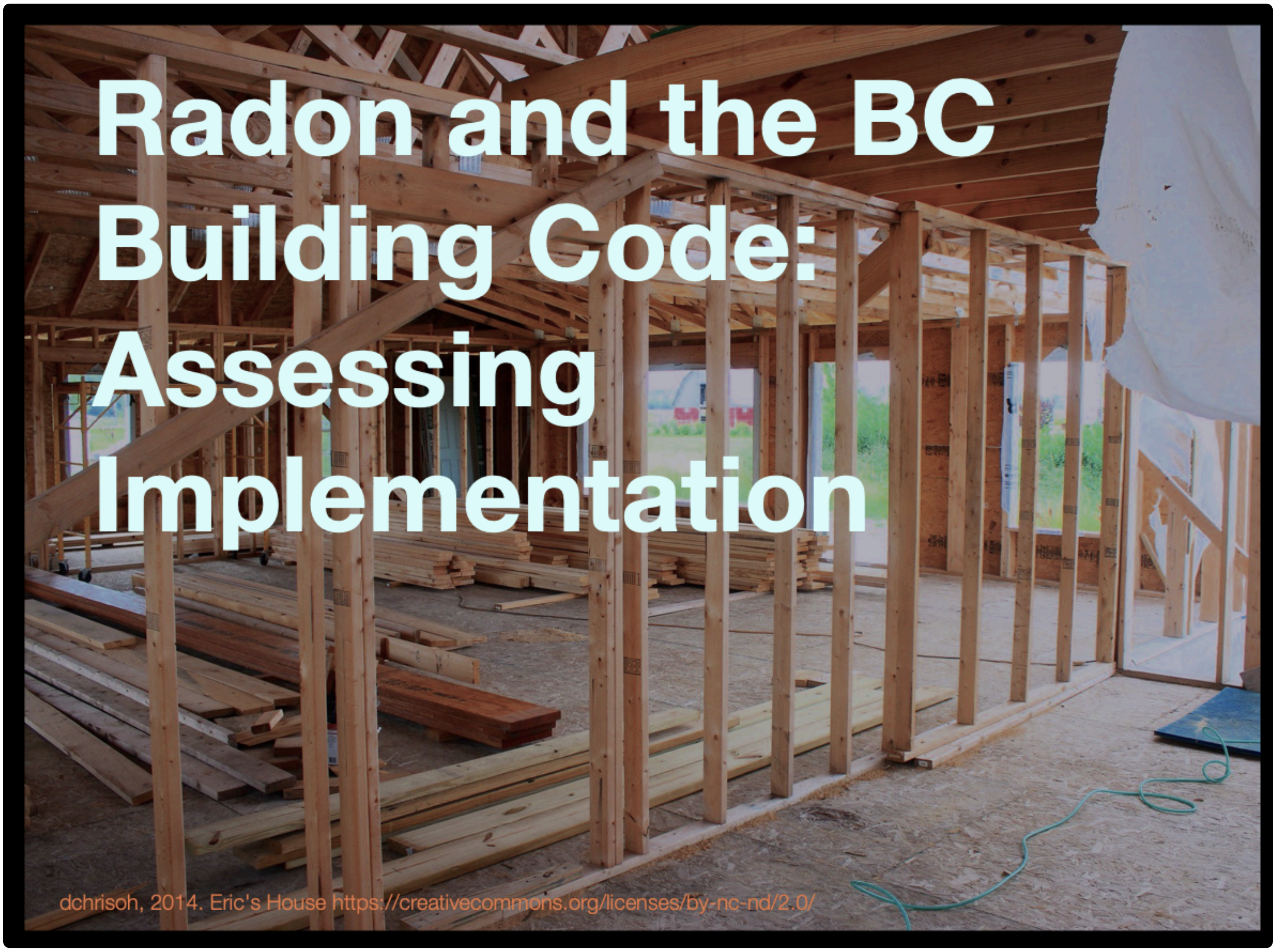

BC LUNG FOUNDATION

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To find project documents, visit BC Lung's website on Radon and Energy Efficiency, at https://bclung.ca/radon-and-energy-efficiency

About our program. The BC Lung Foundation's Healthy Indoor Environments program is focused on providing education, resources, and policy options for addressing priority indoor air pollutants in British Columbia. Canadians spend 90% of their day indoors, with about 70% at home and 20% at work or school. The air we breathe indoors can contain particulates, gases, allergens and fumes that can significantly affect our health in both the short and long term. Knowing the main indoor air pollutants, their sources, and how to reduce them are key to reducing harm to our health. Radon has been identified as the leading environmental carcinogen in Canada. For more information visit our website at https://bclung.ca/programs-initiatives/healthy-indoor-environments-program

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Executive Summary

Radon gas is released from the natural breakdown of uranium found in soils and rocks. Although radon is natural, it can build up inside buildings and become harmful to human health. The BC Building Code 2015 contained new radon measures. These provide for what is colloquially terms an 'extended rough-in'—the bare-bones of a radon system that are cheapest to install at the point of construction but which require occupants to upgrade the system when they move in if elevated radon is a problem.

We sought to study these rough-ins to see whether they were being built correctly, whether the BC Building Code was being followed, if building inspectors were catching problems, and if there was room for improvement. We visited 89 homes in BC's Central Interior (45 during construction and 44 already occupied homes) and conducted interviews with radon mitigators, builders, and municipal building inspectors.

We found that in general the BC Building Code was being followed, but that many Code provisions lacked specificity or direction, allowing builders to get away with substandard systems. The vast majority of homes had significant flaws that would undermine radon system functioning. Using the Canadian Standards Association/Canadian General Standards Board 149.11-2019 as a benchmark, we found systematic failure on a variety of technical aspects of building radon systems.

- Failures that stopped radon from flowing through vent pipes such as: using the wrong fill under the slab (clogging up pipes); not considering concrete dividers (footings) under the slab; multiple bends, turns or horizontal runs in pipes which stopped upward air flow); a lack of insulation of pipes in attics leading to concerns about freezing and pipe blocking; and terminations to the outside which blocked air flow.
- Gaps in the foundation that let radon into living spaces.
- Systemic use of improper pipe liable to degrade under light or become brittle and break over time.
- Systems that did not lend themselves to easily adding a fan (such as having vent pipes built in locations that did not allow fans to be added, or lacking electrical outlets to power fans).

Overall, given, systematic failures in rough-ins, coupled with occupants persistent ignorance of radon and lack of testing, we think the Code provisions are just not working. Mitigators who seek to upgrade these systems often find they have to instead fix them. Our evidence suggests the current Code provisions are doing little to address radon or reduce radon levels in homes.

We propose as solutions that there be major revisions to the BC Building Code radon provisions to ensure well-built passive radon systems (that are proven to reduce radon levels) by incorporating CGSB-149.11-2019 Level 2. We also suggest further study and public consultation on whether to add requirements for active systems (e.g. a fan built in from the start and following CGSB-149.11-2019 Level 3). In the alternative, we suggest clarification of Building Code language on key points and links to overall purposes of radon reduction. This would give greater guidance to builders, trades and labourers and municipal building inspectors who currently are not getting it. We suggest using language already developed by the Canadian General Standards Board, in CGSB-149.11-2019, Radon control options for new construction in low-rise residential buildings.

We also suggest

- There needs to be clearer language on retrofits and how building changes require radon testing and potential mitigation
- Revise locations requiring radon resistant construction/passive systems by reference to updated BCCDC Radon Map.
- Education for builders, trades and building inspectors.
- The need to activate New Home Warranty to make sure radon is understood as an envelope failure and to inform new homeowners to test for radon. We think explicit language in the Code can help— that states unequivocally that when radon is over 200 bq/m^3 this is a sign of envelope failure. We also think BC Housing can introduce relevant policies.
- Improve buyers awareness of radon in real estate transactions— Work with BC Housing/ BC Financial Services Authority and Ministry of Housing to ensure information sharing on radon and mandating attention to testing in real estate transactions, and
- Further study of taxation levers to ensure home radon testing by new occupants and other home occupants.

Photo Credit: Molinaro, M. 2004. House Construction. https://creativecommons.org/licenses/by-nc/2.0/

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1.Introduction: Preventing Radon In New Buildings

(a) Introduction to Radon

Radon gas is released from the natural breakdown of uranium found in soils and rocks. Although radon is natural, it can build up inside buildings and become harmful to human health. Radon is a radioactive gas – when it decays alpha particles are released. When radon is breathed in, alpha particles travel into lung tissue and can break DNA bonds. The World Health Organization has identified radon as a human carcinogen[1] and numerous international studies confirm the link.[2] In fact, radon gas is the number one cause of lung cancer in non-smokers. Lung cancer is a deadly disease, with only one in five patients living beyond five years after diagnosis.[3] While there are many causes of lung cancer, exposure to radon gas is considered the leading cause of the disease after smoking. Radon exposure causes 16% of all lung cancer deaths in Canada or approximately 3,300 deaths each year.[4] This can also be calculated as about 1% of all deaths in Canada.[5] International radiation guidance recommends action levels (or the level of radon gas concentrations in air at which point remedial measures should be taken) between 100 and 300 Bq/m^3. Health Canada chosen the pragmatic compromise of 200 Bq/m^3 as Canada's Radon Guideline.

Most buildings will not exceed the Radon Guideline, however, results vary by geography. In British Columbia, elevated radon is relatively uncommon in Metro Vancouver and the Capital Regional District (Greater Victoria) but the situation is different in many parts of the Interior, including the cities of Prince George, Kelowna and numerous smaller centres, where in some cases over half of homes tested have elevated radon. The British Columbia Centre for Disease Control now has an excellent web-based map of radon readings across the province.

Luckily, radon is easy to test using mass produced radon detectors, easy to fix in existing homes, and easy to prevent in new construction. Ideally, homes will have an impermeable membrane protecting the interior of the home from soil gases, and a good ventilation system to help ensure gases are diluted by outside air. However, the gold standard in radon mitigation are "active sub-slab depressurization systems'— this involves a hole in the foundation

[1] World Health Organization, 2021. Radon and Health. https://www.who.int/news-room/fact-sheets/detail/radon-and-health

[2] For a recent review of the lung cancer risks of radon see United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2019. Sources, Effects and Risks of Ionizing Radiation, Annex B: Lung cancer from exposure to radon. https://www.unscear.org/unscear/en/publications/2019.html

[3] Canadian Cancer Society, 2021. Survival statistics for small cell lung cancer https://cancer.ca/en/cancer-information/cancer-types/lung/non-small-cell-lung-cancer-survival-statistics

[4] Chen, J., Moir, D. and Whyte, J., 2012. Canadian population risk of radon induced lung cancer: a re-assessment based on the recent cross-Canada radon survey. Radiation protection dosimetry, 152(1-3), pp.9-13.

[5] Statistics Canada, 2020. Deaths, 2019. Available at https://www150.statcan.gc.ca/n1/daily-quotidien/201126/dq201126b-eng.htm

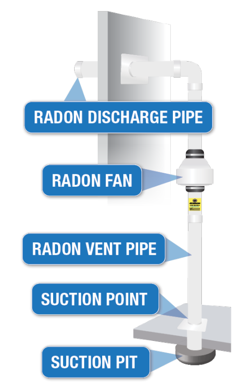

Figure 1: Diagram of Sub-slab Depressurization System. Courtesy of C-NRPP

that allows for a pipe that carries gas from under the building foundation and which vents to the outside, aided by a fan. This was developed in the late 1970s in Elliot Lake, Ontario, when radioactivity was found in homes.[6] The technique has been further refined over 50 years by the US Environmental Protection Agency, Health Canada, the Canadian National Radon Program, and specialized committees of the Canadian General Standard Board.[7]

(b) Radon in Building Codes

While there has been widespread recognition of radon in the mining sector since the mid-twentieth century, residential radon was only discovered in the 1980s, and radon measures only introduced into the Canadian National Building Code in 2000s. The vast majority of Canadian homes and workplaces have neither been tested for radon nor mitigated.

Addressing radon at the point of construction falls into well established legal frameworks for improving the building stock. In Canadian law, homeowners generally have wide leeway in how they design and maintain their indoor environments. While at times governments do offer subsidies for home improvements (such as tax credits or rebates for energy efficiency renovations) these tend to be discontinuous and depend on government political priorities of the day. Alternatively, there are established health, safety and environmental provisions in Building Codes. There are also good economic rationales for radon prevention measures in new construction. Building in radon systems at the point of construction is much less costly for builders or homeowners, because building trades personnel are already on site and the installation can be timed as part of the construction process. Alternatively, a post-construction retrofit will require a specialized visit, time for assessment and some renovation work. From a public health perspective, radon prevention in new construction is an inexpensive and effective way to save and prolong human life. Because radon causes lung cancer, it exerts a significant toll on Canadians' health and health care spending. Health economists who conduct cost effectiveness studies give very favourable results for radon controls in new construction. [8]

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[6] Lance, L. History of Radon Testing and Remediation, Elliot Lake, Ontario 1976-1980. On file with author.

[7] Environmental Protection Agency, 1995, Passive Radon Control System for New Construction EPA 402-95012 https://www.epa.gov/sites/default/files/2014-08/documents/archdraw.pdf; EPA, 2001 Building Radon Out:A Step-by-Step Guide On How To Build Radon-Resistant Homes, https://www.epa.gov/sites/default/files/2014-08/documents/buildradonout.pdf; Health Canada,2010. Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors \ Canadian General Standard Board, 2017. Radon mitigation options for existing low-rise residential buildings (CAN/CGSB-149.12-2017) https://publications.gc.ca/collections/collection_2017/ongc-cgsb/P29-149-012-2017-eng.pdf Canadian General Standard Board, 2019. Radon control options for new construction in low-rise residential buildings (CAN/CGSB-149.11-2019) https://publications.gc.ca/collections/collection_2019/ongc-cgsb/P29-149-011-2019-eng.pdf

[8] Gaskin, J., Coyle, D., Whyte, J., Birkett, N. and Krewksi, D., 2019. A cost effectiveness analysis of interventions to reduce residential radon exposure in Canada. Journal of environmental management, 247, pp.449-461; Gaskin J, Whyte J, Zhou LG, Coyle D. Regional cost effectiveness analyses for increasing radon protection strategies in housing in Canada. Journal of Environmental Radioactivity. 2021 Dec 1;240:106752.

