

Indoor Radon Exposure in British Columbia: A primer for health promotion

by

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1. Introduction

I became interested in indoor radon exposure while working at the Canadian Cancer Society. I was tasked with developing health promotion materials to kick start a new awareness campaign. It became obvious early on that radon is clearly a public health problem supported by vast amounts of research and knowledge. The problem with radon is that this knowledge firstly has not been translated to the public effectively and secondly when the knowledge has been translated there is a gap between awareness and action. There are many government agencies and non-profits working to bring about action on radon. This paper aims to discuss what action has already been taken, the barriers to action and suggestions for how to tackle these barriers.

I no longer work for the Canadian Cancer Society (CCS) and this research was undertaken outside of my health promotion role at the CCS. My position with the CCS did allow me access to conferences and meetings with other non-profits and a unique understanding of the issues of radon awareness and prevention in British Columbia. None of the information I was privy to was confidential. Any and all information shared in this paper could be made common public knowledge if it is not already. There are no ethical issues with disclosing this information. The strategic informants I have talked to would happily share their knowledge with any interested parties.

I am basing my approach for discussing radon on the Ottawa Charter for Health Promotion. The Ottawa Charter for Health Promotion defines health promotion as “the process of enabling people to increase control over and to improve their health” (OCHP, 1986). It goes on to define health and health promotion as “a positive concept emphasizing social and personal resources, as well as physical capacities. Therefore health promotion is not just the responsibility of the health sector, but goes beyond healthy lifestyles to wellbeing” (OCHP, 1986). Health promotion encompasses not only individual lifestyle choices and health taking actions but also healthy public policies and community action.

1.1. Background

Radon is a colourless, odourless, radioactive gas that occurs naturally in soils and rocks as a by-product of uranium decay. It is a part of the natural makeup of the earth found in higher concentrations in some locations than in others. Radon is a main contributor to ionizing radiation exposure in the general population and the most important of the naturally occurring sources (WHO, 2009). Inhaling radon gas leads to ionizing alpha particles interacting with biological tissue in the lungs to cause DNA damage. It is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC) (IARC Monograph, 2012). Radon is the leading cause of lung cancer in people who have never smoked and the second leading cause overall (WHO, 2009). There is no determined safe level of radon exposure. The World Health Organization (WHO) has set a target level of 100Bequerels/metre³ as the acceptable level for indoor radon concentrations. Health Canada has set the acceptable level in Canada at 200Bq/m³ and the US Environmental Protection Agency has set their acceptable level at 150Bq/m³. At indoor radon concentrations above these levels it is recommended that preventative action be taken.

The gas concentrates in enclosed spaces such as mines or houses. Air pressure indoors is usually lower than in the soil under the buildings foundation and the pressure difference brings radon and other gases into the home (Lung Association of BC, 2015). While outdoor radon concentrations have an annual average concentration of less than 10Bq/m³, indoor radon concentrations can range from 20Bq/m³ to 110,000Bq/m³ (Appleton, 2007). Indoor radon levels depend on many factors including the presence of uranium in the ground, weather, floor level, porosity and permeability of bedrock, permeability of soil and structural defects in the building (Al-Zoughool and Krewski, 2009). Radon can enter the house at any point where the soil and home meet such as cracks in the foundation, gaps around pipes, floor drains and unfinished soil crawlspaces (BC Lung Association, 2015). While radon can exist anywhere in the house the highest concentrations are usually found on the lower levels.

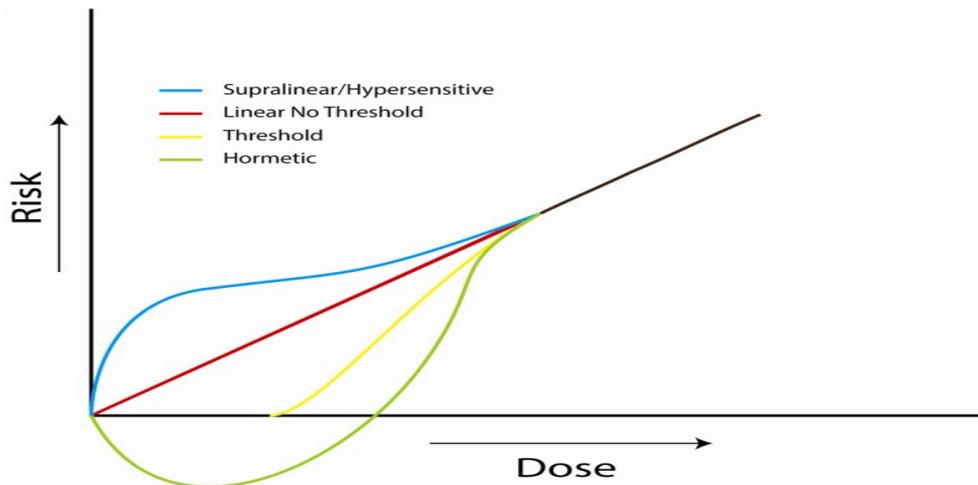
Cancer risks from radon have been historically studied using epidemiological evidence from cohort studies of underground miners in the 1960s however there is evidence of high lung cancer prevalence in miners going back to the 16th century (IARC Monograph,

2012). More recent studies have been conducted using case-control studies of exposures to low doses of residential radon as well as experimental animals exposed to radon. In a combined analysis of case control studies examining the link between radon exposure and lung cancer risk, a significant increase in risk of lung cancer was associated with increased radon exposures (Al-Zoughool and Krewski, 2009). There is no safe level of radon exposure.

1.1.1. *Biological Mechanisms and Risk Model*

As radon-222 decays it emits high levels of alpha radiation and lower levels of beta and gamma radiation (Robertson et.al. 2013). Alpha particles released can cause significant biological damage to exposed tissue; they react with DNA when inhaled into the lungs (Robertson et.al, 2013). The resulting ionizing radiation can cause DNA damage through chromosomal aberrations, double strand DNA breaks, generative reactive oxygen species resulting in an increased chance of carcinogenesis (Robertson et.al, 2013).

The current radon risk model estimates radon risk at low exposures through a linear no threshold model, where potential risks is extrapolated from risks at higher exposure levels (Robertson et.al, 2013). There have been suggestions that there are some protective (hormetic) influences of beneficial cellular mechanisms at lower doses or that similarly there could be hypersensitive responses which increase biological damage at lower levels (supralinear) (Robertson et al, 2013).



Graph from Robertson et.al., 2013

1.1.2. Population Attributable Risk

Peterson et.al (2013) studied the population attributable risk (PAR) for radon in Ontario. As no such study exists for British Columbia I will use the Ontario example as a proxy.

The PAR is an important concept for radon as a public health problem. Many of the lung cancer deaths from radon come from exposures well below the 200Bq/m³ guidelines recommended by Health Canada and even below the 100 Bq/m³ guidelines recommended by the WHO. In Ontario it was found that if all homes above the 200Bq/m³ guideline were remediated 91 lung cancer deaths would be prevented, remediating above 100Bq/m³ would result in 233 deaths prevented and remediating above 50Bq/m³ would prevent 389 lung cancer deaths annually (Petersen et.al, 2013). The biggest impact on reducing lung cancer deaths from radon occur when action is taken at levels of radon exposure lower than the recommended “safe guidelines”.

1.2. Introduction to the Public Health Problem

Early studies of the health effects of radon focused on miners and occupational exposures. While there was increasingly convincing evidence for the link between radon exposure and lung cancer, radon seemed firmly entrenched as an occupational exposure and not as a health risk to the general population (Scheberle, 2004). In 1984 a construction worker at a nuclear generating plant in Pennsylvania set off the radiation monitor as he was entering the facility and before the facility was fully functional and producing radiation. While officials scrambled to find the source of the radiation inside the facility with no success, his home was tested for radiation. It was discovered that the levels of radiation inside his home were 100 times the levels of exposure acceptable for uranium miners (Scheberle, 2004). This catalyzing incident resulted in public demonstrations at a local level and increasing levels of media attention focused on the dangers of radon, leading to the formation of the Radon Action Program at the US EPA in 1985 (Scheberle, 2004).

