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Indoor Radon Characteristics in Canadian Arctic Regions

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Abstract

Radon is a naturally occurring radioactive gas generated by the decay of uranium bearing minerals in rocks and soils. Exposure to indoor radon has been identified as the second leading cause of lung cancer after tobacco smoking. In an indoor environment, there are many factors affecting indoor radon concentrations. Those factors could be different in the Arctic regions than the rest of Canada. Based on the results from recently completed Canadian residential radon survey, this technical note assessed indoor radon characteristics and associated radiation doses in Canadian Arctic regions and compared them to the average radon characteristics in Canada. In Arctic health regions the percentage of homes above 200 Bq/m^3 varied from 0% in Nunavut to 19.6% in Yukon Territory. On average, indoor radon characteristics in the Canadian Arctic regions are similar to the overall indoor radon characteristics in Canada. Although there are no significant differences in indoor radon exposure between the Canadian Arctic and rest of Canada, the average lung cancer incidence rate in the Arctic health regions is a factor of 1.6 higher than the national average lung cancer rate. The higher lung cancer rate in Canadian Arctic is likely due to the higher smoking rate in the northern communities.

Keywords: radon, indoor, lung cancer, tobacco smoking

1. Introduction

Radon is a naturally occurring radioactive gas generated by the decay of uranium bearing minerals in rocks and soils. Radon is invisible, odourless and tasteless and emits ionizing radiation as it decays. As a gas, radon can move freely through the soil enabling it to escape to the atmosphere or seep into dwellings. In the open air, the amount of radon gas is very small and does not pose a health risk. However, in enclosed or poorly ventilated spaces, radon can accumulate to high levels. As radon breaks down it forms radioactive particles called radon decay products or radon progeny. Radon gas and radon progeny in the air can be breathed into the lungs where they breakdown further and emit ionizing radiation in the form of alpha particles. Alpha particles release small bursts of energy which are absorbed by nearby lung tissue and result in lung cell death or damage. When lung cells are damaged, they have the potential to result in cancer when they reproduce. The only known health effect associated with long-term exposure to elevated radon levels in indoor air is an increased risk of developing lung cancer. Several large joint analyses of residential radon exposure and lung cancer incidence in Europe (Darby et al., 2005, 2006), North America (Krewski et al., 2005, 2006) and China (Lubin et al., 2004) provided strong evidence that exposure to indoor radon can increase the risk of lung cancer in the general population. Radon and its decay products have been identified as the second leading cause of lung cancer after tobacco smoking (WHO 2009, IARC 2004, 2012a, 2012b). Based on new scientific information and a broad public consultation, the Government of Canada revised the guideline for exposure to radon in indoor air from 800 to 200 Bq/m^3 in 2007 (Health Canada 2007). The new guideline recommends that remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area.

Indoors, radon concentrations can vary widely, depending on the type of rock underlying the dwelling, house type and structure, building materials used in the construction, ventilation, and other environmental factors including local weather conditions (UNSCEAR, 2009). In 2009, Health Canada launched a national residential radon survey to gain a better understanding of the distribution of radon concentrations in homes across Canada (Health Canada 2012). The survey was completed in 2011 with radon measurements in about 14,000 homes in all administrative areas defined by the provincial and territorial ministries of health across Canada.

The factors that affect indoor radon in the Canadian Arctic regions may be different than those in the rest of

Canada. The objective of this technical note was to assess indoor radon characteristics and associated radiation doses in Canadian Arctic regions and compare them to the average radon characteristics in Canada. Since radon and its decay products have been identified as the second known cause of lung cancer after tobacco smoking, lung cancer incidence rates and smoking rates in the Arctic regions were briefly discussed.

2. Methods

In this study, radon characteristics were determined for the administrative units as health regions. The same units were used in the national residential radon survey (Health Canada 2012). Canada is currently divided into 123 administrative health regions which are defined by the provincial and territorial health ministries (Statistics Canada 2011). Five health regions are completely or partially in the Arctic (north of 60º in latitude). They are, from east to west: Labrador-Grenfell Regional Integrated Health Authority (1014H) in Newfoundland and Labrador, Nunavik (2417F) in Quebec, Nunavut (6201F), Northwest Territories (6101E), and Yukon Territory (6001E), as shown in Figure 1 (for details, please visit Statistics Canada website, Statistics Canada 2011).