The initial radon provisions in the 2010 National Building Code called for a porous layer and membrane to be put down and then a 'rough-in stub'—a small pipe jutting out from the floor which could be upgraded to a full system after occupancy. By 2014, research in British Columbia had found this to be ineffective— the process required occupants to understand radon as a problem, what the pipe was for, to test and to install (or hire someone to install) a complete system. As such there was a low probability that the needed radon mitigation measures would be applied.[9]

The BC Building Code 2015 contained new radon measures. While still stipulating a rough in rather than a complete system, it called for some upgrades— for instance for a full vent pipe to exit the building. The province was divided into two zones, with the radon provisions applying only to areas east of the Coast Mountains. The BC Building Code, 2018 did not alter the radon systems, however, it redefined the applicable geography through providing a list of municipalities for which the radon provisions applied.

This study examines those new provisions, how they are being applied and problems that continue to arise in radon resistant construction in British Columbia.

TABLE 1: RADON INSPECTIONS

Town	Total Homes Inspected	Under construction	Post-Construction/ Occupied
Blind Bay	1	1	—
Coldstream	1	—	1
Golden	1	—	1
Kamloops	14	4	10
Kelowna	28	18	10
Lake Country	7	1	6
Revelstoke	14	7	7
Salmon Arm	3	0	3
Vernon	20	14	6
Total	89	45	44

[9] Rogaza, D., Roberts, H., Swoveland, B. 2014. A Comparison of Three Radon Systems in British Columbia Homes: Conclusions and Recommendations for the British Columbia Building Code. BC Lung Foundation. https://bclung.ca/health-air-quality/radon-and-lung-health/radonaware-outputs

(c) This Project's Research Objectives, Scope, and Methodologies

One of our researchers, Chantal Wilson, is a seasoned engineer and radon mitigation professional, who brought applied experience in radon mitigation to the research. We also consulted with the Canadian National Radon Proficiency Program, and the board members of the Canadian Association of Radon Scientists and Technologists. We were also informed by recent research on radon prevention in construction, a review of existing standards and guidelines on radon in new construction, including best practices guidance from the United States Environmental Protection Agency[10], American Association of Radon Scientists and Technologists (AARST)[11], Health Canada[12], and the Canadian General Standards Board and Standards Council of Canada[13]. In particular, we looked to "Radon control options for new construction in low-rise residential buildings. CAN/CGSB-149.11-2019" as a current guide to best practices in construction for radon.

Our aim was to understand common problems in radon systems in new construction in BC, how prevalent they were and the causes of the problems. We were particularly interested in knowing whether problems with radon systems could be traced to wording of the BC Building Code.

For the quantitative part of the study, Chantal Wilson visited 89 homes in 9 different communities through the Southern Interior (see Table 1). We recruited through general banners and ads on BC Lung's website and social media, Facebook ads targeted at these communities, and through Take Action on Radon, a national radon awareness campaign and word of mouth. We were concerned with the "Part 9" radon provisions—the explicit radon provisions that apply to single family and low-rise construction. Most of the homes we visited were designed as stand-alone single family homes (86) but we did encounter some townhouses (3). We created a checklist to guide visual assessment of radon systems, aimed at evaluating whether pertinent sections of the BC Building Code 2018 were being followed, as well as checking for common problems previously identified by mitigators and other radon professionals. This had some unavoidable limitations in terms of seeing problems out of sight, such as under slab gravel. However, we took the decision to plan for visiting a larger number of homes within our research budget. Because the project was planned prior to the COVID-19 pandemic to be carried out in 2020 it proved difficult to assess individual homes (given safety considerations and homeowners consent). We were able to compensate through a longer than expected study period, and settled for roughly half of homes being inspected at the time of construction.

We also conducted qualitative-oriented semi-structured interviews with radon mitigators (8), and aimed to interview municipal building inspectors (we were able to speak to 4), and builders (4). These interviews asked a series of questions which were often open ended and gave room for

[10] U.S. Environmental Protection Agency, 1994. Model Standards and Techniques for Control of Radon in New Residential Buildings".EPA 402-R-94-009, March 1994.https://archive.epa.gov/epa/sites/production/files/2014-11/documents/model_standards.pdf US Environmental Protection Agency, 2001. Building Radon Out: A Step-by-Step Guide On How To Build Radon-Resistant Homes. EPA/402-K-01-002, April 2001.https://www.epa.gov/sites/default/files/2014-08/documents/buildradonout.pdf

[11]ANSI/AARST CC-1000-2018, Soil Gas Control Systems in New Construction of Buildings. ANSI/AARST RRNC-2020. Rough-In Of Radon Control Components In New Construction Of 1 & 2 Family Dwellings And Townhouses; ANSI/AARST CCAH-2020, Reducing Radon In New Construction Of One & Two Family Dwellings And Townhouses. All available at https://standards.aarst.org

[12] Health Canada, 2014. Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors.https://publications.gc.ca/collections/collection_2012/sc-hc/H128-1-11-653-1-eng.pdf

[13] CAN/CGSB-149.11-2019 ibid.

interview subjects to freely elaborate on their views. This allowed for in depth analysis, but also meant that we could not directly compare views on all topics by all mitigators, builders or inspectors interviewed. As the report will show, these interviews were helpful in confirming problem areas, revealing possible explanations for problems, and proposing solutions.

(d) The Builder Code Is Generally Being Followed

From the outset, our major finding was that the Building Code is generally followed, in the sense that rough-ins were generally being built, and there was some degree of concordence with the Code on many major issues (see Table 2).

This sentiment was also echoed in our interviews.

> *Builders are doing the basic Building Code requirements. The issue is not with the Code being followed, because it is.* (IS-M-1)

> *The builders do what they have to, but unfortunately its not something the Building Code tells you what to do. So e.g. you get sewer pipe not schedule 40, pipes too near walls, pipe that goes through roof and has a roof jack with a flapper—made for vacuum fans to open and shut, and that will stop the system. So they don't get stuff.* (IS-M-6)

That said, and as we document through this report, starting in Part 2, there were some serious issues that need to be addressed.

TABLE 2: COMPLIANCE WITH EXPLICIT FEATURES OF BC BUILDING CODE, 2018

Provision	BC Building Code, 2018 section	Yes	No	Unknown or Not applicable due to specific conditions
Gas permeable layer installed	9.13.4.3 (2)(a)	62	0	26
100 mm (4 in) Sub Slab Piping	9.13.4.3.(3)(b)(i)	57	0	31
4 inch (100 mmm) diameter pipe	9.13.4.3.(3)(b)	74	2	13
Radon pipe appears to be airtight with joints sealed	9.13.4.3.(3)(b)	64	0	21
Vertical Clearance above any air inlet, door or openable window	9.13.4.3.(3)(b)(ii)	68	0	21
Clearance in any direction from (except vertical clearance above) any air inlet, door or openable window	9.13.4.3.(3)(b)(ii)	69	2	18
Vertical clearance above a roof that supports an occupancy	9.13.4.3.(3)(b)(iii)	69	0	20
Clearance in any direction from (except vertical clearance above) a roof that supports an occupancy	9.13.4.3.(3)(b)(iii)	69	0	20
Distance from property line	9.13.4.3.(3)(b)(iv)	70	0	19

2.Concerns: Technical Issues with Radon Rough-Ins in BC

The BC Building Code's radon provisions aim to provide necessary components of a sub-slab depressurization system that are relatively inexpensive to add at the time of construction. The central idea is that building occupants can test for radon once they move in, and if radon levels are high, a fan can be added to turn the system into an active sub-slab depressurization system.

In speaking with mitigators and other radon experts we identified a series of common problems with radon systems. In what follows we identify the problem and how it is addressed in the BC Building Code. Many mitigators also specifically directed us to solutions in CAN/CGSB-149.11-2019, which was generally treated as the gold standard by organizations such as C-NRPP and CARST. We thus make reference to relevant provisions from CAN/CGSB-149.11-2019.

(a) Gravel and Fill

In order for sub-slab depressurization to work, it must be possible for gas to be moved from under the building slab and flow into a vent pipe. Mitigators refer to the movement of air (and gas) in terms of 'communication' (or more, technically, pressure field extension). The standard prescription for a sub-slab depressurization system is to have a 'soil gas collector' begin in the granular layer and then be connected to an above slab vent pipe. If there is good communication, only small amount of suction will be needed to draw air into the collector up and out of the subfloor space. In most houses, only one suction point will be needed.

Alternatively, if there is poor communication multiple suction points and stronger fans will be needed. All too often, mitigators complain about discovering buildings with poor communication in the sub-slab, such as houses built directly on clay, or sand under the slab. Creating a sub-slab layer with good communication is an important first step.

The Buiding Code 2018 seeks to address this issue through specifying "a gas-permeable layer consisting of coarse clean granular material" (9.13.4.3. (1)(b)), "consisting of not less than 100 mm of clean granular material containing not more than 10% of material that will pass a 4 mm sieve, installed below the floor-on-ground" (9.13.4.3 (3)(a)). CAN/CGSB-149.11-2019 provides almost identifical wording (7.1.1.2.3) but also notes that there are available alternatives, such as crushed concrete or specially designed ventilation panels. It notes that any materials should not have sharp edges, because normally a membrane is placed between this material and the slab, and its important not to puncture the membrane.

We were not able to directly check the under the slab, but we heard concerns repeatedly from mitigators who repeatedly found sand or other fill when trying to mitigate homes.

> *Builders don't like the gravel because they think walking on the vapour barrier it will get punctured. So they put sand down—or just local till that meets drainage requirements—and so inspector lets pass—but that makes digging suction pit difficult. So we often use the existing suction point simply*

> *as a test port, and then abandon it, because its easier to just create a suction point somewhere else* (IS-M-3).
>
> *I know the gravel specification is in there, but in Okanagan I wrack my brain—there is so much sand here—at the local gravel pits—they sell something called 'radon sand'—a coarse garbage sand—marketing to builders—as air permeable layer—and inspectors passing it—its just not the right gravel, they will put it 4 inches deep—useless for pulling air through* (IS-M-3).
>
> *It's frustrating, in my area, every time we drill a hole, to find no granular material. I have had one house out of hundreds that I mitigated with granular drainage under the slab* (IS-M-6).

Mitigators suggested that building departments might assess the sub-slab system before material is filled in, giving the opportunity for builders to later "just fill in whatever material is on site and then pack it in tight" (IS-M-6). Because subsequent visits by inspectors come after the slab is poured, the problem is only recognized much later when and if mitigators visit and investigate.

They also complained that the result was that when visiting a house to fix it up, the imagined savings from the rough-in at construction was lost. Rather than replace the under-slab material, mitigators attempt to cut a trench through the material to allow communication— a process they colloquially refer to as 'gopher holing'. The result is a significant increase in costs.

> *You have to tunnel, rip up flooring. You find yourself gopher holing, doing a trench. If wood flooring or tile flooring on a finished basement you cannot gopher hole, unless they want to put in new flooring. If you have to do any under-slab prepping its going to add two thousand dollars to the costs… if we are dealing with finished basements, and it becomes a nightmare situation* (IS-M-6).

We were not able to quantify the occurrence of poor fill being added to the under-slab area. We did ask builders (e.g. for pre-construction evaluation) and 44 of 45 said they added appropriate gravel in line with the BC Building Code's provisions on a porous layer.

However, these concerns point to the need for Inspectors to be careful to ensure these provisions are followed.

(b) Mutiple Footings Spaces

A further problem for sub-slab communication arises where the builder has put in multiple footing spaces. In many cases, the will be a singular continuous area under the slab that can be filled with gravel. However, builders at times put in multiple footings (e.g. to increase structural strength of the foundation), leading to a potential situation where a single suction point for radon only services part of the sub slab. As one building inspector told us, its common in a 20 foot by 30 foot house for there to be strip footing to handle load (IS-BI-2). The BC Building Code radon provisions, however, do not squarely address the problem of a lack of communication between the plenum e.g. filled in spaces between footing. The result is that mitigators find sub-slab layers that are essentially cut off, resulting in good communication in part of the sub-slab layer but not the rest (IS-M-5).

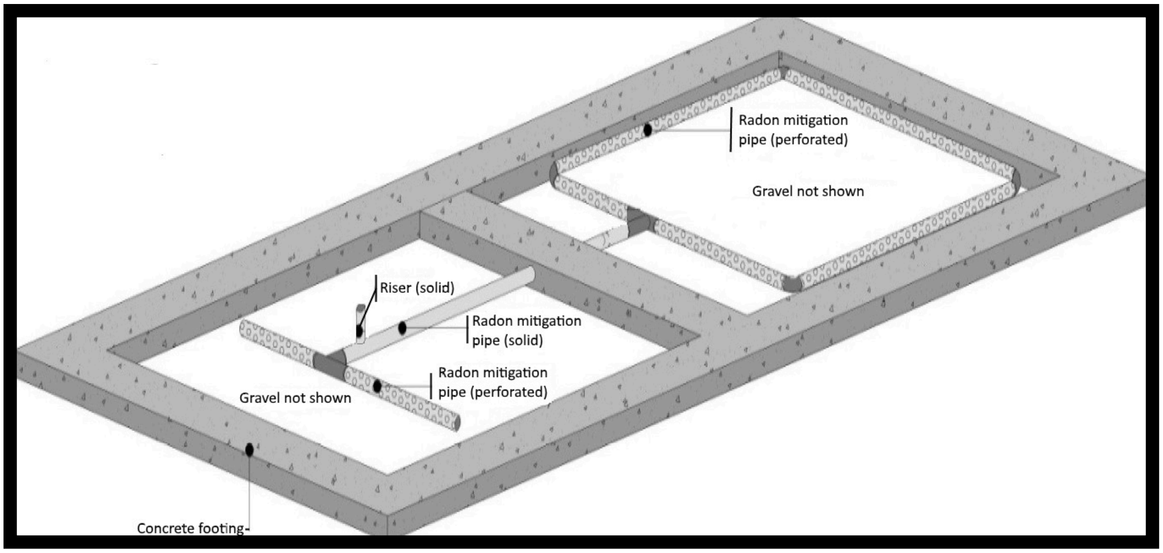

Figure 2. Subfloor Piping Configuration, reproducing CAN/CGSB-149.11-2019 Figure 7.1.2.7.

This is an area that the BC Building Code is unclear on. It only requires that the under-slab collection pipe "opens into each contiguous area of the granular layer" (9.13.4.3 (3)(b)(i)). The notes to Part 9 (at A-9.13.4.3.(2)(b)(i)and(3)(b)(i)) also states, rather cryptically, that "The arrangement and location of the extraction system inlet(s) may have design implications where the footing layout separates part of the space underneath the floor".

