# The Prevalence of High Residential Radon in Two Communities within Thunder Bay District

Oliver Paipoonge and Marathon, Ontario

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## TITLE:

The Prevalence of High Residential Radon in Two Communities within Thunder Bay District


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All authors state they have no conflict of interest in presenting the material in this report.

# Executive Summary

**During the home-heating season of 2017/18, 221 and 151 long-term alpha track radon detectors were distributed to homes in the Thunder Bay District communities of Oliver Paipoonge and Marathon, Ontario, respectively, to determine the prevalence of high residential radon.**

Among the 188 Oliver Paipoonge homes that returned their radon detectors for analysis, 65% had radon in excess of the Health Canada guideline of 200 becquerels per cubic meter ($Bq/m^3$) of air. This result is well above the Canadian and Ontario averages of 6.9% and 4.6%, respectively.

Among the 110 Marathon homes that returned their radon detectors for analysis, 17% had radon in excess of the Health Canada guideline of 200 $Bq/m^3$ of air. This result is also above the Canadian and Ontario averages.

Residents of Thunder Bay District should test their homes for radon, regardless of where they live, and mitigate as appropriate to the lowest practical radon concentration. Smokers, in particular, should consider testing their homes because of the significantly increased risk of lung cancer when smoking and exposure to radon are combined. In addition to private homeowners, landlords and tenants should be encouraged to test for radon and mitigate as appropriate, and public health units should respond to complaints about high radon in residential tenancy arrangements in a manner similar to other health hazards.

Numerous organizations in Thunder Bay District can play significant roles in helping citizens to address the increased risk of high radon in their community. The Thunder Bay District Health Unit (TBDHU) and other community agencies should promote radon awareness, testing, and mitigation, to citizens as well as building and trade associations, real estate associations, banks, and insurers. The Municipality of Oliver Paipoonge and the Town of Marathon should adopt soil gas control measures and require all new homes to be tested for radon prior to sale. Local entrepreneurs are encouraged to become certified in radon testing and mitigation through the Canadian National Radon Proficiency Program. All levels of government should consider programs to make radon testing and mitigation more financially accessible.

# Introduction

The purpose of the current study was to determine the prevalence of high levels of radon in Oliver Paipoonge and Marathon homes. The aim was to develop local recommendations about testing for radon and mitigation, and to inform public policy that would reduce the prevalence of elevated residential radon.

## EPIDEMIOLOGY OF RADON AND LUNG CANCER

Radon is a colourless, odourless radioactive gas that is present to some degree in most soils. From the soil, it can seep into your home and accumulate to dangerous levels. The gas decays into a series of radioactive elements called radon progeny. If you inhale dust covered with these radon progeny, some of that dust remains in your airways. While in contact with your lungs, these radon progeny release ionizing radiation that causes cellular damage. Exposure to this radiation increases your risk of cancer. It is interesting to consider that even a single alpha particle can cause major genetic damage to a cell, so it is possible that radon-related DNA damage can occur at any level of exposure. Therefore, there is probably no threshold concentration below which radon does not have the potential to cause lung cancer. There is a dose-response relationship between exposure to radon gas and the incremental risk of lung cancer. In other words, the more radon you are exposed to, and the longer you are exposed to it, the greater your risk of lung cancer.

Radon concentration is measured in becquerels per cubic meter of air. One becquerel is amount of radioactive material required to generate one nuclear decay per second.

About 85% of lung cancer is caused by smoking – both active smoking and second-hand smoke. Exposure to radon is the second leading cause of lung cancer, after tobacco smoking, and the leading cause of lung cancer among non-smokers. Virtually everyone today knows that smoking tobacco is a cause of cancer. What many people do not know is that radon and tobacco are a particularly potent combination. Active smokers who are also exposed to radon have a one in four chance of developing lung cancer during their lifetime.

Most lung cancers do not cause any symptoms until they have spread too far to be cured. Lung cancer typically has a poor prognosis, usually because it is diagnosed at a late stage and has already spread to other parts of the body. The chance of surviving to 5 years after diagnosis is only 17%.

Nationally, it's estimated that there are more than 3,300 lung cancer deaths (16% of all lung cancer deaths) attributable to radon each year. We could prevent 927 deaths per year if everyone with more than 200 becquerels per cubic meter of air ($Bq/m^3$) remediated their homes to outdoor radon levels. The number of lung cancer deaths that could be prevented increases to 1700 per year if everyone with more than 100 $Bq/m^3$ remediated their homes.

## RESIDENTIAL RADON

Radon levels in soil vary considerably across Canada depending on soil characteristics and underlying geology. The amount of radon in your home is influenced partly by those natural factors, but also by house construction, home maintenance, type of heating system, ventilation, and other characteristics. Properly constructed and ventilated houses can draw less than 1% of their indoor air from the underlying soil, or up to 20% if the foundation is poorly designed, built, and maintained, and if the home is inadequately ventilated. Radon can accumulate to high levels in a home with restricted exterior air exchange and a slight negative pressure that draws soil gas in through cracks or other openings in the foundation. Homes that draw their water from wells can also release radon during washing and showering, although it is generally thought to be small contributor to the overall level of radon in most homes.

Because radon is colourless and odourless, the only way to know if your home has high levels of radon is to test for it. Testing is inexpensive and easy. Health Canada recommends that all homes be tested for radon concentration, and those with radon levels equal to or higher than 200 $Bq/m^3$ of air should have their radon levels reduced. It is not practical to reduce radon levels in your home below that of outdoor air, but it should be reduced as low as practically possible.

In 2012, Health Canada published the results of their Cross-Canada Survey of Radon Concentrations in Homes (henceforth referred to as the Health Canada study), which found that 6.9% of Canadians are living in homes with radon levels at or above the Canadian guideline of 200 $Bq/m^3$ of air. The Health Canada study results were broken down by health region across Canada. For the Thunder Bay District Health Unit (TBDHU), it found that 12% of homes tested had radon levels at or above the Canadian guideline, which was 50% higher than the Ontario average. Unfortunately, the sample size in our health region was small and the TBDHU geographic area is large, so it is hard to draw conclusions about the amount and distribution of radon in this area from the Health Canada study.

To gain a deeper understanding of the local distribution of high residential radon, the TBDHU conducted a radon prevalence study in 2016 within the City of Thunder Bay. The results showed that 16% of Thunder Bay homes had radon in excess of the Health Canada guideline of 200 $Bq/m^3$ of air. This result was well above the Canadian and Ontario averages of 6.9% and 4.6%, respectively. The prevalence of excessive radon varied significantly by city ward with McIntyre at 43%, Neebing at 30%, Red River at 15%, Current River at 13%, Northwood at 5%, and McKellar at 2%. No homes with elevated radon were found in Westfort. The Thunder Bay study only examined the City of Thunder Bay, and the high degree of geographic variability within the City suggested that there may be other areas in the Thunder Bay District with very high residential radon. As such, a decision was made to conduct another radon prevalence study, this time in select communities surrounding the City.

National efforts to motivate people to test and remediate their homes for high radon have been met with mixed success. Expressing radon risk at large geographic scales often fails to motivate individuals to assess their personal risk, and it conceals significant local geographical variation. Research has shown that people make their decision about whether to test for radon based on their perceived community concern, perceived susceptibility, perceived severity of radon exposure, social influence by others, tobacco use, and the presence of children in the home. In order for public health units and municipal governments to plan effective policy, more local level information is needed.

# Methods

This was a prevalence study that used a convenience sample of residents from Oliver Paipoonge and Marathon who volunteered following an advertising campaign. A sufficient number of detectors were purchased to distribute to 221 and 151 residential homes in Oliver Paipoonge and Marathon, respectively, as well as duplicates and blanks for quality assurance purposes. Each participant in this study was provided with a long-term (3-month) alpha track radon detector to measure the level of radon in their home. The availability of radon kits for residents was advertised in the newspaper, the health unit website, on social media, and via the radio. Participants were required to apply online or in person at the TBDHU. The intended sampling period was October 2017 to March 2018 (home-heating season), when radon concentrations are usually highest. The cost of the kit and the laboratory processing and report were free to participants as an incentive to participate.

### ELIGIBILITY CRITERIA

Applicants wishing to participate in the study were required to answer a pre-test eligibility questionnaire either online or in person. To be eligible, participants had to have a residence within the Municipality of Oliver Paipoonge or the Town of Marathon for the duration of the study. They also had to have the ability to read, write, and follow instructions in English, and agreed to complete pre- and post-test questionnaires about their radon awareness, the type of home they lived in and radon mitigation attitudes. Both homeowners and renters were eligible. The detectors were meant to be placed on the lowest lived-level in which someone in the household spent an average of at least four hours per day. The participant had to provide a reasonable expectation that the detectors could remain in place undisturbed for at least three months. People living in apartment buildings above the ground floor were excluded. Candidates had the option to pick up or have the radon detector delivered.

### DATA COLLECTION

Radon concentration varies considerably by the hour, day, week and season, so a long-term (3-month) test was required to get an accurate assessment of radon levels in a home. This study used AT-100 Long Term Alpha Track Kits manufactured by AccuStar. The detectors were deployed by the participants following instructions provided. Instructions were in both written and video format, and verbal reinforcement was provided when the detectors were distributed. Some participants received duplicate detectors for quality assurance purposes. Those participants who received duplicate detectors were instructed to place the two detectors within 10 cm of each other. The radon detectors were to be sealed according to manufacturer's requirements at least 91 days after deployment and returned to TBDHU or the Oliver Paipoonge Library along with a post-test evaluation form.

Participants who did not return their detector after 91 days received three or more email and telephone reminders to promote detector return. The TBDHU mailed the returned detectors in multiple batches at different times to the AccuStar Laboratory in Medway, Massachusetts, USA for analysis. The laboratory emailed the results to the TBDHU. The TBDHU then emailed the results to the contact email address provided by the participant.

