Radon

Environmental estimates (circa 2011): Supplemental data

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1. Data for lifetime excess cancer risk estimates

Overview

The summary data used to calculate lifetime excess cancer risk and the results for radon are provided in the tables below. For more detailed information on supporting data and sources, see below for each exposure pathway.

i. Environmental Concentrations

Exposure pathway	Units	Average	Maximum	Notes
Outdoor air	Bq/m³	24		
Indoor air	Bq/m³	97		

ii. Calculated Lifetime Cumulative Exposure

Exposure pathway	Lifetime cumulative exposure (average level) (Bq)	Lifetime cumulative exposure(maximum level) (Bq)
Outdoor air	763,935	
Indoor air	47,212,568	

iii. Unit Risk Factor

Exposure route	Health Canada	US EPA	CA OEHHA
Inhalation		4.86^{-10} per Bq	

Sources for Unit Risk Factor:

- United States Environmental Protection Agency Federal Guidance Report 13. Cancer Risk Coefficients for Environmental Exposure to Radionuclides (1999).

iv. Lifetime Excess Cancer Risk (per million people)

	Average[1]			Maximum[2]
Exposure pathway	Health Canada	US EPA	CA OEHHA[3]	
Outdoor air	--	371		
Indoor air	--	22,945		

[1]Lifetime excess cancer risk based on average intake x cancer potency factor from each agency
[2]Lifetime excess cancer risk based on maximum intake x highest cancer potency factor
[3]California Office of Environmental Health Hazard Assessment

Supporting data by exposure pathway

i. Outdoor air

Outdoor air concentrations are based on data published in peer-reviewed literature and government reports. A ranking system was used to select data most representative of Canadian conditions circa 2011:

1. Canadian data collected in 2000 or more recently, sample duration of 24 hours or longer;
2. US studies of similar currency and sample duration;
3. Studies from northern European countries of similar currency and sample duration;
4. Canadian, US or European studies with data collected prior to 2000 and similar sample duration; and
5. Studies with sample duration of less than 24 hours regardless of country or collection date, or studies from countries not comparable to Canada.

Rank: 4	Author: Grasty RL (1994)				Location: Canada (national survey)				
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
323	78 communities in summer	1990-91	Bq/m³	3 months			23 (weighted by number of samples per community)		

We assume radon is present at these levels in all outdoor air, although concentrations may vary greatly from one location to another.

Sources for outdoor air data:

- Grasty RL. (1994). Summer Outdoor Radon Variations in Canada and Their Relation to Soil Moisture. Health Physics 66 (2) pp:185-193.

ii. Indoor air

Indoor air concentrations are based on data published in peer-reviewed literature since 2000. A ranking system was used to select data most representative of Canadian conditions circa 2011:

1. Canadian data collected in 2000 or more recently, sample duration of 24 hours or longer;
2. US studies of similar currency and sample duration;
3. Studies from northern European countries of similar currency and sample duration;
4. Canadian, US or European studies with data collected prior to 2000 and similar sample duration; and
5. Studies with sample duration of less than 24 hours regardless of country or collection date, or studies from countries not comparable to Canada.

Rank: 1 Author: Health Canada (2012) Location: Cross-Canada

Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
13,814	13,814 homes across Canada	2009-2011	Bq/m³	3 months	<15	5657	97	47	

Note: samples taken from lowest floor in home

Rank: 1 Author: Chen J et al (2009) Location: Winnipeg, MB

Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
130	117 homes	2008	Bq/m³	3 months	20	483	143		112

Note: samples taken from main floor

Rank: 1 Author: BCCDC (2007) Location: BC

Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
1,378	Homes in 28 cities	2007	Bq/m³	Unknown			2 (lowest city) 94 (mean of 28 city means) 135 (highest city)		

Note: samples taken from main floor

Rank: 1 Author: Chen J et al (2008) Location: Ottawa, ON

Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
95	93 homes	2006 - 2007	Bq/m³	4 months	8	1,525	110		74

Note: samples taken from lowest floor in home

Rank: 1 Author: Gratton et al (2004)* Location: Baie-Johan-Beetz, Quebec

Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
20	17 homes in higher potential area	2004	Bq/m³	7 days	49 (ground floor) 49 (basement)	229 (ground floor) 432 (basement)	95 (ground floor) 351 (basement)		

Note: samples taken from lowest floor inhabited
* As summarized by Dessau JC et al (2004)

Rank: 1	Author:	DSP de la Monteregie (unpublished)*				Location:	Saint-Andre d'Argenteuil, Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
40	40 homes	2001	Bq/m³	7 days	20	951			69

Note: samples taken from basements
* As summarized by Dessau JC et al (2004)

