RISK ASSESSMENT FOR RADON EXPOSURE IN VARIOUS INDOOR ENVIRONMENTS

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Using data from a number of radon surveys, it was assessed that on average, radon progeny concentrations in Canadian homes are about three times higher than in school buildings, 4.7 times higher in public buildings and indoor workplaces, and 12 times higher than in outdoor air. Canadian statistics show that most Canadians spend ~70% of their time indoors at home, 20% indoors away from home and 10% in outdoors. Due to relatively higher radon concentration in residential homes and longer time spent indoors at home, the exposure at home contributes to 90% of the radon-induced lung-cancer risk.

INTRODUCTION

Radon ($^{222}\text{Rn}$) is a naturally occurring radioactive gas generated by the decay of uranium-bearing minerals in rocks and soils. When radon gas escapes from the ground outdoors, it gets diluted and does not pose a health risk. However, in confined spaces, i.e. indoors, radon can accumulate to relatively high levels and become a health hazard when inhaled. In the air, radon decays further to its progenies or decay products. Radon gas contributes relatively little to the dose to the lung. It is the inhalation of the short-lived solid radon decay products and subsequent deposition on the walls of the airway epithelium of the bronchial tree that delivers most of the radiation dose to human lungs. Radon and its short-lived progenies in the atmosphere are the most important contributors to human exposure from natural sources of radiation, and have been identified as the second leading cause of lung cancer after tobacco smoking.$^{(1-5)}$

Based on epidemiological studies on lung cancer risks associated with residential radon exposure$^{(6-8)}$, the Government of Canada lowered the Canadian radon guideline for indoor environments from 800 to 200 Bq/m$^3$ in June 2007$^{(9)}$. This prompted a new wave of radon testing, with measurements carried out across Canada in homes, schools, offices and public buildings. In this study, average radon concentrations in different indoor environments are summarized based on published survey results and postings of project reports from local and federal governments and research organizations.

It is well known that the risk of radon-induced lung cancer increases with exposure to radon progeny and the duration of the exposure. Because radon is everywhere in varying concentrations, time-activity data are a key component of exposure assessment. In this study, radon gas concentrations are combined with time-location information and radon equilibrium factors to generate time- and location-weighted exposure estimates and to calculate associated contributions to the health risk from various indoor environments.

RADON LEVELS IN VARIOUS ENVIRONMENTS

Radon is present everywhere in the air in varying concentrations. As demonstrated in the first cross-Canada residential radon survey in 19 cities in the 1970s, it is more likely to find high indoor radon concentrations in some geographic locations in Canada than others$^{(10)}$. Since the first survey, many local governments, especially where elevated radon was observed, initiated radon surveys in residential homes, school and public buildings as well as various other indoor workplaces. Table 1 summarizes available data from a number of these surveys.

A total of 7866 long-term measurement data were available for homes; the population weighted average radon concentration was 119 Bq/m$^3$. Radon measurements were available for a total of 1132 school buildings; the average concentration was 61 Bq/m$^3$, about half of radon concentration found in homes. Local civil facilities, provincial and federal buildings are all counted here as public buildings. Radon measurements were reported for a total of 1668 public buildings; the average radon concentration was 38 Bq/m$^3$, only ~32% of that in residential homes.

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dose to human lungs. Health risk associated with radon exposure depends on radon progeny concentration, represented by the radon equilibrium equivalent concentration (EEC) which is estimated by measured radon gas concentration times the equilibrium factor $F_{eq}$ (a factor describing the degree of disequilibrium between radon gas and its progeny). The characteristics of radon decay products differ.