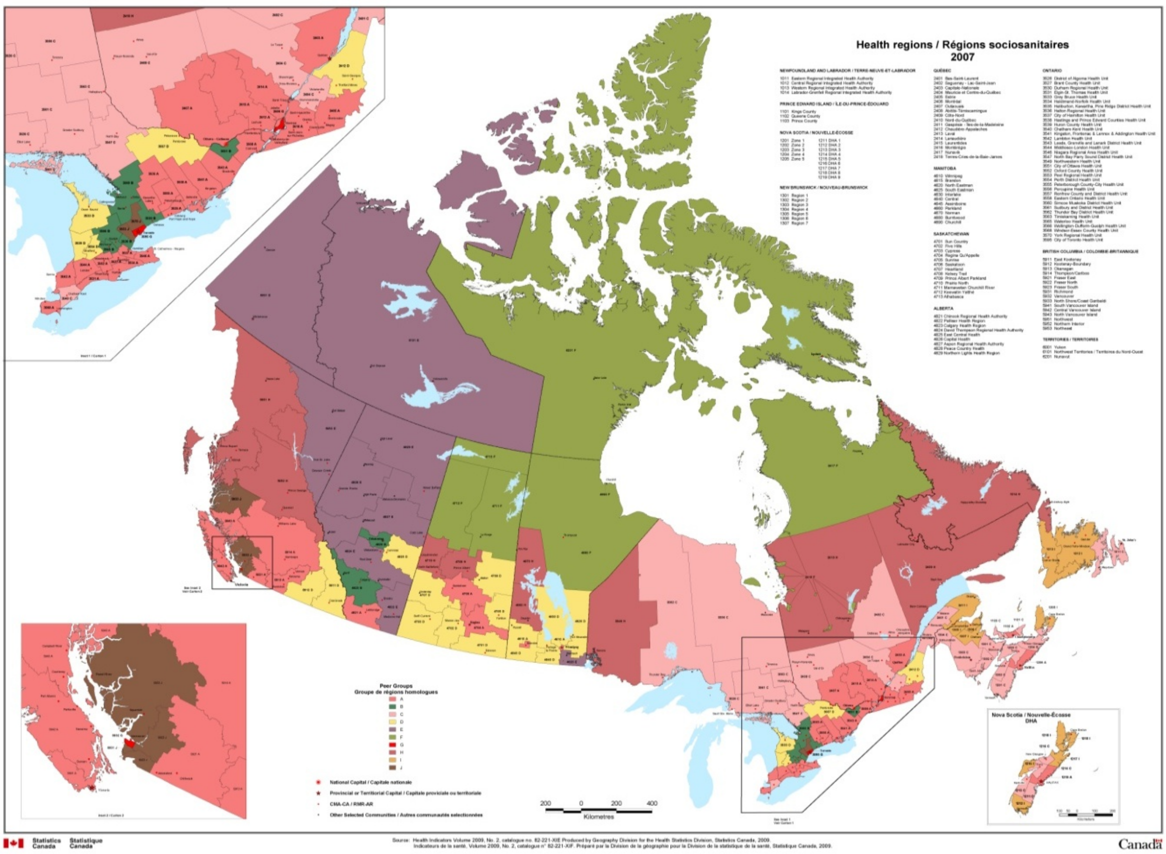

Figure 1. Health regions and peer groups in Canada (for detailed view, visit Statistics Canada Website) (Statistics Canada 2011)

Results of indoor radon measurements were taken from the summary report of the national radon survey (Health Canada 2012). The survey was started in 2009 and conducted over 2 years during the heating seasons (October to April) of 2009/10 and 2010/11. Long-term radon measurements were performed in all the homes surveyed. The observed radon concentrations in Canadian homes follow a log-normal distribution (Chen et al. 2012). Because of the wide distribution in radon concentrations, a central estimate alone, such as arithmetic mean (AM) or geometric mean (GM), will not be able to represent the distribution. Therefore, the percentage of homes above 200 Bq/m^3, the Health Canada current radon guideline (Health Canada 2007), was chosen to characterise the radon concentration level in a given health region. The average characteristics for the Arctic regions and for Canada are population weighted averages. Populations as of July 2012 were used (Statistics Canada 2013c).

