ☐ 2-Story	☐ Side by Side ☐ Duplex	☐ Trailer/Mobile Home
☐ Split-Level ☐ 3-Story	☐ Row House ☐ Townhouse	☐ Other (specify):

Year Constructed	Building Footprint Area (sqft)	Number of Storeys (incl. basement)	Heating Fuel Type (check all that apply)
			☐ Natural Gas ☐ Propane ☐ Oil ☐ Wood ☐ Electric

Heat Delivery System (check all that apply)
☐ Furnace ☐ Stove ☐ Hydronic/Radiant Water ☐ Heat Pump ☐ Baseboard ☐ Fireplace ☐ Heat Recovery Ventilator

5. GROUND FLOOR CHARACTERISTICS

Basement or lowest ground level type (check all that apply)
☐ Finished ☐ Partially Finished ☐ Concrete ☐ Open Ground ☐ Unknown
☐ Unfinished ☐ Crawl Space ☐ Indoor Parking ☐ No Basement ☐ Other (specify):

5. GROUND FLOOR CHARACTERISTICS continued

What types of openings are in the basement? (check all that apply)

☐ Sump ☐ Cracks around foundation walls ☐ Gap in foundation ☐ Bath/Kitchen Fan ☐ Dryer ☐ Stairs
☐ Drain ☐ Humidify/air condition drain ☐ Various Cracks ☐ Water Supply ☐ Furnace ☐ Other (specify):

Is there plumbing in the basement/crawlspace?

☐ Yes ☐ No ☐ N/A

Type of slab on grade floor of basement/crawlspace?

☐ Poured Concrete ☐ Earth/dirt ☐ Rock ☐ Other (specify):

Type of foundation walls?

☐ Poured Concrete ☐ Cinder Block ☐ Brick ☐ Stone ☐ Wood ☐ Other (specify):

Sub-slab building composition (check all that apply)

☐ Fine ☐ Wet ☐ Gravel ☐ Sand ☐ Clay ☐ Other (specify):
☐ Coarse ☐ Dry ☐ Dirt ☐ Rock ☐ Don't Know

Poly or other membrane under slab?

☐ Yes ☐ No ☐ Partial ☐ Don't Know ☐ Other (specify):

6. MOTIVATION AND INTENTION

If the detector shows a high radon level in your home, do you intend to reduce that level?

☐ Yes ☐ No ☐ Maybe

If no or maybe, why not? Specify:

Reasons that caused you to test your building or want to test initially (check all that apply)

☐ Friend's suggestion
☐ Doctor's suggestion
☐ Buying the building
☐ Selling the building, thought it was a good idea
☐ Selling the building, buyer asked for it to be done
☐ Read an article about radon
☐ Attended a public information session
☐ Concern for children
☐ Renovating anyway
☐ BC Lung Radon Study
☐ Other Radon Program
☐ Other (specify):

7. OCCUPANT INFORMATION

Does anyone regularly sleep in basement?	How many hours per day is anyone in basement?	How often are windows open (days/year) in basemement?

8. PAST BUILDING CHANGES (complete only if you are aware of renovations or upgrades which have been done to the building)

Date of Last Work (e.g. Nov / 27 / 2013)

Cost of Work

What was the radon concentration prior to work done?

_____ Bq/m³ OR _____ pCi/l OR ☐ Didn't Test ☐ Tested but Unsure

Who performed the work? (check one only)

☐ Homeowner ☐ Local Handyman ☐ Friend / Relative
☐ C-NRPP Certified Mitigator ☐ Builder During Construction ☐ Other Professional

Was a permit issued for this work?

☐ Yes ☐ No ☐ Unsure

Type of Building Change (check all that apply)

☐ Radon mitigation ☐ Made addition to building ☐ Insulation ☐ Finished or converted basement
☐ Changed or upgraded main ventilation or heating system ☐ Windows ☐ Other (specify):

If you checked Radon Mitigation above, was an indicator installed that would advise you of how well the system is working? ☐ Yes ☐ No ☐ Don't know

If yes, was it an audible alarm? ☐ Yes ☐ No ☐ Don't know

If you checked Radon Mitigation above, type of radon mitigation (check all that apply)

☐ Fill some foundation cracks/holes ☐ Active SSD ☐ Fan added to passive SSD
☐ Fill all foundation cracks/holes ☐ Passive SSD ☐ Ventilation
☐ Seal sump/drain/membrane(s) ☐ Roof discharge ☐ Installed during construction
☐ Crawlspace/membrane depressurization ☐ Sidewall discharge ☐ Capped pipe

If system is now active SSD, where is the fan?

