

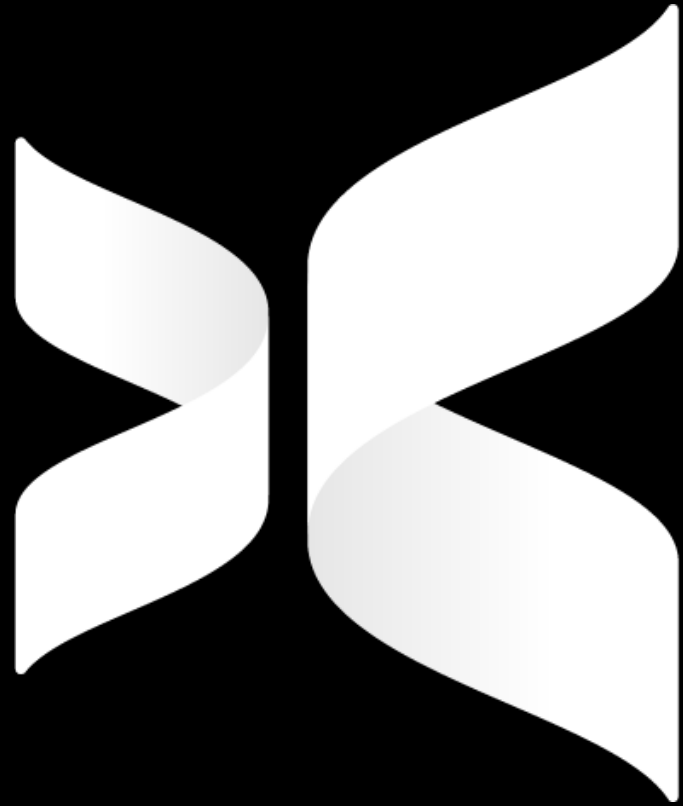
To view an archived recording of this presentation please click the following link:

<https://youtu.be/GgoOYqhPF9k>

Please scroll down this file to view a copy of the slides from the session.

#### Disclaimer

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**Arnie Charbonneau**  
**Cancer Institute**  
Robson DNA  
Science Centre



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Cancer Institute**  
Robson DNA  
Science Centre