### QUALITY ASSURANCE

For validation purposes, manufacturers typically recommend that 5% of detectors be allocated as blanks and 10% be assigned to households as duplicates. As such, duplicate detectors were randomly distributed to 10% of homes.

Nineteen detectors were retained unopened in their packaging as blanks. They were opened, immediately sealed and sent for analysis with the first batch of returned detectors.

## ANALYSIS

Planning for the study involved a sample size calculation. The base sample size required, under standard assumptions, for a sampling error of 10% in each unit for which an independent estimate is desired was 200 for Oliver Paipoonge (i.e., 100 each for Oliver and Paipoonge) and 137 for Marathon. Because the municipality in this study are quite small, a finite population adjustment was utilized, which lowers the effective sample size required to achieve a fixed level of sampling error. With the finite population adjustment applied, the effective sample size required to achieve a sampling error of 10% was 183 for Oliver Paipoonge and 125 for Marathon.

The number of households with usual residents was obtained from Statistics Canada. "Households with usual residents" excludes short-term residents, such as those that only

live in the home during the summer months. In addition to sample size, consideration was given to the anticipated return rate. It was estimated, based on the City of Thunder Bay study, that the return rate would be about 80%. As such, in order to obtain 183 returned radon kits from Oliver-Paipoonge, and 125 from Marathon, we needed to distribute 221 and 151 kits to Oliver Paipoonge and Marathon respectively.

The laboratory reported the average radon exposure of each detector in Bq/m$^3$ of air. The main outcome analyzed was a dichotomous variable indicating whether or not the radon test result was above or below the Health Canada guideline of 200 Bq/m$^3$ of air.

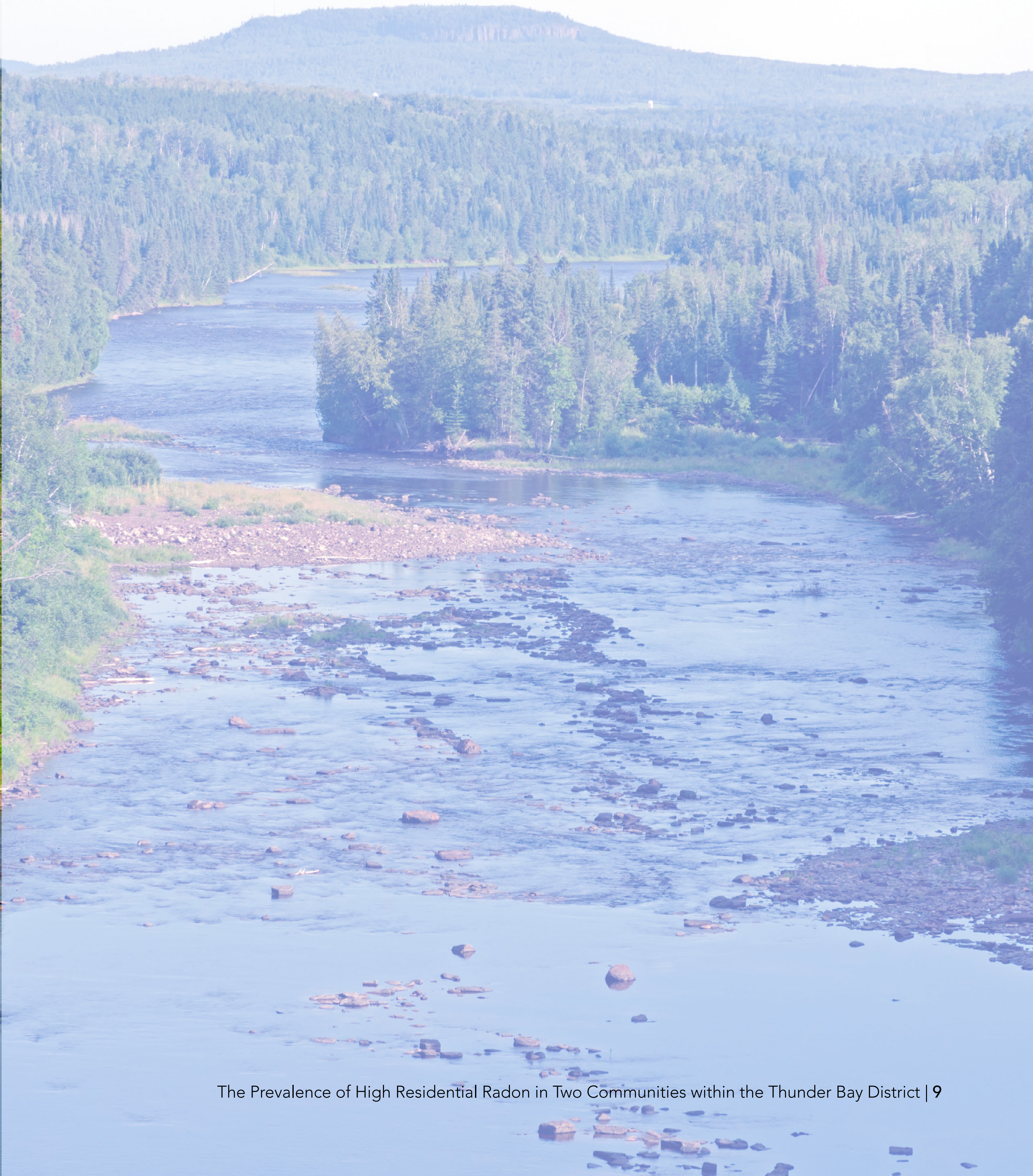
All data were tracked in Microsoft Excel before being converted to Stata 13 format for further analysis.

## CONSIDERATIONS

For participants with duplicate detectors, the average of the two results was used. However, some participants with duplicate detectors did not place the units 10 cm apart as instructed. For these participants, only the highest reported radon exposure was analyzed.

Some participants did not return their deployed radon detectors to TBDHU until well after their testing period ended and they had sealed the detector. When there was more than 60 days between the end of the testing period and return to the lab, the lab was unable to report a result. These participants (n=4) were excluded from analysis.

# Oliver Paipoonge Results



# Oliver Paipoonge Results

Of the 221 households that received radon kits, 189 returned their detector(s) and received their report. We excluded one detector from analysis because more than 60 days had past between the testing period and return to the lab, so its results were invalid. Therefore, the final number of households included in analysis was 188, yielding a response rate of 85%. Of the 22 assigned duplicates, 20 were returned. Figure 1 diagrams the disposition of all Oliver Paipoonge detectors.

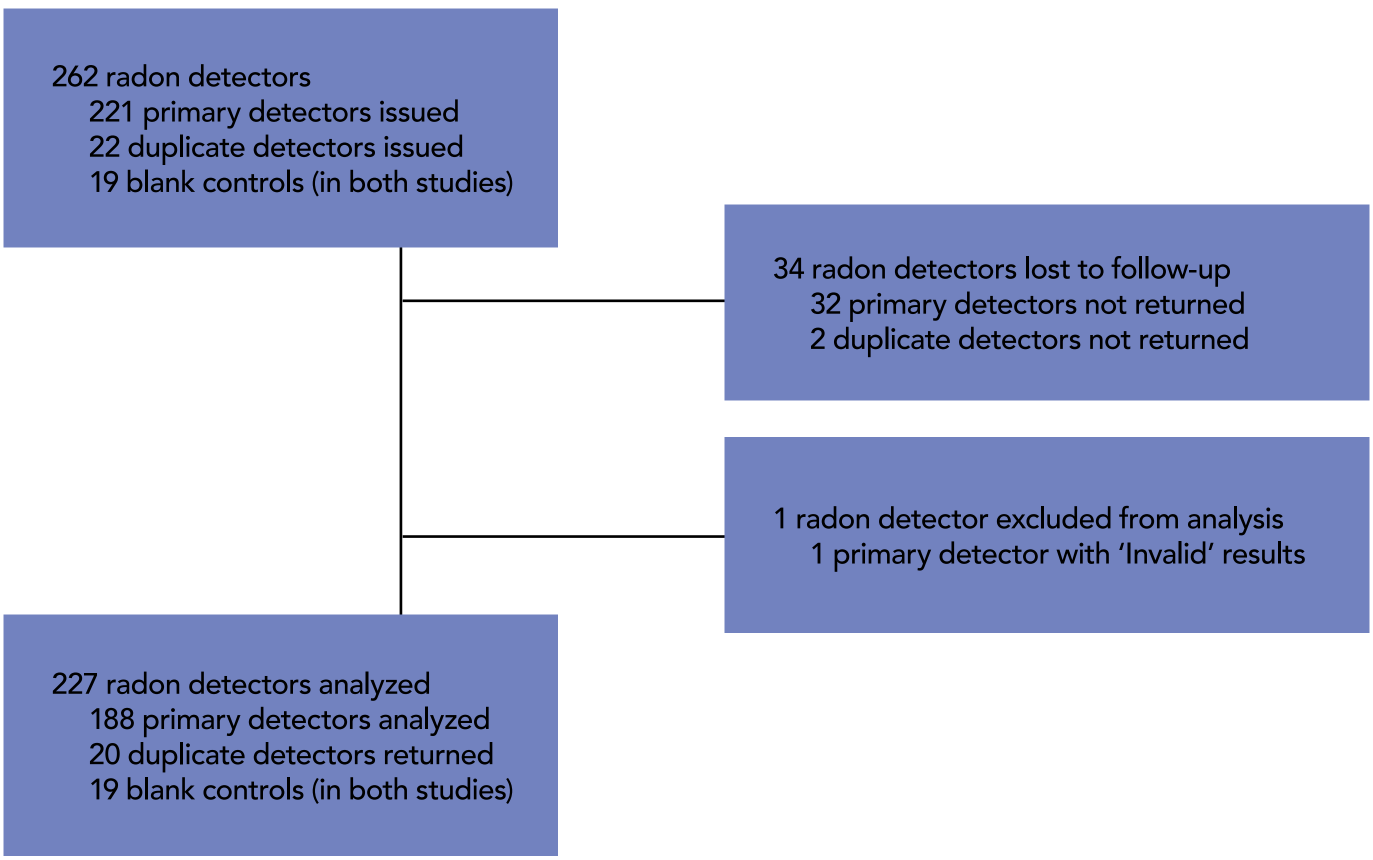



Figure 1. Accounting of Oliver Paipoonge detectors

## QUALITY ASSURANCE

The 19 blank detectors sent for analysis indicated no significant contamination. All of the blanks had radon concentrations less than the detectable level of the alpha-track detector used.