☐ Fan in basement
☐ Fan in attic
☐ Fan in garage
☐ Fan outdoors

If you checked any Sub Slab Depressurization (SSD) above, ways the system is connected to below the slab (check all that apply)

☐ Core through slab with _____ penetrations ☐ Connected to sump ☐ Other (specify):
☐ Under membrane in crawlspace (was membrane sealed to walls and at seams? ☐ Yes ☐ No)

If you checked Ventilation above, what type (check all that apply)

☐ Heat recovery ventilator connected to furnace ☐ Air cleaner connected to furnace ☐ Fresh air brought in
☐ Heat recovery ventilator not connected to furnace ☐ Air cleaner not connected to furnace ☐ Other (specify):

Contractor Name (if a Contractor was used)	Contractor Email	Contractor Phone

APPENDIX 2:

Analysis of Building Survey Results

Section 1. Detector ID and Exposure Period

n/a

Section 2. Contact and Building for Detector Placement

Information collected in Section 1 and 2 was necessary for administering participant test results, except the following question, which was used to determine any association between radon level and the type of ownership:

Q: For the Building, do you (check all that apply):

	n Yes	n No	Yes – Avg Bq/m^3	No – Avg Bq/m^3
Own	426	60	294	267
Rent	38	448	266	293
Work	16	470	188	294
Live	66	420	303	289
Rent to tenants	35	451	165	301

Results of Analysis:

- There is an association between 'Work' from the building and lower radon concentrations.
- Analysis shows an association between 'Rent to tenants' and lower radon concentrations.

Section 3. Detector Placement Details

Information collected in this section was used to determine any association between radon level and the following: Height of detector placement; who placed the detector; whether or not the detector was placed per instructions; what floor the detector was placed; and, the type of room where the detector was placed.

Q: How many feet above the floor?

Feet	n	Avg Bq/m^3
4	3	214
5	60	225
6	62	265
7	21	179

Results of Analysis:

- The t-Test did not confirm any associations.

Q: Who placed the detector?

	n	Avg Bq/m^3
Owner	4	144
C-NRPP Certified Measurement Professional	0	Na
Program Volunteer	141	241
Maintenance Professional	0	Na
Other (specify)	0	Na

Results of Analysis:

- Analysis completed did not find any association between radon concentration and the individual placing the detector.

Q: Able to place per instructions?

Results of Analysis:

- Only 21 respondents checked this box out of 486 responses. There was no difference in radon concentrations.

Q: What floor?

	n	Avg Bq/m^3
Basement	294	343
Main	171	217
Second	6	120
Third	1	44

Results of Analysis:

- Analysis indicates there is a clear association between the radon detector being located lower in the home and finding higher radon concentrations.

Q: What room?

Results of Analysis:

- Analysis found no association between radon concentrations and the room tested.

Q: Type of Space?

	n	Avg Bq/m³
Closed	49	188
Open Concept	95	262

Results of Analysis:

- Although the mean radon concentration is notably higher in 'Open Concept' spaces than in 'Closed', the difference still fails the t-Test so may be attributed to chance.

Section 4. Building

Information collection in this section was used to determine any association between radon concentration and the following: the type of home; year of construction; the building footprint; the number of storeys; the heating fuel type; and, the heat delivery system.

Q: Type of Home?

	n	Avg Bq/m³
Single Detached - Bungalow	168	322
Single Detached - Split-level	38	308
Single Detached - 2-story	180	291
Single Detached - 3-story	22	320
Semi-Detached - Side by Side	1	215
Semi-Detached - Row House	1	459
Semi-Detached – Duplex	20	279
Semi-Detached - Townhouse	15	151
Other - Trailer/Mobile Home	0	na
Other (Specify)	27	101

Results of Analysis:

- Analysis found no meaningful differences in radon concentrations with the type of home tested.

Q: Year Constructed

	n	Avg Bq/m^3
Before 1964	96	227
1964 to 1971	119	362
1972 to 1977	132	325
1978 or later	85	197

Results of Analysis:

- Analysis confirms that the average radon concentration in homes built from 1964 to 1977 is higher than in homes constructed before or after this period.

Q: Building Footprint

	n	Avg Bq/m^3
Under 1050 sqft	31	271
1050-1250 sqft	35	238
1251-2401 sqft	38	217
2401 sqft or more	29	198

Results of Analysis:

- Although it appears at a glance that radon concentration is lower as the building footprint grows, analysis does not confirm any association. The apparent differences are still attributable to chance.

Q: Number of Storeys?

	n	Avg Bq/m^3
1	17	157
2	356	300
3	70	305
4	15	163

Results of Analysis:

- Analysis confirms that radon concentrations in 2 and 3 storey buildings are higher than in homes with just 1 storey or 4 storeys, so those observed differences are very unlikely to be chance.