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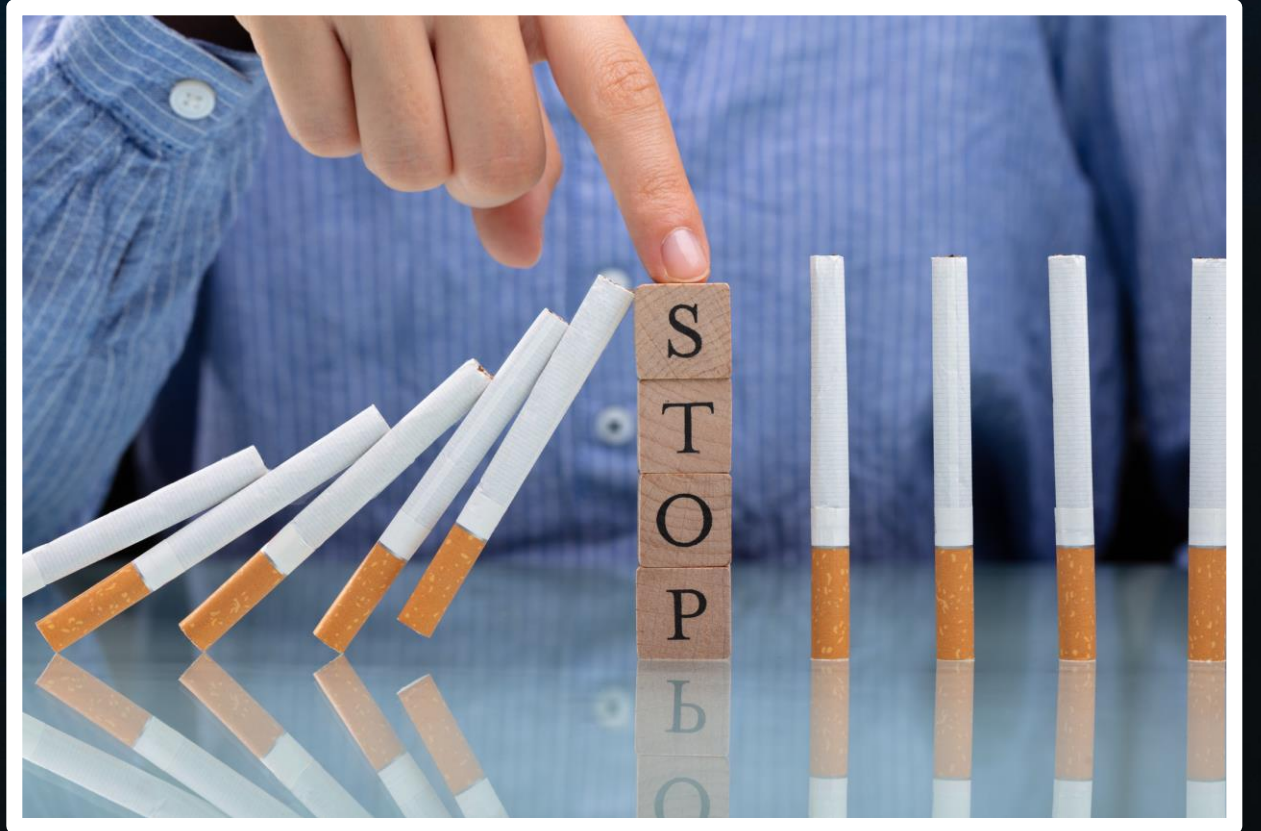


## DNA SCIENCE at the **University of Calgary**

The University of Calgary, located in the heart of Southern Alberta, both acknowledges and pays tribute to the traditional territories of the peoples of Treaty 7, which include the Blackfoot Confederacy (comprised of the Siksika, the Piikani, and the Kainai First Nations), the Tsuut'ina First Nation, and the Stoney Nakoda (including Chiniki, Bearspaw, and Goodstoney First Nations). The City of Calgary is also home to the Métis Nation of Alberta (Districts 5 and 6).