Of the 20 duplicate detectors returned, 12 were deployed correctly (i.e., 10 cm apart from each other). For these households, we averaged the radon level measured by the primary detector and the radon level measured by the duplicate detector. Analysis of the duplicate detectors indicated little variation. None of the duplicates differed by more than 30 Bq/m$^3$, with 75% differing by less than 12 Bq/m$^3$.

Eight duplicate detectors were not deployed 10 cm apart from each other, and they may have been placed in different rooms or on different levels of the household by participants. For these 8 households, we analyzed the highest radon level measured by either the primary or duplicate detector.


## RADON PREVALENCE

In Oliver Paipoonge, 65% of the sampled homes had concentrations at or exceeding the Health Canada guideline of 200 Bq/m$^3$ of air. Table 1 indicates the proportion of homes tested that exceeded various threshold concentration values.

**Table 1. Homes tested in Oliver Paipoonge for radon with concentrations exceeding various threshold values*.**

| Radon Concentration (Bq/m$^3$) | Number of homes | Percent of homes tested |
|---|---|---|
| 100 or higher | 164 / 188 | 87% |
| 150 or higher | 142 / 188 | 76% |
| 200 or higher | 122 / 188 | 65% |
| 400 or higher | 42 / 188 | 22% |
| 600 or higher | 24 / 188 | 13% |

* Different agencies recommend different radon threshold concentrations above which homes should be remediated. The Health Canada guideline suggests that homes with radon concentrations of 200 Bq/m$^3$ or higher should be remediated. The United States Environmental Protection Agency recommends that homes with radon concentration of approximately 150 Bq/m$^3$ be remediated. The World Health Organization recommends that countries should adopt a reference standard of 100 Bq/m$^3$ if possible.

The prevalence of high radon varied across Oliver Paipoonge. In the geographic boundary of the former Township of Oliver, 58% of the sampled homes had radon concentrations exceeding the Health Canada guideline of 200 Bq/m$^3$ of air. Significantly higher, 72% of sampled homes in the former Township of Paipoonge had radon concentrations exceeding the Health Canada guideline of 200 Bq/m$^3$ air.

Figure 2 provides this information in map format, showing the proportion of homes with high radon (200 Bq/m$^3$ of air or higher). In order to preserve the confidentiality of study participants, we placed a fine 1km x 1km grid over the areas where homes were tested. We calculated the proportion of homes with high radon (200 Bq/m$^3$ or higher) within each cell of the grid. This distribution of high radon is more clearly seen at this level of aggregation. It also makes clear that there is significant variability in radon levels even at this relatively small scale.

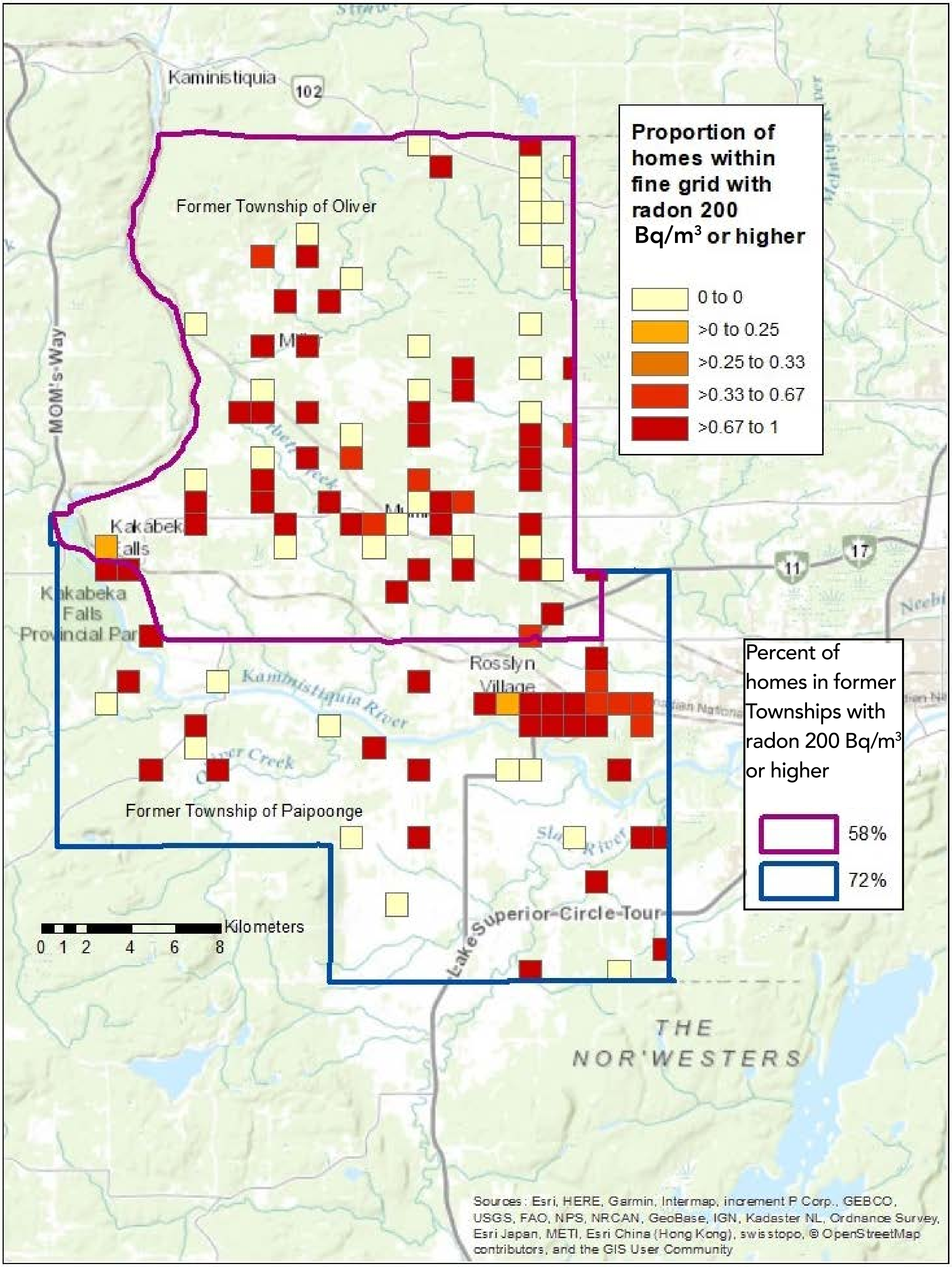



Figure 2. Proportion of Oliver Paipoonge homes with high radon (200 Bq/m³ or higher) within each 1km x 1km grid cell.

## HOME CHARACTERISTICS

Radon concentration is known to vary according to a number of home characteristics. The age of the home reflects building standards of the era in which it was built. The presence of openings in the foundation, such as cracks or a sump hole may act as a portal of entry for radon gas from the soil. We did not ask participants about cracks in their foundation, but we did ask about the type of foundation, the type of basement floor (if applicable) and presence of a sump hole. Radon concentration also varies depending on the level of the home tested, with lower levels generally having higher concentrations. Table 2 shows the proportion of homes that tested above the Canadian guideline of 200 Bq/m$^3$ of air by home characteristics.

Following the Health Canada guidelines, we instructed participants to place the radon detector on the lowest level of their home where they spend at least four hours per day. Most participants (99%) placed the radon detector in their basement or on their ground floor. It is important to note that in homes where the radon detector was placed above the basement level, the radon concentration reported may underestimate the highest level of radon in the home.

More homes built after 1961 had high levels of radon compared to those built earlier. More homes with sealed and unsealed sump holes had high levels of radon than those without. Also, as expected, people who tested their basements reported higher levels of radon than those who tested a different floor. More homes on private wells had high levels of radon compared to those on municipal water. More homes with full basements had high levels of radon compared to those with partial basements, crawl spaces, or no basement. More homes with poured concrete basement floors had higher levels of radon than those with different floor types. Finally, more homes heated by natural gas, propane, or geothermal energy had high levels of radon compared to those with other heating types. Regardless of the home characteristic in each category, the proportion of homes with radon at or above 200 Bq/m$^3$ of air still remained well above the Canadian and Ontario averages of 6.9% and 4.6%, respectively.

**Table 2. Percentage of homes in Oliver Paipoonge with a radon concentration of 200 Bq/m$^3$ or higher, by home characteristic.**

| Home characteristic | Homes tested with characteristic | Percent with radon concentration of 200 Bq/m$^3$ or higher |
|---|---|---|
| YEAR BUILT | | |
| 1960 or before | 19 | 48% |
| 1961-1990 | 89 | 67% |
| 1991 or later | 68 | 71% |
| PRESENCE OF SUMP HOLE | | |
| Unsealed sump hole | 123 | 68% |
| Sealed sump hole | 8 | 75% |
| No sump hole | 40 | 58% |
| WATER SOURCE | | |
| Private well | 167 | 65% |
| Municipal | 20 | 55% |
| FLOOR TESTED | | |
| Basement | 115 | 76% |
| Ground floor | 71 | 47% |
| Second level | <5 | 50% |
| BASEMENT TYPE | | |
| Core floor | 10 | 30% |
| Crawl space | 12 | 33% |
| Partial, full basement | 165 | 70% |
| BASEMENT FLOOR (multiple responses accepted) | | |
| Poured concrete | 157 | 69% |
| Earth/dirt | 18 | 33% |
| Other (e.g, wood, rock) | 21 | 62% |
| FOUNDATION WALLS (multiple responses accepted) | | |
| Poured concrete | 88 | 65% |
| Cinder block | 53 | 70% |
| Wood | 44 | 66% |
| Other (e.g., brick) | 22 | 27% |
| HEATING TYPE (multiple responses accepted) | | |
| Natural gas | 120 | 68% |
| Electric | 25 | 56% |
| Oil | 16 | 56% |
| Propane | 24 | 75% |
| Wood | 53 | 47% |
| Other (e.g geothermal) | 10 | 60% |

## RADON AWARENESS

We asked participants about their awareness of radon as a health hazard, if they would encourage others to conduct a radon test, and how often they discussed radon with others during the course of the study. As shown in Figure 3, participants became more aware of radon as a health hazard from before and after the testing period. As seen in Figure 4, most participants discussed radon with others about once a month or more during the study period.