Q: Heating Fuel Type

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Natural Gas	456	30	291	286
Propane	0	486	Na	291
Oil	0	486	Na	291
Wood	35	451	303	290
Electric	53	433	326	287

Results of Analysis:

- Analysis indicates variations in radon concentrations could be explained by randomness and are not associated with a specific heating fuel type.

Q: Heat Delivery System

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Furnace	445	41	285	360
Stove	20	466	424	285
Hydronic/ Radiant Water	21	465	301	290
Heat Pump	5	481	306	291
Baseboard	38	448	321	288
Fireplace	88	398	317	285
Heat Recovery Ventilator	4	482	318	291

Results of Analysis:

- Analysis does not confirm any associations between the heat delivery system and radon level.

Section 5. Ground Floor Characteristics

Information collected in this section was used to determine any association between radon concentration and the following: the basement or lowest ground level type of construction; type of openings in the basement; whether or not there is plumbing in the basement; the type of slab on grade floor of the basement/crawlspace; type of foundation walls; type of sub-slab building composition; and, whether or not there's poly or other soil gas membrane under the slab.

Q: Basement or lowest ground level type?

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Finished	265	221	306	273
Unfinished	32	454	275	292
Partially Finished	172	314	294	289
Crawl Space	38	448	154	303
Concrete	194	292	286	294
Indoor Parking	7	479	264	291
Open Ground	13	473	189	294
No Basement	15	471	122	296
Unknown	2	484	174	291

Results of Analysis:

- Analysis found an association between having a 'Crawl Space' and lower radon concentrations.
- Analysis did not find a significant association between 'Open Ground' and lower radon concentrations.
- Analysis confirmed an association between 'No Basement' and lower radon concentrations.

Q: What types of openings are in the basement?

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Sump	27	459	253	293
Drain	334	152	318	232
Cracks around foundation walls	54	432	295	290
Humidify/air condition drain	13	473	294	291
Gap in Foundation	12	474	257	292
Various Cracks	109	377	257	301
Bath/Kitchen Fan	244	242	302	280
Water Supply	330	156	308	256
Dryer	355	131	302	262
Furnace	394	92	298	261
Stairs	312	174	305	266
Other	31	455	295	291

Results of Analysis:

- The t-Test confirms a clear association between having a 'Drain' opening in the basement and higher radon concentrations.

Q: Is there plumbing in the basement/crawlspace?

	n	Avg Bq/m^3
Yes	404	298
No	38	180
N/A	24	366

Results of Analysis:

- Analysis indicates the presence of plumbing in the basement/crawlspace is associated with higher radon concentration.

Q: Type of slab on grade floor of basement/crawlspace?

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Poured Concrete	463	23	294	221
Earth/dirt	12	474	142	295
Rock	1	485	155	291
Other	6	480	309	291

Results of Analysis:

- Analysis found an association between the 12 buildings with an Earth/dirt floor and lower radon concentration. However, caution should be used interpreting this result as 10 of these 12 also have a crawlspace which could be a confounding factor.

Q: Type of foundation walls?

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Poured Concrete	453	33	292	270
Cinder Block	17	469	204	294
Brick	1	485	266	291
Stone	1	485	266	291
Wood	21	465	251	293
Other	6	480	78	294

Results of Analysis:

- None of the possible associations could be confirmed.

Q: Sub-slab building composition?

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Fine	1	485	85	291
Coarse	3	483	96	292
Wet	0	486	na	291
Dry	4	482	180	292
Gravel	41	445	300	290
Dirt	3	483	211	291
Sand	7	479	280	291
Rock	2	484	335	291
Clay	5	481	243	291
Furnace	394	92	298	261
Stairs	312	174	305	266
Other	31	455	295	291

Results of Analysis:Results of Analysis:

- Too few people provided responses to be able to confirm any associations.

Q: Poly or other membrane under slab

	n	Avg Bq/m^3	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Yes	2	206	294	221
No	11	195	142	295
Partial	0	na	155	291
Don't Know	131	241	309	291

Results of Analysis:

- Only 13 responses out of 468 responded with a known answer, so not enough data was available to confirm any associations.

Section 6. Motivation And Intention

Information collected in this section was used to determine the following: if participants plan to mitigate if the radon level is high, and reasons that caused people to test their building.