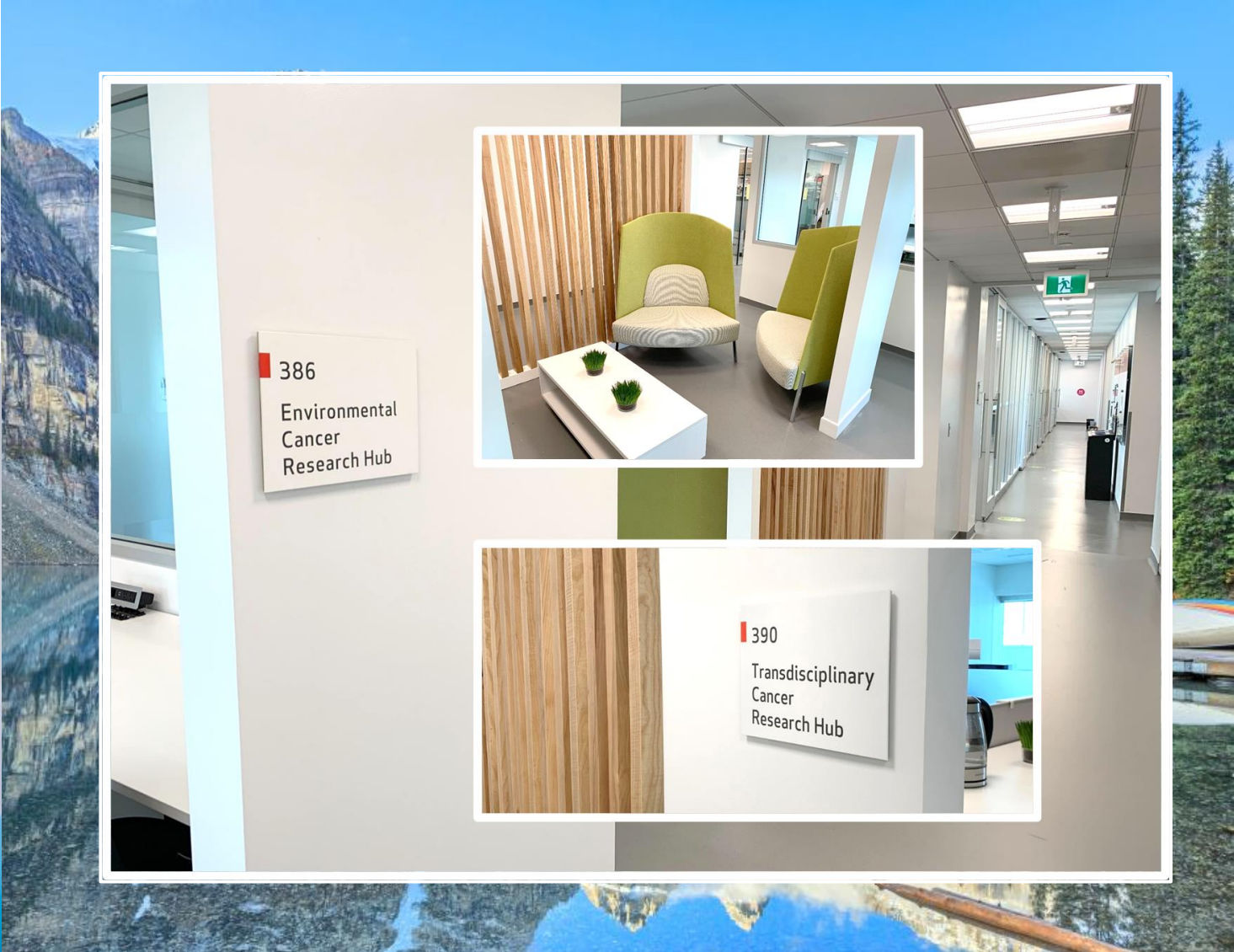


Adobe Stock | #197863750





**Arnie Charbonneau  
Cancer Institute**  
Robson DNA  
Science Centre



# Environmental cancer research hub



ÉTUDE  
NATIONALE

# EVICT RADON

NATIONAL  
STUDY



Canadian  
Cancer  
Society



Health  
Canada



Alberta  
Real Estate  
Foundation

Health Canada

lung health starts now lung health foundation

Yukon University

BC CANCER RESEARCH  
Provincial Health Services Authority

Canadian Nuclear Laboratories  
Laboratoires Nucléaires Canadiens

SFU SIMON FRASER UNIVERSITY