In the survey, single family homes were randomly selected in each health region. The survey was targeted to have about 100 radon measurements in a health region. As indicated in a previous study on sample size required for a community radon survey (Chen et al. 2008), a large sample size, such as one to several thousand samples in a typical community of several tens of thousands of homes, can definitely provide high quality results with a very small uncertainty. However, from a cost-effectiveness point of view, a random sampling with a sample size of one to several hundred can serve the survey purpose well with an acceptable uncertainty of less than 25% for distribution parameters (such as AM and GM) as well as the percentages of homes above the Canadian radon guideline (Chen et al. 2008).

Once indoor radon concentrations are characterised, associated radon inhalation doses can be estimated. Based on the United Nations Scientific Committee on the Effects of Atomic Radiation (2009) formula, the annual effective dose due to inhalation of indoor radon and radon progeny for a population in a given area, E_{Rn}, was assessed

$$E_{Rn}(nSv)=C_{Rn}\ x\ 0.4\ x\ 7000\ x\ 9 \quad (1)$$

where C_{Rn} is the arithmetic mean (AM) radon concentration in the units Becquerel per cubic metre (Bq/ m^{-3}). The typical value of 0.4 was used as the equilibrium factor for radon indoors. A recommended value of 9 nSv (Bq/m^3 per hr.) was used to convert the radon equilibrium-equivalent concentration to the population effective dose, assuming an 80% home occupancy time (i.e. 7,000 hours). The population dose due to indoor radon exposure is proportional to the arithmetic mean indoor radon concentration in an area (UNSCEAR, 2009).

3. Results

Table 1 summarises the characteristics of indoor radon in the five Arctic health regions. Due to very limited radon data available in the North, over-sampling (twice of the average sampling in other health regions) was required for the Arctic regions. However, the recruitment in Nunavik was extremely difficult where only 9 participants were identified. In total, the five Arctic regions represent about 5% of homes tested for radon in the current survey (Health Canada 2012) even though those regions represent only 0.5% of Canadian population.

Table 1. Characteristics of exposure to indoor radon in Canadian Arctic regions

Health Region	Population	Num. Homes tested	% homes > 200Bq/m^3	GM Bq/m^3	GSD	AM Bq/m^3	Annual Effective Dose mSv
Labrador-Grenfell Regional Integrated Health Authority	37,545	201	3.0	20.5	2.65	37.6	0.9
Nunavik	10,937	9	11.1	20.8	3.52	45.9	1.2
Nunavut	30,799	78	0.0	9.3	1.48	10.3	0.3
Northwest Territories	43,198	185	5.4	38.6	3.01	69.5	1.8
Yukon Territory	32,276	225	19.6	87.2	3.06	175	4.4
Canadian Arctic Region	154,755	698	7.1	37.2	2.66	70.3	1.8
Canada	32,576,074	13807	6.9	41.9	2.77	72.2	1.8

Radon characteristics varied widely, which was similar to the results for all health regions across Canada where the percentage of homes above 200 Bq/m^3 varied widely from 0% to 44%. In Arctic health regions the percentage of homes above 200 Bq/m^3 varied from 0% in Nunavut to 19.6% in Yukon Territory. Nunavut is a unique territory in that many homes are built on stilts because of the permafrost. This architectural factor means many homes in Nunavut will not suffer from infiltration of any radon that is able to find its way to the surface of the earth. However, the population weighted average percentage of homes above 200 Bq/m^3 in the Arctic health regions, was 7.1%, which was comparable to the Canadian national average of 6.9%.

The observed radon concentrations in Canadian homes follow a log-normal distribution (Chen et al. 2012). This was also true for the Arctic health regions. A log-normal distribution is characterised by two parameters, the geometric mean (GM) and geometric standard deviation (GSD). The parameters (GM and GSD) varied significantly from one Arctic health region to the other. However, the population weighted GM and GSD for the Canadian North were 37.2 Bq/m^3 and 2.66, respectively which were similar to the Canadian national average of

GM=41.9 Bq/m^3 and GSD=2.77 (Chen et al. 2012).

The annual effective doses due to indoor radon (based on Eq. 1) were lower in Nunavut (0.3 mSv) and higher in Yukon Territory (4.4 mSv); the difference was more than a factor of 15. However, the population weighted annual effective dose due to indoor radon exposure in the Canadian Arctic region was the same as the national average of 1.8 mSv.