### Table 1. Summary of radon concentrations in various indoor environments

| City/region/province       | Population (2016) | Building function | Number of places tested for radon | AM ± SD (Bq/m³) | Range (Bq/m³) | Reference # |
|----------------------------|-------------------|-------------------|-----------------------------------|----------------|--------------|-------------|
| Prince George              | 74 003            | Homes             | 1436                              | 185            | (<DL, 1550)  | 11          |
|                            |                   | School buildings  | 44                                | 30             | (<DL, 240)   | 12          |
|                            |                   | Civic facilities  | 10                                | 38             | (<DL, 150)   | 13          |
|                            |                   | Federal buildings | 14                                | 25 ± 40        | (<DL, 148)   | 14          |
| Castlegar                  | 8 039             | Homes             | 158                               | 373            | (<50, 1250)  | 15          |
|                            |                   | School buildings  | 13                                | 100            | max. 855     | 12          |
| Okanagan region            | 362 258           | Homes             | 217                               | 137 ± 163      | (<DL, 1410)  | 16, 17      |
|                            |                   | Schools/daycares  | 131                               | 44             | (<DL, 400)   | 12          |
|                            |                   | Federal buildings | 59                                | 40 ± 51        | (<DL, 276)   | 14          |
| Calgary                    | 1 392 609         | Homes             | 2382                              | 126            | (<15, 3440)  | 18          |
|                            |                   | Provincial buildings | 185                          | 111 ± 92       | (<DL, 850)   | 16, 17      |
|                            |                   | Federal buildings | 27                                | 43             | (<DL, 288)   | 19          |
| Edmonton                   | 1 321 426         | Homes             | 170                               | 101 ± 62       | (<DL, 386)   | 16, 17      |
|                            |                   | Provincial buildings | 10                             | 24             | (<DL, 58)    | 19          |
|                            |                   | Federal buildings | 119                               | 19 ± 14        | (<DL, 169)   | 14          |
|                            |                   | Homes             | 266                               | 99 ± 116       | (<DL, 1525)  | 16, 17, 20  |
|                            |                   | Federal buildings | 255                               | 30 ± 41        | (<DL, 408)   | 14          |
| Gaspesie region            | 90 311            | Homes             | 174                               | 158 ± 270      | (<DL, 2923)  | 16          |
|                            |                   | School buildings  | 19                                | 76 ± 116       | (15, 663)    | 21          |
|                            |                   | Federal buildings | 40                                | 122 ± 251      | (<DL, 1580)  | 14          |
| Laurentides region         | 589 400           | Homes             | 78                                | 88 ± 124       | (<DL, 757)   | 16          |
|                            |                   | School buildings  | 22                                | 57 ± 65        | (15, 453)    | 21          |
| Outaouais region           | 382 604           | Homes             | 62                                | 111 ± 170      | (<DL, 917)   | 16          |
|                            |                   | School buildings  | 24                                | 44 ± 37        | (15, 206)    | 21          |
| Saskatchewan               | 1 098 352         | Homes             | 1604                              | 153 ± 132      | (<DL, 2165)  | 16, 17      |
|                            |                   | School buildings  | 424                               | 73 ± 91        | (11, 1243)   | 22          |
|                            |                   | Provincial buildings | 56                            | 47 ± 32        | (<DL, 120)   | 23          |
|                            |                   | Federal buildings | 342                               | 71 ± 91        | (<DL, 530)   | 14          |
| Nova Scotia                | 923 598           | Homes             | 758                               | 130 ± 247      | (<DL, 2690)  | 16, 17, 24  |
|                            |                   | School buildings  | 377                               | 62 ± 46        | (<DL, 1312)  | 25          |
|                            |                   | Provincial buildings | 20                        | 27             | (<DL, 200)   | 26          |
|                            |                   | Federal buildings | 581                               | 38 ± 69        | (<DL, 870)   | 14          |
| Prince Edward Island       | 142 907           | Homes             | 113                               | 46 ± 67        | (<DL, 415)   | 16, 17      |
|                            |                   | Senior housings  | 38                                | 43 ± 37        | (11, 169)    | 27          |
|                            |                   | School buildings  | 46                                | 68 ± 58        | (10, 305)    | 27          |
|                            |                   | Public buildings  | 8                                 | 34 ± 46        | (12, 146)    | 27          |
|                            |                   | Federal buildings | 51                                | 25 ± 31        | (<DL, 204)   | 14          |
| Yukon                      | 35 874            | Homes             | 225                               | 175 ± 309      | (<DL, 2360)  | 16          |
|                            |                   | School buildings  | 32                                | 65 ± 58        | (6, 430)     | 28          |
|                            |                   | Federal buildings | 56                                | 58 ± 53        | (<DL, 290)   | 14          |
| Canada*                    | 7866              | Homes             | 1132                              | 61             | (<DL, 1312)  | 14          |
|                            |                   | School buildings  | 1668                             | 38             | (<DL, 1580)  | 14          |