University of Victoria

UBC THE UNIVERSITY OF BRITISH COLUMBIA

HARVARD UNIVERSITY

FOX CHASE CANCER CENTER  
TEMPLE HEALTH

IOWA

UNIVERSITY OF CALGARY

UNIVERSITY OF SASKATCHEWAN

uOttawa

UNIVERSITY OF WATERLOO

QUEEN'S UNIVERSITY

UNIVERSITY OF TORONTO

DALHOUSIE UNIVERSITY

UNIVERSITÉ LAVAL

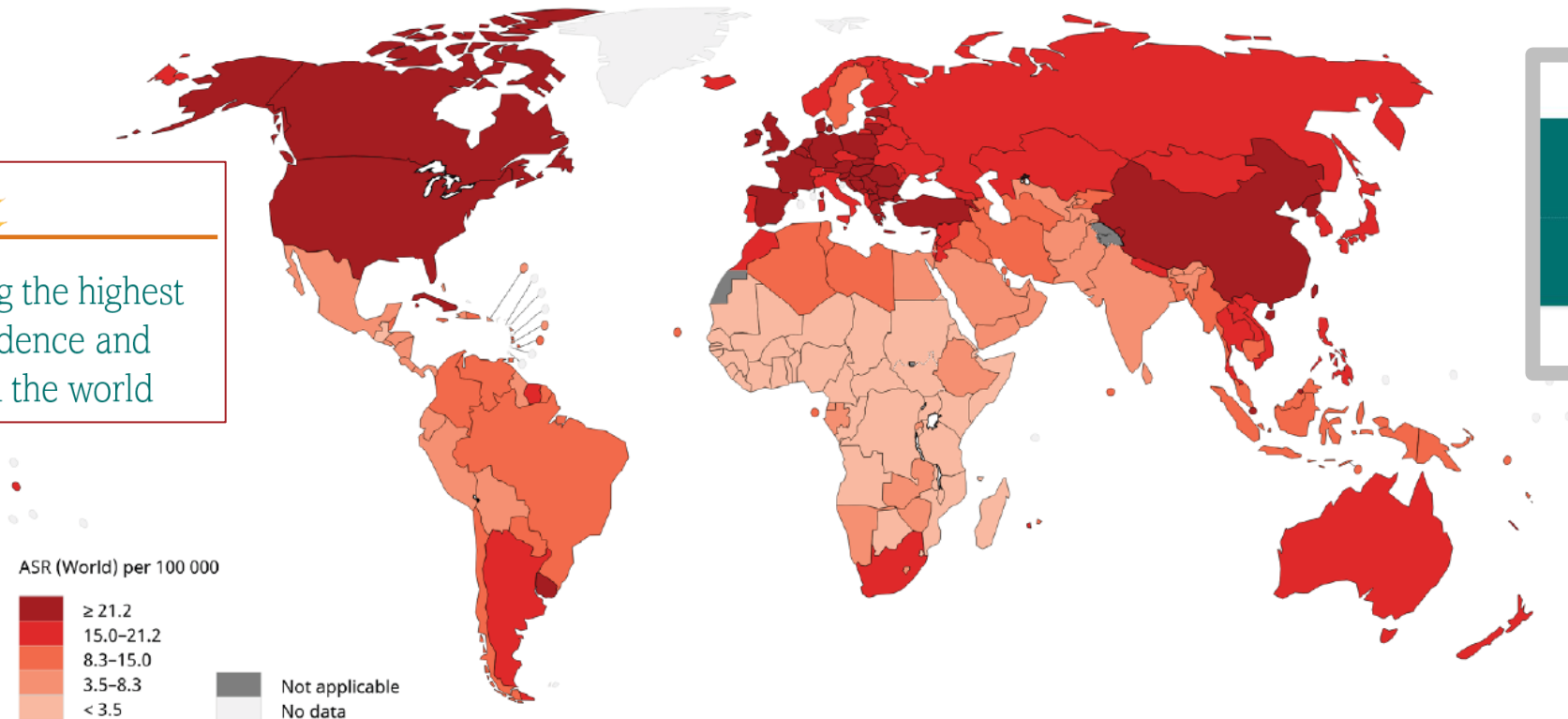
Yukon Northwest Territories Nunavut British Columbia Alberta Saskatchewan Manitoba Ontario Quebec Prince Edward Island New Brunswick Nova Scotia Newfoundland and Labrador

[www.evictradon.org](http://www.evictradon.org)