4. Discussion

The only known health effect associated with long-term exposure to elevated radon levels in indoor air is an increased lifetime risk of developing lung cancer. The risk of developing lung cancer from radon depends on the level of radon and how long people are exposed to those levels. The survey results showed no significant difference of average radon characteristics for homes in the Canadian Arctic and the rest of Canada. The population weighted annual effective dose due to indoor radon exposure in the Canadian Arctic is the same as the national average, i.e. 1.8 mSv. Although average indoor radon in Canadian Arctic regions did not differ significantly from the Canadian average, it is of interest to examine lung cancer incidence rates and compare those in the North with the statistics for the rest of Canada. Since radon and its decay products have been identified as the second leading cause of lung cancer after tobacco smoking, a look at the smoking statistics would also be of public interest.

Canadian cancer incidence data are available on the website of Statistics Canada for the most recent years up to 2007 (Statistics Canada 2013a). Canadian smoking statistics can be found in Table 105-0501 from the Statistics Canada website (Statistics Canada 2013b). For smoking, the most relevant indicator to the present study was the percentage of current daily smokers in a given administrative unit. Even though long term smoking history is known to be more relevant to lung cancer development, this study used smoking statistics available from 2003 to 2011 on the website of Statistics Canada (2013b). Table 2 summarized indoor radon exposures, lung cancer incidence (averaged from 1996 to 2007) and current daily smoking rates (averaged from 2003 to 2011) for the five Arctic health regions. For comparison, Canadian average statistics were also included in Table 2.

Table 2. Characteristics of indoor radon exposure, lung cancer incidence (averaged from 1996 to 2007) and current daily smoking rate (averaged from 2003 to 2011) in the Canadian Arctic regions

Health Region Name	% homes > 200Bq/m^3	Annual Effective Dose mSv	Lung Cancer Incidence per 100,000 (1996 - 2007)	Current daily smoker % (2003 - 2011)
Labrador-Grenfell Regional Integrated Health Authority	3.0	0.9	34.7	24.8
Nunavik	11.1	1.2	74.1	- [a]
Nunavut	0.0	0.3	250.5	51.9
Northwest Territories	5.4	1.8	70.4	28.8
Yukon Territory	19.6	4.4	56.8	25.6
Canadian Arctic Region	**7.1**	**1.8**	**95.0**	**34.0**
Canada	**6.9**	**1.8**	**58.1**	**16.4**

[a]: smoking data for Nunavik were marked as “not applicable” in Statistics Canada Tables (Statistics Canada 2013b).

As shown in Table 2, among the five health regions in the North, lung cancer incidence rates varied from 35 per 100,000 population in Labrador-Grenfell to 250 per 100,000 population in Nunavut. Among the five Arctic regions, Nunavut has the highest lung cancer incidence rate with lowest radon level indoors. The lung cancer incidence rate in Nunavut is more than 4 times of Canadian average while the estimated annual effective dose from radon exposure in Nunavut is less than 20% of the Canadian average radon dose. As can be seen in Table 2, Nunavut has the highest smoking rate among the Arctic regions (smoking statistics were not available for Nunavik according to Statistics Canada). The smoking rate in Nunavut is more than 3 times of the national average. Since tobacco smoking is the primary leading cause of lung cancer (IARC 2004, 2012a), the much higher than average smoking rate could likely be the main contributing factor to the much higher than average lung cancer incidence rate in Nunavut.

5. Conclusions

Even though local geology, climate and housing can be different in the Canadian Arctic region compared to other areas of Canada, on average, indoor radon characteristics in the Arctic region appeared to agree very well with the overall indoor radon characteristics in Canada. As expected, the average radon concentrations, such as percentages of homes above 200 Bq/m^3 vary widely from one health region to the other. Among the five Arctic health regions, indoor radon exposure is lower in Nunavut and higher in Yukon Territory.

Although there are no significant differences in indoor radon exposure between the Canadian Arctic and rest of Canada, the average lung cancer incidence rate in the Arctic health regions is a factor of 1.6 higher than the national average lung cancer rate. The higher lung cancer rate in Canadian Arctic is likely due to the higher smoking rate in the northern communities.

It is well known that tobacco smoking is the primary cause of lung cancer (IACR 2004, 2012a). As summarised in the Radon Handbook issued by the World Health Organization (2009), indoor exposure to radon and radon progeny contributes to about 3 to 14% of all lung cancers depending on the average radon concentration in a community. Due to the high smoking rate in the Arctic communities, radon awareness and protective actions to reduce indoor radon exposure should be integrated with tobacco control programs in order to effectively improve the healthy living in the northern communities.

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