Q: If the detector shows a high radon level in your home, do you intend to reduce that level?

	n	Avg Bq/ m^3
Yes	351	288
No	7	255
Maybe	107	308
Don't Know	131	241

Results of Analysis:

- No associations were confirmed.
- The majority of participants (351 responses) answered 'Yes.'
- Of those who answered 'No' or 'Maybe', 80 answered "If no or maybe, why not? Specify:" with the following results:

	n
Cost is a barrier	51
Renting the home	11
Will make own assessment of radon level even if over 200 Bq/m^3	9
Need more information	4
Need to clear with strata	2
May move instead	1
Elderly, so wouldn't bother	1
About to move anyway	1

Results of Analysis:

- The majority of respondents (51/80 responses) indicated cost is the biggest barrier to mitigation.
- A portion of respondents indicated they would still make their own judgment whether to mitigate even with results above the Health Canada guideline.

Q: Reasons that caused you to test your building or want to test initially (check all that apply)

	n Yes	n No	Yes - Avg Bq/m^3	No - Avg Bq/m^3
Friend's suggestion	57	429	259	295
Doctor's suggestion	3	483	431	290
Buying building	3	483	391	290
Selling building - voluntary	3	483	180	292
Selling building - buyer request	2	484	455	290
Read an article about radon	169	317	296	288
Public information session	45	441	339	286
Concern for children	59	427	394	277
Renovating anyway	12	474	265	292
BC Lung Radon Study	283	203	279	308
Other Radon Program	18	468	395	287
Other	70	416	303	289

Results of Analysis:

- As all respondents were participants in a BC Lung Study, it is unsurprising that the majority of participants (283 responses) indicated this 'BC Lung Study' was the top reason for testing their home.
- A significant portion of participants (169 responses) indicated, 'Read an article about radon' as a top reason for testing their home.
- Concern for children' (59 responses) was also a popular reason for testing for radon. This was also the one motive confirmed by t-Test to be associated with higher radon levels.

Section 7. Occupant Information

Information collected in this section was used to determine any association between radon concentration and the following: Does anyone regularly sleep in the basement; how many hours per day is anyone in the basement; and, how often windows are open in the basement.

Q: Does anyone regularly sleep in the basement?

	n	Avg Bq/m^3
Does anyone regularly sleep in basement? (Yes)	42	240
Does anyone regularly sleep in basement? (No)	96	240
Does anyone regularly sleep in basement? (Other)	2	83

Results of Analysis:

- There is no association between radon level and inhabitants sleeping in the basement.

Q: How many hours per day is anyone in the basement?

Hours	n	Avg Bq/m^3
1	32	285
2	9	224
3	5	224
4	6	336
5	2	461
6	2	278
7	1	348
8	7	110
9	1	300
10	10	214
11	0	na
12	6	356
13	0	na
14	3	537
15	3	317
16	4	119
17	0	na
18	1	204
19	0	na
20	1	233
21	0	na
22	0	na
23	0	na
24	1	204

Results of Analysis:

- No association was found between radon levels and time spent in the basement.

Q: How often are windows open (days/year) in basement

- With only 54 responses to this question, no association could be confirmed.

Section 8. Past Building Changes

It's important to note that information provided in this section was reported by the homeowner. For example, the participant's idea of what active Sub-slab Depressurization (SSD) constitutes may not completely conform to the same definition as one performed by a C-NRPP certified radon mitigation professional. Second, this section only includes 10 respondents who indicated a prior measurement result out of 486 total respondents, which is too low for a meaningful result. However, the radon test results pre and post-mitigation are of interest.

Nine summaries of before work and after measurements

Original Bq/m^3	Bq/m^3 after work	Type of work
241	133	Not specified
662	681	Homeowner filled some foundation cracks/holes, sealed sump/drain/membrane
1484	74	Radon mitigation by C-NRPP Certified Mitigator – main ventilation, windows, furnace, hot water, don't know if indicator installed
100	152	Homeowner performed unspecified work
350	226	Local Handyman changed ventilation
625	607	C-NRPP Certified Mitigator performed unspecified work
699	200	Homeowner installed active SSD with fan in basement
800	59	Radon mitigation by Homeowner – indicator installed, filled all foundation cracks/holes, active SSD with sidewall discharge, fan outdoors
973	18	Radon mitigation by C-NRPP Certified Mitigator– indicator installed, filled some foundation cracks/holes, active SSD with roof discharge and fan in attic and one slab penetration

Observations:

- There were two examples of a C-NRPP professional significantly reducing radon concentration with active SSD (1484 Bq/m^3 to 74 Bq/m^3, and 973 Bq/m^3 to 18 Bq/m^3).
- There were two examples of variable effectiveness of homeowners installing active SSD (699 Bq/m^3 to 200 Bqm^3, and 800 Bqm^3 to 59 Bq/m^3).
- There was one example of a modest reduction due to a change in ventilation by a handyman (350 Bq/m^3 to 226 Bq/m^3).
- There was one example of efforts by a homeowner sealing cracks, holes, and sump/drain/membrane resulting in no meaningful change (662 Bq/m^3 to 681 Bq/m^3).