Canada's national research study to  
**UNDERSTAND & ENGINEER OUT RADON**

# LUNG CANCER CRISIS

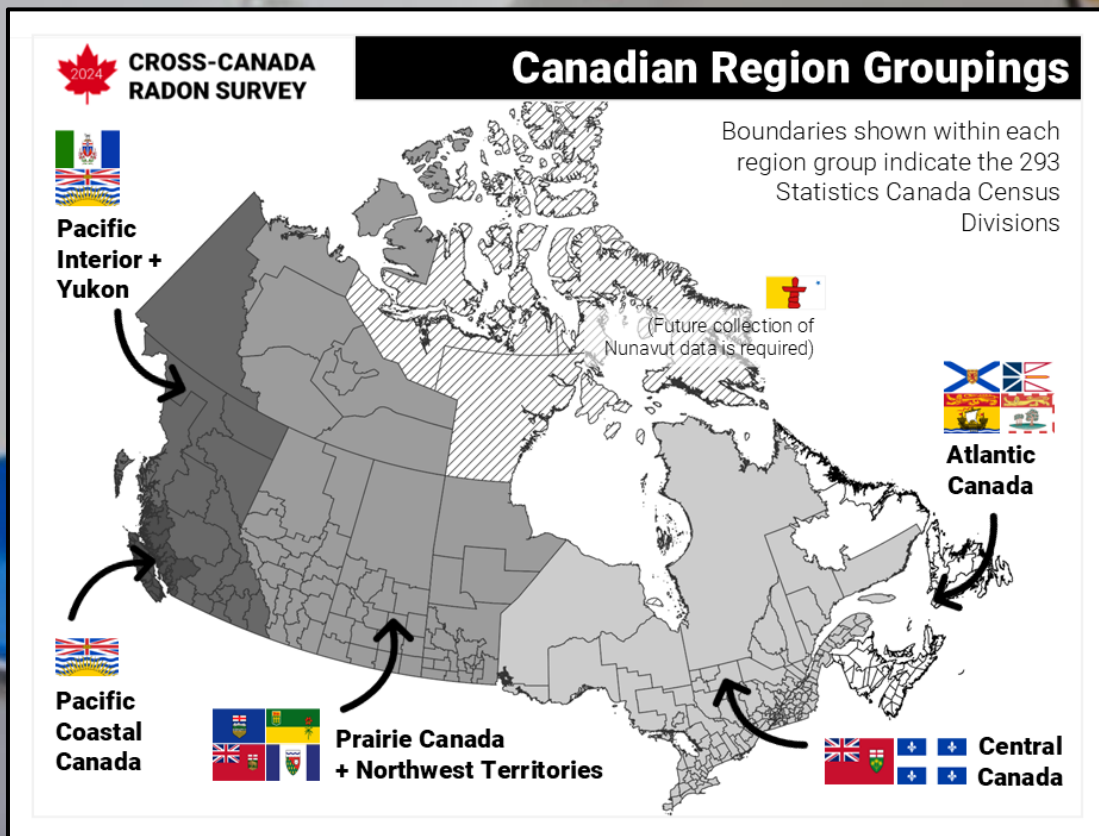
Image C Estimated age-standardized mortality rates (ASMR) for lung cancer, both sexes, all ages, World, 2018



Canada has among the highest lung cancer incidence and mortality rates in the world