In the 1980s there was a lack of information on the risks of indoor radon exposure on the general population (Zielinski et. al., 2006). Initial case control studies had mixed findings and did not provide conclusive evidence of the risks of radon exposure (Zielinski et. al., 2006). Each individual study had small sample sizes and struggled with uncertainties in the radon exposure measurements but when the analyses were pooled and adjustments for measurement errors made, the risk estimates for radon increased substantially (Al-Zoughool and Krewski, 2009). Combined analysis of studies conducted in North America (Krewski et al., 2005), Europe (Darby et.al, 2004) and China involving a total of 12,000 cases and 21,000 controls have been pooled for analysis (Zielinski et. al., 2006). It is now accepted by the scientific community that tens of thousands of lung cancer deaths each year are a direct result of radon exposure (Zielinski et. al., 2006). In the mid-1990s on the back of the emerging evidence, the WHO established their International Radon Project with the goals of developing public health policy and resources including a database of residential radon levels, regulations, estimation of the global disease burden and public health guidance for awareness and mitigation (Zielinski et. al., 2006).

While the US EPA and the WHO established programs in the 1980s and the early 1990s, Canada has been slow to implement national guidelines and actions on radon. A national radon program (NRP) was established to support research, education and public awareness of radon but not until the early 2000s (Chen et.al, 2015). It was only in 2007 that Canada dropped their guideline for acceptable level of radon in indoor air from 800 Bq/m³ to 200 Bq/m³ (Copes and Scott, 2007). This level is still higher than the WHO at 100Bq/m³ and the USA at 150Bq/m³.

Radon exposure is a difficult public health issue to galvanize public action even though it is a known carcinogen and exposure is preventable; it provokes very little outrage (Copes and Scott, 2007). Because radon gas is naturally occurring, is undetectable by smell or sight, takes years for the exposure to lead to the disease and does not result in an immediate catastrophic event it has a perceived risk that is less than the actual risk (Copes and Scott, 2007).

A major problem for public health is that in a 2014 survey conducted by the Canadian Cancer Society only 4% of 1238 respondents had tested their homes for radon and only 15% were aware that radon was the second leading cause of lung cancer (Eggerston,

2015). A survey conducted in 2011 by the Homeowner Protection Centre showed that 92% of homeowners were not aware of radon as an issue. Awareness of radon as a carcinogen is in its infancy in Canada.

Tobacco use, coupled with radon exposure, is another concern for public health. The Lung Association of BC (2015) and the Canadian Cancer Society (2015) state that a lifelong smoker not exposed to radon has a one in eight risk of developing lung cancer, which increases to a one in three risk when also exposed to radon. This differs dramatically from the one in twenty risk of lung cancer for a non-smoker exposed to high levels of radon. There is a strong synergistic relationship between radon exposure and smoking. It is estimated that 86% of radon related cancer deaths are in current and former smokers (Lantz et.al, 2013).

1.3. Testing and Remediation

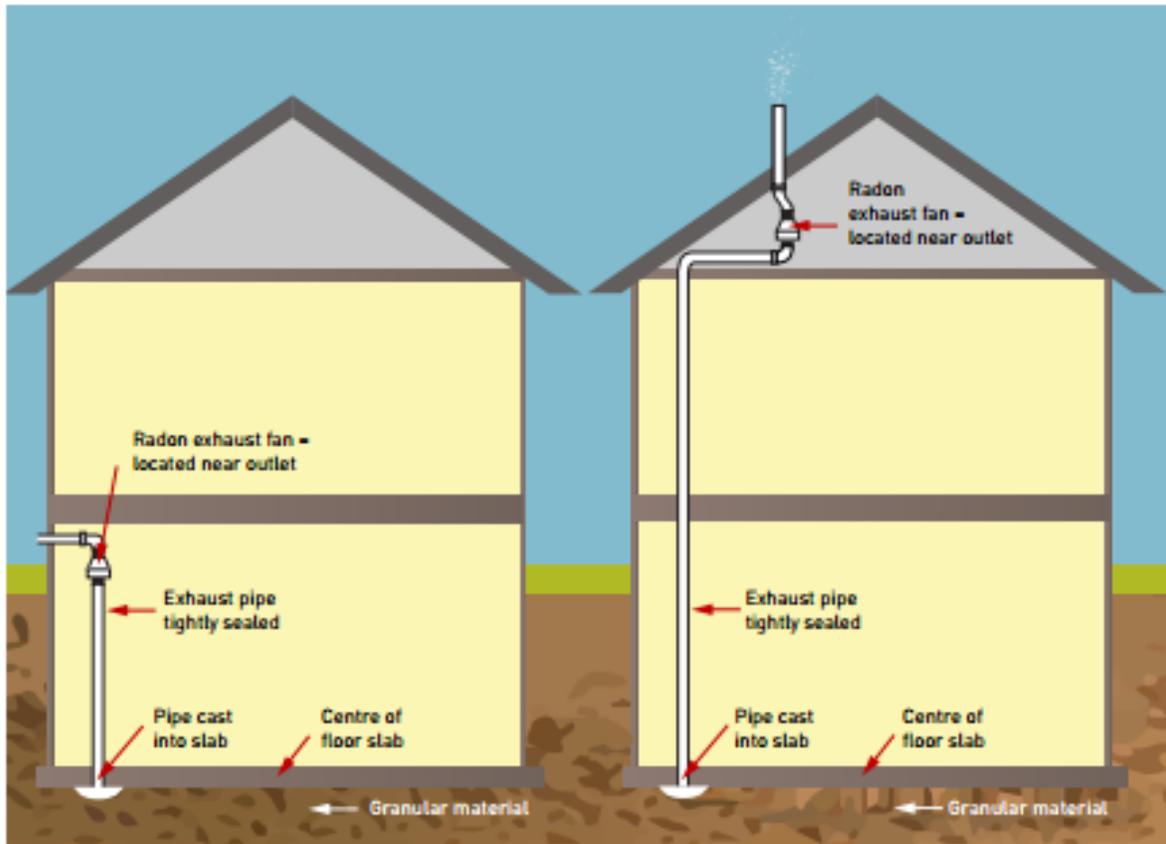
Accurate testing of indoor radon is a challenge because the concentration can vary hourly, daily, seasonally, and by location of test, because of building ventilation and even atmospheric conditions (Air Quality and Health Workshop, 2012).

The standard method for testing indoor radon levels is by long-term passive alpha track detectors. The detector should be placed in the lowest lived-in level of the home in an area that is likely to not be disturbed during the length of the test (CMHC, 2010). The detectors should not be placed on an outside wall, in a kitchen or bathroom, near a floor drain, in drafts from heating or cooling vents or sources of heat such as fireplaces or stoves as all of these conditions can affect the validity of the test (CMHC, 2010). The testing should be done over approximately 3 months and during the winter months when houses are sealed up tighter and have less air flow through doors and windows.

There are short term tests available, which take 7 days, but Health Canada recommends that they are followed up with a long term test if results are high, to ensure accuracy (www.radoncontrol.ca). The radon industry is also marketing a digital radon monitor that will give daily, weekly and yearly measures of radon levels in a home. At almost \$300 the cost could be a barrier to many families (www.radoncontrol.ca).