There are a host of possible solutions, such as requiring holes in the footings to allow the passage of air through. Again, our visual inspection of homes could not show this. However, we did hear from a mitigator (IS-M-5) and a municipal building inspector (IS-B1-2) on the need for the Code to address the problem. CAN/CGSB-149.11-2019 provides explicit direction as follows (at section 7.1.2.6)

> *A soil gas collector shall be provided with at least one suction point for each sub-slab area (in other words each plenum) that is confined by the surrounding footings or be connected to another soil gas collector served by one or more suction points. The design chosen shall create an effective depressurization across the entire sub-slab area.*

CAN/CGSB-149.11-2019 also provides an illustration, reproduced here as Figure 2.

One building inspector suggested this approach, without specifically mentioning CAN/CGSB-149.11-2019:

> *I don't think holes for air passage for footing is sufficient—holes in footing are not included in Code, we need pipe for each section* (IS-BI-2).

Figure 3: Awkward Soil Gas Collector. Photo credit: John Kostelnick, Okanagan Radon

(c) Soil Gas Collector

An important part of a sub-slab depressurization system is the soil gas collector— pipe that extends below the slab into the permeable layer and which can collect gas (which, if everything goes according to plan, will then flow through the system and be vented outside). The BC Building Code does not specify what type of pipe, beyond specifying that it "has one or more inlets that allow for the effective depressurization of the gas-permeable layer"(9.13.4.3.(2)(c)(i)). As well, there is not a tight specification of the size of the pipe, however, the pipe is specified as 100 mm for above floor, and the presumption is a similar size would go under the floor.

We did hear complaints from mitigators on this issue, some of whom identified the problem that they found the end of the pipe could be buried in compacted material, effectively stopping suction (or 'dispersal of the vacuum field') (IS-M-5) (For an illustration see Figure 4(a) below. We were directed to specialized equipment made by some manufacturers, such as RadonX, which creates a specialized perforated pipe (see Figure 4(b)):

> *if the Code required perforated pipe it would reach out and in essence make the suction pit better, rather than just the one opening. Even if you have good aggregate, and not a perforated pipe, you will need a larger fan, and will be noisier and people will have issues. So if pipe down the centre of the foundation—10 feet away from the exterior wall if possible, and perforated, and with good gravel and everything sealed you could mitigate with a very small fan* (IS-M-5).

Alternatively, CGSB-149.11-2019 has detailed instruction on the issue of sub-slab piping (7.1.1.2.6.1 to 7.1.3.2.5). It calls for 100m (4 inch) piping that is near or directed towards the centre of the floor, specifies length, and provides specific configurations.

Figure 4: Addressing Blockage in Soil Gas Collectors. (a) Left. Photo taken with scope inside soil collector showing end blocked by rock Photo courtesy of anonymous builder, of home included in this study. (b) Right. Specialized soil gas collector pipe. From Ipex's RadonX Brochure. https://ipexna.com/resources/document-repository/radonx-brochure/

(d) Gaps in Foundation

One of the key principles of radon resistant construction is that the building envelope—including the foundation—protect against radon ingress. This is why building codes have long called for a gas impermeable membrane. Further, a gapless foundation will also help depressurize the sub-slab— reducing the amount of energy needed to draw radon up and be vented out through the pipe. (Alternatively, if there are significant gaps in the foundation a radon fan will pull air from conditioned space into the sub-slab area, wasting energy used to heat or cool the air, as well as demanding more fan strength).

There are numerous potential causes for gaps in the foundation, such as unfinished plumbing cutouts, regular cracks, or, more recently in BC in newer homes, concrete shrinkage (see Figures 5 and 6 below). Radon mitigation professionals are familiar with these problems, and a regular part of their work when they visit homes and install radon systems is to identifying gaps in the foundation and seal them— for instance using fillers for cracks in foundation cement or spraying foam into gaps. A simple but dramatic test that is widely used involves drilling a hole in the foundation (that might later be used for a vent pipe), placing the output of a fog machine below slab, and watching for fog. Figure 5(c) below reproduces a photograph of a fog test under conditions of a significant concrete shrinkage.

The BC Building Code (2018) at 9.13.4.2 provides for floor assemblies separating conditioned space to have an air barrier system (referencing 9.25.3).

- 9.25.3.2(1) gives the broad details— the air barrier system should provide an effective barrier to air infiltration caused by the stack effect (e.g. the process whereby hot air rises and creates low pressure that sucks in radon and other soil gases).
- 9.25.3.2(2) suggests a polyethylene sheet is a common way of doing this and refers the user to CAN/CGSB-51.34-M, "Vapour Barrier, Polyethylene Sheet for Use in Building Construction."
- 9.25.3.3 provides further specifications, such as that if a flexible sheet material is used, all joints shall be sealed (9.25.3.3 (2)) and that if there are any penetrations of the air barrier system, they should be sealed to maintain the integrity of the system (9.25.3.3(6)).
- Any hatches or sumps should have weatherstripped around their perimeters to prevent air leakage (9.25.3.3(7)).
- 9.25.3.6(5) provides for the slab to be sealed around its perimeter to the inner surfaces of adjacent walls using flexible sealant.

The Notes to Part 9 spell out broadly the basis for the radon provisions, but in describing the vapour barrier system appear to give considerable leeway to builders conflicting concerns— the barrier should "seal the interface between the soil and the occupied space, so far as is reasonably practicable" (Notes to Part 9, A-9.13.4).

We heard repeated concerns about gaps in foundations, such as people seeing plumbing knock outs under tub open to dirt (IS-M-5), and, in newer construction, "the grand canyon crack around foundation" caused by concrete shrinkage (IS-M-4, similar concerns from IS-M-5, IS-M-7, IS-M-8, IS-BI2, and IS-BI-3).

Our house visits confirmed these problems (see Table 2 and Figures 5 and 6). In older homes, it was often difficult to identify some of these problems. For instance, furniture might have been in the way, drywall might obscure plumbing cutouts, or occupants unable to offer explanations. Table 2 thus has a high number of 'unavailable' readings in occupied homes. However, the visits during the construction process were revealing— and in many cases information came from not only visual inspection but the open discussions with the builders themselves. The fact that none of the homes under construction we visited used flexible sealants or moving joints is telling. As part of the inspections, Chantal Wilson made a judgment call concerning whether a problem would significantly effect the operation of the radon system. As Table 2 indicates this was found to be the case in a large majority of homes.

In interviews we heard repeatedly from mitigators and inspectors that builders were not showing an overall functional understanding of radon mitigation, and so not reading the Building Code in terms of the overall purpose of preventing radon ingress. Mitigators and building inspectors also spoke of builders not using available solutions.

> *Spray foam, sealing needed to close that gap. Builders need to use caulking on top afterwards—-- eg. use sausage guns—cheap caulking—to seal from the top* (IS-M-4).
>
> *making sure there is a really good seal before sealing the concrete—the rock and the pipe is a given —but making sure the seal is tight and nobody compromises until concrete poured* (IS-BI-3).
>
> *we need to work on the sealing joints on the concrete slabs—caulking—I have yet to see it in a house, e.g. with working joint sealed* (IS-M-8).

One building inspector (IS-B1-2) went into this in considerable detail, feeling that builders were not doing a good job. The Code effectively relies on 6 millimetre polyethylene sheets to serve as a vapour barrier and for there to be good sealant where it meets the concrete foundation slab. However, "concrete finishers are brutal to poly". He noted that there are problems with use of Insulated Concrete Forms (ICF) which uses blocks of polystyrene foam with space in between to pour concrete. However, there are not good compatible sealants available and some sealants will interfere with foam blocks. The common solution becomes one of simply not sealing properly. He also noted there are significant problems with sealant. Many builders (or their staff) use incorrect sealant tape (e.g. using sheathing tape approved for outside contexts, and usually made red by the manufacturer, but not the type approved for use with a poly membrane—which is typically blue). The result is that there is poor adherence of the poly membrane to the concrete. He also noted that inspectors have a hard time seeing concrete shrinkage because of the time lags between visits and shrinkage occurring.

The CGSB standards (at 7.1.4.5) gives significant detail on the soil gas barrier under concrete slabs, spelling out in much more specificity what should be done under different conditions, such as how to seal entry points in the slab (7.1.5), from sumps ((7.1.5.1), floor drains (7.1.5.2), and openings through slab for plumbing fixtures (7.1.5.3). There are clear diagrams that show when the sub-slab membrane is sealed to a concrete wall (at Figure 7.1.4.5.5, p. 17) and when it is sealed to footings prior to pour (Fig. 7.1.4.5.6, p. 17) and how to seal the sub-slab membrane horizontally to concrete footing when insulation is between the foundation wall and floor slab (Figure 7.1.4.5.7, p. 18).

TABLE 3: FOUNDATION SEALING ISSUES												
	Under Construction						Occupied Homes					
	Yes	No	Unavail-able	Not applica-ble	Blank	May significantly impact radon rough in use	Yes	No	Unavail-able	Not applicable	blank	May significantly impact radon rough in use
Slab / wall joint sealed with flexible sealant	0	41	2	2		39	2	12	30	0		39
Seal is a moving joint to accommodate slab contraction	0	28	1	16	0	33	1	8	31	4	0	36
Sumps have an airtight lid	3	0	1	38	3	0	1	2	41	0	0	0
Plumbing cutouts are sealed	19	9	5	9	3	23	6	5	25	10	5	31
Pipes and service penetrations in foundation sealed	25	5	15	0	0	0	7	3	34	1	1	0
conduit extending into porous layer is sealed	7	14	12	12	0	22	8	22	9	3	2	28

Figure 5. Gaps at Slab Joint: (a) Shrinkage at joints (top left) (b) Unsealed slab to wall joint (top right), (c) Fog Test on a Poorly Sealed, Shrunken Concrete Foundation Slab (bottom left) Photos from Chantal Wilson, from this study house visits. (d) Moisture Seeping Up Through the Slab. Photo courtesy of John Kostelnick, Okanagan Radon, not taken for this study.

Figure 6: Cutouts and Poor Seals Create Gaps in the Foundation. (a) Remaining cutout left unfinished after occupancy (top left). (b) Gravel visible around sump (top right). (c) Gaps remaining around electrical conduit (bottow left). (d) Plumbing Cut-outs Remain Unsealed near bathtub (bottom right). All photos Chantal Wilson, from site visits for this study.

(e) Location of Pipe and Room for Fans

Radon mitigators are acutely aware of problems with where pipes are located, because this can significantly impact on whether they can put on fans. As Table 4 shows, it was quite common for there to be insufficient space for the fan. Our site visits showed that pipe might be built into a wall, not sufficient height in attic to put fan, or the pipe being pt too close to the wall or other mechanical equipment (such as furnaces). Figure 7 illustrates representative cases. We heard a lot of concerns:

> Q:Have you come across faulty installation of radon systems in your work? *A: Yes….locations where comes out of floor, if converting, the location is poor for putting in a fan* (IS-M-8).
>
> *it's often hidden and in the wall—with a load bearing 2 x 6 wall through it. So in the finished basement you can't find it* (IS-M-3) (also IS-M-4, IS-BI-3).
>
> *Every system that we have seen is not installed properly—so we are often removing sections of the system — Because cannot fit fan—its in wall cavity* (IS-M-2).

A further concern is that a hidden pipe might get ruptured by accident.

> *They are putting pipes in wall, what if someone hangs a picture on wall and punctures pipe? So the system needs to be designed to protect the stupid. So provide guidance on where the pipe is. So casing, or outside. But then make sure to put in fan* (IS-BI-2).
>
> *Heating guy broke a 90 degree bend in the pipe apart in a box joint end, and that created an incomplete connection in a little space which was really hard to deal with* (IS-M-4),

As Table 4 shows, we found the most common problem was that there was not sufficient space provided to allow for the addition of a fan—in 23 of 89 homes visited (or 26 percent). This was likely because the pipe was pushed into a corner of the room or located in wall cavity. There is a clear gap in the Building Code, in that there is no specification of location. We heard that designing the system so a fan can be added should be common sense: "The building inspectors should be smart enough to say needs to be accessible" (IS-M-4). We also heard that better specification in the Code might help: "If Code required pipe to come up vertically next to a hatch it would be way simpler" (IS-M-4).

CGSB-149.11-2019 provides specifications for fan space, including that the rough-in stub protruding above the floor slab shall be located in an accessible location to allow it to be converted to a passive or active system (7.1.7.2); that the portion of the passive stack passing through unconditioned space (i.e. the attic) shall be located such that sufficient space is available to allow for future installation of an active system (7.2.2.4), specification of how much space is needed (e.g., 1 m (3.3 ft) of space in each direction including vertically, is sufficient to cut the pipe and install a fan), and a distinct section on future system activation provisions (at 7.2.5) including providing for a cylindrical space of height not less than 1200 mm (4 ft) and a diameter not less than 500 mm (1.6 ft) for the future installation of a radon active soil depressurization (ASD) fan (7.2.5.1).

Figure 7: Examples of no room for fan. (a) Behind water heater and central vacuum (top left), (b) behind furnace (top right), (c) squeezed into narrow attic space (bottom left), (d) built into wall assembly, (bottom right). Photos from Chantal Wilson from site visits for this study.

TABLE 4: LOCATION OF PIPE AND ROOM FOR FANS						
	Under construction			Occupied homes		
	Yes	No	Unavailabl e or not applicable	Yes	No	Unavailabl e or not applicable
Pipe allows access to areas requiring maintenance, inspection or replacement	43	0	2	33	2	9
Pipe does not block doorways, windows, access switches, controls, or electrical panels	43	0	2	36	5	8
Cylindrical space of height not less than 1200 mm (4ft) and diameter not less than 500 mm (1.6ft) provided for the future installation of a radon fan	27	13	5	25	10	9

(f) Electrical Outlets for Fans

Updating the radon system with a fan implies an available electrical source. Ensuring close proximity to an outlet should be relatively inexpensive at the time of construction, whereas rerouting wires, or opening up walls after occupancy will be significantly more (one mitigator —IS-M-2— suggested $20 at time of construction versus $400 post occupancy).

One building inspector explained current practice:

> *If there is no plug, we plug it into an extension cord to do the testing. We then unplug it, because an extension cord would not be to Code, and we then ask the homeowner to arrange to have a plug put in and then plug in the fan* (IS-BI-2).

Our site visits included a question about whether a hardwired electrical outlet was located near a future fan location. In homes under construction 13 had this, 20 did not, and for 12 we could not answer this question. In occupied homes 14 had a nearby outlet, 15 did not, and for 15 it could not be determined.

We heard repeatedly about the need for this to be better, notably from building inspectors: “There should be a mandate to install a designated electrical source” (IS-BI-3, see also IS-BI-4). We found no specifications concerning outlets in the Building Code. Alternatively, CGSB-149.11-2019 takes the position that this should be in the attic, and has a specific provision spelling this out (s. 7.2.2.6) with an accompanying diagram.