Rank: 1	Author:	Savard et al (1998); Savard et al (1999a); DSP des Laurentides (2002)*				Location:	Oka, Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
241	241 homes in higher potential areas	1996 - 2002	Bq/m³	1 month	18	10,500			490 (zone 1) 285 (zone 2) 131 (zone 3) 126 (outside predefined zones)

Note: samples taken from basement or ground floor
* As summarized by Dessau JC et al (2004)

Rank: 4	Author:	Savard et al (1999b); DSP des Laurentides (unpublished)*				Location:	Saint-Andre d'Argenteuil, Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
39	39 homes in higher potential area	1998	Bq/m³	1 month	61	2,737			251

Note: samples taken from lowest floor inhabited
* As summarized by Dessau JC et al (2004)

Rank: 4	Author:	LeTourneau et al (1994)					Location:	Winnipeg, Canada	
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
~ 28,465	4,448 homes	1983-1990	Bq/m³	2 x 6 months			120.4 (bedroom) 197 (basement)		

Note: samples taken in bedroom and basement at each location

Rank: 4	Author:	Levesque et al (1995)*				Location:	Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
900	420 homes in high potential area, 474 homes in low potential areas across Quebec	1988	Bq/m³	2 x 6 months					34.9 (high potential basement) 34.4 (low potential basement 19.8 (high potential ground floor) 16.5 (low potential ground floor)

Note: samples taken from basement or ground floor
* As summarized by Dessau JC et al (2004)

Rank: 4	Author:	Doyle et al (1990)*				Location:	Maniwaki and Saint-Agathe, Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
159 (basement) 84 (ground floor)	Homes in 3 areas	1988	Bq/m³	5 months					19 – 91 (lowest - highest area GM, basement) 10 – 43 (lowest - highest area GM, ground floor)

Note: samples taken from basement or ground floor
* As summarized by Dessau JC et al (2004)

Rank: 4	Author: Carriere et al (1987)*						Location: Mont-Laurier, Shawville, Saint-Honore, and Oka, Quebec		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
153 (basement) 104 (ground floor)	Homes in 4 areas	1981 to 1985	Bq/m³	6 to 12 months					24 – 1,567 (lowest - highest area GM, basement) 14 – 327 (lowest - highest area GM, ground floor)

Note: samples taken from basement or ground floor
* As summarized by Dessau JC et al (2004)

Rank: 4	Author: Carriere et al (1983)*				Location: Shawville, Otter Lake, Fort-Coulonge, Campbell's Bay, Grand Calumet, Quebec				
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
17	Homes in 5 areas	1981	Bq/m³	9 to 12 months	28 (basement) 10 (ground floor)	177 (basement) 82 (ground floor)			

Note: samples taken from basement or ground floor
* As summarized by Dessau JC et al (2004)

Rank: 5	Author: Letourneau et al (1984)						Location: Canada (national survey)		
Samples (n)	Site	Sample Date	Units	Sample Duration	Min	Max	Mean (AM)	Med	Geomean (GM)
13,457	Homes in 19 cities	1977-1980	Bq/m³	Grab sample					5.2 (lowest city) 20.4 (mean of GMs) 57.0 (highest city)

Note: samples from basement or ground floor

Sources for indoor air data:

- BCCDC (British Columbia Centre for Disease Control) 2007. Table of radon measurements.
- Carriere PE, Legare J. 1987. Radon and radon daughters in homes of radioactive anomalies of Quebec – One year study. Indoor Radon II-Proceeding of the second APCA International specialty conference. New Jersey:42-58. Cited in Dessau et al 2004.
- Carriere PE. 1983. Mesures des derives du radon dans l'air certaines maisons privees du Pontiac. Rapport Interne. Ministere de l'Environnement du Quebec. Cited in Dessau et al 2004.
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- Chen J, Tokonami S, Sorimachi A, Takahashi H, and Falcomer R. 2008. Preliminary Results of Simultaneous Radon and Thoron Tests in Ottawa. Radiation Protection Dosimetry 130 (2): 253-256.
- Dessau JC, Gagnon F, Levesque B, Prevost C, Leclerc JM and Belle-Isles JC. 2004. Le Radon au Quebec Evaluation du Risque a la Sante et Analyse Critique des Strategies d'Intervention. Institut National de Sante Publique du Quebec.