Remediation of homes that have radon levels above the guideline of 200Bq/m³ should ideally be completed by a trained radon mitigation specialist. In Canada, the Canadian National Radon Proficiency Program (C-NRPP) is responsible for training, best practices and certifying Radon Mitigation Professionals and Radon Measurement Professionals (C-NRPP, 2015). They are supported by the Canadian Association of Radon Scientists and Technologists (CARST), which supports radon professional working in Canada (CARST, 2015). Currently there are 251 Certified Radon Measurement Professionals and 133 Certified Radon Mitigation Professionals registered in Canada (CARST, 2015). In many locations across Canada there are no certified Radon Professionals. It is possible to do the remediation work or to hire a contractor to do the work. The Canadian Mortgage and Housing Corporation (CMHC) has developed a comprehensive guide to remediation (CMHC, 2010).

When remediating a home the goal is to eliminate openings to the soil through the foundation and to decrease the pressure in the soil beneath the building so that radon gas no longer enters the building (Air Quality and Health Workshop, 2012). This can be accomplished in a number of ways, including a simple exhaust fan diverting air from the crawlspace or basement to the outdoors, increasing the mechanical ventilation in the home, sealing cracks and open sumps in the basement or installing a sub slab depressurization system (Air Quality and Health Workshop, 2012)(CMHC, 2010). The remediation method selected will depend on routes of radon entry, cost involved, severity of the problem and energy costs to run the system. Sometimes several methods will need to be employed to fix the problem efficiently (CMHC, 2010).



Basic Diagram of a Sub Slab Depressurization System (Health Canada, 2015)

2. Methodology

2.1. Goal and Objectives

The goal of this paper is to provide a comprehensive resource for health promotion professionals tackling the issue of radon, using British Columbia as a case study. This goal will be met by achieving the following objectives:

- Critically reviewing the literature on radon and health risks to accurately describe the current health burden and distribution of radon in British Columbia
- Critically reviewing the current programs and organizations working to prevent radon exposure in British Columbia
- Discussion of the Ottawa Charter for Health Promotion in the context of radon
- Identifying barriers to radon exposure prevention
- Offering a set of recommendations to mitigate the barriers to radon exposure prevention and improve knowledge translation

2.1.1. *Critical Literature Review*

To explore and answer the question of interest a critical literature review was conducted. There were two main areas of interest for the critical literature review: the effect of indoor radon exposure on health and risk reduction behaviours. The articles were obtained using scholarly databases (e.g. MEDLINE, Psych INFO). The key search terms used for the first area of interest were 'radon', 'radon awareness', 'radon Canada' and 'radon health effects'. The key search terms used for the second area of interest were 'radon prevention', 'radon risk reduction behaviours', 'environmental health risk reduction', 'environmental health promotion' and 'radon risk communication'. Literature was excluded from the search if the primary content was related to mitigation practices,

radon testing standards, dosimetry, or focused on prevalence in countries other than Canada. Additionally documents and reports from a variety of government agencies such as the World Health Organization (WHO), Health Canada (HC), the Environmental Protection Agency (EPA), the International Agency for Research on Cancer (IARC), Work Safe BC, and the British Columbia Centre for Disease Control (BCCDC) were reviewed for specific information relating to current studies, best practices and policies.

2.1.2. *Review of Programs and Services*

Many non-profit agencies, building associations and research agencies in British Columbia and Canada have established radon programs or activities. In particular, the Canadian Cancer Society, the BC Lung Association, Work Safe BC, the David Suzuki Foundation, the Northern and Interior Health Authorities, the BC Centre for Disease Control, Health Canada and the Canada Mortgage and Housing Corporation (CHMC) have been working to reduce the impact of radon in the province. To develop a comprehensive picture of the work being done in the province a review of these organizations' current publications and websites as well as a series of informal interviews with key informants from of several these organizations were conducted.

3. Radon in British Columbia

3.1. The Health Burden of Radon in British Columbia

Radon is second only to smoking as the main cause of lung cancer in Canada (Krewski, et al., 2005), causing approximately 10% of lung cancer cases in Canada, which translates to roughly 2000 cases a year (Krewski, et al., 2005). In British Columbia an estimated 2500 people will die of lung cancer in 2015, approximately 250 of these can be attributed to radon (Canadian Cancer Society, 2015).

3.2. Distribution of Radon in British Columbia

Indoor radon measurement data in Canada have been collected by Health Canada since 2003 (Chen et.al, 2008). The data is collected with the help of provincial governments, non-profits and the radon-testing industry. The Cross Canada Survey of Radon Concentration in Homes was published by Health Canada in 2012. The results show that there are no areas of the country that are radon-free. In British Columbia 7.9% of the homes tested had radon levels greater than Canada's guideline of 200Bq/m³ (Health Canada, 2012). The second method of radon distribution maps the geology, aerial gamma ray spectrometry and stream and lake sediment geochemistry (Hystad et. al., 2014). This method classes geographic areas into low, medium and high levels of radon vulnerability (Branion-Calles et.al., 2015).

Researchers at the British Columbia Centre for Disease Control (BCCDC) have developed a more detailed model than the previous radon potential maps, which predicts radon concentrations based on 12 factors including information about the soil composition, winter temperatures and precipitation levels, dominant age of homes and the proportion of homes in need of major repairs (Branion-Calles et.al., 2015).

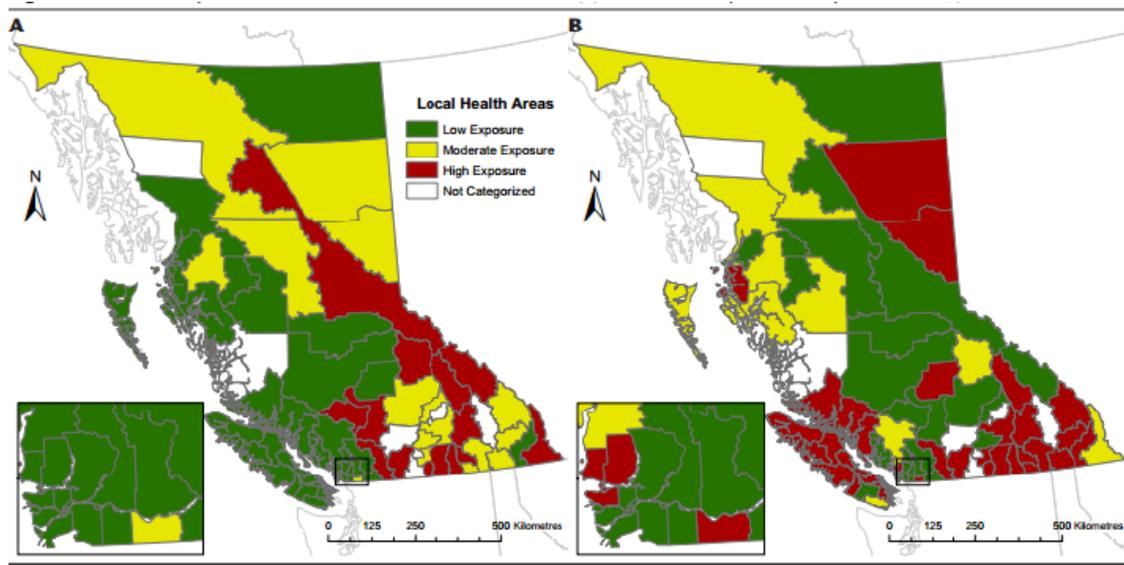


Figure 1: Radon Exposure classifications (A) household-measurement based (B) radon potential map of Canada (from Rausch and Henderson, 2013)