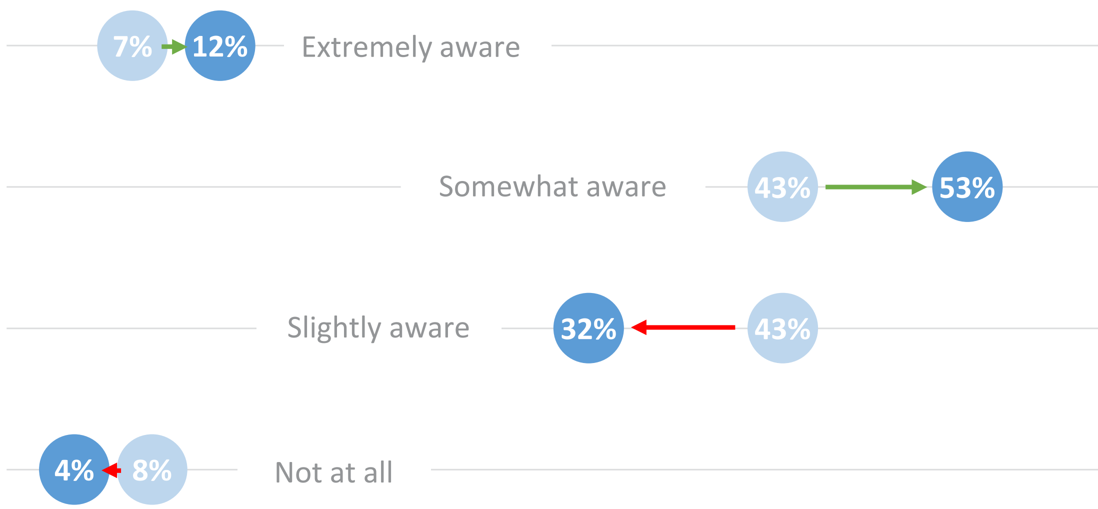



Figure 3. Participants' awareness of radon as a health hazard pre- and post-study.

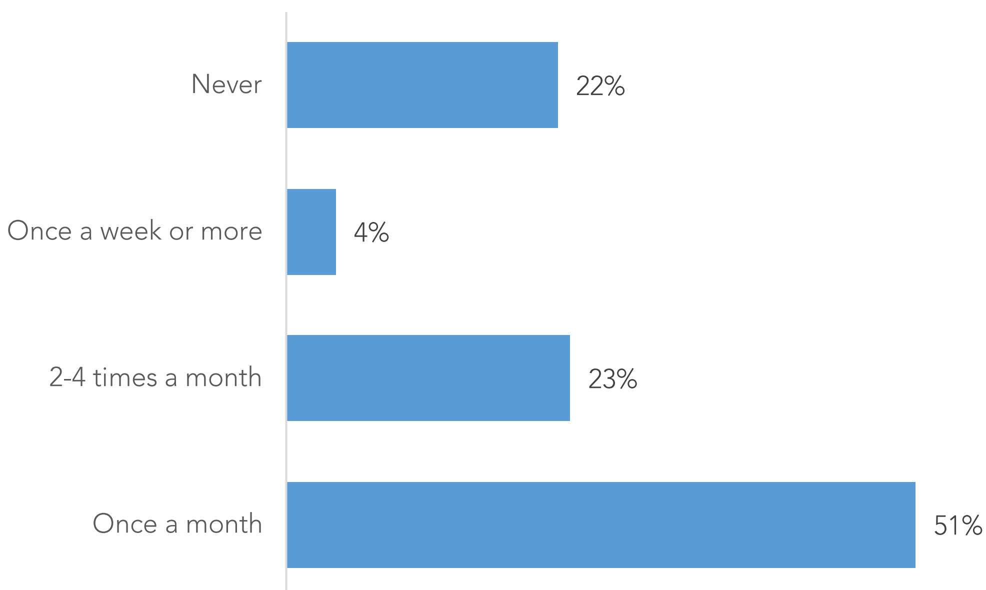



Figure 4. How often participants discussed radon after study enrollment.

### RADON MITIGATION

We also asked participants about their willingness to remediate their home if high levels of radon were detected, barriers to doing so, and behaviours they may change. As shown in Figure 5, 75% of participants reported they would likely mitigate their home if high radon levels were found. As shown in Figure 6, the biggest barriers to mitigating their home were cost, resources, and knowledge. As shown in Figure 7, some participants were willing to modify certain risk behaviours if high radon levels were found in their home; mainly spending less time in the lowest level of their home.

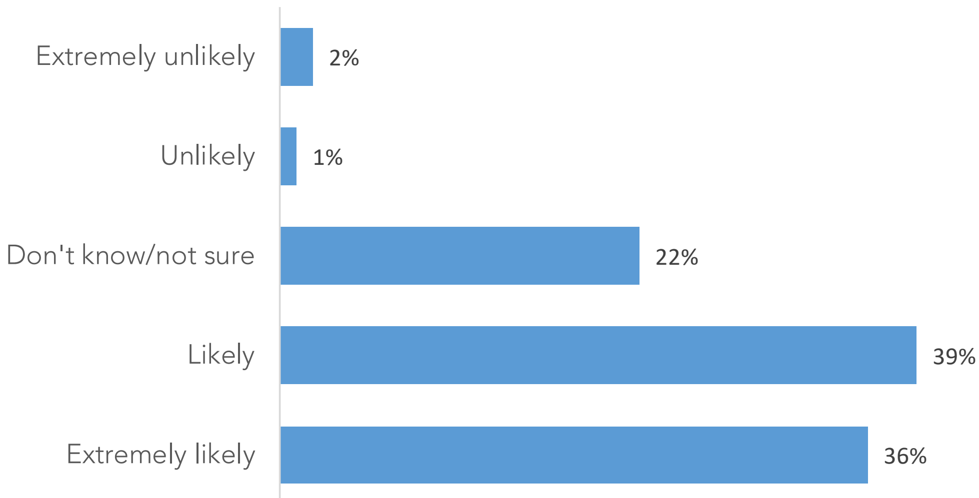



Figure 5. Participants' willingness to remediate their home if high levels of radon were detected.

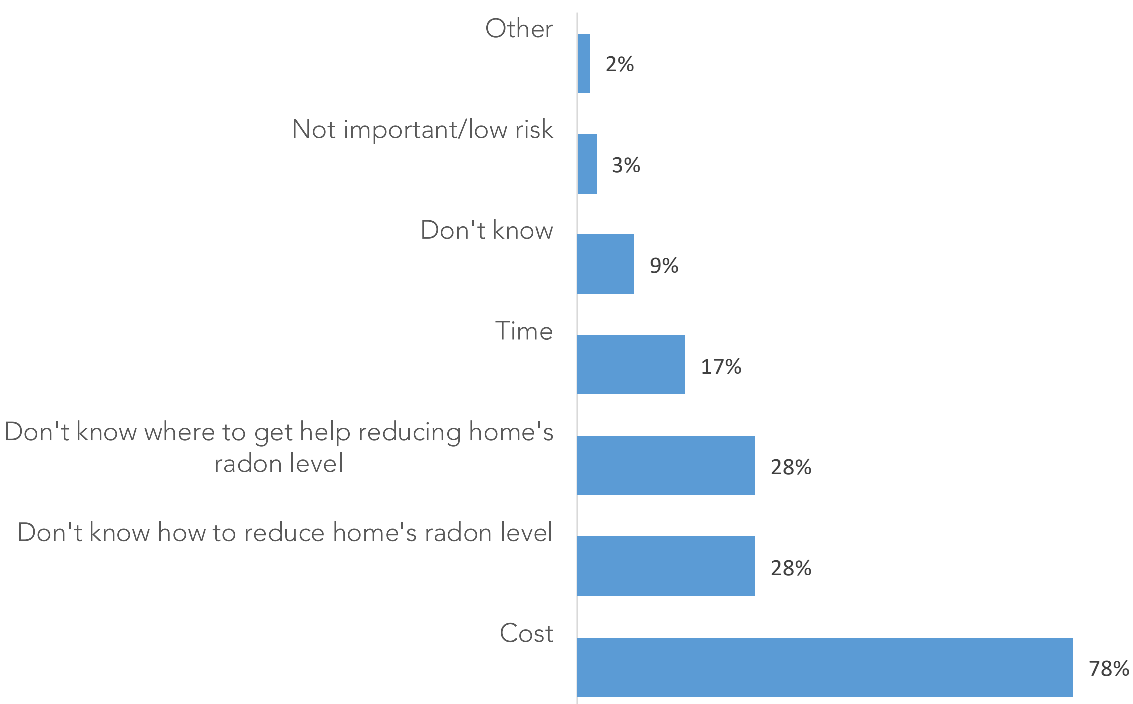



Figure 6. Participants' perceptions of the biggest barriers to radon mitigation.