- Doyle PJ, Grasty RL, and Charbonneau BW. 1990. Predicting geographic variations in indoor radon using airborne gamma-ray spectrometry. Current research, Part A, Geological Survey of Canada, Paper 90-1A, 27-32. Cited in Dessau et al 2004.
- Direction des Sante Publique des Laurentides, 2002. Unpublished. Cited in Dessau et al 2004.
- Direction des Sante Publique des Laurentides, date unknown. Unpublished. Cited in Dessau et al 2004.
- Direction des Sante Publique de la Monteregie, date unknown. Unpublished. Cited in Dessau et al 2004.
- Gratton M, Lacroix MA, Lizotte A, and Rouillon P. 2004. Campagne de depistage du radon domiciliaire a Baie-Johan-Beetz. Rapport presente dans le cadre du cours Formation professionnelle en entreprises ENV 778, Supervisees par Gagnon F, Universite de Sherbrooke. Cited in Dessau et al 2004.
- Health Canada. 2012. Cross-Canada Survey of Radon Concentrations in Homes - Final Report. Environmental and Workplace Health. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/survey-sondage/index-eng.php.
- Letourneau EG, Krewski D, Choi NW, Goddard MJ, McGregor RG, Zielinski JM and Du J. 1994. Case-Control Study of Residential Radon and Lung Cancer in Winnipeg, Manitoba, Canada. American Journal of Epidemiology 140 (4): 310-322.
- Letourneau EG, McGregor RG and Walker WB. 1984. Design and Interpretation of Large Surveys for Indoor Exposure to Radon Daughters. Radiation Protection Dosimetry 7 (1-4): 303-308.
- Levesque B, Gauvin D, McGregor RG, Martel R, Gingas S, Dontigny A, Walker WB and Lajoie P. 1995. Etude d'exposition au radon222 dans les residences de la province du Quebec. Cited in Dessau et al 2004.
- Savard M, Dessau JC, and Pellerin E. 1999a. Le radon a Oka – mesures complementaires de concentrations de radon Regie regional de la santé et des services sociaux des Laurentides, Direction de la santé publique, St-Jerome). Cited in Dessau et al 2004.
- Savard M, Pellerin E, and Dessau JC. 1999b. Evaluation des risques de surexpositions au radon dans un secteur des collines de Saint-Andre-Est-Municipalite de Saint-Andre-d'Argenteuil (Rapport de la Direction regionale de la santé publique des Laurentides). Cited in Dessau et al 2004.
- Savard M, Dessau JC, and Pellerin E. 1998. Le radon a Oka – Rapport d'intervention de santé publique (Regie regional de la santé et des services sociaux des Laurentides, Direction de la santé publique, St-Jerome). Cited in Dessau et al 2004.

iii. Dust

Exposure to radon via ingestion of dust is expected to be negligible.

iv. Drinking water

Radon may be present in drinking water but is quickly volatilized to indoor air. Exposure via ingestion of drinking water is negligible.

v. Food and Beverages

Exposure to radon via foods and beverages is expected to be negligible.

2. Data quality for lifetime excess cancer risk estimates

Only publicly available data were used to calculate these indicators. Data that are not publicly available may produce different results.

No systematic method for measuring data quality was possible, so we provide the following assessments of how well the data used may represent the actual Canadian average levels. Quality is rated higher when there are data from a number of Canadian monitors, or from Canadian studies that show results similar to other comparable studies. Quality is rated lower when data from few monitors or studies were available, and lowest when estimates are based on non-Canadian data. Others may rate data quality differently.

Exposure Pathway	Data Quality	Notes
Outdoor air	Moderate	• Radon in outdoor air was measured in a number of Canadian cities in 1990-1991. While we do not expect levels to change over time, given outdoor levels of radon are a product of geology and soil moisture, data from areas not previously measured may affect the estimate of average levels.
Indoor air	Moderate - High	• Indoor radon levels have been measured in thousands of homes across Canada over the past 30 years, and the results suggest levels can vary widely, depending not only on local geological characteristics, but also on building structure and condition. New data from ongoing surveys may affect the estimate of average levels.

3. Data for mapping concentrations

The national map was created using radon measurements from the Cross Canada Radon Survey (Phase I & II). It displays the percentage of home radon measurements in each health region above the current Canadian guideline of 200 Bq/m^3.

i. Provincial measurements – By level

The tables below show the percentage of tested homes in each province and territory that fall with different levels. The World Health Organization reference level is currently 100 Bq/m^3, and the current Canadian guideline is 200 Bq/m^3.