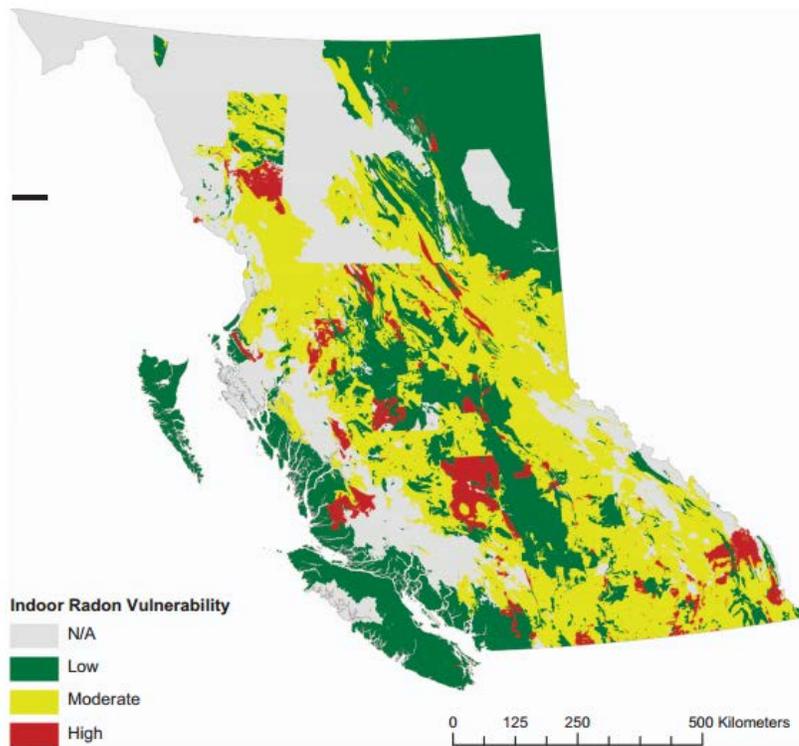


Figure 2: Indoor radon vulnerability map based on BCCDC model (from: Brannion-Calles et.al., 2015)

While mapping and measuring radon levels can be helpful tools to identify higher risk areas, there are no radon free areas in British Columbia. Health Canada has shown that 95% of Health Regions have had at least one home test above the 200 Bq/m³ guideline

(Air Quality and Health Workshop, 2012). If a home has contact with the ground there will be some radon exposure, the question is how much. As two houses in the same neighbourhood can have drastically different radon levels the only way to know the level of exposure is to test each individual home (Health Canada, 2015).

3.3. Existing Radon Awareness and Management Programs

There are radon awareness and management programs at the national, provincial and municipal level. The Federal Government has responsibility and jurisdiction over policy development for radon measurement, certification of mitigation professionals, mitigation guidelines and federal building codes. It also conducts research on the radon burden in Canada and produce educational materials for the public and special interest groups.

The BC Provincial Government has jurisdiction over health programs and provincial building codes, and currently outsources the responsibility for education and awareness to the BC Lung Association, funding their Radon Aware program. This program advocates to local governments and industry representatives, produces education materials and in the past has hosted educational forums around the province.

3.3.1. *Health Canada (National)*

Health Canada has a Radiation Health Assessment Division that is tasked with promoting and protecting the health of Canadians by assessing and managing risks posed by radiation exposure. The National Radon Program (NRP) has been responsible for testing all federal buildings to identify federal workplaces requiring remediation (Health Canada, 2015). Over 1, 431 buildings have been tested with approximately 7% testing above the 200Bq/m³ guidelines and requiring remediation (Health Canada, 2015). The NRP has also completed a two year project to gather long term measurements of radon concentrations from 14,000 households across Canada. The survey results have been published and used to inform radon vulnerability maps as well as a host of print and web based materials to be used for public awareness (Health Canada, 2012). Health Canada's public awareness strategy is targeted to homeowners, health professionals and the building industry. Health Canada representatives also attend trade shows and public forums to help share information about the health risks of

radon and what homeowners can do to minimize their risk. There are limitations on what Health Canada can do with their resources. It relies heavily on the provinces, non-profits and local organizations to work in smaller communities.

3.3.2. *Canada Mortgage and Housing Corporation (National)*

The Canadian Mortgage and Housing Corporation (CMHC), in partnership with Health Canada, have developed a guide to radon management for Canadian homeowners. It clearly lays out how to measure radon levels, how to reduce radon levels and how to deal with contractors (CMHC, 2010). CMHC has been researching effective ways to protect homes from radon exposure for over 20 years (Tracy et.al, 2006). It has contributed to rewriting the national building code with respect to soil gas problems (Tracy et. al, 2006). The challenge for radon advocates is to get radon code written into all provincial and municipal building codes.

3.3.3. *Canadian Association of Radon Scientists and Technologists (National)*

The Canadian Association of Radon Scientists and Technologists (CARST) is a national association with the goals of promoting public awareness of radon measurement, and ensuring quality standards are developed and adopted in radon measurement, radon mitigation and in construction of new radon reduction techniques. It provides a community for education, sharing of ideas, resources and research. CARST provides an effective partnership between radon professionals in the field and other interested public and private organizations (such as Health Canada, Canada Mortgage and Housing Corporation, and others) (CARST, 2015). CARST hosts an annual conference where professionals from industry and radon experts from around the world can come together and collaborate on public health policy, newest technological advances and current research.

3.3.4. *David Suzuki Foundation (National)*

The David Suzuki Foundation has been involved with radon awareness and advocacy initiatives since 2007 (David Suzuki Foundation, 2015). Its main focus has been on advocating to the federal government to lower the Health Canada radon action level to

100Bq/m³ in line with European standards and WHO recommendations (David Suzuki Foundation, 2015). It also works to raise awareness and break down information for homeowners into a simple three step process (David Suzuki Foundation, 2015).

The infographic is a vertical banner with three distinct sections. The top section is light blue and features a house icon in a circle. The middle section is a darker blue and features a radiation warning symbol in a circle. The bottom section is the darkest blue and features a person wearing a hard hat and safety vest in a circle. Each section contains a numbered heading and a brief description of the step.

- 1. BUY A RADON DETECTOR**
Test your home for radon. One-time radon test kits are available from some hardware stores, businesses specializing in radon detection and mitigation, the Radiation Safety Institute and many lung associations across Canada for \$30 to \$60.
- 2. MEASURE CONCENTRATIONS**
Measure concentrations over a period of at least 90 days, ideally during cooler seasons when windows are closed.
- 3. TAKE ACTION**
If test results show elevated levels of radon, look for a certified radon professional in your area to advise you on mitigation options.

Recommendations to Canadian home owners (David Suzuki Foundation, 2015).

3.3.5. *British Columbia Centre for Disease Control (BCCDC) (Provincial)*

The British Columbia Centre for Disease Control (BCCDC) has been heavily involved in research to map and model the distribution of radon in British Columbia, including a new model published in 2015, which is the most accurate predictor of population level radon distribution (Brannion-Calles, 2015). The BCCDC has been working heavily with partners at the provincial health authorities and non-profits to get testing kits out to the population and the results back to the BCCDC for analysis. The National Collaborating Centre for Environmental Health (NCCEH) is housed at the BCCDC and has produced several reports of recommendations for radon testing and mitigation in schools and other public buildings.

3.3.6. *The Lung Association of British Columbia (Provincial)*

The Lung Association of British Columbia (LABC) has been the most active promoter of radon awareness in the province. It has put together an information campaign that travels around the province to bring knowledge of radon to building trade shows and community events. The LABC has an active radon awareness program that has been funded by the provincial government to conduct studies of radon exposure in high risk

communities such as Prince George and Castlegar. The results show that for Prince George 1436 out of 2000 tests distributed were returned and 29% of these had radon levels above the Health Canada action level of 200Bq/m³ (LABC, 2014). For one particular postal code in Prince George 56% of the 502 tested homes were above the action level (LABC, 2014). The results show that for Castlegar 148 of 230 test kits were returned and 59% of these had radon levels above the Health Canada action level of 200Bq/m³ (LABC, 2014). These two studies help to build further awareness of radon as a health issue in British Columbia communities.

The LABC strategy for awareness targets local governments, BC residents, building professionals and policy makers (Radon Aware, 2015).