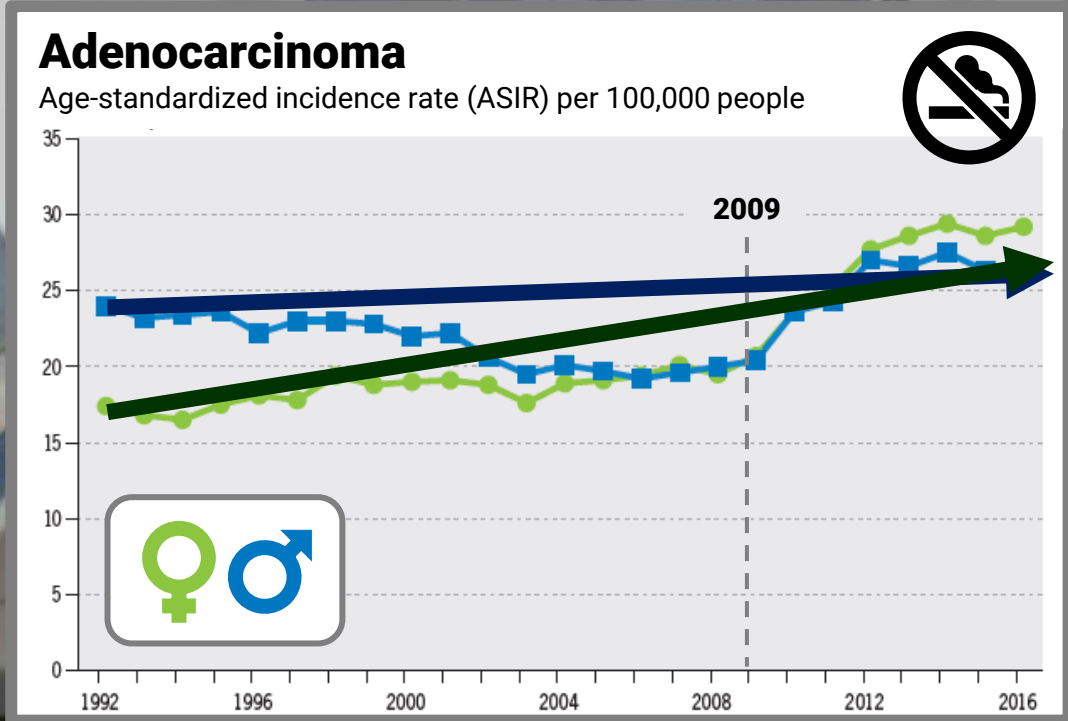
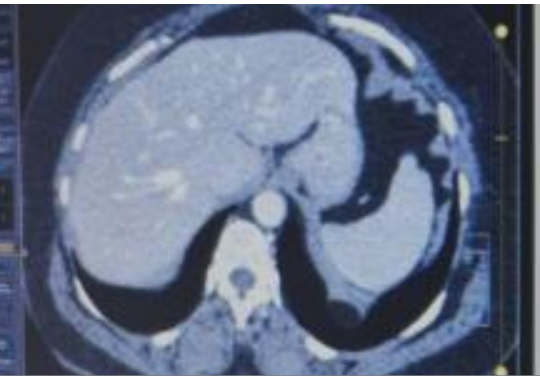
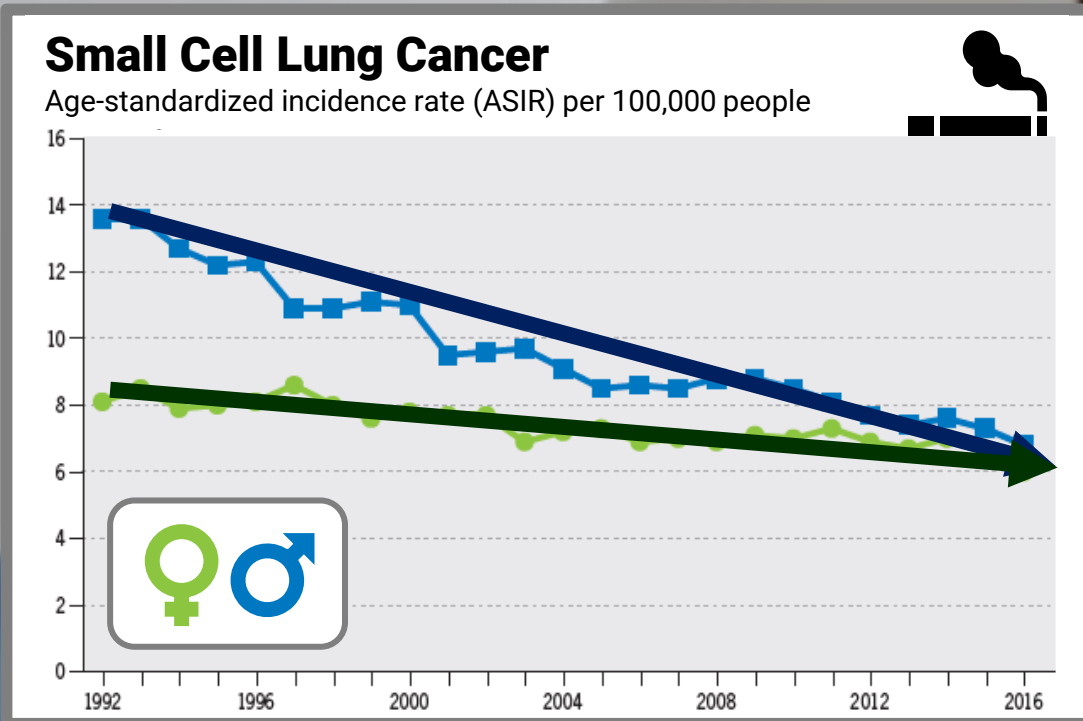