Radon Measurements in Canada
(Percent >100, >200, >600 Bq/m³ by Provinces and Territories)

Province/ Territory	Homes	≤ 100 Bq/m³	>100 - 200 Bq/m³	>200 – 600 Bq/m³	>600 Bq/m³
BC	1812	82.2%	9.8%	6.6%	1.4%
AB	1124	67.6%	25.8%	6.0%	0.6%
SK	1200	51.9%	32.3%	14.8%	1.0%
MB	1180	49.9%	26.7%	20.9%	2.5%
ON	3930	75.0%	16.9%	7.2%	1.0%
QC	1779	77.4%	12.8%	8.7%	1.1%
NB	825	54.9%	20.5%	18.4%	6.2%
NS	591	79.2%	12.2%	6.1%	2.5%
PE	111	87.4%	9.0%	3.6%	0.0%
NL	712	83.6%	10.4%	4.8%	1.2%
NU	80	100.0%	0.0%	0.0%	0.0%
NT	186	78.0%	16.7%	4.8%	0.5%
YT	225	56.4%	24.5%	13.3%	5.8%
CANADA	**13,755**	**70.9%**	**18.0%**	**9.5%**	**1.6%**

Source: Cross Canada Radon Survey Year 1 (2009-2010) & Year 2 (2010-2011)

ii. Provincial measurements – Results

We used 100 Becquerels per cubic meter (Bq/m^3) to represent the average level in Canadian homes, but levels can vary regionally and from home to home, making it difficult to estimate the average accurately. Radon levels are influenced by building structure, age and condition, and because of differences in these factors, can be elevated in one home but not in the home next door. It is not possible to predict whether any one home will have a high level of radon and it is recommended that all homes be tested.

The tables below provide a summary of provincial and territorial radon measurements reported over the past 30 years. Many individuals may have had their homes tested independently, but those results are not publicly available.

2009-2010 Cross Canada Radon Survey - Phase 1 Results (Bq/m3) by Province and Territory
(n = number of samples)

LOCATION	< DL* (n)	Min (n)	Max (n)	Mean (n)
British Columbia	<15 (321)	15 (562)	2941 (562)	102 (562)
Alberta	<15 (26)	15 (490)	1391 (490)	103 (490)
Saskatchewan	<15 (23)	15 (528)	1718 (528)	138 (528)
Manitoba	<15 (33)	16 (530)	1903 (530)	168 (530)
Ontario	<15 (306)	15 (1547)	5657 (1547)	106 (1547)
Quebec	<15 (190)	15 (548)	2923 (548)	108 (548)
New Brunswick	<15 (46)	15 (344)	5590 (344)	202 (344)
Nova Scotia	<15 (96)	15 (196)	1695 (196)	110 (196)
Prince Edward Island	<15 (18)	15 (36)	415 (36)	88 (36)
Newfoundland	<15 (124)	15 (227)	831 (227)	86 (227)
Nunavut	<15 (65)	15 (10)	41 (10)	25 (10)
Northwest Territories	<15 (20)	15 (67)	924 (67)	90 (67)
Yukon	<15 (6)	16 (97)	1375 (97)	161 (95)

* Levels less than 15 Becquerels/cubic metre reported only as <15

Summary of Radon Measurements (Bq/m^3) Prior to 2009

(n = number of samples)

			Various rooms: lowest floor, ground floor, living area, lowest inhabited floor (may include basement)					Basement only			
Location	Ref	Sample Year	< DL* (n)	Min (n)	Max (n)	Mean (n)	Geo-mean	Min (n)	Max (n)	Mean (n)	Geo-mean (n)
BRITISH COLUMBIA											
Vancouver	1	1977 - 1990					5.2 (823)				
Atlin	2	2007				118 (12)					
Barriere	2	2007				201 (38)					
Blue River	2	2007				153 (2)					
Castlegar	2	2007				240 (38)					
Clearwater	2	2007				447 (50)					
Cranbrook	2	2007				50 (88)					
Fernie	2	2007				78 (10)					
Fort Nelson	2	2007				67 (50)					
Fort St. John	2	2007				50 (68)					
Kamloops	2	2007				39 (75)					
Kelowna	2	2007				83 (71)					
Kimberly	2	2007				99 (24)					
Little Fort	2	2007				114 (6)					
Nelson	2	2007				120 (71)					
Pemberton	2	2007				29 (15)					
Penticton	2	2007				108 (68)					
Prince George	2	2007				127 (75)					
Queen Charlotte Island	2	2007				16 (67)					
Quesnel	2	2007				53 (68)					
Squamish	2	2007				29 (26)					
Stewart	2	2007				37 (5)					
Terrace	2	2007				40 (70)					
Trail	2	2007				107 (67)					
Valemount	2	2007				79 (47)					
Vancouver (GVRD)	2	2007				18 (135)					
Vernon	2	2007				73 (65)					
Victoria	2	2007				19 (58)					
Whistler	2	2007				26 (58)					