3.3.7. *The Canadian Cancer Society, BC and Yukon Division (Provincial)*

The Canadian Cancer Society BC and Yukon (CCS BCY) has been working in partnership with the LABC to increase awareness of radon across the province. The CCS BCY commissioned public awareness surveys to determine the level of awareness of radon across the province. With support from Health Canada it have trained 16 new mitigation specialists in Cranbrook by remediating a local home (CCSBCY, 2015). Currently it is working to build capacity in the construction industry to support and train building inspectors and building mitigators, working with homeowners to test more residential properties and to support and raise awareness of radon with the real estate industry (CCS BCY, 2015).

The CCS BCY is conducting a survey of BC Radon stakeholders to determine and develop policies for advocacy work going forward.

3.3.8. *The Northern and Interior Health Authorities (Regional)*

The Interior Health Authority (IHA) has piloted a project to test all daycares in their region. Of the 852 daycares in the region, 360 returned their tests for analysis and 11% or 39 daycares tested over the Health Canada action level (Batalyan, 2015). The IHA has taken an active role in promoting radon awareness across the region trying out

creative approaches such as a radon poster competition in area schools (Batalyan, 2011).

The Northern Health Authority (NHA) has partnered with the BCCDC and the LABC to distribute radon test kits for their research studies as well as to promote radon awareness in Prince George and the surrounding areas. They have been funded by the BC Cancer Agency as part of the Northern Cancer Control Strategy to sell radon test kits throughout the northern region (NHA, 2015). The Northern Cancer Control Strategy funding has allowed northern health to attend home shows, health fairs, community presentations, and develop collaborative partnerships in an effort to increase radon awareness (Air Quality and Health Workshop, 2012).

3.3.9. *The Donna Schmidt Memorial Lung Cancer Prevention Society (Local)*

The Donna Schmidt Memorial Lung Cancer Prevention Society was founded by Dana Schmidt after his wife died of lung cancer due to radon, the fund distributes test kits free of charge to anyone residing in the Castlegar region of BC. The money raised is also used to help residents refit their homes if high radon levels are detected (Air Quality and Health Workshop, 2012). Dana Schmidt has been a pioneer in radon awareness and testing, bringing a personal face and passion to the public health problem.

4. Discussion

4.1. Gap between awareness and action

At the 2012 Air Quality and Health Workshop in Vancouver, many of the presenters spoke of the gap between awareness of the health effects of radon and taking action to protect against risks. I would also argue that there is an initial gap in awareness of radon outside of identified high risk communities, which still sits around 10% awareness of radon across the country, leaving 90% of the population unaware (Homeowner Protection Centre, 2011).

The Homeowner Protection Centre (2011) has produced a decision tree (Appendix A) that shows all the points at which a person may drop out of the decision making process if they are lacking in knowledge. Three critical points include learning about radon as an issue, deciding to test and deciding to remediate (Homeowner Protection Centre, 2011). Other critical concerns include optimistic bias, the fact that there is no safe level of exposure and the long latency period of radon exposure. There are many factors that could explain this inaction. Key to the issue of radon is that multiple actions need to be taken to ensure protection. There is no quick fix that can be purchased or handed out.

4.1.1. Education and Awareness

To date the majority of the education and awareness initiatives in the province have focused on getting information about radon to homeowners in high risk communities. Print materials handed out at trade shows, through building associations and through municipal governments have been the preferred methods of information dissemination. In the case of radon there needs to be more than just an awareness of the problem. People need to care about radon as an issue and be concerned that it could have a devastating effect on their families and their health. In order to get people motivated to seek out action after initial awareness, health promotion initiatives need to answer the

question of why should I care? Print materials are not the way to personally engage people in radon prevention. Best practice for raising awareness is to assess, through public survey, the target audience's current perceptions of radon risk, health effects and willingness to test and to target the awareness campaign accordingly (WHO, 2009). Unfortunately in British Columbia the funding does not exist to accurately assess the public's perception of radon. Where the message is lost in translation is when organizations are targeting their campaign on getting people to test their houses when they do not yet have a strong enough understanding of radon as an issue (WHO, 2009). There is a mismatch between public perception of radon and the health promotion message.

4.1.2. **Poster Contest for students**

The University of Kansas puts on an annual national poster competition for high school students about Radon. This was attempted on a smaller scale in the Interior Health Authority. A poster competition is a great idea as long as there is education and support given to the students. If the goal is to raise awareness and have students educate their families about the risks of radon, they should have the factual information correct. They should also not be scared but informed (poster below 2012 winner).



4.1.3. Deciding to test

Weinstein et al. (1998) tested the precaution adoption process model (PAPM) on home radon testing. The precaution adoption process model has seven stages 1) unaware of the health action; 2) aware but not personally engaged; 3) engaged and trying to decide what to do; 4) decided not to act; 5) decided to act but have not yet acted; 6) acting; and 7) maintaining the new health-protective behaviour (Weinstein et.al, 1998). They hypothesize that adoption of health protective behaviours is too complex to be explained with a simple equation and that different strategies must be employed at each stage of the model. They showed that by matching an intervention to the stage of the model people were more likely to take action (Weinstein et.al, 1998). For example with radon testing categorizing people into these 7 categories can help tailor the message or identify barriers to action encountered at each step of the model.

Currently in British Columbia most residents are at stage 1 and 2 of this model; they may know what radon is but do not have a personal engagement with the problem. Where radon initiatives have been successful in BC are in communities that have been identified as high risk, such as Castlegar and Prince George. In these communities there are many personal stories of how radon exposure has affected residents' health, which are used to engage the community. Programs through the BCLA and CCS BCY are very effective in working with residents at stages 1-2.

In other countries and jurisdictions, social marketing campaigns that focused on the benefits of protecting your family, instead of focusing on the risks of radon, have been successful (WHO, 2009). A case study in Montana found that digital signage in strategic locations targeting at risk groups increased the purchase of radon test kits (Larsson, 2015).

4.1.4. Deciding to remediate

Cost of remediating homes and the lack of remediation professionals available as discussed above can be a barrier to taking further action. Often the perception is that remediation is prohibitively expensive, but on average the cost falls between 1,000-2,000 dollars (Homeowner Protection Centre, 2011). However, when someone decides to act there are not enough resources in place. There are currently only 133 certified

radon remediation professionals across Canada. While C-NRPP is working to educate and certify more professionals it is currently a barrier to action. The other barrier at this stage is simply the lack of people who have reached the stage of remediation. In a 2014 survey by the Canadian Cancer Society only 4% of respondents had tested their homes for radon.

4.1.5. *Optimistic bias*

Optimistic bias, the belief that your own risks are less than the risks of your peers has been studied with people's perceptions of radon. When people were asked if they thought their risk of radon exposure was above average, average or below average, 50.6% believed they were below average, 43.7% believed they were at average risk and only 5.8% said their risk as above average (Weinstein et.al, 1998). Even though information presented can convince people that there are serious risks related to radon exposures there is resistance to the belief that they are at risk themselves (Weinstein et.al, 1998). With optimistic bias there is also the risk that it can increase the more information people are provided (Weinstein et. al, 1998).

The radon distribution maps presented earlier, while a great tool for focused and targeted radon campaigns and for predicting higher than average concentrations of radon and radon exposure risk, can also contribute to optimistic bias. When people look at the maps and see that their area is green it offers a false sense of security. Radon exists in all areas of the province, not just in the areas marked higher risk.

If your entire neighbourhood tested with low levels of radon why would you also decide to test? People think that if their neighbour tested and has low levels of radon they should be fine. Radon levels are determined by not only geography but also construction practices resulting in dramatically different radon levels on the same street.

4.1.6. *No safe level of radon exposure, latency period*

Another overlooked factor is that there is no safe level of radon exposure – the majority of cancers are caused by low and moderate long term radon exposure, very few have high exposure (WHO, 2009). So while Health Canada recommends taking action at a level of 200Bq/m³, the recommendation is based on having a target or goal and not on

safe exposure levels. Recent studies have shown that 95% of cancer cases from radon occurred at an exposure level of below 200Bq/m³ (CARST, 2015). Implementing a threshold amount is useful because to say that there is no safe level of exposure and also that it is impossible to eliminate all radon from the air is a contradictory and not helpful message for public health (Neznal and Neznal, 2008). However the threshold amount should be lower than the current amount recommended by Health Canada.