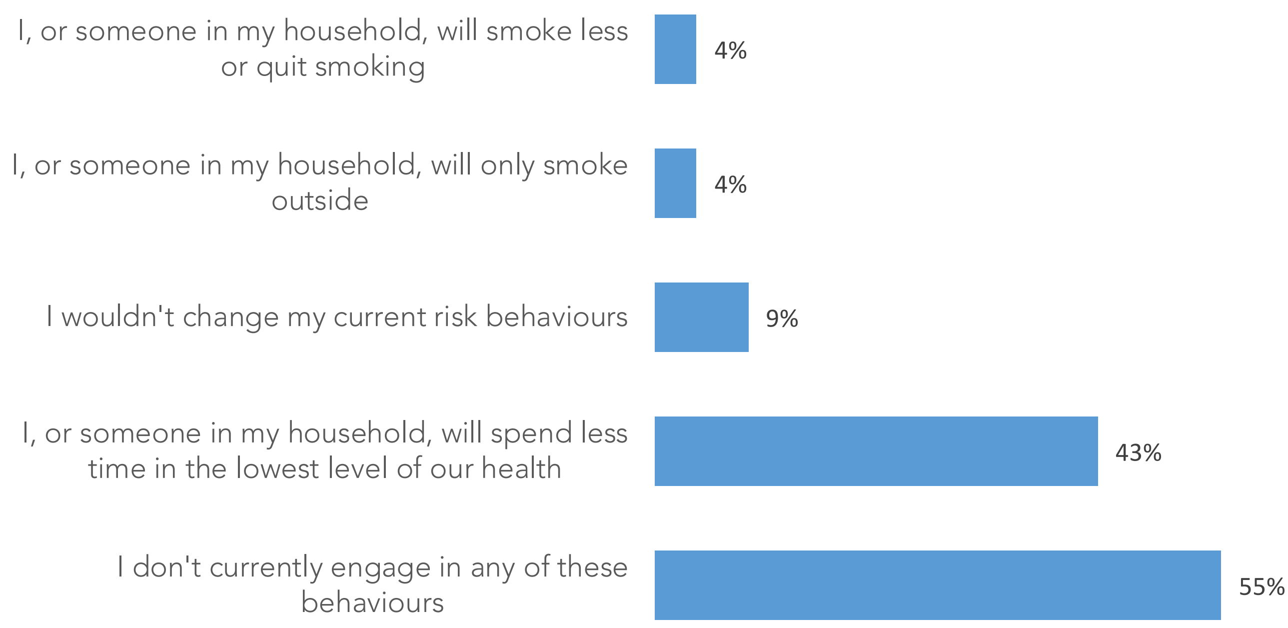



Figure 7. Behaviours participants are willing to modify if high radon levels were found in their home

# Marathon Results

# Marathon Results

Of the 151 households that received radon kits, 113 returned their detector(s) and received their report. We excluded three detectors from analysis because more than 60 days had past between the testing period and return to the lab, so their results were invalid. Therefore, the final number of households included in analysis was 110, yielding a response rate of 73%. Of the 16 assigned duplicates, 12 were returned. Figure 8 diagrams the disposition of all Marathon detectors.

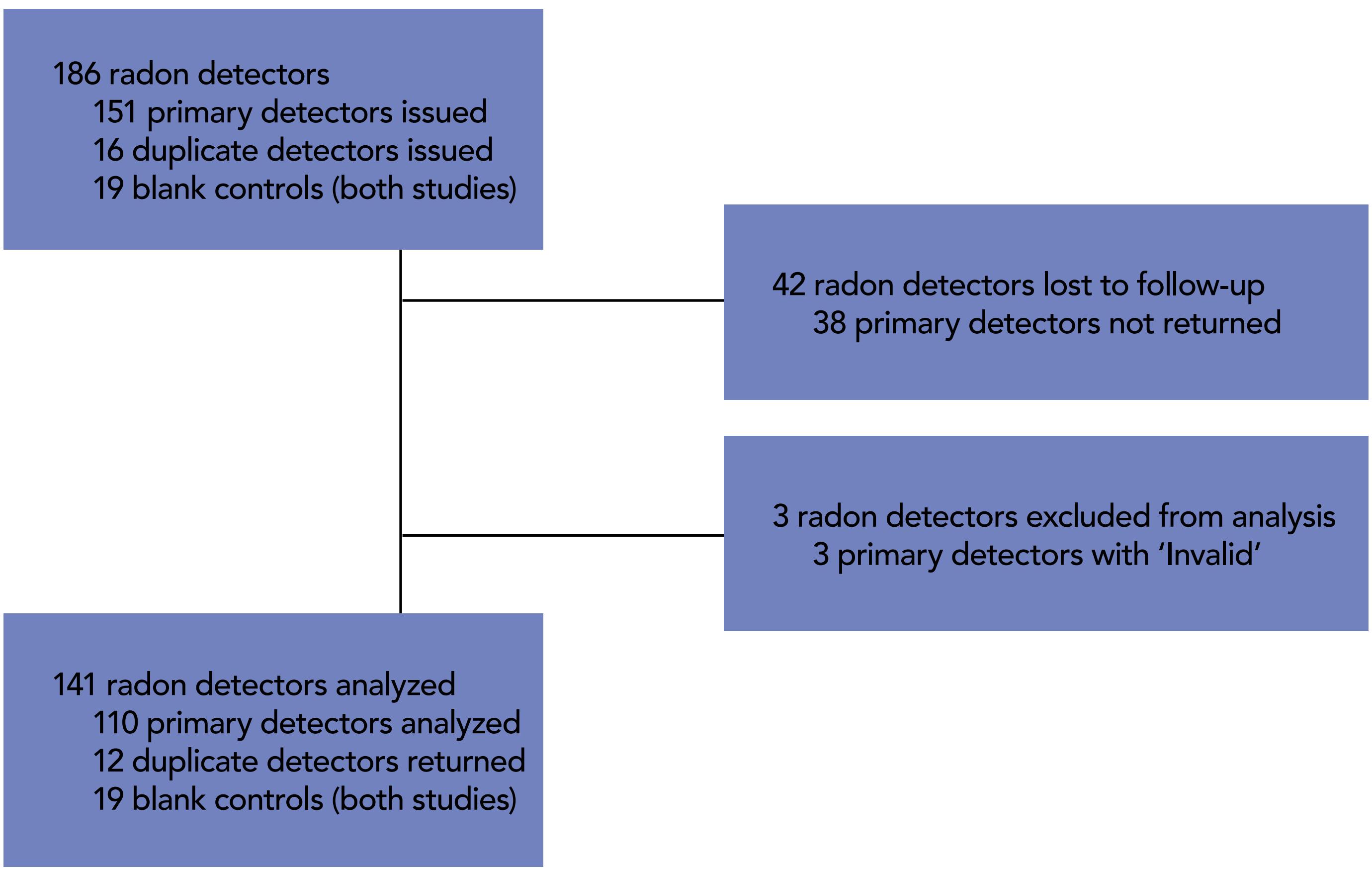



Figure 8. Accounting of Marathon detectors

## QUALITY ASSURANCE

The 19 blank detectors sent for analysis indicated no significant contamination. All of the blanks had radon concentrations less than the detectable level of the alpha-track detector used.

Of the 12 duplicate detectors returned, 10 were deployed correctly (i.e., 10 cm apart from each other). For these households, we averaged the radon level measured by the primary detector and the radon level measured by the duplicate detector. Analysis of the duplicate detectors indicated little variation. None of the duplicates differed by more than 44 Bq/m$^3$, with 60% differing by less than 15 Bq/m$^3$.

Two duplicate detectors were not deployed 10 cm apart from each other, and they may have been placed in different rooms or on different levels of the household. For these two households, we analyzed the highest radon level measured by either the primary or duplicate detector.

## RADON PREVALENCE

In Marathon, 17% of the sampled homes had concentrations at or exceeding the Health Canada guideline of 200 Bq/m$^3$ of air. Table 3 indicates the proportion of homes tested that exceeded various threshold concentration values.

**Table 3. Homes tested for radon with concentrations exceeding various threshold values*.**

| Radon Concentration (Bq/m$^3$) | Number of homes | Percent of homes tested |
|---|---|---|
| 100 or higher | 77/110 | 70% |
| 150 or higher | 37/110 | 34% |
| 200 or higher | 19/110 | 17% |
| 400 or higher | 8/110 | 7% |
| 600 or higher | <5/110 | 2% |

* Different agencies recommend different radon threshold concentrations above which homes should be remediated. The Health Canada guideline suggests that homes with radon concentrations of 200 Bq/m$^3$ or higher should be remediated. The United States Environmental Protection Agency recommends that homes with radon concentration of approximately 150 Bq/m$^3$ be remediated. The World Health Organization recommends that countries should adopt a reference standard of 100 Bq/m$^3$ if possible.

The prevalence of high radon varied across Marathon. Figure 9 provides this information in map format, showing the proportion of homes with high radon (200 Bq/m$^3$ of air or higher). In order to preserve the confidentiality of study participants, we placed a fine 200m x 200m grid over the areas where homes were tested. We calculated the proportion of homes with high radon (200 Bq/m$^3$ or higher) was within each cell of the grid. This distribution of high radon is more clearly seen at this level of aggregation. It also makes clear that there is significant variability in radon levels even this relatively small scale.