ALBERTA										
Calgary	1	1977 - 1978				11.5 (900)				
Edmonton	3	1980				17 (603)				
SASKATCHEWAN										
Regina	3	1980				49.2 (961)				
Saskatoon	3	1980				15.5 (770)				
MANITOBA										
Brandon	3	1980				31.1 (561)				
Winnipeg	3	1980				57 (563)				
Winnipeg	4	1983 - 1990			120 (4448)				197 (4448)	
Winnipeg	5	2008	20 (116)	483 (116)	143 (116)	112 (116)				
ONTARIO										
Sudbury	1	1977 - 1987				21.5 (772)				
Thunder Bay	1	1977 1988				20.0 (627)				
Toronto	1	1977 - 1989				11.5 (751)				
Ottawa	6	2006 - 2007	8 (93)	1525 (93)		74 (93)				
QUEBEC										
Montreal	1	1977 - 1981				10.7 (600)				
Quebec City	1	1977 - 1982				10.4 (584)				
Sherbrooke	1	1977 - 1984				13.3 (905)				
Campbell's Bay	7	1981	16 (3)	58 (3)			16 (5)	64 (5)		
Fort-Coulogne	7	1981	10 (6)	33 (6)			10 (11)	134 (11)		
Grand Calumet	7	1981		24 (1)			24 (2)	55 (2)		
Shawville	7	1981	30 (5)	82 (5)			30 (8)	177 (8)		
Otter Lake	7	1981		46 (1)			51 (3)	105 (3)		
Mont-Laurier Phase I	8	1985								76 (21)
Mont-Laurier Phase II	8	1985								83 (25)
Oka sector 1 (highest risk)	8	1985				327 (18)				1567 (18)
Oka sector 2	8	1985				34 (40)				75 (40)
Oka sector 3	8	1985				54 (3)				103 (3)
Shawville	8	1985				27 (16)				69 (13)
St-Honore Phase I	8	1985				14 (7)				24 (13)
St-Honore Phase II	8	1985				26 (20)				53 (20)
Maniwaki - non-uranium zone	9	1988				31 (70)				43 (70)
Maniwaki - uranium zone	9	1988				43 (35)				91 (20)
Saint-Agathe	9	1988				10 (70)				19 (69)

Saint-Andre d'Argenteuil	10	1998	6 (39)	2737 (39)		251 (39)				
Quebec survey - higher risk zone	11	1992-1993				19.8 (420)				34.9 (420)
Quebec survey - other zone	11	1992-1994				16.5 (474)				34.4 (474)
Oka zone 1 (highest risk)	12, 13, 14	1996, 2002	18 (203)	10,500 (203)		490 (203)				
Oka zone 2	12, 13, 14	1997, 2002	37 (178)	9,626 (178)		285 (178)				
Oka zone 3	12, 13, 14	1998, 2002	33 (200)	3,190 (200)		131 (200)				
Oka - undefined zone	12, 13, 14	1999, 2002	40 (24)	650 (24)		126 (24)				
Mont Saint-Hilaire	15	2001					20 (40)	951 (40)		69 (40)
Baie-Johan-Beetz	16	2004	49 (20)	229 (20)	95 (20)		49 (20)	1432 (20)	351 (20)	
NEW BRUNSWICK										
Fredericton	1	1977-1980				24.4 (455)				
Saint John	1	1977-1983				10.0 (867)				
NOVA SCOTIA										
Nova Scotia survey	17	1990	15 (779)	5920 (779)	108 (779)					
PRINCE EDWARD ISLAND										
Charlottetown	1	1977-1979				15.2 (814)				
NEWFOUNDLAND										
Saint John's	1	1977-1985				11.1 (585)				
Saint Lawrence	1	1977-1986				32.6 (435)				

Sources for provincial estimates:

- McGregor RG, Vasudev P, Letourneau EG, McCullough RS, Prantl FA, and Taniguchi H. 1980. Background Concentrations of Radon and Radon Daughters in Canadian Homes. Health Physics 39: 285-289.
- BCCDC (British Columbia Centre for Disease Control) 2007. Table of radon measurements.
- Letourneau EG, McGregor RG and Walker WB. 1984. Design and Interpretation of Large Surveys for Indoor Exposure to Radon Daughters. Radiation Protection Dosimetry 7 (1-4): 303-308.
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  Savard M, Dessau JC, and Pellerin E. 1999a. Le radon a Oka – mesures complementaires de concentrations de radon Regie regional de la santé et des services sociaux des Laurentides, Direction de la santé publique, St-Jerome). Cited in Dessau et al 2004.*
- Direction des Sante Publique des Laurentides, 2002. Unpublished. Cited in Dessau et al 2004.
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