# LUNG CANCER INCIDENCE

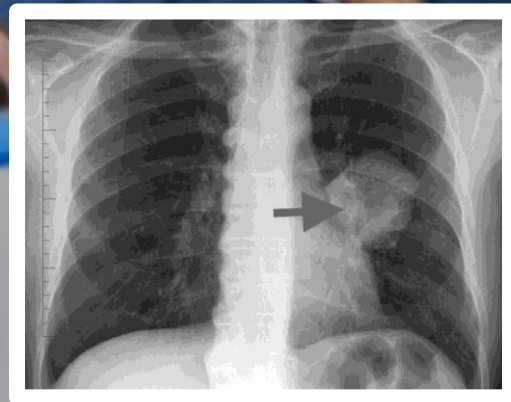


| REGION                     | PROVINCE     | Total # lung + bronchus cancer diagnoses IN 2024 |
|----------------------------|--------------|--|
| Pacific Coastal            | BC           | 2800   |
| Pacific Interior and Yukon | BC           | 1200   |
|                            | YK           | 21   |
| Prairie and NWT            | AB           | 2800   |
|                            | SK           | 860  |
|                            | MB           | 970  |
|                            | NWT          | 21   |
| Central                    | ON           | 10700  |
|                            | QC           | 9900   |
| Atlantic                   | NB           | 870  |
|                            | NS           | 1150   |
|                            | PE           | 160  |
|                            | NL           | 600  |
| <b>Canada</b>              | <b>Total</b> | <b>32052</b>                                     |