Figure 8: Example of Horizontal Runs in a Radon Pipe. Photo Credit: Chantal Wilson from site visits for this study.

(g) Elbows and Horizontal Runs

The current provisions in the BC Building Code provide the basis for building a 'rough-in' rather than what radon mitigation experts consider a passive sub-slab depresurization system. One key difference relates to how the stack is constructed. In passive sub-slab depressurization systems, the system is built as vertically as possible to make use of the stack effect in a home (e.g. the process whereby warmer air rises) to draw radon containing soil gas from beneath the slab and exhaust it outdoors. The more a stack bends with elbows or has horizontal runs, the less likely is it to draw radon out unless a fan is attached. (As will be discussed later in this report, very few home occupants are testing for radon and adding a fan).

A further issue is air in the pipe can be moist, leading to condensation, or the radon pipe may be vertical at the roofline and open to the outside, letting rain water in. In a vertical stack, any condensation or rain water will flow under the slab and into the permeable layer under the slab, with no significant repercussions. However, if there are horizontal runs, water can pool— reducing further the flow of air through the pipe and potentially causing problems with weight or mold growth.

This problem came up repeatedly in discussions with mitigators and municipal building inspectors.

> *I have seen 10 or 11 90 degree elbows from leaving slab to get to roof—8 or 9 often—that is ridiculous because defeats any passive flow through a vertical pipe* (IS-M-1).
>
> *We are finding that builders are not doing vertical runs—generally because the stack is placed in the mechanical room and its not possible to go straight up from there, so there is a real need to move over a few feet, then vent* (IS-BI-2).
>
> *Slope is a big issue—you cannot have two litres of water in an elbow—I have seen 40 feet horizontal —with no slope—and so with condensation problems* (IS-M-2).
>
> *We had to cap and abandon two passive systems, because installed in a finished home with various curves in the finished area—90s—and in doing so creates condensation problems—and we have dumped one to two litres of stagnant water from the pipe. We couldn't change it, creating considerably cost* (IS-M-2).
>
> *I have cut in pipe to remove section to install a fan. So you look down at the fitting and you see two inches of water, because pipe graded the wrong way and condensation collecting at bottom* (IS-M-5).

Our mitigation professional made an assessment of whether horizontal runs were minimized (e.g. looking to see if, given the configuration of the building, it wouldn't have been possible to make a vertically oriented stack). In new construction, of the 25 homes where such an assessment was possible, runs were minimized in only 13 homes. In occupied homes the rate was a bit worse—with runs minimized in only 6 of 18 homes. As Table 5 shows, we found 18 homes (or 20 percent of homes studied) with four or more 90 degree elbows—which would create multiple horizontal runs— and likely the problems as discussed above.

We were also concerned about potential long term damage to the stack from horizontal runs (e.g. with weight issues from water accumulation, or simply sagging). We found five pre-construction homes where there were horizontal runs that were not supported every six feet, and three occupied homes with this problem.

A residual problem relates to insulation of horizontal runs. If horizontal runs are to be allowed, condensation could be reduced through insulation. As such one mitigator noted:

> *In multi-unit buildings, the radon rough-in can be tied together (or even in a large home with multiple suction points)—and with horizontal pipes you get problems needing insulation—or else heat loss and condensation……Part 9 needs minimum R value of pipes that run horizontally* (IS-M-4).

Overall, the BC Building Code lacks guidance on the issue of elbows and runs, stating only that accumulation of moisture in the pipe should be prevented (s. 9.13.4.3.(3)(b)(vii)). At least one building official felt that there was a significant problem with the BC Building Code not having requirements on upwards slopes to avoid moisture collection (IS-BI-2).

By contrast, CGSB-149.11-2019 contains detailed provisions for building passive stacks, including special provisions for when horizontal runs are necessary. This includes using 22.5 degree fittings to better guide air through the pipe, minimum slopes to ensure water does not pool and minimization of exposure to cold temperatures such through insulation if located in unconditioned spaces (see 7.1.3 and 7.2.2)

TABLE 5: NUMBER OF ELBOWS ON ABOVE SLAB PIPING

	Under construction			Occupied		
Number of elbows	90 degree	45	22.5	90	45	22.5
	Number of homes					
0	4	4	4	4	2	3
1	1	0	0	2	2	1
2	6	10	0	7	10	0
3	2	2	0	1	2	0
4+	**11**	**9**	**0**	**7**	**1**	**0**
Unavailable or not applicable	20	20	38	21	23	38

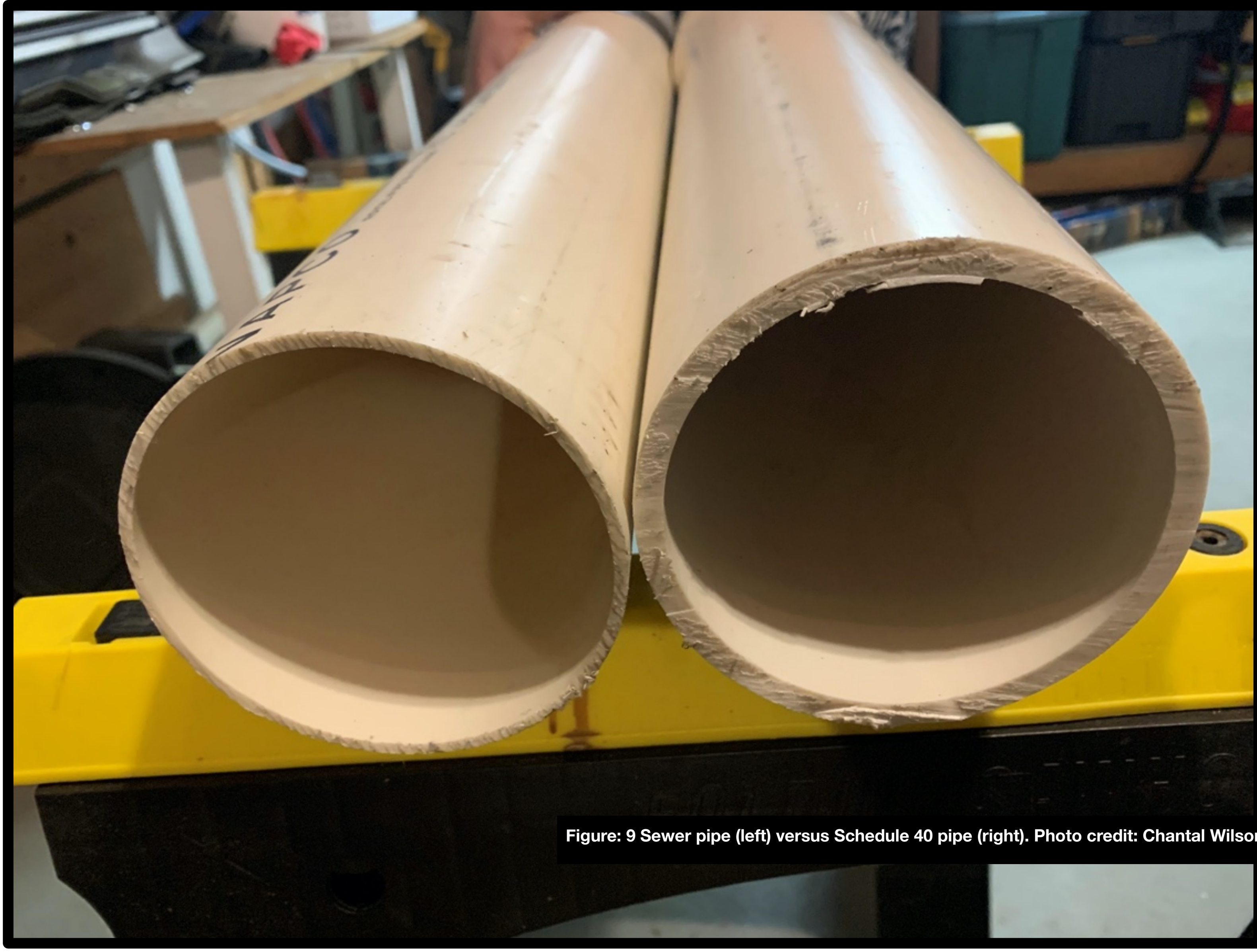

Figure: 9 Sewer pipe (left) versus Schedule 40 pipe (right). Photo credit: Chantal Wilson.

(h) Incorrect Use of Sewer Pipe

We heard more about incorrect piping than any other issue, with mitigators, building inspectors and even one builder being quick to point out the problem of incorrect piping being used.

it's the white PVC 4 inch that goes in—often the same as perimeter drain (IS-B2).

The pipe—that's my biggest issue—they are running sewer pipe all the way through the building—9 x out of 10 plumbers do it—and switch to ABS at roof—its too thin (IS-M-3),

It gets brittle (IS-M-1).

When exposed to UV light it will break down and crack and the crack will penetrate down below the roof creating water vapour problems in the attic (IS-M-2, see also IS-M-4).

Sewer pipe can leak, but it also degrades over time if exposed to light (IS-BI-2).

I hate use of sewer pipe—I have to cut out sewer pipe and create a pressure test to seal both ends—to put to 2 or 3 pci, and hear air leaking out the joints—the pipe is not designed for pressure—its designed for below grade only—its just for drainage (IS-M-2).

The sewer pipe might be broken or break higher up, or if not perforated pipe need larger fan, and if pipe freezes off and there are breaks then radon will be pushed into the living space (IS-M-4).

There seems to be a universal use of light wall sewer pipe… It will get passed (IS-M-5).

TABLE 6: TYPE OF PIPE USED						
	Under construction			Occupied homes		
	Yes	No	Not applicable or could not be determined	Yes	No	Not applicable or could not be determined
Above Grade Pipe is Schedule 40	0	42	3	1	35	8
CSAB 182.1	42	0	3	35	1	8

The radon provisions of the BC Building Code do not specify type of pipe. However, the BC Plumbing Code (2.2.5.11) spells out allowable forms of pipe, of which ASTMF628, “Acrylonitrile-Butadiene Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe With a Cellular Core,” is the most common. Mitigators and building inspectors typically referred to “Schedule 40” pipe. CGSB-149.11-2019 requires any above grade radon piping to meet Schedule 40 specifications (7.1.3.1.3).

Our home visits showed that plastic drain pipe (CSAB 182.1) was almost always used instead of Schedule 40 pipe (See Table 6). Schedule 40 pipe is more expensive (in the range of a dollar or two per foot for the sewer pipe versus seven dollars a foot for the better pipe). At five dollars a foot for a forty foot pipe, this represents a $200 increase in costs. As well, at least one company offers a specialized radon vent pipe system.[14]

We found alternating strategies by mitigators on how to deal with sewer pipe when upgrading rough-ins.

> *Whatever I am adding in—lets say its roughed in through basement, I don’t change the pipe and replace with SK40—it would cost thousands—so I put system in… I do sometimes abandon it, and find a new exit point, but typically I just install using the existing sewer pipe. If its curving on higher floors it can get very expensive* (IS-M-5).
>
> *We try to replace sewer pipe—you need the thicker walled PVC pipe, otherwise there is risk of damage and cracking and radon entering the home* (IS-M-8).

One reason to keep the pipe is cost to the homeowner. For instance, if an existing pipe is routed through walls, replacing the pipe might involve reconstructing walls and replacing drywall, which can run to the tens of thousands of dollars. Alternatively, mitigators might be concerned about liability if they do not replace the pipe— for instance, a fan coupled to faulty piping might inadvertently push radon into the home.

[14] Ipex Inc. 2022. RadonX™ Soil Gas Venting. https://www.ipexna.com/products/plumbing-and-mechanical/gas-venting-systems/radonx-soil-gas-venting/

There was a further problem with with fittings.

> *At every joint on the way up on the pressure side there is potential for leakage –so cracks or leaks you now have radon spewing into a space as well as water vapour—which you don't want in a wall cavity or your attic!* (IS-M-2)
>
> *As a plumbing inspector, when we see black piping in a house there needs to be a test to show it doesn't leak. You can do it with air if you cap it off. What you would need to do is put in a clean out —that's also a miss in the Building Code radon provisions—you then put in a test ball, pump it up with a bike pump and we make sure no water coming past, and holdng water and joints not leaking* (IS-BI-2).
>
> *The sewer pipe is not pressure tested* (IS-M-4).
>
> *Even if Schedule 40 pipe is used I would still recommend a leak test. 30% of the time I find pipes that are not glued. So still needs a test* (IS-BI-2).
>
> *There are testing requirements in the Plumbing Code for drainage pipes* (See "testing of drainage systems" 2.3.6) *It's a requirement during the inspections that all the waste piping be tested. Is it in the Code that that happens in front of an inspector? Yes in many municipalities the inspector does it on site. Usually we go to top floor of house and tap. So we could easily test the radon pipe* (IS-BI-2).

While there is no air or water pressure testing mentioned in the radon provisions of the BC Building Code, it is required in the BC Plumbing Code (at s. 2.3.6). CGSB-149.11-2019 also requires air or hydraulic pressure testing of pipes (s. 7.2.3.2).