*Population weighted arithmetic mean (AM) from available data in this table.
significantly in different indoor environments. Many environmental factors as well as human activities and habits affect the value of $F_{eq}$. Measured $F_{eq}$ values vary widely from as low as 0.1 to as high as 0.8. Radon equilibrium factors in school and public buildings can differ significantly from those of residential dwellings. This is due primarily to the different indoor environmental conditions required or created by the activities that take place within the buildings, especially with respect to ventilation and aerosol particle concentrations. Based on a recent review on $F_{eq}$ in various indoor environments\(^{(29)}\), we applied $F_{eq} = 0.6$ to Canadian homes and $F_{eq} = 0.4$ for school and other public buildings in this assessment.

The average radon progeny concentrations of 71.4 Bq/m$^3$ ($0.6 \times 119$ Bq/m$^3$) in homes, 24.4 Bq/m$^3$ ($0.4 \times 61$ Bq/m$^3$) in schools and 15.2 Bq/m$^3$ ($0.4 \times 38$ Bq/m$^3$) in public buildings including indoor workplaces were used here to assess radon exposures in various indoor environments.

Radon also presents in outdoor air. However, measurements of outdoor radon levels are very limited in Canada. In this assessment, we take the worldwide averages of 10 Bq/m$^3$ and $F_{eq} = 0.6$ for radon in outdoor air recommended by the UNSCEAR\(^{(29)}\). Radon progeny concentration of 6 Bq/m$^3$ ($0.6 \times 10$ Bq/m$^3$) was used in the current assessment for all outdoor locations.

## TIME-ACTIVITY PATTERN

Time-activity data are a key component for population exposure assessment. Radon concentrations in different environments are combined with time-location information to generate time-weighted estimates for radon exposure. The General Social Survey: Canadians at work and home conducted by the Statistics Canada\(^{(30, 31)}\) provided updated time-activity data, representative of the Canadian population. The average daily time spent in major locations by age groups are summarized in Table 2.

Generally speaking, Canadians spend ~21 h (90% of daily time) indoors. Young children and seniors spend more than 70% of their daily time indoors at home. On average, students spend ~5 h or 20% of the daily time indoors in school. Outdoor activities including time in vehicles only count for ~10% of the time.

## CONTRIBUTION ASSESSMENT FOR RADON EXPOSURE IN MAJOR LOCATIONS

Annual radon exposure can be estimated with knowledge of time-activity patterns, which specify where and how individuals spend their time, along with knowledge of radon activity concentrations in each microenvironment or physical space, as given in Table 2 for exposures in major locations by age.
groups. For infants, it is assumed that the time spent indoors other than home is most likely in civic facilities or public buildings where the mean of EEC is 15.2 Bq/m$^3$. For young children, daycares are assumed to be the most common indoor locations outside the home. In Canada, the majority of child care is through unregulated arrangements, such as in the caregiver’s home. In this study, the EEC of 71.4 Bq/m$^3$ is assigned to daycares. No information was found for radon progeny concentration in vehicles, so it is assumed that radon levels in a vehicle are the same as in outdoor air.

Table 3 provided total annual exposures for different age groups and percentage contributions by location major locations. The total annual exposure depends on the amount of time spent indoors, especially indoors at home. It is highest for infants (98% of time at home), and then decreases with increased age until people become seniors, retired from work and spending more time at home. From the percentage contribution by location for the three major locations, one can see that exposure indoors contributes ~99% to the total annual exposure, and the majority comes from exposure at home. Exposure outdoors counts for only ~1% of the total annual exposure.