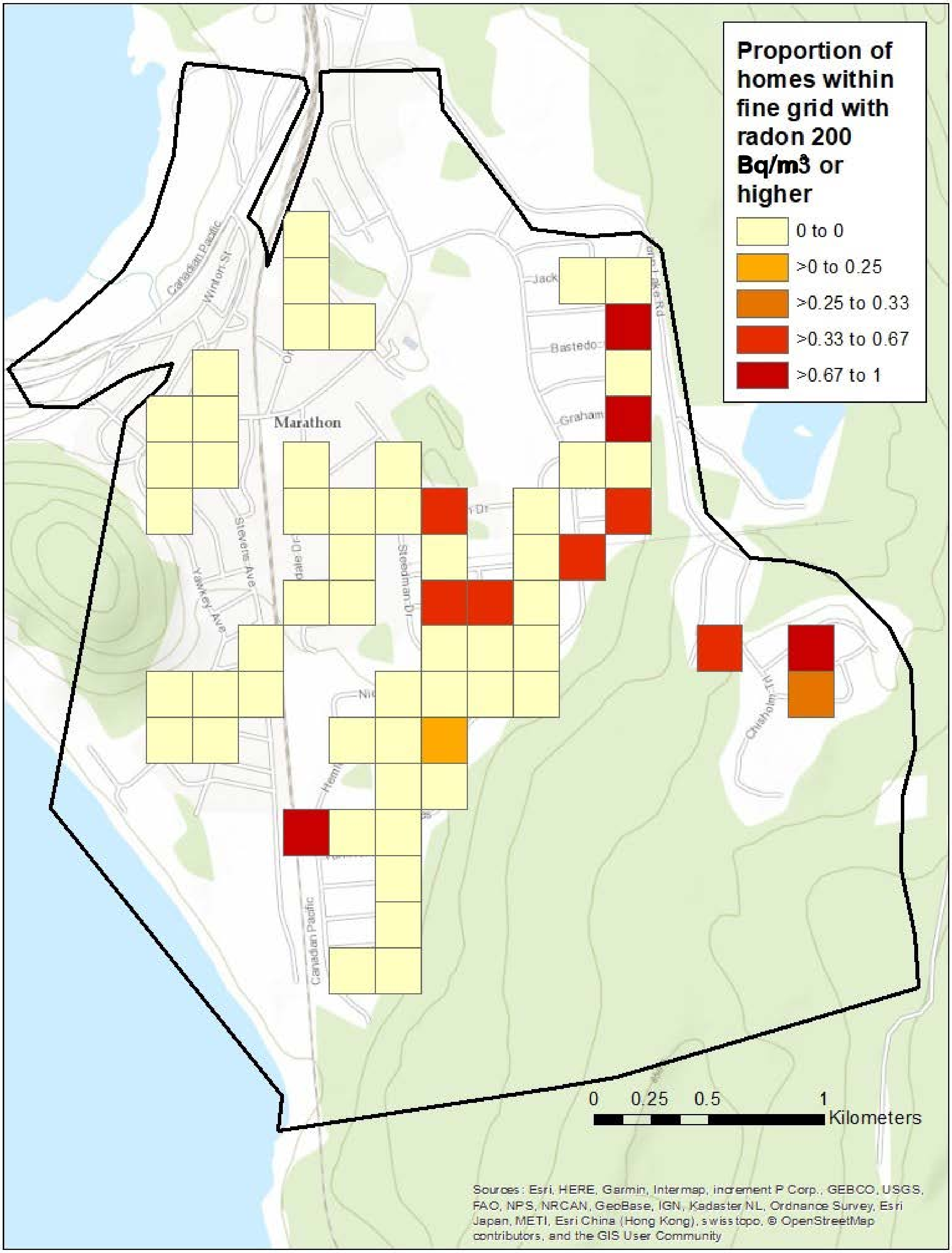



Figure 9. Proportion of Marathon homes with high radon (200 Bq/m$^3$ or higher) within each grid cell.

## HOME CHARACTERISTICS

Radon concentration is known to vary according to a number of home characteristics. The age of the home reflects building standards of the era in which it was built. The presence of openings in the foundation, such as cracks or a sump hole is important because they may be a portal of entry for radon gas from the soil. We did not ask participants about cracks in their foundation, but we did ask about the type of foundation, the type of basement floor (if applicable) and presence of a sump hole. Radon concentration also varies depending on the level of the home tested, with lower levels generally having higher concentrations. Table 4 shows the proportion of homes that tested above the Canadian guideline of 200 Bq/m$^3$ of air broken down by home characteristics.

Following the Health Canada guidelines, we instructed participants to place the radon detector on the lowest level of their home where they spend at least four hours per day. Most participants (96%) placed the radon detector in their basement or on their ground floor. It is important to note that in homes where the radon detector was placed above the basement level, the radon concentration reported may estimate the highest level of radon in the home.

More homes built after 1981 had high levels of radon compared to those built earlier. More with unsealed sump holes had high levels of radon than those with sealed or no sump hole. Also, as expected, people who tested their basements reported higher levels of radon than those who tested a different floor. More homes with partial or full basements had high levels of radon compared to those with crawl spaces, or no basement. More homes with poured concrete basement floors had higher levels of radon than those with different floor types. Finally, more homes heated by electric or wood had high levels of radon compared to those with other heating types.

**Table 4: Percentage of homes with a radon concentration of 200 Bq/m$^3$ or higher, by home characteristic.**

| Home characteristic | Homes tested with characteristic | Percent with radon concentration of 200 Bq/m$^3$ or higher |
|---|---|---|
| YEAR BUILT | | |
| 1960 or before | 28 | 0% |
| 1961-1980 | 35 | 11% |
| 1981-2000 | 55 | 27% |
| PRESENCE OF SUMP HOLE | | |
| Unsealed sump hole | 17 | 41% |
| Sealed sump hole | <5 | 0% |
| No sump hole | 65 | 12% |
| WATER SOURCE | | |
| Municipal | 110 | 17% |
| FLOOR TESTED | | |
| Basement | 65 | 85% |
| Ground floor | 44 | 11% |
| Second level | <5 | 50% |
| BASEMENT TYPE | | |
| Core floor | 6 | 0% |
| Crawl Space | <5 | 0% |
| Partial, full basement | 101 | 19% |
| BASEMENT FLOOR (multiple responses accepted) | | |
| Poured concrete | 99 | 18% |
| Earth/dirt | 5 | 0% |
| Other (e.g., wood) | <5 | 0% |
| FOUNDATION WALLS (multiple responses accepted) | | |
| Poured concrete | 82 | 15% |
| Cinder block | 10 | 20% |
| Wood | 16 | 19% |
| Other (e.g., brick) | <5 | 0% |
| HEATING TYPE (multiple responses accepted) | | |
| Electric | 67 | 21% |
| Oil | 11 | 0% |
| Propane | 43 | 16% |
| Wood | 25 | 24% |
| Other (e.g., solar) | 6 | 17% |

## RADON AWARENESS

We asked participants about their awareness of radon as a health hazard, if they would encourage others to conduct a radon test, and how often they discussed radon with others during the course of the study. As shown in Figure 10, participants became more aware of radon as a health hazard from before and after the testing period. As shown in Figure 11, most participants discussed radon with others about once a month or more during the study period.

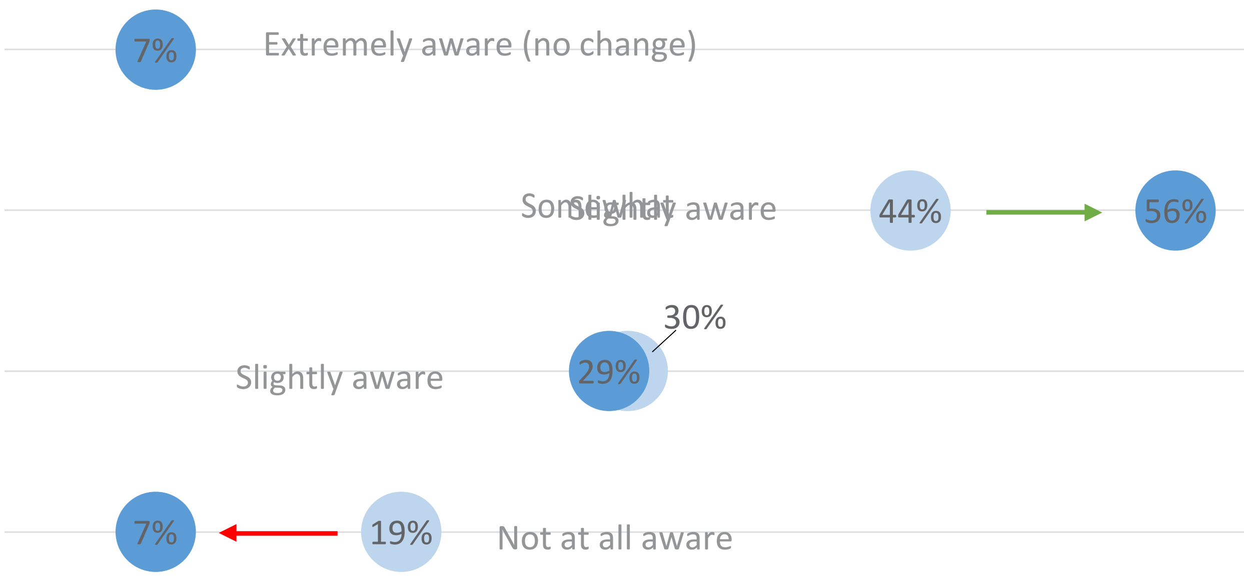



Figure 10. Participants' awareness of radon as a health hazard pre- and post-study.