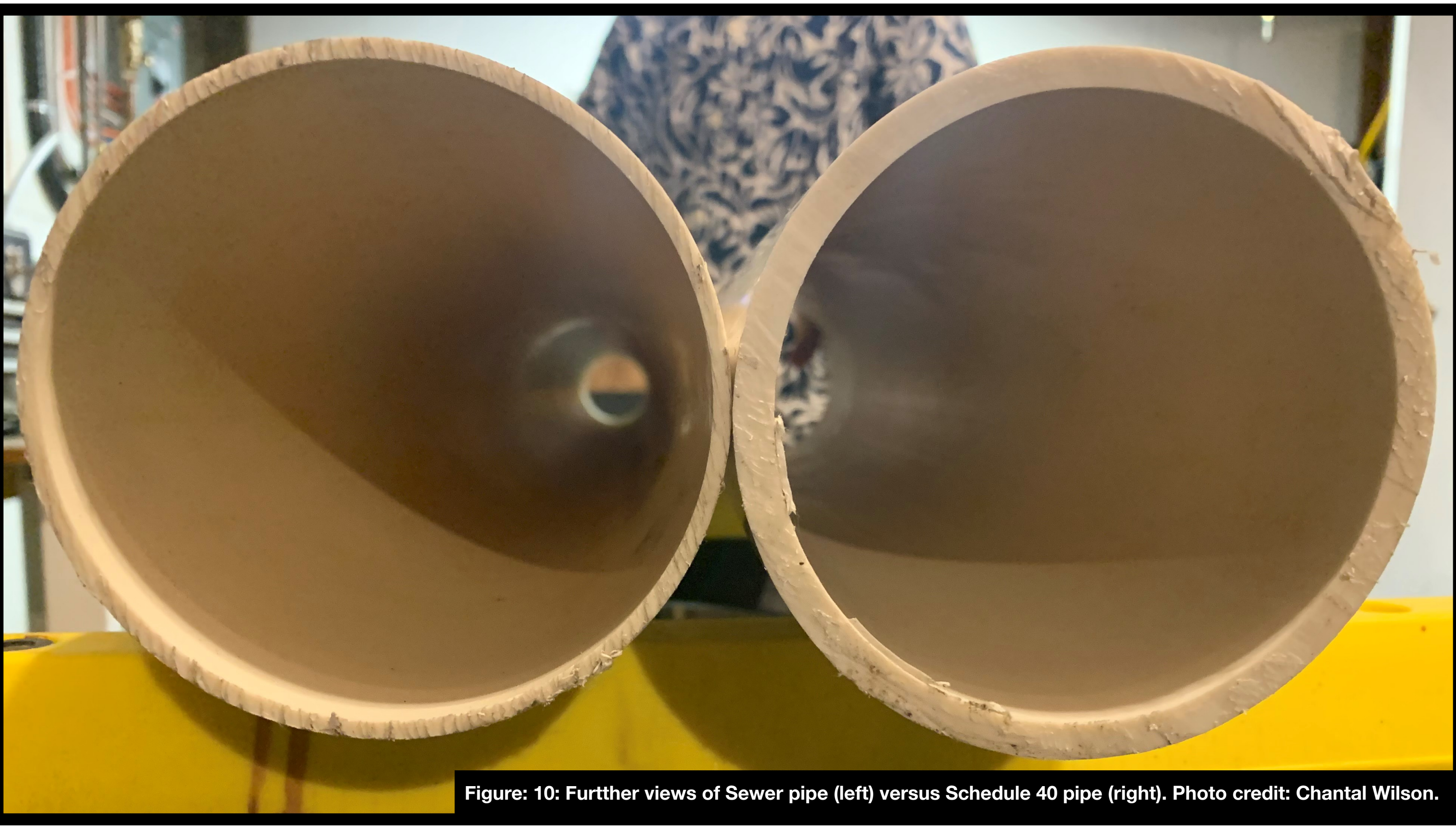

Figure: 10: Furtther views of Sewer pipe (left) versus Schedule 40 pipe (right). Photo credit: Chantal Wilson.

(i) Labelling

The Code calls for the vent pipe to be labelled every 1.2 m and at every change of direction (9.13.4.3.3(b)(viiii)). Another common approach (also found in CGSB-149.11-2019 at s. 8.1.1.2) is to have specific words to be used warning against tampering or disconnecting. As Table 7 shows, most systems were not properly labelled, although there was slightly better performance in this regard in the homes under construction as compared to already occupied homes. Given other problems, few mitigators, builders of building inspectors dwelt on it and it rarely came up in conversations. It does point to a lax attitude towards the Code provisions. Alternatively, standardized stickers could be used that convey important information, such as the need not to tamper or for post-occupancy testing.

Figure 11: Radon labelling on a vent pipe. The informal and non-standardized labelling is typical. Photo credit: Chantal Wilson as part of this study.

TABLE 7: RADON PIPE LABELLING

	Under construction			Occupied homes		
	yes	No	Unknown or not applicable	Yes	No	Unknown or not applicable
Labelled "Radon Vent Pipe" every 1.2m and at every change in direction	20	18	7	7	23	14
Labelled "This is a component of a radon reduction system. Do not tamper with or disconnect" every 1.8m and at every change in direction	10	28	7	11	27	16

(j) Insulation and Freezing

The BC Building Code radon provisions do require that the vent pipe be protected from frost closure by insulating the pipe if there is a frost closure problem (9.13.4.3.(3)(b)(vi)). We found that most vent pipes did exit through the roof, where the common procedure was to create a protection from snow. However, we did not find any pipes were insulated in the attic (see Table 8).

Mitigators also had strong opinions on this front.

> *Typically in our region insulation is above second story, so there is an uninsulated void in attic* (IS-M-1).
>
> *Anything would help for insulating the pipe would make a difference* (IS-M-2).
>
> *Insulate last 6 feet of pipe. I would love to see that required. I have never seen one where the builder has insulation* (IS-M-5).
>
> Q; Have you come across faulty installation of radon systems in your work? *Yes…. unconditioned attic spaces where the piping is not insulated* (IS-M-8).
>
> *In multi-unit buildings, the radon rough-in can be tied together (or even in a large home with multiple suction points)—and with horizontal pipes you get problems needing insulation—or else heat loss and condensation…R40 insulation is 14 or 20 inches—but pipe will not have insulation and that can take…Part 9 needs minimum R value of pipes that run horizontally* (IS-M-4).

One approach to the fact that the current provisions on frosting and insulation are not being followed is to provide more clarity. The single sentence in the current Building Code might not be sufficient to explain the problem of frosting and there is no further guidance in the notes. CGSB-149.11-2019 provides that the portion of the passive stack passing through habitable space shall be located within walls that are completely surrounded by conditioned space (7.2.2.3), and that the section of the passive stack passing through unconditioned space (i.e. an attic) shall be insulated to a minimum thermal resistance of 2.47 m^2K/W (R-12) to maintain the stack effect flow momentum and to minimize condensation on the inside of the pipe (7.2.2.5).

TABLE 8: PIPE END AND FROST PROBLEMS

	Under construction			Occupied homes		
	Yes	No	Unavaliable or not applicable	Yes	No	Unavaiable or not applicable
Pipe terminates on roof (as opposed to sidewall or gable end)	43	1	1	30	2	12
Is radon pipe protected from sliding or falling snow?	36	5	4	30	1	13
Pipe protected from frost closure by insulating pipe in attic (or utilizing other frost prevention methods)	0	28	17	0	35	54

(k) Terminations and Weather Shielding

The termination point of the system (whether rough-in, passive or active system) can give rise to a number of problems. The BC Building Code has fairly clear rules around terminations being close to air inlets or openable windows (9.13.4.3 (3)(b)(ii)) or occupancies (9.13.4.3 (3)(b)(iii) and our site visits confirmed these are for the most part followed.

However, the provisions on weather shielding have proven to create considerable problems. The provision at issue (s. 913.4.3(3(b)(v) states that the termination should be shielded from the weather in accordance with Sentence 6.3.2.9.(4). To find 6.3.2.9(4) one needs to look up that separate section of the Building Code which deals with ventilation, where one finds that

> Exterior openings for outdoor air intakes and exhaust outlets shall be shielded from the entry of snow and rain and shall be fitted with corrosion-resistant screens of mesh having openings not larger than 15 mm, except where experience has shown that climatic conditions require larger openings to prevent the screen openings from icing over.

Further, but also difficult to access, guidance is given at Notes to Part 9 (A-9.13.4.3) which says that radon vent pipe terminations should be installed in a similar manner to plumbing vent terminals (and refers to the Plumbing Code, Appendix A, Division B, A-2.5.6.5.(4)) (This covers permissible distances). The Notes also stated that “the extraction opening (the pipe) should not be blocked” (at A-9.13.4.3.(2)(b)(i)and(3)(b)(i)) e.g. to ensure the system is working.

Generally, builders do tend to simply leave an open vent pipe, which technically does not conform to the Code. This will not in itself be overly problematic, in the sense that in most cases moisture should flow through the pipe to the sub-slab permeable layer and then filter into the ground. As discussed above in the section on elbows and horizontal runs, the radon system should be designed to handle some moisture and water flow.

However, we did also hear reports of radon systems where weather protection techniques seemed to go too far in the opposite direction— being capped off at the top, preventing any moisture getting in but also not allowing any air (or radon) to flow through the system (IS-M-6). One mitigator reported that builders in Kamloops regularly put on caps and have been told to do so (IS-M-2). We were also told, and given photos of “j hook” or “double gooseneck” tops that had frozen over, preventing any air flow (see Fig. 12) One building inspector confirmed enforcing these practices:

> At final we expect that most radon terminations that are vertical to the sky are capped to keep out unwanted moisture and birds, insects etc….We also give contractors the option to install a j hook configuration or a T type to prevent water ingress (Email from BI-4).

The use of caps, and goosenecks, and lack of use of screens was also confirmed in our visual inspections (see Table 9). All of the capped terminations we found were located in Kamloops in buildings under construction.

CGSB-149.11-2019 provides that the exterior pipe termination of the passive stack terminated above the roof top shall be directed vertically (7.2.4.6) and have a mesh screen made of low pressure drop stainless steel mesh (s. 7.2.4.7)

TABLE 9 TERMINATIONS		
Termination Type	Under construction	Occupied Homes
Capped	4	3
Open	27	13
Screen	0	2
Weather Hood	1	0
Gooseneck	3	2
Not applicable or unknown	10	24

Figure 12: Terminations. (a) Left: Frozen J Hook Termination on Vent Pipe. Photo Courtesy of John Kostelnick, Okanagan Radon. Not taken for this study.(b) Right: Specially designed radon vent pipe termination. Ipex Inc. RadonX Product Brochure

3. Concerns: Processes Around Building Rough-Ins, Testing, and Activating Systems

(a) Coordination with Ventilation Systems

The BC Building Code has provisions for heating season mechanical ventilation (s. 9.32.3), and this is increasingly done with heat recovery ventilators to help with energy savings. CGSB-149.11-2019 does not speak to coordinating radon systems with ventilation systems. That said, radon specific research from the Canadian National Research Council, led by Liang (Grace) Zhou and conducted in Prince George, has shows that heat recovery ventilation systems can work well in tandem with passive sub-slab depressurization. A well functioning HRV together with a well-built passive sub-slab depressurization system can often be sufficient to reduce radon to low levels (in the study to below 80 Bq/m^3) without the need to add a fan to the radon system.[15]

We also heard from some radon mitigators on this topic, some of whom are acutely aware of how heat, ventilation and air conditioning (HVAC) systems operate, in part because adjusting them can be an effective mitigation solution in some situations.[16] We heard from mitigators that there could be significant radon problems if the ventilation system was not properly balanced.

> *I balance HVAC systems as part of doing radon. If the HVAC vents in one room and the doors to that room are closed, then all the return air is sucked out and you can get terrible depressurization, allowing radon to be sucked in. We can close all the doors in the basement and do smoke detector tests and measure, or open doors to see changes to figure out the pressure differentials. If a teenager is living in the basement one would expect the door to that room to be constantly closed, and we play with air dampers, metal joint liners and other devices to make sure the room doesn't go negative* (IS-M-4).
>
> *In the summer, an inversion pressure plane can develop, e.g. when it's 90 degrees Fahrenheit outside and 70 degrees inside. You can get a reverse draft and pressure can build up under the slab even more, and if the building is sealed up for energy efficiency—and if there isn't good make up air an extremely low pressure and high radon situation can develop* (IS-M-5)
>
> *The Code allows for fresh air makeup to be tied to when the furnace is running. But if your furnace doesn't come on, you have no makeup air and so no equalization of air pressure.… If people are going to have high efficiency furnaces, then an HRV should be part of the package, and leave ventilation to that system—and forget about dampers on the furnace* (IS-M-5).

We were also told about considerable behavioural issues with heat recovery ventilators.

> *That damper can be on a timer—and so you get some air in—but when people here it running they can mess with the timers –people think HRVs are energy gobblers and they turn it off…I cannot tell you how many HRVs I have plugged in and explained to people to leave it on!* (IS-M-5)

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[15] Zhou, L.G., Berquist, J., Li, Y.E., Whyte, J., Gaskin, J., Vuotari, M. and Nong, G., 2021. Passive soil depressurization in Canadian homes for radon control. *Building and Environment*, 188, p.107487.

[16] Using HVAC systems for mitigation is described in Health Canada, 2010. Reducing Radon Levels in Existing Homes: A Guide for Profesisonal Contractors, ibid. at chapter 7.

Academic researchers have also found that users operation and maintenance of HRVs can be unreliable, such as not recalibrating them, turning them off, or not cleaning filters.[17]

We also heard about problems with exhaust fans.

> *I have seen drops of several pascals across slab differential just because of kitchen range hood or dryer—say the furnace not running, damper closed, no intake—then your house goes looking for air and it goes to the slab—those are significant forces. I had a house with a horrible radon problem, and mom was doing 3 or 4 loads a day—and the pressure drop due to dryer was 4 or 5 pascals as soon as dryer fired up* (IS-M-5).

Our home visits confirmed that HRVs were at times not balanced. However this data should be qualified— for homes under construction, balancing might occur at a later date, and for occupied homes, most homes did not have HRVs and of those that did we could not answer the question for many of them.

(b) Gaps in Inspection

Inspectors generally make two visits to houses and small buildings, first before the slab is poured, and a second during framing. At the first visit the inspectors would look for the radon pipe, rock and any impermeable membrane/vapour barrier (IS-BI-1, IS-M-1)). It would be at this point that the inspector might look to make sure sealing is done properly (IS-BI-3). However, the inspection captures only one point in time in a larger process. So "you don't know what happens later and it might be covered up" (IS-BI-3). There is another visit during framing, at which point the inspectors would look for pipe up through attic to roof (IS-BI-1).

Inspectors did not generally have a formalized checklist but relied on their understanding of the Building Code plus specific issues for which problems were common (IS-BI-1). One inspector told us they did not have a checklist as a matter of policy but did have a procedure manual which referenced radon (IS-BI-1). Another inspector said they had neither a checklist or manual but simply used the Building Code itself and that the relevant things to look for were 'in my head' (IS-BI-2). Another said there was a checklist (IS-BI-3). The general rule is that builders need to expect anything that does not match the Code will be called out (IS-BI-1, IS-M-1). Builders do generally know that inspectors are inspecting radon systems (IS-M-1). In larger buildings there is a system of relying on letters of assurance from engineers and architects. Plan checkers would make a note on the plan showing they checked for radon (IS-BI-1).

We asked inspectors and mitigators why an inspector might miss aspects of a rough-in. Reasons given included:

- Lack of education of inspectors/ building officials (IS-B1-1, IS-M-1, IS-BI-2). Only one inspector had prior training in radon (IS-BI-2), and two others stated they did not (IS-B1-1, IS-BI-3). We also heard that there was no specific conferences or training made available on the subject (IS-BI-1).

[17] Holsteijn, I.R.C.V., Li, I.W.L., Valk, I.H.J. and Kornaat, I.W., 2016. Improving the energy and IAQ performance of ventilation systems in Dutch dwellings. *International Journal of Ventilation*, 14(4), pp.363-370; Pereira, P.F. and Ramos, N.M., 2021. The impact of mechanical ventilation operation strategies on indoor CO2 concentration and air exchange rates in residential buildings. *Indoor and Built Environment*, 30(9), pp.1516-1530.