**Table 3. Total annual exposures by age groups and contributions from exposure at various locations.**

| Age group  | Total annual exposure (h Bq/m3) | % Contribution by location | Location       |
|------------|---------------------------------|----------------------------|----------------|
| Infants (<1 y) | 566 851                        | 98.3%                      | Indoors at home |
| Young children (1–4 y) | 563 399                        | 1.1%                       | Indoors away from home |
|               |                                 | 0.6%                       | Outdoors + in vehicle |
| Children (5–11 y) | 489 909                        | 82.0%                      | Indoors at home |
|               |                                 | 17.0%                      | Indoors away from home |
|               |                                 | 1.0%                       | Outdoors + in vehicle |
| Adolescents (12–19 y) | 483 572                        | 91.1%                      | Indoors at home |
|               |                                 | 7.8%                       | Indoors away from home |
|               |                                 | 1.2%                       | Outdoors + in vehicle |
| Adults (20–59 y) | 452 439                        | 89.8%                      | Indoors at home |
|               |                                 | 9.1%                       | Indoors away from home |
|               |                                 | 1.1%                       | Outdoors + in vehicle |
| Seniors (60+ y) | 507 284                        | 92.3%                      | Indoors at home |
|               |                                 | 6.3%                       | Indoors away from home |
|               |                                 | 1.4%                       | Outdoors + in vehicle |

**RADON RISK ASSESSMENT**

There are several radon risk models in the literature. In all risk models, lifetime risk of radon-induced lung cancer increases with increased exposure to radon progeny. The lifetime risk estimates could vary significantly between the various risk models considered. A previous study on variation range assessment for Canadian population risk of radon-induced lung cancer based on various risk models found that the lifetime risk estimates based on the EPA/BEIR-VI model agreed reasonably well with the averages of risk estimates from the five risk models considered in that study. In this study, the EPA/BEIR-VI radon risk model was used to assess radon risk. The mathematical form of the EPA/BEIR-VI model for the excess relative risk, $e$, is given as:

$$
e(a) = \beta(W_{5-14} + 0.78W_{15-24} + 0.51W_{25+})\Phi_{age}(a)$$

where $a$ is age in years. The parameter $\beta (=0.0634)$ represents the increase of risk per unit exposure, expressed as excess relative risk per Working Level Month (WLM) ($1 \text{ WLM} = 6.37 \times 10^{-5} \text{ h Bq/m}^3$ EEC of radon). For a given radon exposure pattern, the cumulative exposure, $W$ (expressed in WLM), can be calculated as the weighted summation of three time-since-exposure windows, namely $W_{5-14}$ the exposure incurred between 5 and 14 y before age $a$; $W_{15-24}$ the exposure incurred between 15 and 24 y before age $a$ and $W_{25+}$, the exposure incurred 25 y or more before age $a$. Exposure in the last 5 y is not biologically relevant to lung-cancer risk. $\Phi_{age}$ is a function decreasing with attained age.

The formulae for the calculation of lifetime risk of lung cancer are described in the BEIR IV report. Briefly, the lifetime risk of lung cancer is given by the sum of the risks of lung-cancer death for each year $i$: 

$$\text{Lifetime Risk} = \sum_{i=1}^{\infty} e(i)$$
where $R_e$ is the absolute risk of lung cancer for a given exposure pattern; $h_i$ and $h_i^*$ are the lung cancer and overall mortality rates for age $i$, respectively, and $e_i$ is the excess relative risk due to exposure to radon progeny for age $i$. The lifetime probability of lung-cancer mortality is then the summation over years $i$ from 1 to 110. A lifespan of 110 y is assumed. This study uses the Canadian age-specific mortality rates\(^{(35)}\) averaged over 5 y from 2008 to 2012.

Lifetime risks were calculated for exposure patterns (as given in Table 3) during the lifetime at three major locations. The results are presented in Figure 1. Baseline risks, $R_0$, were also calculated for comparison, they are risks when $e_i = 0$ in above equation.

The lung-cancer risks are zero for males under the age of 10 and for females under the age of 20. The lifetime baseline risks of lung cancer (i.e. by age of 110) are 0.075 for males and 0.057 for females. Exposures to radon anywhere increase the risk of developing lung cancer over the course of the lifetime. The results in Figure 1 showed that exposure at home contributes to the majority of the increased risk of lung cancer.

Relative risk (RR) is defined as $\text{RR} = R_e/R_0$, where $R_0$ is the baseline risk. The RR describes the proportional increment in lung-cancer risk posed by
radon exposure beyond the baseline. By converting the results of absolute risks in Figure 1 into relative risks, we can more clearly see the significant contributions of exposure at home to radon-induced lung cancer, as demonstrated in Figure 2.