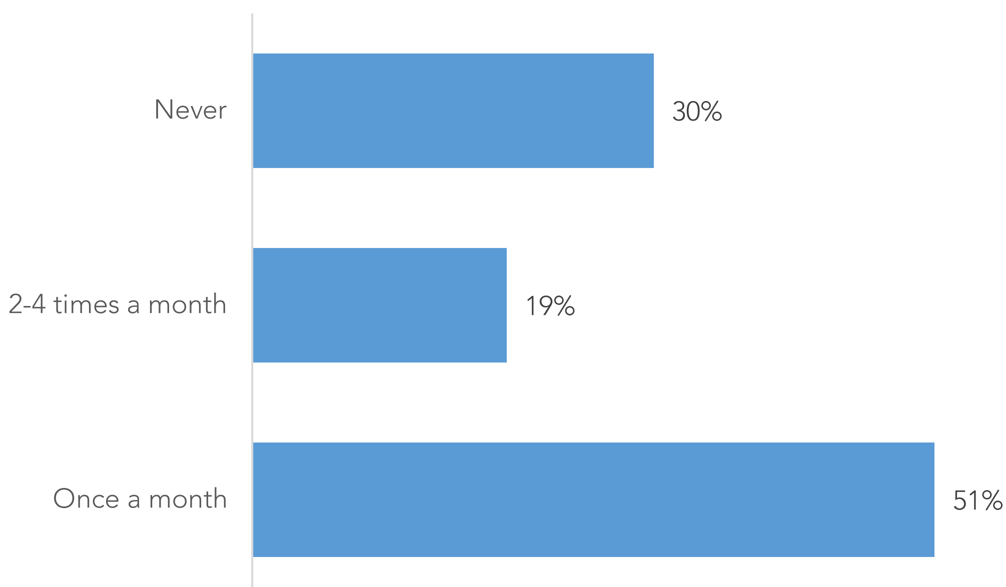



Figure 11. How often participants discussed radon after study enrollment.

## RADON MITIGATION

We also asked participants about their willingness to remediate their home if high levels of radon were detected, barriers to doing so, and behaviours they may change. As shown in Figure 12, 75% of participants reported they would likely mitigate their home if high radon levels were found. As shown in Figure 13, the biggest barriers to mitigating their home were cost, resources, and knowledge. As shown in Figure 14, some participants were willing to modify certain risk behaviours if high radon levels were found in their home; mainly spending less time in the lowest level of their home.

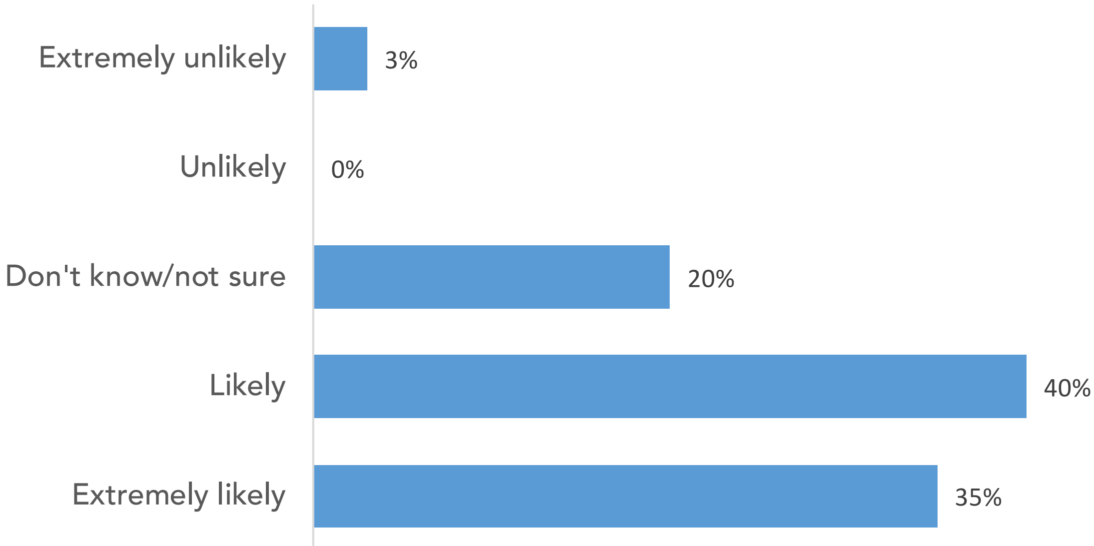



Figure 12. Participants' willingness to remediate their home if high levels of radon were detected.

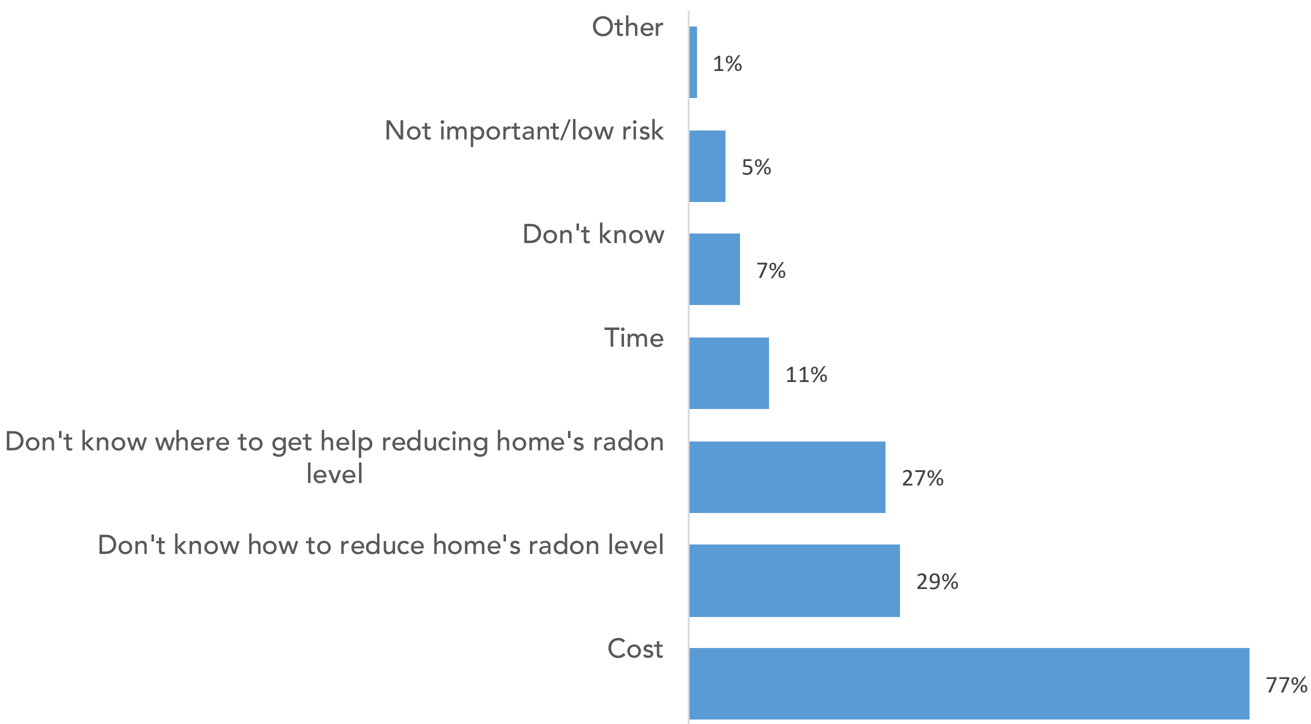



Figure 13. Participants' perceptions of the biggest barriers to radon mitigation.

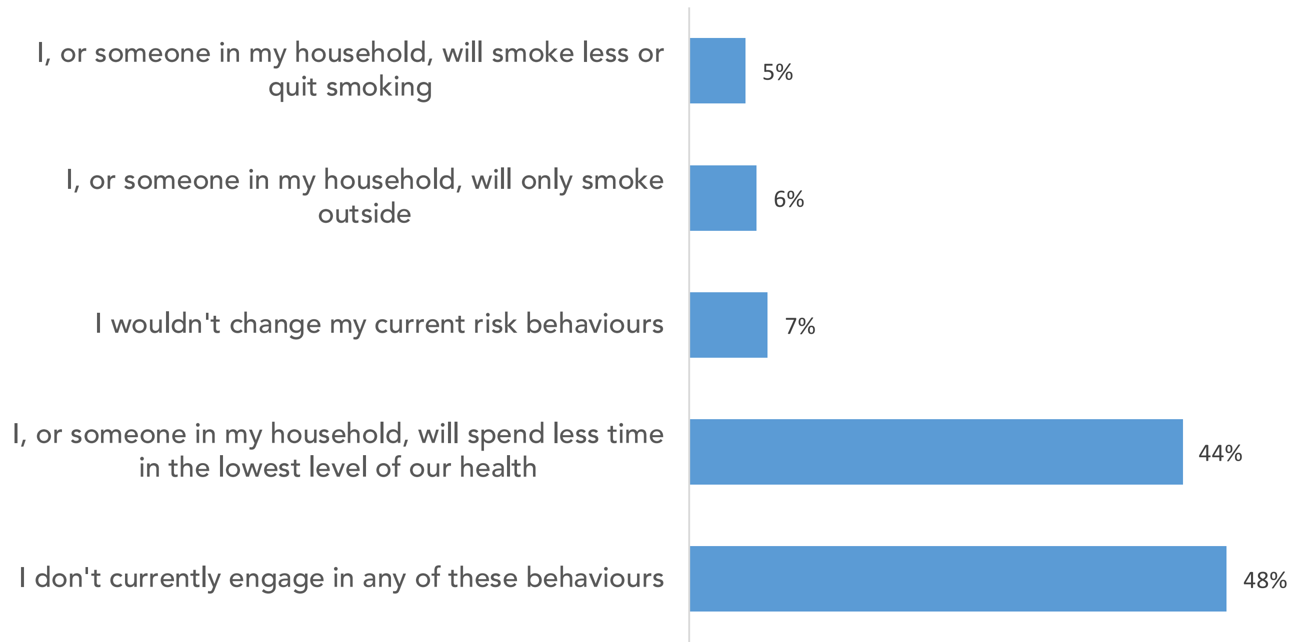
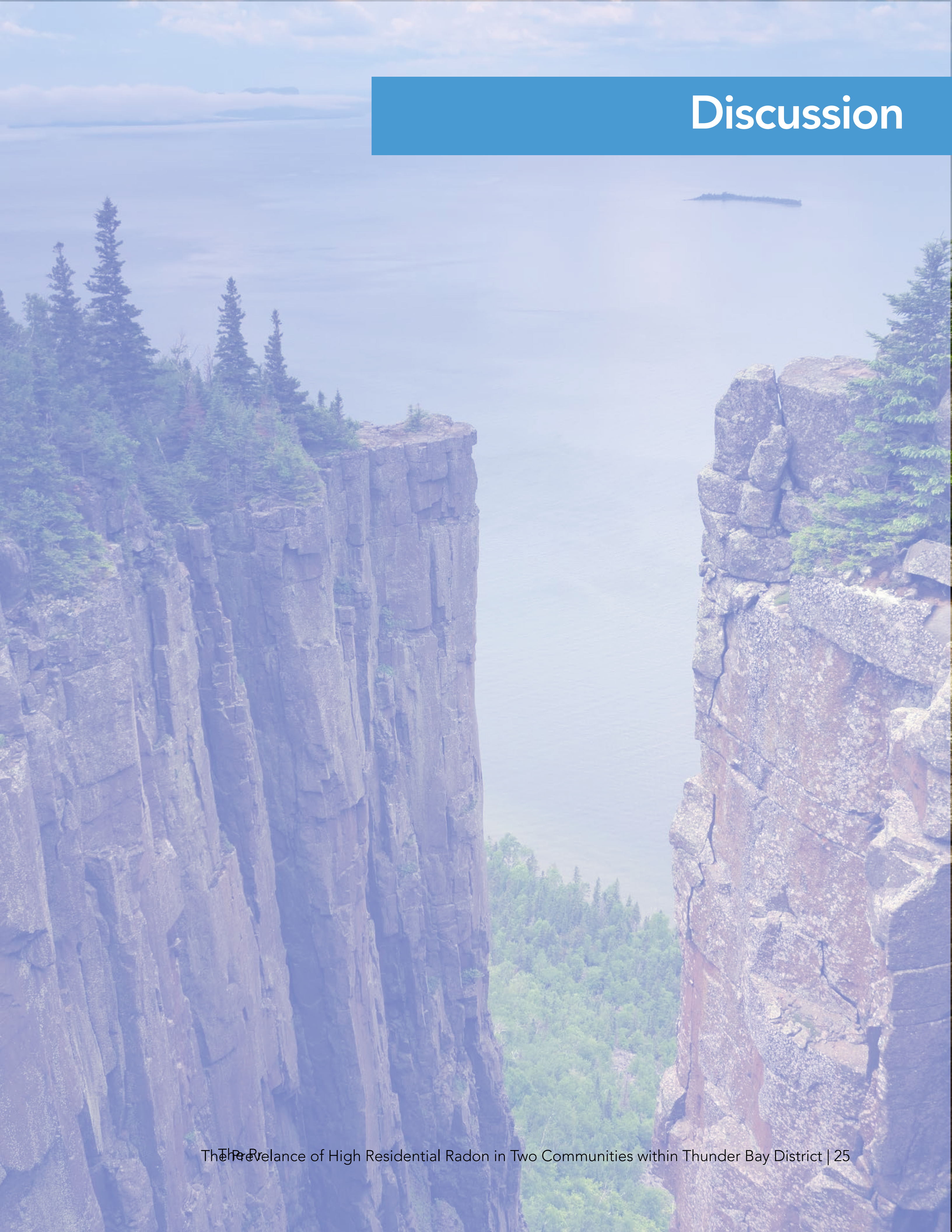