TABLE 10: HEAT RECOVERY VENTILATION IN HOMES								
	Under construction				Occupied			
	Yes	No	Unknown	Not Applicable	Yes	No	Unknown	Not applicable
Home has an HRV	33	10	0	0	18	26	2	0
Was HRV Balanced?	9	9	17	10	4	1	17	22

- "The previous inspector just approached it from a low knowledge standpoint. Just looking to see if pipe there and then signing off. I have seen countless mistakes" (IS-M-8).
- A lack of trained inspectors in general or new inspectors: "A lot of new inspectors are coming through the province…In rural areas inspectors are given the car keys, inspection slips, and go" (IS-BI-2).
- Lack of a broader understanding in municipal building departments (IS-M-2).
- A lack of understanding of the reasons behind the Code provisions, leading to a poor interpretation of the Code (IS-M-2).
- One official said " I would say most inspectors are not really passionate about radon" ((IS-BI-3).
- "In outlying communities there is a trust relationship between contractors and inspectors—so inspectors don't always check" (IS-M-1)
- Ignoring radon mitigation professionals: "I have talked to other mitigators who felt the inspectors didn't recognize our certification. So the inspectors are ignoring radon mitigators, because we are a new profession. We need a bridge into the building inspectors so they can absorb and accept what we are saying" (IS-M-3).
- "One gets too busy and you don't see the problems" (IS-B1-1).
- Not the inspectors fault but under-description in the Code: "The inspectors are approving bad piping and hidden locations, because the BC Building Code doesn't specifically specify the pipe or location" (IS-M-3). "Building officials in difficult situation—Code needs to be more clearly written and there is too much wriggle room—and for inspectors to demand things like perforated pipe would just issue in builders complaining to MLAs and cities about being badly treated (IS-M-4). "As an official you cannot ask for anything higher than the Code. That's been enforced now with the *Building Act*, and the removal of authority from municipalities" (IS-BI-3)

Our findings are consistent with these explanations. Its worth highlighting two that are the easiest to fix: Better education for inspectors and improvements to the BC Building Code radon provisions.

(c) Post Occupancy Testing

As it currently stands, the BC Building Code is designed to deliver a physical product for new owners and occupants. It does not cover post-occupancy conduct. For radon, this poses unique challenges because the Code only specifies the construction of a rough-in, with upgrades to be made upon testing.

We asked homeowners and builders about testing or delivery of test kits. The numbers for occupied homes are telling— that a majority of people had not tested, and almost no builders had provided test kits (see Table 11). Here it is important to recall the recruitment methods— which involved some advertising through Take Action on Radon—a national radon awareness campaign that had recently given away over a thousand test kits in the Central Okanagan. Our results are likely skewed towards more homeowners being aware of radon than a purely random sample would be. By contrast, Statistics Canada reports 55% of households in BC (not in apartments) had heard of radon, of which only 7% had tested, but better results for the Kelowna census metropolitan area, with 82% of households (not in apartments) having heard of radon and of those 61% saying they had not tested.[18]

This problem of post occupancy testing came up a lot in our conversations.

> *The most important thing is for us to concentrate on is the post occupancy testing. I think there are a lot of people who think they are secure and they are not.* Q: Why aren't new homes tested after occupancy? *A: None are. I know this.* Q: How do you know this? *Because no requirement to be tested. If they were testing people would be calling me for work* (IS-M-1).

> *A lot of people think once a radon system in the situation is dealt with— the builders don't relay the information— I am assuming its inspected but as soon as they get it in don't need to test for radon. So I have done maybe 5 tests, and no mitigations, on anything post 2012* (IS-M-7).

> *At the moment a big issue is that the builder gives the home to the homeowner and leaves, and homeowners have no idea that they need to conduct a long term test after occupancy. Its often only through Take Action on Radon awareness campaigns that people conducted a test and learnt there was a problem. I am often learning that people were never told about the need for test* (IS-M-8).

TABLE 11: POST OCCUPANCY TESTING

	Under Construction			Occupied Homes		
	Yes	No	Unknown or not applicable	Yes	No	Unknown or not applicable
Home was tested for radon	2	42	1	19	25	0
Builder will or has provided the homeowner a long term radon test at time of occupancy	0	32	13	1	42	1
If home is occupied, does the Homeowner know where the radon rough-in is located?	4	0	41	25	17	1

[18] Statistics Canada, 2022.Knowledge of radon and testing. Table: 38-10-0086-01.

Photo Credit: Andy Harper. Blower Door Close Up. https://creativecommons.org/licenses/by-nc/2.0/

(d) Retrofits

We heard some confusions and problems around radon and retrofits from interview subjects and in our routine outreach work.

In principle, new building code provisions apply to additions only. However, a new addition might also effect radon levels throughout a building. There are general provisions in the Code such as an alteration cannot lessen existing performance. However, there is little guidance in the Code to the effect that a retrofit might require a whole building to be (re)tested for radon or asking builders/ homeowners to ask whether the alteration might increase the potential for elevated indoor radon levels. Health Canada recommends that homeowners should always consider re-testing whenever major renovations are performed that might substantially change the ventilation or airflow in the home or the use of the rooms in the lowest-occupied level.[19]

We heard from some mitigators that the Code might also create over-reach— if an existing house has low radon, its unlikely that a rough-in would be needed in an extension, or it might make more sense to first build, then test and mitigate if need be (IS-M-4). This suggests some rewording of the Code to give inspectors the discretion to apply the Code on a house by house basis given evidence of radon.

In some cases, the Code allows for alternative solutions, with assurances from architects or engineers. One building official felt that C-NRPP certified radon professionals could also do this with respect to radon issues in retrofits. As he explained. "I have a case now, where someone has an existing garage and wants to convert to a guest suite—so there is existing slab… I thought to accept test results from a mitigator showing low radon in lieu of an engineer" (IS-BI-2).

[19] Health Canada, 2017. Guide for Radon Measurements in Residential Dwellings (Homes). https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html at section 5.1

Radon pipe likely to be hard to access after drywalling. Photo Credit: Chantal Wilson.

(e) Post Occupancy Rough-In Upgrades and Mitigation

Radon mitigators are trained and routinely put in sub-slab depressurization systems from scratch. The central motivation of the 'rough-in' provisions of the Building Code are to reduce costs for homeowners relative to hiring mitgators to start fresh. But some mitigators we spoke to suggested their having to change systems was relatively expensive— that the putative savings of installing rough-ins at the point of construction was erased by having them visit.

> *The costs are equal to or slightly more than having nothing done in the first place. The biggest cost on any project is labour, and going in and fixing someone elses problem creates more labour costs than the start. There is definitely a way the price could be lower if passive system, straight, insulated—its so close I can taste it. It just needs that fine tuning. Then mitigator could diagnose, size for a fan, and turn it on—would save in labour and reduce cost of systems* (IS-M-8).
>
> *if rough-in done wrong…If you just stick a fan on, won't necessarily work. Putting a fan is an unnecessary expense* (IS-M-6).

High costs were also implied by mitigators whose policy it is to replace sewer pipe (as discussed above). Alternatively, some mitigators were keeping sewer pipe in to reduce costs for homeowners, with predictable spin-off effects in terms of the long-term viability of the system.

Currently, there are no requirements as to what tradespeople or professionals might add fans after testing. At least one mitigator felt that C-NRPP certified radon mitigators should be doing this work exclusively (IS-M-8). Here there are significant repercussions in terms of long term energy use. Mitigators are trained in sizing fans, using proper pressure measurements. This can result in a different of fan size of 100s of watts.[20] As well, an oversized fall can also pull conditioned air from the house (e.g. excessive negative pressure under the slab sucks conditioned air below the slab and then through the vent pipe). In some measure, building in good passive sub-slab depressurization systems, together with Heat Recovery Ventilators/balanced ventilation from the get go, could avoid the need for fans.

[20]Health Canada, 2010 Reducing Radon Levels in Existing Homes: A Canadian Guide for Professional Contractors, ibid.

4. Explanations for Current Problems

(a) *Builders Rarely Go Beyond Letter of the Code*

Some BC builders do work hard to use new technologies and create a public profile of concern about radon.[21] That said, we repeatedly heard the sentiment that builders only worked to the letter of the Code and seldom went beyond.

> *The builders do what they have to, but unfortunately it's not something the Building Code tells you what to do. So e.g. you get sewer pipe not schedule 40, pipes to near walls, pipe that goes through roof and has a roof jack with a flapper—made for vacuum fans to open and shut, and that will stop the system. So they don't get stuff* (IS-M-6).
>
> Q: What do you think the main reasons are for faulty installation? *A: The overall rush during the construction process—multiple trades in at this point of construction—putting in construction, granular fill—they probably just call plumber to do it quickly—rather than taking the time to understand how the system works and just focused on meeting minimum standards. Builders don't seem too too concerned whether radon systems are well installed* (IS-M-8).
>
> Q:How would you gage interest in radon in your community, among builders? *A: For the builders, there is just basic radon knowledge purely because of the BC Building Code. Its another thing you have to do. There isn't a deep engagement with the topic. So just narrowly following the Code* (IS-M-2).
>
> *The builders—there is a lag—some don't care and just following building inspector—but some are trying—I know of one—but generally just following the Building Code and advise of inspectors* (IS-M-3).
>
> Q: How would you gage interest in radon in your community..among builders: *A:For the most part there is a lack of interest, just another box to tick, and that's where it ends. The builders who I have engaged are no more interested than the general public. The proactive engagement has been limited to just getting the rough-in past inspection* (IS-M-4).

The builders and inspectors we spoke to were also quick to describe their competitors in the terms of not going beyond letter of the Code:

> *Other builders are aware of it, but not that they have changed their procedures – its just an expense and a hassle at a time so a lot of time trying to do the minimal* (IS-B-1).
>
> *the system of pipes and inspections—the city is all over it—but there would only be a handful of builders that are reaching out to learn more—but most just chasing green sticker and label of pipe* (IS-B-2).
>
> *Custom home builders tend to know, but 50% is spec stuff done cheap and just to pass inspection—so clear confirmation. For us it's a competitive advantage to be good at this and its not hard—the spec builders will be doing the bare minimum—doubling seal, and penetrations sealed well is probably the key thing from our point of view—could HVAC play a part—hard to say –the pipe up through roof—I think its an issue for us but we spend more time and money* (IS-B-3).
>
> *They are only as attentive as they are forced to be. So the majority of the builders build strictly to Code. They will only give you the minimum, and a small percent want to go to a higher level* (IS-BI-3).

[21] For example see RDC Fine Homes, 2022. Radon Mitigation. https://www.rdcfinehomes.com/news/2018/9/6/whistler-rd-modular-construction-and-radon-mitigation/

(b) The Code itself has Significant Gaps

In our interviews, we appeared to hear gaps in the Code as the most significant explanation for problems. C-NRPP mitigators now follow CGSB-149.11-2019 and the mitigators we talked to often described the gaps between the BC Code and that standard.

> *Not using correct materials because Code doesn't specify* (IS-M-1).
>
> *If you read CGSB-149.11-2019, which the mitigators have to follow, the piping is not correct, the layout of the passive system is not correct, the insulation of the pipe isn't correct, and usually the termination point above the roof involves double 90s, which CGSB says don't do –creates freezing and lack of airflow ---building code is silent on this* (IS-M-1).
>
> *The main reasons are that the Building Code under specifies. E.g. is not CGSB standard 149.11, 2019. That's where the SB 40 v. sewer pipe comes in* (IS-M-2).
>
> *Building inspectors don't have time or care, so the Code could be much clearer with illustrations so the plumbers could follow it* (IS-M-4).
>
> *If the Code doesn't specifically tell us we won't have authority to reject things on inspection. Otherwise it's out of our hands. Even the pipe specs are difficult for us. That would be a huge thing to get into the Code. So lets say its in the Plumbing Code—then even an interpretation would be enough* (IS-BI-1).

Our analysis in Part 2 confirmed the problem of lack of prescription in the Code and the much better descriptions and provisions in CGSB-149.11-2019.

(c) Trades Lack Awareness of Radon

Builders and building officials (and some mitigators) did give us a fairly good picture of how builders put in the rough-ins. The initial permeable layer before the slab is poured is conducted by construction personnel in house— such as general labour crews that do concrete preparation. Cement finishers would pour the slab. Later the vent piping is put in by plumbing contractors (IS-BI-1, IS-B2, IS-M-1, IS-M-8). We were told that "the concrete guys are the roughest guys showing up" (IS-BI-1) requiring very explicit instructions, the plumbers know very little about radon, and overall there is poor coordination. One building official said that the plumbers were not touching radon systems in their area, so the "builder himself or a carpenter or a general labourer does it" (IS-BI-2). Overall, different people put the pipe in the slab and through the roof, without contiguous knowledge through the system installation. The result is that systems are highly ineffective (IS-M-6).

> *Primarily plumbers are putting it in because they do plastic pipes. They want to get job done, but in terms of understanding the dynamics—their eyes glaze over on a job site when explain what they have done under the slab… Little things that are simple to address don't get addressed because principles not understood* (IS-M-5).
>
> *My opinion is that the trades people do what building department says is bare minimum. That's all their knowledge. They don't have knowledge of radon* (IS-M-6).
>
> *Plumbers put in piping. They know nothing about radon and just putting the pipe in and why it works irrelevant. They don't want to do it. Contractors tell them its part of the plumbing contract. Right now they are doing it the cheapest, easiest way, and that's the sewer pipe issue* (IS-M-1).

Q:What do you think the main reasons are for faulty installation? *A:Lack of understanding. I made inquiry a couple of times. I don't think there is even a one day course for people putting in the rough -in systems. CNRPP gives us a lot, but I don't think plumbers even have a rough-in unit in training. I get told I don't need 40 pipe at suppliers—so plumbers not seeing big picture* (IS-M-5).

What happens is we get called in when a plumber or geo-technician makes system active but still tests high. So we do a full diagnostic to make the system work. So there is a 'stab at it' approach from plumbers and HVAC workers—I have never seen a successful system from a plumber (IS-M-8).

(d) Home Occupants Do Not Understand Rough-Ins

As discussed in the section above on post-occupancy testing, homeowners often do not understand or know about radon. We heard repeatedly from mitigators (and one builder) that homeowners are unaware of radon.

If you don't know you have high radon, you don't call a mitigator. So very few people testing. Its just sitting there because no one knows what the radon level is (IS-M-6).

We don't do rough-ins in new builds because people don't ask (IS-M-7).