Radon has a very long latency period so there are no discernible health effects until a lung cancer diagnosis is made. It is difficult to press upon people the urgency and importance of a problem when the negative outcome will not manifest for decades.

4.2. Equity – social determinants

There has not been a study conducted in Canada looking at the demographics of people who are more likely to be exposed to radon gas or who are in less of a position to take control over their exposure risks.

Several reports have identified certain high risk factors for radon exposure. Basement suites are more likely to have higher levels of radon, and are often occupied by renters or tenants of lower socioeconomic status. Renters do not have any protection for radon exposure built in to their tenancy agreements. If they test for radon levels and find they are elevated they are at the mercy of their landlord to remediate.

Homes on reserves are under sampled when sampling from the general population for radon levels is occurring (Health Canada). The First Nations Health Authority (FNHA) has responsibility for the health of First Nations people on reserves. The FNHA employs environmental health officers who are tasked with healthy housing as part of their mandate. Their focus is on safe drinking water, mold, communicable disease control, food safety, waste disposal, and sewage systems (FNHA, 2015). Radon is a less important priority when there are imminent threats to public health.

Radon awareness materials in British Columbia are almost entirely in English and targeted primarily to an educated male audience. A study conducted in 1994 in the USA looking at perception of environmental health risks based on race and gender found that

white men produced mean risk perception rating that were lower than white women, women of colour and men of colour (Flynn et.al, 1994). The theory they put forth is that white men see less risk in the world because they create, manage and control large aspects of it (Flynn et.al, 1994). Health promotion professionals are missing a large portion of their intended audience who may be more likely to take action to mitigate the risks of radon to their health.

A study of risk perception in high vs. low numerate populations (Keller et.al, 2009) points to using graphical displays to communicate risk more effectively. They developed a risk ladder (Appendix B) that compared the risks of smoking with the risks of radon exposure. This risk ladder was better able to communicate accurate risk perception to low numeracy populations (Keller et.al, 2009).

4.3. Testing, building and remediation

As of January 2015, building codes in British Columbia have radon requirements for new construction. Developers are required to rough-in subfloor depressurization systems and vent pipes to the outdoors (Government of BC Bulletin, 2014). However it is only required for new construction and only in the parts of the province deemed to be high risk for radon. While these regulations are the toughest and most protective in Canada they still do not go far enough (LABC, 2015). Federal building codes recommend that new home construction have radon mitigation measures in place but they are not enforced (NCCEH, 2008).

Radon testing takes several months and is most accurate when done in the winter months. This makes it less likely that the testing will be performed. After deciding to test the home residents need to find a radon test kit (not readily available in local hardware stores, often only online), follow the many step directions and conditions on where to place the device, remember that the device is there, when the test is over package up the detector properly and mail away to a lab for results. If all these steps are done correctly and at the appropriate time, residents will be mailed the results of their test. A further barrier however is that the results of the test may show that you have elevated

levels of radon in your home but with no explanation of what needs to be done to decrease them.

The Lung Association of BC is currently advocating for greater use of short term but potentially less accurate radon tests in order to reduce the testing barrier (LABC, 2015).

There is still a lack of mitigation professionals; this industry is still in its infancy. It is a chicken and egg scenario where until demand is higher more contractors will not pay for certification. However, until there are mitigation professionals certified in every community and available to remediate properties, the demand will not grow. There are guidelines for do-it-yourself remediation and for uncertified contractors to follow but it is still a barrier that a simple low-cost solution might not be available.

4.4. What is the role of health promotion in radon policy and research?

Advocacy groups have seen a great deal of success in getting the federal government to lower the Health Canada recommended action level from 800bq/m³ to 200bq/m³. Organizations like CARST have united radon stakeholders nationwide to pool resources and research, pushed for a consistent health promotion message about radon coming from all groups, and developed a Canadian training program to address the lack of mitigation experts.

Changes in policy have the potential to reduce exposures across the entire population. Until now most radon work in Canada has been focused on building awareness of radon as a public health problem. The goal of public health moving forward should be to focus on reducing barriers to take action at a population level. When tests come back to the labs we get a snapshot of radon concentrations in that one home, that one community. What is missing from the research is the evaluation of what is happening to all the tests that don't come back. We should be asking qualitative questions instead of collecting purely quantitative data. After the tests go out we should be following up to find out: Did you send your test back? Why or why not? If your test showed a level of radon greater than 200bq/m³ did you take steps to remediate? Why or why not? These answers should inform the direction of radon policy and research going forward.

4.5. The case for a Provincial Radon Program

Federally, radon is not a priority. Health Canada is not moving on anything new or substantial. Policy wise there is no movement towards lowering the acceptable levels of radon as stated in the guidelines. Currently in the province of British Columbia there is no coordinated radon program. The Radon Aware program is funded by the Provincial Government and run by the BC Lung Association. This funding is being diminished year after year. The lack of resources makes it difficult to launch a comprehensive health promotion initiative.

The BC Centre for Disease Control, the Lung Association of BC and Health Canada do work together to keep each other informed of their programs but there is no fully integrated national to provincial to local program. There seems to be a strong culture of communication between groups but a long way to go before there is a culture and practice of deep collaboration. The organizations I spoke with (LABC, CCS BCY, and HC) were well informed of the other groups programs but were still duplicating many aspects of their education and awareness programs.

With the decrease in funding the strategy of the Radon Aware program has recently changed to focus on leveraging partnerships. A main priority is moving towards work on the built environment and planning departments of local governments in higher risk areas. The BC Lung Association is working with the radon industry to make the training program for mitigators more accessible and with real estate agents and home inspectors to get radon on their priority list for home inspections. The reach and impact that these two groups have would be more influential than awareness campaigns targeted to individual homeowners.

A three pronged program of research, advocacy and education, coordinated province wide with each partner playing to their strengths could make a significant impact on radon awareness and policies. The BCCDC has long been focused on research and the science behind radon exposure but not outreach to the general public. The BC Lung association is strong in mobilizing communities and volunteers as well as having connections at the local government level. The David Suzuki Foundation and the

Canadian Cancer Society have solid reputations in BC for lobbying the provincial government for changing legislation.

A provincial program that focuses on educating the home building and renovating industry, certifying more mitigators, advocating for short term testing for radon added to standard home inspections and backing up these methods with research and evaluation instead of focusing campaigns on individual awareness could significantly reduce radon exposure in British Columbia.

Prior to researching this paper I had a solid idea that awareness of radon was not leading to taking action. What I have realized since reading and reviewing the literature and programs is that awareness of radon is still in its infancy in Canada. Working to getting people to take action is secondary to raising awareness and understanding of the risks of radon. Recent surveys showing that only 10-15% (CCS, 2014) of Canadians are aware of radon as an issue – this is too low for concrete action to be taken. The focus going forward should be on advocating for provincial legislation that will protect the public as a whole and not focus on changing individual behaviours. Focus should also be on raising awareness amongst the groups that can make a difference on a macro level such as real estate boards, local governments, home inspectors and the building industry.

4.5.1. *Priorities for a Provincial Program*

The program identified above would be the ideal solution, a multipronged approach covering 100% of the population. With funding shortfalls and other provincial and national priorities taking precedence the goal of having every home tested in BC and Canada is unlikely to be realized in the near future. Prioritizing vulnerable populations by testing all daycares, schools and public housing units is the place to start. Second priority would be testing all homes on reserves. Vulnerable populations do not have a great amount choice of where they live and are less likely to be informed of the risks of radon or the means to do anything about their risk.