Even though lung cancer was not observed among young children, their exposures to relatively higher radon concentrations at home contribute to significant increases in relative risks later in their life. This was clearly demonstrated for females, where a rapid increase in relative risks around age 20 can be seen. Figure 2 also indicates that exposure to radon at average Canadian levels adds considerably to the risk of lung cancer for all age groups, and that the relative risk for people exposed increases steadily from early adulthood to late middle age.

Risks of radon-induced lung cancer relative to the baseline risk can vary over the lifetime depending on varying exposure pattern and other environmental factors. Regardless the risk values, risks due to exposure at home always contribute to ~90% of the risk due to total exposure at all locations.

CONCLUSIONS
The risk of radon-induced lung cancer increases with exposure to radon progeny and the duration of the exposure. On average, radon progeny concentrations in Canadian homes are about three times higher than in school buildings, 4.7 times higher than in public buildings and indoor workplaces, and 12 times higher than in outdoor air. Canadian statistics showed that most Canadians spend ~70% of their time indoors at home, 20% indoors away from home and 10% in outdoors.

Due to relatively higher radon concentration in residential homes and longer time spent indoors at home, exposure at home contributes to 90% of the radon-induced lung-cancer risk. The assessment results clearly indicate that reducing radon exposure
in residential homes is the most important and most effective way for prevention of radon-induced lung cancer.