I have been contacted by a few people to look at the rough in—I am not seeing a lot. Almost all the homes I have been to have no rough-in. [My city] is growing massively, but a lot of people think once a radon system in, the builders don't relay, I am assuming its inspected but as soon as they get it in don't need to test for radon. So I have done maybe 5 tests, and no mitigations on anything post 2012 (IS-M-7).

One mitigator said he worked mostly as a home inspector (about 80 percent of his time) and noted that "Very few people know about radon—I know the disclosure statement asks about radon but only one out of 50 people who contact us show concerns about radon" (IS-M-6).

There was a general consensus among mitigators that most people do not understand the radon systems (IS-M-1, IS-M-2, IS-M-4, IS-M-5, IS-M-6,IS-M-7, IS-M-8) .

Home buyers have no clue. If they see these pipes they don't see what they are for. The pipes are not properly labelled. If the homeowner asks contractor, the contractor says 'there is a radon system you don't need to worry' (IS-M-1).

Homeowner are saying to me 'Someone put some piping in and I don't get it'. They don't understand it—and assume its working (IS-M-2).

One mitigator pointed out that the lack of labels on the pipes and the incorrect choice of piping contributed to the problem:

There is a general lack of understanding with public about what the pipe is--people won't know—its behind the furnace, or hot-water tank. One of the reasons for requiring white SK40 is to identify it (IS-M-5).

(e) Poor Communication Between Builders and Homeowners

We heard a number of times that builders would imply that the radon system was working.

> *The radon ready systems are being sold by builders as a radon system, even if not ready* (IS-M-4).
>
> *Buyers are just told- 'meets code' and more often than not hoodwinked into thinking radon system in place and don't need to worry* (IS-M-4).
>
> *Occupants generally do not know what a rough-in is. Builders say it's already a radon system. I hear that a lot. The story grows as they tell it. Builders probably said there was a radon pipe and didn't know protocols for testing* (IS-M-6).

We asked builders and building officials if they had specific communication protocols for communicating about radon and were told not.

> Q: Do you leave any documents, directions, devices with new home owners? *Yes. They get a walk through, and introduction to home, here is how to check filters, thermostats—there is not usually a conversation around radon. There is a turnover binder—National has a package—and we have our own internal document—but there isn't a radon portion* (IS-B-2)
>
> Q: Do you leave any radon specific documents, directions, devices with builders? *A: Nothing no*. (IS-BI-3).

As well and as we documented in the section on post-occupancy testing, almost no builders are leaving detectors with occupants.

Photo credit: Warren, J. 2008 Construction Site. https://creativecommons.org/licenses/by-sa/2.0/

5. Solutions Going Forward

(a) Better Technical Specifications

We heard repeatedly that the BC Building Code needs to have more explicit instructions on radon, and that those instructions should be for building adequate passive radon systems. For instance, we asked one municipal building inspector if they were aware of radon guidance from Health Canada. S/he responded:

> *I don't know what they are. The Code might have references but it's a huge set of two volumes and we won't look up stuff unless its spoon-fed to us. If you put it out there, it's easy to learn. Inspectors don't have time to search for answers, but if its offered up they are more than willing to look. …* Q: Do you think the radon provisions should be changed? If so, how? *A:If they can get specific on the acceptable pipe, or other areas where failing—room for a fan, needs to be protected from frost/insulation—if it's written in there it gives us teeth. If its wishy washy we get pushback. Builders will say 'show it to me in the Code'. Builders can sue us if we order something not in the Code. We do get called out- and we do have to buck up* (IS-BI-1).

> *Building officials are in a difficult situation. The Building Code needs to be more clearly written and there is too much wriggle room* (IS-M-4).

In Table 12 we list technical issues (discussed in Part 2) and compare current Building Code provisions to those in CGSB-149.11-2019. If the current Code was unclear and much better alternative language was available we concluded the problem would likely be solved by Code changes. This exercise suggested that in most cases clarifying the Code would be a good first step (multiple footing spaces, blockages of soil gas collector, location of pipe and room for fan, electric outlet for fan, elbows and horizontal runs, incorrect pipe, and insulation and freezing). However, in some areas, the problem was, rather, that the Code was not being followed. This appeared to be the case for issues of poor fill, and pipe labelling. For the remaining issues we felt that Code changes might contribute, but that overall there was sufficient description in the Code for someone with a reasonable background in radon but absent such knowledge mistakes were likely. Here we thought there could be clearer language in the Code, as well general purposive descriptions to help people with the reasoning behind the Code provisions, but also that more education was needed by builders, trades and labourers and building inspectors (gaps in foundation, terminations and weather shielding).

Some issues discussed in Part 3 can also be addressed through Code changes. More could be said on how radon systems can work in concert with HRVs, and we expect mechanical ventilation requirements of the Code will also be upgraded in the future. There could be clearer language on the need for post-occupancy testing (see below) as well as how radon is influenced by retrofits.

TABLE 12: POTENTIAL FOR CODE CHANGES			
Issue	BC Building Code provisions	CGSB 149.11-2019	Most likely solutions
Poor fill	Calls for "a gas-permeable layer consisting of coarse clean granular material (9.13.4.3. (1)(b)), "consisting of not less than 100 mm of clean granular material containing not more than 10% of material that will pass a 4 mm sieve, installed below the floor-on-ground" (9.13.4.3 (3)(a)).	CAN/CGSB-149.11-2019 provides almost identifical wording (at s. 7.1.1.2.3) but also notes that there are available alternatives, such as crushed concrete or specially designed ventilation panels.	Not a Code problem, but one of inspection, builder education and oversight of labourers and trades
Multiple footing spaces	Unclear and only requires that the underslab collection pipe "opens into each contiguous area of the granular layer" (9.13.4.3 (3)(b)(i)). The notes to Part 9 (at A-9.13.4.3.(2)(b)(i)and(3)(b)(i)) also states, rathery cryptically, that "The arrangement and location of the extraction system inlet(s) may have design implications where the footing layout separates part of the space underneath the floor."	CAN/CGSB-149.11-2019 provides explicit direction (at section 7.1.2.6)	Code changes can likely remedy
Blockages of soil gas collector	Pipe not clearly specified, only that it "has one or more inlets that allow for the effective depressurization of the gas-permeable layer"(9.13.4.3.(2)(c)(i)).	has detailed instruction (ss. 7.1.1.2.6.1 to 7.1.3.2.5). It calls for 100m (4 inch) piping that is near or directed towards the centre of the floor, specifies length, and provides specific configurations.	Code changes can likely remedy
Gaps in foundation	9.13.4.2. provides for floor assemblies separating conditioned space to have an air barrier system (referencing s. 9.25.3). 9.25.3.2 (1) gives the broad details; 9.25.3.2(2) suggests a polyethylene sheet 9.25.3.3 provides further specifications, including sealing (s. 9.25.3.3(6) and weatherstripping (s. 9.25.3.3(7)).	At section 7.1.4.5 gives significant detail on the soil gas barrier under concrete slabs, with clear diagrams	Likely Code changes could help, but given already sufficient information in the Code this may require better overal description of purposes of provisions, including them in a single space in Code, plus education of builders, trades and inspectors
Location of Pipe and Room for Fans	Clear gap in the Building Code, in that there is no specification of location	Detailed specifications at 7.1.7.2, 7.2.2.4, 7.2.5, and 7.2.5.1	Code changes can likely remedy
Electricial Outlets for Fans	Clear gap in the Building Code	At s. 7.2.2.6 with an accompanying diagram.	Code changes can likely remedy

TABLE 12: POTENTIAL FOR CODE CHANGES			
Issue	BC Building Code provisions	CGSB 149.11-2019	Most likely solutions
Ebows and horizontoal runs	States only that accumulation of moisture in the pipe should be prevented (s. 9.13.4.3.(3)(b)(vii).	Describes a passive sub-slab depressurization system (at section 7.2);any bends in the system should be made with 22.5 degree fittings (s. 7.2.2.2), minimum slopes to ensure water does not pool and minimization of exposure to cold temperatures such through insulation if located in unconditioned spaces (see ss.7.1.3 and ss. 7.2.2)	Code changes can likely remedy
Incorrect Pipe	The radon provisions of the BC Building Code do not specify type of pipe. However, the BC Plumbing Code (at s.2.2.5.11) spells out allowable forms of pipe.	Requires any above grade radon piping to meet Schedule 40 specifications (s. 7.1.3.1.3).	Code changes can likely remedy
Insulation and Freezing	Requires that the vent pipe be protected from frost closure by insulating the pipe if there is a frost closure problem (9.13.4.3.(3)(b)(vi)).	Specifies insulation requirements if passive stack passing through unconditioned space (i.e. an attic) and gives reason why at s. 7.2.2.5).	Code changes can likely remedy
Labelleing pipe	The Code calls for the vent pipe to be labelled every 1.2 m and at every change of direction (9.13.4.3.3(b)(viiii)).	s. 8.1.1.2 specifies label is to have specific words to be used warning against tampering or disconnecting.	Likely requires stricter language in Code as well as builder and trades awareness
Terminations and weather shielding	S. 913.4.3(3(b)(v) states that the termination should be shielded from the weather in accordance with Sentence 6.3.2.9.(4). 6.3.2.9(4) states that “exterior openings for outdoor air intakes and exhaust outlets shall be shielded from the entry of snow and rain and shall be fitted with corrosion-resistant screens of mesh having openings not larger than 15 mm, except where experience has shown that climatic conditions require larger openings to prevent the screen openings from icing over. Notes to Part 9 (s.A-9.13.4.3.(2)(b)(i)and(3)(b)(i)) states that “the extraction opening (the pipe) should not be blocked”	Rhe exterior pipe termination of the passive stack terminated above the roof top shall be directed vertically (7.2.4.6) and have a mesh screen made of low pressure drop stainless steel mesh (s. 7.2.4.7)	Clearer language plus builder/trades education

Proper Passive Radon Systems

CGSB-149.11-2019 provides for different "levels" of radon system, each of which adopts all of the requirements of the lower level. Level 2 provides for passive radon systems. While some interview subjects shied away from directly criticizing the Code, It came as little surprise that many thought the CGSB-149.11-2019 Level 2 specifications should be adopted in full into the BC Building Code.

> *I would agree with making CGSB standards part of Code. If passive installations done at time of construction it would be wise in the design phase and most beneficial to homeowner…There is definitely a way the price could be lower if passive system, straight, insulated—its so close I can taste it. It just needs that fine tuning. Then mitigator could diagnose, size for a fan, and turn it on—would save in labour and reduce cost of systems. I would advocate for the CSGB 2019 standard.* (IS-M-8)

> *the standard needs to be beyond the BC Building Code—so the Building Code could reference CGSB 149.11—and say it meets that* (IS-M-2)

> *Adopting the CGSB standards into the Code would be a good starting point also. There are a lot of grey areas so that would solidify understanding. Certainly a passive system (Level 2) and no point for putting in an active system if low radon* (IS-M-4).

In our view there are two very clear advantages to building well-functioning passive systems from the get go. First, they often do the job on their own— that is they function sufficiently to address the radon problem in many homes. While passive systems are not a substitute for testing and mitigating, they will lower radon levels on a statistical basis. As National Research Council evidence from Zhou et al. (ibid) shows, passive systems, especially in conjunction with balanced HRVs are often sufficient. Second, passive systems do not use electricity and so reduce energy use relative to active systems. We agree on the need for the Code to be updated to include passive systems in locations that need radon preventive measures in new construction.

At least one mitigator reminded us that CGSB 149.11-2019 should not be taken as the final word:

> *The CGSB standard Is great, but some things could be improved upon. It's a living breathing animal…it specifies Schedule 40 pipe—ABS, PVC, but some of those, like ABS can be confused with plumbing pipes, and there are worries about homeowners cutting into it—so the hope is there could be a specific requirement for distinct pipe* (IS-M-2)

Photo Credit. Rogers, P. 2007. Construction Site. CC BY-SA 2.0

(c) Should Fans Be Added at the Time of Construction?

We also heard debate over whether to add active systems.

> *Personally if I was building houses right now, I wouldn't be satisfied with leaving the house with just a passive system, but instead put in a fan, so if someone moves in and tests, with passive system, then fan remediated very quickly, so why not just spend the money to put an inexpensive fan in now. So why waiting to test? There are houses without high radon, but for the expense—its so minor—then why not put it in all—they don't use much power* (IS-BI-3).
>
> *I think a passive system at the time of construction is best… not every house will have a radon source—so I think active systems in each home is a waste of money and resources* (IS-M-8).

Overall, we heard good reasons on both sides of the debate.

On the positive side, a fan can be added to a radon system at construction but left unplugged. This would allow home occupants to test for radon and then simply plug the fan in. While there would be added costs (in terms of many unused fans, it would be much easier for homeowners to address radon levels. Passive systems (rather than an active system waiting for activation) may give homeowners a false sense of security that radon is addressed, even though we know that in many homes passive systems are inadequate to reduce radon levels below guidelines.

On the negative side, the proper sizing of fans implies a greater role for professional mitigators at the construction side. (In section 5(d) below we cover concerns with the skill level of existing trades). Also, It is likely difficult to get fan size precise prior to occupancy, given houses may shift and change once built (for instance, cracks appear in the foundation due to concrete shrinkage). Implementing active systems across the built environment will create a large number of unnecessary fans with spin off environmental effects and costs (e.g. in production and distribution of plastics and metals).

We suggest in the near term the focus can be on building passive systems properly, coupled with proper notice and education of new occupants. As we noted earlier (sections 2(e) and 3(a)) such passive systems, especially in conjunction with an HRV are effective in lowering radon levels to below Guidelines in a large number of cases. We suggest, however, further study and consultation on the issue of active systems. For instance, newer technologies might include radon monitors which can activate fans or HRVs when radon readings are elevated. Such products are now on the market, such as the Radostat, sold by Radon Environmental, which uses real-time continuous radon sensors to activates HRV/ERVs when radon levels exceed 150 Bq/m^3.[22] We suggest further studies to determine whether these are cost effective, energy efficient and reliable alternatives when scaled up to a provincial role out, and whether they are better than the alternative of enhanced methods for having occupants test and upgrade systems with fans.

[22] Radon Environmental Management Corp. 2022. Radostat. https://radoncorp.com/radostat

(d) Education and Training

The quantitative results and our analysis of technical issues suggest significant gaps in education by builders, trades, and inspectors. As discussed above under terminations (section 2(h) one inspector asked builders to put caps on the radon rough-in, effectively blocking any passive flow of air and radon through the system. We also heard this sentiment from both mitigators and building inspectors.