4.5.2. Coordinated US Federal Radon Program

The United States has developed a coordinated national strategy that would be a good model for Canada and BC to emulate. They have enlisted 9 different federal agencies to commit to radon action and update their progress. Below are the agencies that have signed on and their areas of responsibility.

- Department of Defense – on military base education and remediation
- Department of Energy – Research, radon protocols and training
- Environmental Protection Agency – Standards of Practice
- Department of Agriculture – rural housing properties
- General Services Administration – Daycares
- Health and Human Services – Healthy Homes initiative, cancer control programs
- Department of Housing and Urban Development – public housing radon testing
- Bureau of Indian Affairs – testing/remediating tribal schools and residences
- Veterans Affairs – testing and mitigation through home loan program for veterans

4.6. Ottawa Charter for Health Promotion – Actions

4.6.1. Build healthy public policy

The work that has been done building healthy public policy in radon is in its infancy. Lowering the radon level guideline for mediation from 800Bq/m³ to 200Bq/m³ is a start but still leaves Canada above the WHO recommended level and, as has been established, there is no safe level of radon exposure. Building codes and policies in Canada are not uniformly written nor are they uniformly enforced. While BC has some of the tighter restrictions on radon prevention at the building stage, they are only applicable to some parts of the province and only apply to new construction. There is currently no requirement to have homes tested for radon as part of building inspections or during real estate transactions. At all levels of government and in all sectors of the building industry, radon policies need to be developed and enforced. Promotion of healthy policies through tax breaks or subsidies for remediation would help in gaining the support of industry.

4.6.2. Create supportive environments

A supportive environment for radon health promotion would be having an abundance of information sources all consistently giving the same message so that the public is aware

of radon as an issue. But it must go even further. A supportive environment would have tests available in many locations hardware stores, health centres, through non-profits, through local government structures, through health inspections and through real estate agents. The ideal environment would have radon mitigation professionals available and ready to get to work at the convenience of the homeowner. Cinching the mesh on the net tight, so that at every stage of the radon continuum from awareness to testing to remediation there are constant reminders and supports and people do not slip through the gaps.

4.6.3. *Strengthen community action*

Where radon health promotion actions have been the most successful is where there has been sustained community engagement with the issue. Castlegar is a key example of governments, non-profits and community organizations all working together to educate their residents, provide test kits and instructions, offer subsidies for remediation and advocate for healthy policies. The social support was as important as the material supports offered. Making radon everyone's problem galvanized community involvement.

4.6.4. *Develop personal skills*

Health literacy is an important skill to be able to obtain and understand health promotion information in order to make healthy decisions. In this area public health professionals have a role to play in translating knowledge to the general public in a way that clearly conveys the importance of the issue, that people can understand the consequences of inaction, and motivates people to take corrective action. It is not enough to tell people they must take action it is imperative that people understand the risk to personal health that radon poses so that they can take control of their own health.

4.6.5. *Reorient health services*

The Regional Health Authorities in BC do not see health promotion as a top priority and radon falls very far down their list. Only the northern health authority and interior health authority currently have any sort of radon programs and in each of these two health authorities the radon portfolio has been given to one individual who has radon listed as a small portion of a much bigger portfolio. To have greater impact resources need to be

allocated throughout the health authorities making use of already in place education and awareness programs and channels.

5. Recommendations for Public Health Action

5.1. Nationally

1. A coordinated national effort to make radon awareness a priority is the key to further action. Next steps need to be a coordinated federal campaign with support and resources in place to address the problem.
2. Health Canada should lower the health action level of 200bq/m³ to 100 bq/m³ in line with the WHO recommendation (WHO, 2009). There is no safe level of radon exposure. At this level more people will be protected against radon exposure.
3. Increase access to mitigation courses for professionals as well as do-it-yourself materials and tutorials. Currently only 133 radon mitigation professionals are certified in Canada.
4. Student radon poster competition, with appropriate educational component

5.2. Provincially

5. Provincial radon programs should be working together in a more integrated way than they currently are. There are multiple complimentary campaigns from the BC Lung Association, Canadian Cancer Society and the David Suzuki Foundation all with a slightly different focus. To combine resources and come out with one strong message with increased funding would be more effective than individual information campaigns.
6. Radon regulations should be enacted as part of the BC Tenancy Act. Requiring building owners and homeowners with basement suites to test regularly for radon levels and remediate if required.

7. Radon professionals should be working with real estate boards and agencies to have policies in place surrounding radon testing. In the USA radon levels need to be disclosed if known and can be a selling feature if they are low. Building inspectors should be looking for radon mitigation systems and radon risk potential, especially in high risk areas of the province.
8. Provincial governments should adopt the most recent federal guidelines for building codes and have them strictly enforced with the most up to date requirements for radon mitigation. BC has the most stringent building code of any province but it could be more strictly enforced.
9. Radon awareness and mitigation programs should be incorporated into the current work being done by FNHA environmental health officers.
10. Radon awareness should be incorporated into Environmental Health training at BCIT, UBC, SFU and other programs province wide.
11. School level education and outreach in the form of presentations and a poster contest in science classes.

5.3. Locally

12. Reporting on radon levels has typically been done using broad geographic areas. For health promotion activities knowing the radon levels on a community level is much more effective in mobilizing action (Henderson et.al, 2012). The case studies of Castlegar and Prince George show that when communities are involved in testing initiatives and information is known at the postal code level residents are more likely to act.

5.4. All levels of government

13. There should be financial incentives offered to test your home and to remediate. Homeowners and landlords should be reimbursed for the cost of the test once they have returned it for analysis, encouraging people to follow through with testing.

Remediation costs should be tax deductible and funding made available for low income residents to remediate if necessary.

14. All levels of government should enact legislation for workplaces, schools, daycares and government buildings to ensure that they are tested and if necessary remediated when the radon levels are greater than 100Bq/m³.
15. There needs to be an improvement of risk communication strategies, incorporating psychology and behaviour change models into information campaigns. Agencies across Canada are currently sending out the same message in the same way and it has so far not been widely successful. There needs to be a reduction in optimistic bias and a more realistic risk perception around radon. Communications should focus on the benefits of radon testing and remediation and not only the risks.
16. Most radon kits are currently sent to labs in the USA for analysis. If test kit results could be tailored with further information about radon mitigation professionals in their community or where to go for support and assistance homeowners may be more inclined to take action. Readout of results without context is not motivating to take action especially if the home tests close to the recommended levels.
17. As part of education on radon dangers provide mitigation education up front. Get the message out that mitigation can be quick and easy and not too costly, remove the barrier of fear right at the outset of learning about the issue. Have the message that it is a serious issue but one that can be easily fixed front and centre in the campaign.
18. Incorporate radon education materials into smoking cessation programs. Radon disproportionately affects smokers and targeting them as a high risk group could have a drastic effect on lung cancers attributable to radon exposure and smoking.
19. Adopt policies and support programs that are firmly aligned with a health promotion approach to taking action.

6. Critical Reflection

The Master in Public Health program at Simon Fraser University exposed me to so many different perspectives on what is public health. Fellow students, faculty, lecturers and administrators all helped to form the lens through which I see public health issues outside of academia.

Core competencies developed through this capstone includes:

CC3: Methods of Population and Public Health Assessment, Diagnosis and Analysis

CC4: Environmental and Occupational Health

CC6: Partnerships, Professionalism, Collaboration and Advocacy

PH2: Health Promotion, Advocacy and Public Health Policy.

I came into the program excited and passionate about public health but with a very naïve understanding of what public health entailed. Through meeting fellow students and discussing their backgrounds, their passions and even knowing now what direction their careers have taken have expanded the scope of how I view public health as a profession.

What I take away from this program and consider the most valuable aspect of the MPH program are the skills and ability to advocate for healthy public policy.