REFERENCES

1. National Research Council. Health Effects of Exposure to Radon: BEIR VI (Washington, DC: The National Academies Press) (1999).
2. World Health Organization (WHO). WHO Handbook on indoor radon (Geneva: WHO) (2009) ISBN 978-92-4-154767-3.
3. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSEAR). UNSCEAR 2006 Report, Annex E – Sources-to-effects assessment for radon in homes and workplaces. United Nations, New York, 2009.
4. International Commission on Radiological Protection (ICRP). Lung cancer risk from radon and progeny and statement on radon. ICRP Publication 115. Ann. ICRP 40(1) (2010).
5. International Commission on Radiological Protection (ICRP). Radiological protection against radon exposure, ICRP Publication 126. Ann. ICRP 43(3) (2014).
6. Lubin, J. H. et al. Risk of lung cancer and residential radon in China: pooled results of two studies. Int. J. Cancer 109, 132–137 (2004).
7. Darby, S. et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 330(7485), 223–227 (2005).
8. Krewski, D. et al. Residential radon and risk of lung cancer: a combined analysis of 7 North American case-control studies. Epidemiology 16, 137–145 (2005).
9. Health Canada. Government of Canada Radon Guideline. 2007. Available at: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/radiation/radon/government-canada-radon-guideline.html. Accessed 21 August 2018.
10. McGregor, R. G., Vasudev, P., Letourneau, E. G., McCullough, R. S., Prantl, F. A. and Taniguchi, H. Background concentration of radon daughters in Canadian homes. Health Phys. 39, 285–289 (1980).
11. British Columbia Lung Association. Prince George: community-wide radon testing results. 2014. Available at: http://www.radonaware.ca/database/files/library/Raden_Home_Testing_Results_2014___Prince_George.pdf. Accessed 21 August 2018.
12. British Columbia Centre for Disease Control. Radon in British Columbia work places. Final report RS2006-DG09. November 2009.
13. City of Prince George. Radon testing in civic facilities – interim results. Staff report to council, October 31 2016. Available at: https://www.princegeorge.ca/cityhall/mayorcouncil/councilagenda惦minutes/Agendas/2016/2016-11-21/documents/RTC_Civic_Facilities_Interim_Radon_report_.pdf. Accessed 21 August 2018.
14. Whyte, J., Falcomer, R. and Chen, J. A comparative study of radon levels in federal buildings and in residential homes. Health Phys. (2018) in press.
15. British Columbia Lung Association. Castlegar: community-wide radon testing results. 2014. Available at: http://www.radonaware.ca/database/files/library/Radon_Home_Testing_Results_2014___Castlegar.pdf. Accessed 21 August 2018.
16. Health Canada. Cross-Canada survey of radon concentrations in homes—final report. 2012. Available on http://www.hc-sc.gc.ca/ewh-scnt/alt_formats/pdf/radiation/radon/survey-sondage-eng.pdf. Accessed 21 August 2018.
17. Chen, J., Bergman, L., Falcomer, R. and Whyte, J. Results of simultaneous radon and thoron measurements in 33 metropolitan areas of Canada. Radiat. Prot. Dosim. 163, 210–216 (2015).
18. Stanley, F. K. T., Zarezadch, S., Dumais, C. D., Dumais, K., MacQueen, R., Clement, F. and Goodarzi, A. A. Comprehensive survey of household radon gas levels and risk factors in southern Alberta. CMAJ 5, 255–264 (2017).
19. Government of Alberta. Summary of radon testing in provincial buildings, 2007-2008. Communication with G. Hughes, Ministry of Labour, 3 May 2018.
20. Chen, J., Tokonami, S., Sorimachi, A., Takahashi, H. and Falcomer, R. Results of simultaneous radon and thoron tests in Ottawa. Radiat. Prot. Dosim. 130, 253–256 (2008).
21. Poulin, P., Leclerc, J. M., Dessau, J. C., Deck, W. and Gagnon, F. Radon measurement in schools located in three priority investigation areas in the province of Quebec, Canada. Radiat. Prot. Dosim. 151, 278–289 (2012).
22. Government of Saskatchewan. Radon testing results in schools. Communication with T. White, Ministry of Education, 23 May 2018.
23. Government of Saskatchewan. Radon testing results in workplaces. Communication with M. Peterson, Ministry of Central Services, 20 July 2018.
24. Chen, J., Moir, D., Pronk, T., Goodwin, T., Janik, M. and Tokonami, S. An update on thoron exposure in Canada with simultaneous $^{222}Rn$ and $^{220}Rn$ measurements in Fredericton and Halifax. Radiat. Prot. Dosim. 147, 541–547 (2011).
25. Government of Nova Scotia. Reports of radon testing in schools 2008-2017. Communication with R. Parsons, Transportation and Infrastructure Renewal, 20 July 2018.
26. Merseeve, H. Does radon pose a risk to Nova Scotia workers? Presentation at Radon Exposure in Nova Scotia: Challenges and Solutions Workshop, Halifax, May 26th 2016. Available at: https://www.carst.ca/resources/May2016%20Nova%20Scotia%20Workshop/HM%20radon-Halifax-hm.pdf. Accessed 21 August 2018.
27. PEI Department of Health. Phase 2 – radon survey at selected sites Prince Edward Island. Final report, June 2009. Available at: http://www.gov.pe.ca/photos/sites/health/file/Radon%20Report%20Phase%202.pdf. Accessed 21 August 2018.
28. Government of Yukon. 2016/17 radon monitoring results from schools. Available at: http://www.education.gov.yk.ca/radon-monitoring.html. Accessed 21 August 2018.
29. Chen, J. and Harley, H. A review of indoor and outdoor radon equilibrium factors – part I: $^{222}Rn$. Health Phys. 115, 490–499 (2018).
30. Statistics Canada. General Social Survey: Canadians at work and home. Detailed information for 2016 (cycle 30). Available at: http://www23.statcan.gc.ca/imdb/
31. Matz, C. J., Stieb, D. M., Davis, K., Egyed, M., Rose, A., Chou, B. and Brion, O. Effects of age, season, gender and urban-rural status on time-activity: Canadian Human Activity Pattern Survey. Int. J. Environ. Res. Public Health 11, 2108–2124 (2014).
32. Chen, J. Canadian population risk of radon induced lung cancer – variation range assessment based on various radon risk models. Radiat. Prog. Dosim. 177, 83–86 (2017).
33. Environmental Protection Agency. EPA assessment of risks from radon in homes. Office of Radiation and Indoor Air. Washington DC, 2014.
34. National Research Council. Biological Effects of Ionizing Radiation (BEIR) VI Report. Health effects of exposure to radon (Washington DC: National Academy Press) (1999).
35. Statistics Canada. Data source: Canadian vital statistics. Available at: http://www5.statcan.gc.ca/cansim/ pick-choisir?lang=eng&p2=33&id=1020551. Accessed 21 August 2018.