Figure 14. Behaviours participants are willing to modify if high radon levels were found in their home.



# Discussion

# Discussion

**The present study found that 65% of Oliver Paipoonge homes and 17% of Marathon homes had radon levels that were in excess of 200 Bq/m$^3$ of air. The prevalence of high residential radon in Oliver Paipoonge and Marathon is significantly greater than the Ontario and Canadian averages.**

The Health Canada study found that the prevalence of high residential radon in Canada and Ontario averaged 6.9% and 4.6%, respectively. The findings of the current study show that the prevalence of high residential radon is 13 times higher in Oliver Paipoonge and over three times higher in Marathon compared to the provincial average.

Our previous study in the City of Thunder Bay showed that 16% of homes had high radon levels, with one ward as high as 43%. In that study, wards with a significant rural composition were more greatly affected than urban wards. Thus, we anticipated other areas in Thunder Bay District, particularly rural or semi-rural areas, to have high residential radon. However, the finding in the present study that 65% of homes in Oliver Paipoonge had high levels of residential radon was troubling.

Oliver Paipoonge may have high levels of residential radon due to an interaction of factors. These include: local geology (i.e., underlying rock containing uranium and/or soil that is permeable to radon gas); house construction (i.e., dwelling characteristics which allow entry of radon such as cracks in the foundation or unsealed sump holes), and occupant activities (i.e., implementation of radon mitigation strategies). Our analyses revealed that the proportion of homes without characteristics known to allow radon entry also had high radon. For instance, sump holes and foundation cracks are both viable radon entry points. However, even the proportion of homes without these 'entry points' had radon levels. About 58% of homes tested without a sump hole and 30% of homes tested without a basement (i.e., core floor) had radon levels 200 Bq/m$^3$ of air or higher. This suggests that geologic characteristics of Oliver Paipoonge may have great impact on high levels of residential radon in the area.

It is important, however, to recognize that this study design is not able to disentangle the reasons for high radon homes. Because of the noted complex interaction of geologic, house, and occupant factors, residential radon concentration can vary greatly over a local area. Many studies have found even side-by-side neighbours can have greatly different residential radon concentrations. The maps in Figure 2 and Figure 9 reveal that homes with high radon are located in close proximity to homes with low radon. Thus, as Health Canada and other agencies have emphasized, it is important to test your home for radon. It is even more imperative to test your home if you live in an area with an increased prevalence of high residential radon, like Thunder Bay, Oliver Paipoonge, or Marathon.

The participants in this study reported a high level of awareness of radon as a health hazard, and a willingness to mitigate their homes if high radon levels were found. This should not be surprising given that the study is based on a convenience sample of people who expressed an interest in having their homes tested for radon. This degree of awareness and willingness to act may not be representative of the general populations of Oliver Paipoonge and Marathon, ON. People motivated to take part in a radon study may also be more health conscious and radon-aware than the general population.

A further limitation of the current study was the inclusion of participants who deployed their radon detectors for less than the recommended 91 days. Further analyses revealed that inclusion of these participants did not significantly change the distribution of homes with high vs. low residential radon. Further, a small number of participants kept their radon detectors deployed for longer than the home-heating season (i.e., May and June). We also included these participants in analyses as the majority were homes with high residential radon. This suggests that even though some factors may have differed during the end of these homes' testing periods (e.g., opened windows, no snow on ground, less hot air rising), radon was still present at levels in excess of 200 $Bq/m^3$ of air, which require further attention.

The current study had a relatively small number of duplicate and control detectors. Although none of the duplicate and control detectors indicated measurement problems in this study, future radon research studies should budget for more extensive and better deployment of controls. The increased use of blank detectors should include a set of blanks attached to duplicate detectors and a set of detectors that remain at the laboratory that are run during the processing, along with a set of detectors that remain at the health unit and are mixed in with the batches being returned. The extra blank detectors would serve to increase the confidence that sampling was not contaminated.

# Recommendations

This study has a number of implications for public health and for further research.

## PUBLIC HEALTH

1. The TBDHU and other partner agencies should promote radon awareness and testing, including disseminating the results of this study, to motivate residents to test their homes for radon, and to mitigate their homes as appropriate.

2. Residents of Thunder Bay District should test their homes for radon with a long-term 3-month detector and mitigate as appropriate.

3. Radon awareness, testing and mitigation campaigns should especially target smokers because of their increased risk of lung cancer when smoking and exposure to radon are combined.

4. Radon awareness campaigns should inform residents that the Health Canada guideline of remediating radon levels at 200 $Bq/m^3$ or above is based on many factors, and that each person should decide what level of risk they are willing to live with. The World Health Organization recommends a much lower guideline limit of 100 $Bq/m^3$. Although radon cannot be eliminated entirely from a home, there is no "safe" level of radon. Radon should be remediated to the lowest practical level.

5. The Municipality of Oliver Paipoonge and the Town of Marathon should implement the soil gas control measures of the Ontario Building Code and require all new homes to be tested for radon prior to sale.

6. While some radon mitigation work is simple enough for homeowners to do themselves, some mitigation jobs are beyond the skills of the average homeowner. Local entrepreneurs should be encouraged to become certified in radon testing and mitigation through the Canadian National Radon Proficiency Program.

7. A significant fraction of participants indicated that finances would be barrier to mitigating their homes for high radon. Not all types of radon mitigation are costly. Nonetheless, all levels of government should consider programs to make radon testing and mitigation more financially accessible.

8. Radon is a known environmental health hazard. Landlords and tenants should be encouraged to test for radon and mitigate as appropriate. Public health units should respond to complaints about high radon in residential tenancy arrangements in a manner similar to other health hazards.

9. Building organizations, real estate associations, building trades and professions, and banks and insurers offer promising opportunities for further radon awareness building. The cost of remediating radon is small in the context of buying a house, and buyers and sellers may be particularly motivated to act when the radon concentration in the home could affect the selling price.

## FURTHER RESEARCH

1. Conducting radon prevalence studies at the local level is expensive, time-consuming and logistically difficult. Local public health units have limited resources to conduct such research studies, and yet radon is known health hazard prevalent in many communities. The Ministry of Health and Long Term Care should allocate specific funding to health units to support radon awareness and local prevalence research. This is especially important given that the Ontario Building Code requires that radon prevalence be demonstrated before soil gas control measures are required to be implemented.

2. It would be valuable to extend this study to other municipalities in Thunder Bay District. The expense and logistical complexity would likely be similar to the present study.

3. Additional research should be conducted into the causes of high radon. In particular, it should be determined why radon levels are so much higher in Oliver Paipoonge. Some possible hypotheses about the high proportion of homes tested with high residential radon in Oliver Paipoonge: the underlying geology, the age structure or other characteristics of the homes, and the possible presence of radon in well water.

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