Initially I was focused on international aid and working with HIV positive populations overseas. My first big epiphany when working in Uganda was that the people there definitely did not need my help. What they needed were funding, supplies and local political action. It shifted my focus to changing what policies I could at a local level back home in Canada.

My practicum involved conducting qualitative research on housing and services for women with concurrent mental health and addictions issues who were also affected by violence. Working through focus groups surveys and the resulting knowledge translation project to address these women's concerns and to give them a voice in the policy decisions being made that would affect their services was an extremely powerful experience.

Leaving the academic world completely behind me for the past four years and coming back late to finish this capstone has been a challenge. After four years working as a public health professional I feel that I have a deeper understanding of the role that public health can play in the health care system and wider society but also have felt the limitations and frustrations within this profession. At the Canadian Cancer Society being heavily involved in advocacy activities some successful (indoor tanning bans for teenagers, smoking in public spaces) but more unsuccessful (cosmetic pesticide bans, radon awareness, flavoured tobacco) was eye opening to the power that government and industry have to influence the health of the population. Healthy public policies do a lot more to protect the health of citizens than broad based public health campaigns to eat healthier, exercise more and avoid contact with environmental hazards.

In my current position I get the opportunity to work with health care professionals who are conducting research to advance the health of either their patients, improve processes within the health authority and are passionate about health care. I have the opportunity to encourage and support innovative public health projects and provide knowledge translation opportunities.

By coming back to this capstone I have been reminded of why I wanted to be a part of this profession in the first place. Despite the frustrations and the sometimes slow moving process of policy development and acceptance, the excitement when milestones and successes are achieved is addictive.

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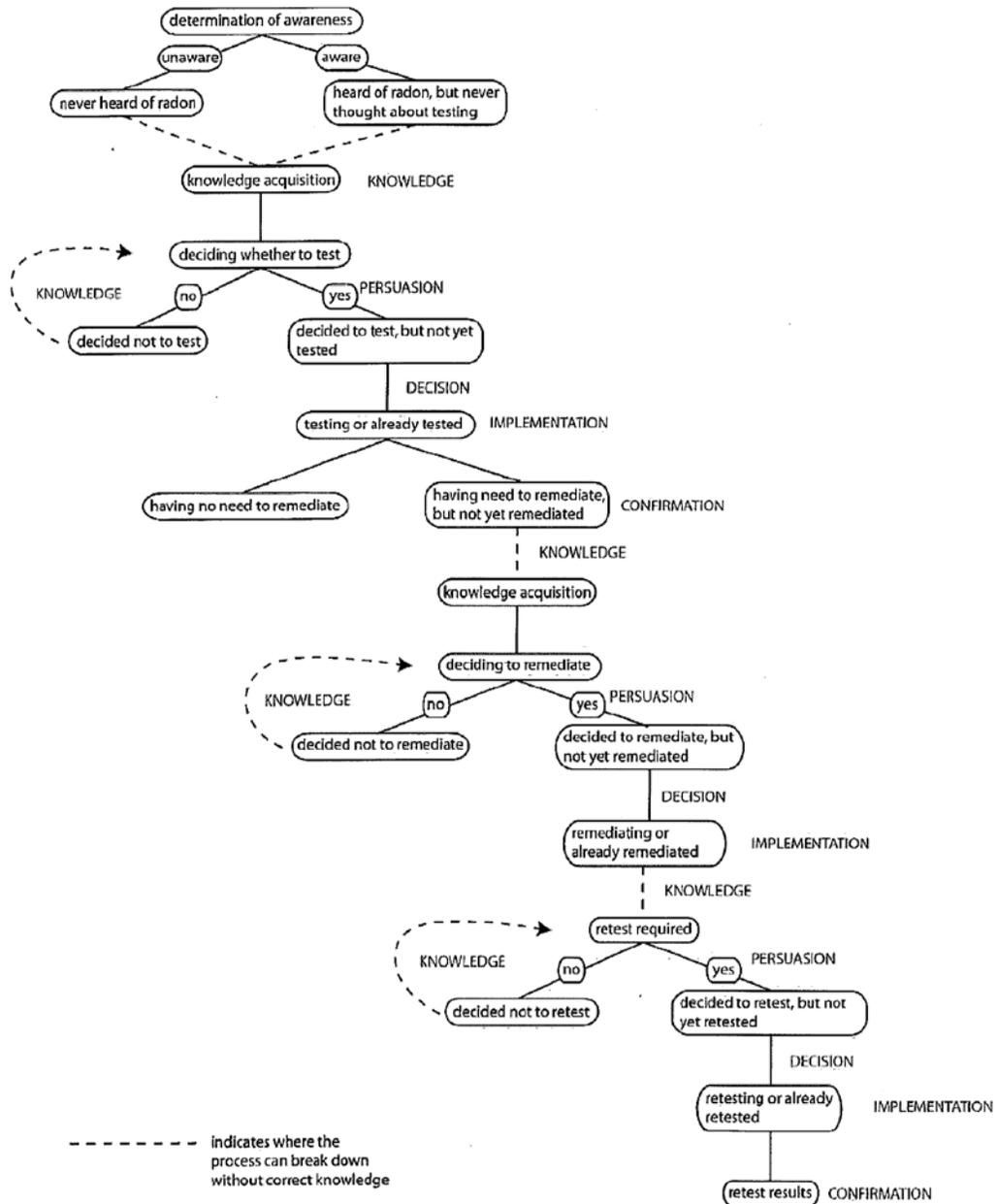
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Appendices

Appendix A:

Homeowners radon decision making process (Homeowner Protection Centre, 2011)



Appendix B:

Risk Ladder Comparison (Keller et.al, 2009)

Cancer Deaths from Lifetime Radon Exposure

Radon Level (Bq/m ³)	Extra Cancer Deaths (out of 1000 people)	Equivalent Smoking Risk	Advice
4000	500 In 1000	 10 Packs per Day	<p>HIGH TO VERY HIGH RADON LEVELS</p> <p>Measurements near the upper end of this range are much higher than the EPA action guideline. Exposure to such levels is very dangerous. For residents living in homes at the higher end of this range, action should be taken within the next couple of weeks to substantially reduce their exposure. If prompt action is not possible or is not effective, they should consider moving until the radon levels are reduced. Exposure to levels at the lower end of the range is also unsafe. Residents living in homes at these levels should act to reduce the readings within the next couple of months.</p>
1600	200 In 1000		
800	100 In 1000	 2 Packs per Day	
400	50 In 1000		<p>MODERATE TO HIGH RADON LEVELS</p> <p>Measurements in this range are above the EPA action guideline. Exposure to these levels is a significant risk if it extends over many years. Residents should carefully evaluate the causes of their elevated levels and make plans to reduce the levels permanently. To minimize the cumulative risk, this permanent action should be completed in the next year or two. In the meantime, residents may want to avoid prolonged exposure to areas of the home where the levels are highest.</p>
150	20 In 1000	 8 Cigarettes per Day	
74	10 In 1000		<p>LOW TO MODERATE RADON LEVELS</p> <p>Measurements in this range fall below the EPA action guideline. Radon levels at the lower end of this range present a low health risk. Radon levels at the higher end of this range, extended over a lifetime, present a moderate health risk. Any plan to lower the levels should be carefully evaluated to be sure that it is likely to be effective, since it is often difficult to reduce levels below this range. Many authorities do not recommend trying to reduce levels in this range, especially for homes near the lower end. Residents who decide to try to reduce their levels below this range can take several years to act without adding significantly to their risk.</p>
37	5 In 1000	 2 Cigarettes per Day	
19	2.5 In 1000		
4	0.5 In 1000		<p>VERY LOW TO LOW RADON LEVELS</p> <p>Measurements in this range are no higher than the outdoor „background“ level in many areas. Exposure to these levels does not call for action. Even at these low levels, there is a small risk associated with lifetime exposure to radon. However, authorities agree efforts to reduce radon levels still further are likely to be expensive and ineffective.</p>