> *There is way more education required. So in [my regional district] I have a background in radon but most inspectors do not understand it. E.g. I am asked 'I see bedrock in basement what do I do?' So they don't get seriousness of radon and whats acceptable and what isn't. I had one inspector say 'cover bedrock in epoxy'* (IS-B1-2).
>
> Q: What do you think should be done to ensure proper implementation of the BC Building Code provisions? *A: We definitely need to get building inspectors better trained up on this. I have talked to other mitigators who felt the inspectors didn't recognize our certification. So inspectors ignoring radon mitigators—because we are a new profession—we need a bridge into the building inspectors so they can absorb and accept what we are saying* (IS-M-3).
>
> *I would love to find an unfinished basement with system in place and show inspectors* (IS-M-4).

To this end we were given direction to attend conferences, give lectures, or attach training to Continuing Professional Development Credits of the Building Officials Association of BC (IS-M-1, IS-BI-2). There was some openness to specific courses for inspectors, if not too difficult or long, such as under 4 hours in total: "If it was tailored into a 2 to 4 hour period I would expect a great response, especially if it was during the off season in the winter " (IS-BI-2) .

There was considerable concern about the training level of rough-in installers:

> Q: What do you think should be done to ensure proper implementation of the BC Building Code provisions? *A: Mandatory one day training for rough in installers—these are tradesmen who know pipe, but they need a training module, by the industry wide. Who? I imagine there is some kind of plumbers trade association—it should start at the trade school level with apprenticeship—in terms of launching the existing certified people* (IS-M-5).
>
> Q: What would you recommend to help builders do a better job with radon? *A: Education… Builders are busy, they wouldn't turn down, e.g. professional development, but they really are not searching out an issue, unless there is suddenly a big issue or someone dies--- so unless direct relationship to the issue, not overly aware* (IS-B-1).

C-NRPP offers a specialized training for Controlling Radon in New Canadian Homes (CRNCH) Installers. This provides specific training on installing and maintaining radon rough-in systems, including active-ready and passive systems without fans. It requires less course work than normal mitigation professionals.

We fielded the idea of certification for radon installers for BC and heard some skepticism.

> *People are not running in droves to this industry… to line up 400 or 500 mitigators to do everything is head scratching. Because of training number of people and finding them* (IS-M-8).

We also heard from a builder who thought this was more than was necessary:

> *CNRPP certification does not mean much to us, in terms of who we work with—maybe I am over-simplifying, but it feels like the solutions are basic and easy to accomplish*(IS-B1).

Our view is that installing radon systems is no more demanding than other tasks regularly performed by plumbers. What is needed is sufficient guidance to them, or other trades, in the form of updated Building Code provisions, available education, and proper scrutiny by building inspectors.

(e) Post-Occupancy Testing

To a limited degree, building good passive systems may create a safer fall back position when occupants do not test. However, even if passive systems (or systems with fans waiting to be plugged in) were standardized in new builds there would still be a problem with post-occupancy testing. We heard from mitigators and building officials about some possible solutions and could also build on prior research we had conducted on radon issues.

(a) **Explicit guidance in standards.** This is present in CGSB-149.11-2019. Here there is a provision that the builder either leave a C-NRPP certified listed and approved long-term radon testing device and instructions to the new occupants or have a C-NRPP radon measurement professional conduct a long term test (7.1.7.1, see also 7.2.6.1). The BC Building Code could provide guidance on this—and the Notes to Part 9 do speak of the potential need to upgrade to active radon systems but do not specify the need to test. However, there are no provisions in the *Building Act* SBC 2015, c.2 for the Code to extend beyond initial construction. This means that such guidance cannot be turned in mandates.

(b) **Real estate transactions**. Currently there is some guidance from the British Columbia Financial Services Authority on radon, to the effect that it is a latent defect in the sale of a home. Unfortunately, this requires the seller to have knowledge of any radon problem, which many sellers will not have.[23] Alternatively, some US states have statutes that requires sellers to pass on pre-written statements to buyers. These generally explain that radon may be a present danger in the property, explain the legal duties of sellers concerning radon, and advise testing.[24] In previous reports BC Lung has recommended this be adopted in British Columbia. [25] We think something stronger is needed. A requirement that radon be tested prior to a sale raises problems of delaying real estate transactions by a minimum of three months, and likely more given guidance to test during the heating season. However, a radon holdback could be mandated— the buyer is to hold back a portion of the sale price to be held in trust until testing and necessary mitigation is performed.

(c) **Municipalities deny final occupancy permits pending delivery of test results.** Some of the mitigators we talked to promoted this idea.

> *It would be nice to have an occupancy test. Especially with newer tight homes* (IS-M-7).
>
> *Not having final occupancy permit would help—and would make builders think about what they are doing…I charge $100 for testing, including the kit. So its reasonable that we mitigators could be paid by the municipality, so just attach the fee to the permit application, and the municipality hires us. The owner pays the municipality. Building permit fees are around 3,500 dollars. I doubt anyone*

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[23] British Columbia Financial Services Authority, 2020. Radon Precautions Guidelines. https://www.bcfsa.ca/industry-resources/real-estate-professional-resources/knowledge-base/guidelines/radon-precautions-guidelines

[24] Minnesota Statutes § 144.496, *Minnesota Radon Awareness Act.* For a description see Minnesota Public Health, Radon and Real Estate. https://www.health.state.mn.us/communities/environment/air/radon/radonre.html

[25] Quastel, N. 2020. Radon in Real Estate: Summary for Policymakers. Available at https://bclung.ca/programs-initiatives/healthy-indoor-environments-program/current-projects/radon-real-estate/summary

would even know if it went up by a 100 dollars. People wouldn't squawk at that. Some changes to building bylaws could be done. Seems if we want to get on top of this, you need to test the homes, so this is an avenue to get this done, and doesn't disrupt the municipality that much. There are licensed measurement professionals in the area, and my requirement is just to give the owner and city results… A provisional permit won't get people out of their house, but if you want the provisional permit to go through, e.g. for next real estate transaction—so you would have to say you don't have final occupancy in the real estate transaction—that would leave permits open and that would be an issue (IS-M-6).

Some inspectors we spoke to were against the idea as impractical.

I cannot see a post- occupancy permit happening….we did have a provisional occupancy permit in our bylaw—but there is a real problem once people are in there—an insurance thing—would extend the contractors insurance (IS-BI-1).

Q: Do you think there is a way to impose requirements for post occupancy testing? *A: Its probably going to be difficult, at the local government level, once the occupancy is complete the file is complete and archived.* Q: What about making it provisional? *A: We don't want provisional occupancies—too many loose ends—MIABC would not want that. I worked once for a regime with provisional occupancies, and there has been a real push to eliminate, we want everything completed* (IS-BI-3).

Another thought it was tricky but possible.

Conditional occupancy permits are hard because people in there. But it can be done (IS-BI-2).

(d) **Information packages for new homeowners**. This could come in a number of guises. One clear option is for this to cover all real estate transactions, including the purchase of new homes.[26] One building inspector (who rejected the idea of a condition on the occupancy permit) thought that municipalities could attach radon information to the occupancy permit (IS-BI-1). Another felt that "Every municipality should have a brochure with permit and handout. Some municipalities do have handouts to help builders with rough-ins. But more education and awareness needed." (IS-BI-2) BC Housing, in overseeing the New Home Warranty system (see below, s.5 (e)) could also direct an information package be sent to new home owners. We think this is an obvious move and we discuss further reasons for doing this below under New Home Warranty provisions. We did hear some concerns that a purely voluntaristic approach might not fully succeed:

"Instruction manual?—no one reads it—you have this problem with HRVs, and people start to ignore those packages…We need an angle where there is a real incentive for the homeowner to do it—because as a measurement professional we see its hard for people to keep pucks in place" (IS-M-8).

We think a better approach is to implement a system of informing new occupants, give it time to become established and evaluate it to determine whether its successful or needs improvement.

(e) **Taxation levers.** One building official did suggest that municipalities have some room in taxation (IS-BI-2). We think this is an interesting idea, but which needs further study. Levers to consider might include adding a special levy onto property taxes for those who do not

[26] See Minnesota Statutes § 144.496, *Minnesota Radon Awareness Act* ibid.

complete radon tests, or making the BC homeowners grant conditional on submitting a radon test.

(f) **Notice on title.** The *Community Charter* SBC 2003, c .26 at section 57 provides a mechanism for a notice of title to be registered in the Land Title Registry for a property that is in an unsafe condition, or which contravened bylaws. One building official suggested a local government might use this provision as a backstop method for enforcing radon testing. This would in effect be creating a financial penalty and administrative hassle of removing the notice as the punishment for not testing for radon and submitting results within a specific time (IS-B-2). We think this may be possible, but procedurally cumbersome, and other options should be explored first.

(f) Engagement with Home Warranty

The New Home Warranty system is a central pillar of consumer protection in new homes—providing protection against defects in labour and materials. If no home should have elevated radon, then, prima facie, the presence of radon would represent a defect. This in turn is likely to drive builders to take radon more seriously.

Currently, neither BC Housing nor private providers in BC have explicit policies on radon. Alternatively, Tarion—Ontario's public sector new home warrant provider—has determined that radon represents a major structural defect, with warranty coverage for high radon, independent of building code provisions, for seven years. BC Lung has already produced existing reports on this issue.[27] We think there is a good legal argument for elevated radon to be considered a building envelope defect in BC allowing for 5 year coverage. [28]

We think there is space for BC Housing to adopt clear policies on radon, and in turn create clear information for new homeowners as to their rights—including asking builders and/or warranty providers to ensure new homeowners have the requisite information on radon upon taking occupancy. BC Housing could also adopt sticks— making elements of New Home Warranty protection only accessible for persons who test for radon.

We heard opinions about how BC Housing could drive radon action this way.

> *Put liability through Home Warranty, then they would change their tune. So everyone they talk to about flashing etc. is BC Housing—so BC housing really controls this* (IS-BI-2).
>
> *Say you make it a requirement for warranty, then you have to test and put fan in—from a position of time spent, a builder is not going to want to do that—its cheaper and easier just to put the fan in* (IS-BI-3).

There are challenges with the informal resolution processes built into the current New Home Warranty legislation: Almost all issues are dealt with by builders informally and there is virtually no case precedent on coverage issues. We also heard comments from builders that suggested any issues with new home warranty would get resolved quickly.

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[27] BC Lung. Radon Rights and Duties: New Home Warranty Providers. Available at https://bclung.ca/radon-rights-and-duties-for-new-home-warranty-providers; also see Quastel, N. 2020. Radon: Rights and Liabilities in Construction Law. Legal Brief No. 2 Healthy Indoor Environments, British Columbia Lung Foundation.

[28] Homeowner Protection Act Regulation, B.C. Reg. 29/99, Schedule 3, s. 2

> *We would always address issues in house. We are happy to lend people our testers—and would help people work on it. We say it orally* (IS-B-3).

There are also psychological and social reasons new homeowners may not want to put up a fight. As one owner-builder noted, they wanted to maintain good relations with the contractor even though they knew the rough-in was shoddily built.

> *Our builder seemed to know the Code, and I don't think this was something really brought to his attention. I am a well versed consumer—and this issue was third or fourth place on my list of concerns—it didn't cross my mind* (IS-OB-1).

One municipal building inspector spoke to adding specific wording in the Code that would make it easier for claims to proceed under New Home Warranty.

> *if the Code directly required a fan —the only way I see forward is to make the fan a code requirement—and if it was a warranty issue it would be that the builders would put the fan in* (IS-BI-3).

Our view is that builders should not be encouraged to create unnecessary energy draw in homes. However, we are encouraged by the idea that the right wording in the BC Building Code could help trigger New Home Warranty claims on radon. For instance, if the BC Building Code stated clearly that radon prevention measures in new homes should be designed to ensure radon levels under 200 Bq/m^3 that would make it clearer that elevated radon was a building envelope defect. We also think there could be clear information provided to homeowners by builders as to the location of the pipe, what it is for and the need to test.

(g) Locations Requiring Rough-Ins

During the time it took us to complete our research, the British Columbia Centre for Disease Control (BCCDC) released a new Radon Map for the public, based on data collected by the British Columbia Radon Data Repository. [29] The BC Building Code 2018 list of communities is out of date in the sense that it is possible to see many communities on the map with an evident radon problem but which are not mentioned in the Code. As part of our own Community Testing initiatives, we have talked to building officials and residents who were unclear whether radon provisions applied in their community. The issue of which communities require radon-resistant construction needs to be revisited and include data from the BCCDC Radon Repository and Map.

At the same time, the map also needs to be upgraded. The map shows insufficient test results for many communities. BC Lung's Community Testing program works together with Take Action on Radon, a national awareness program, to increase the number of communities in BC with good sample sizes of radon testing—and delivers results to the BCCDC.

As we gain awareness of geographical variation in radon risks, it becomes clearer that we need a a principled basis for inclusion and exclusion of locations in the Code. For instance, the Code might use a median radon level of under 40 Bq/m^3 or less than 3 percent of homes tested have elevated radon as the point where radon systems are not required in new construction. We recommend further study to establish this cutoff on the basis of widely accepted risk assessment principles.

[29] British Columbia Centre for Disease Control, 2022. BC Radon Map. https://bccdc.shinyapps.io/bcradonmap/

8. Conclusions and Recommendations

We recommend revisions to the Building Code as follows.

- Ensure well built passive radon systems by incorporating CGSB-149.11-2019 Level 2.

- Clarification of Building Code language, greater detail and link to overall purposes of radon reduction to address current problems, including: multiple footing spaces, blockages of soil gas collection, gaps in the foundation, location of the pipe and rooms for fans, electrical outlets for fans, elbows and horizontal runs, labelling, proper piping, insulation and freezing, and terminations, drawing on language from the CGSB-149.11-2019.

- Make clear that homes must not have radon levels at or above 200 bq/m^3, and radon at or above 200 bq/m^3 represents envelope failure.

- Clearer language on retrofits and how building changes require radon testing and potential mitigation.

- Revise locations requiring radon resistant construction/passive systems by reference to updated BCCDC Radon Map.

We further recommend

- Further study on whether the Code should require active radon systems.

- Support for testing programs to ensure all communities in BC have sufficient sample sizes to know radon prevalence.

- Risk analysis to establish the appropriate cutoff point for locations to be included in the list of where radon resistant construction is required.

- Education for builders, trades and building inspectors.

- BC Housing ensure radon considered by New Home Warranty.

- Improve buyers awareness of radon in real estate transactions— Work with BC Housing/ BC Financial Services Authority and Ministry of Housing to ensure information sharing on radon and mandating attention to testing in real estate transactions.

- Further study of taxation levers to ensure home radon testing by new occupants and other home occupants.

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