# LUNG CANCER INCIDENCE



# LUNG CANCER INCIDENCE



**TWO OF FIVE LUNG CANCERS**  
ARE **NOT** DUE TO **TOBACCO** SMOKING

# **ENVIRONMENTAL** LUNG CANCER



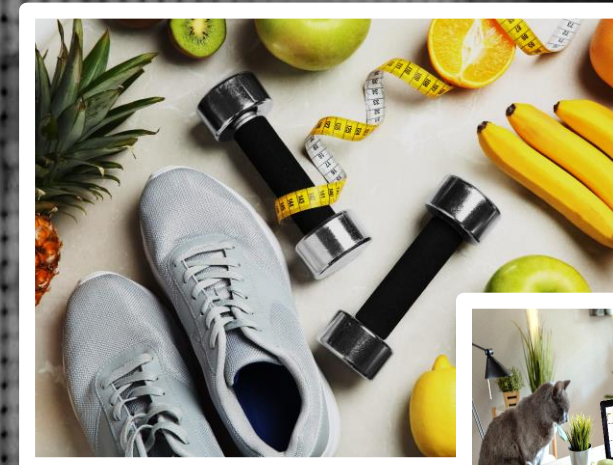
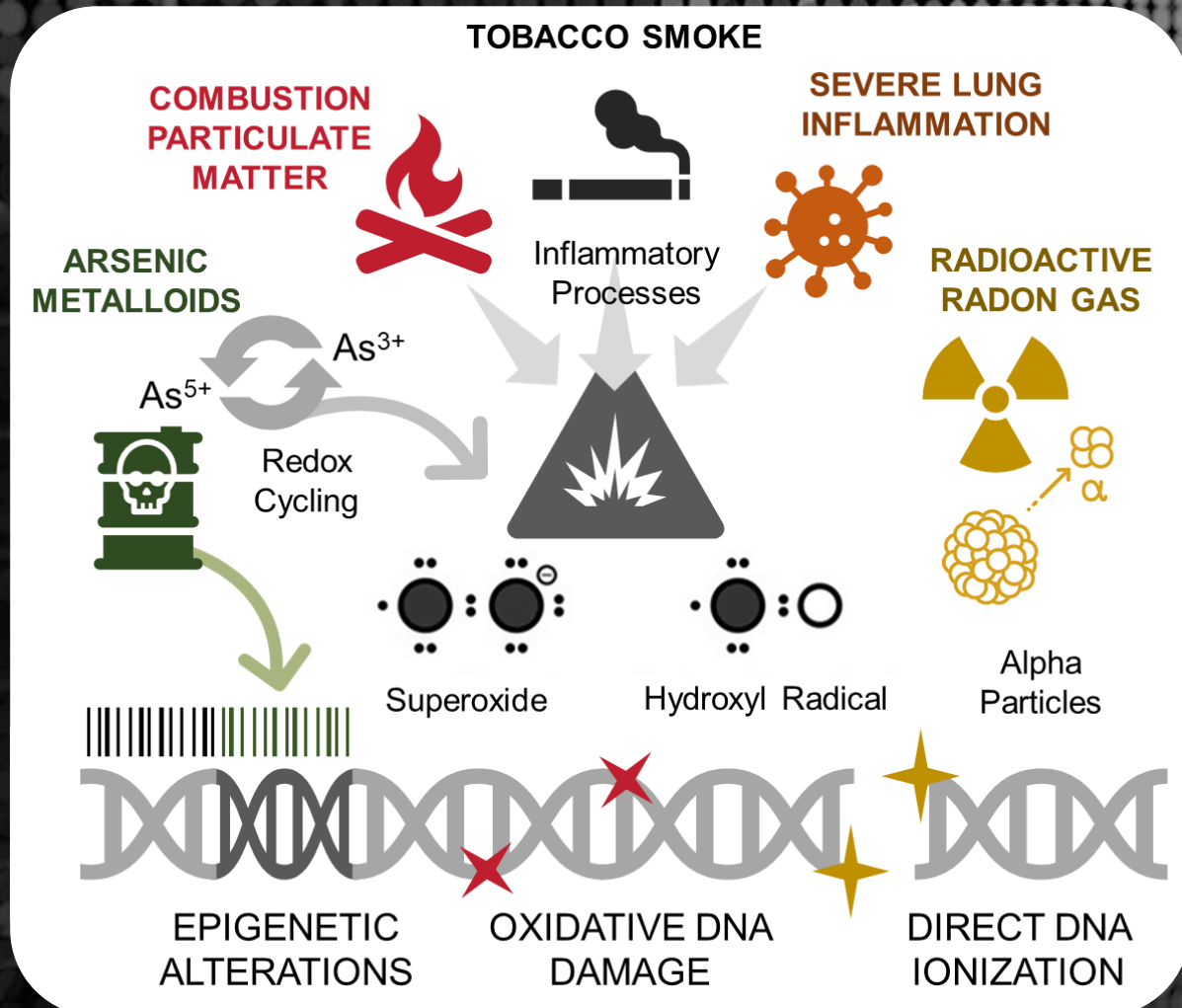
**AIR POLLUTION (forest fire, industry)**

**ASBESTOS**

**ARSENIC**

**RADON GAS**

# CAUSES OF LUNG CANCER



**RISK MODIFIERS**



# ENVIRONMENTAL CANCER RISK =

**CAUSES**

**x**

**MODIFIERS**



## **LIKELIHOOD**

probability  
of being  
exposed



## **DOSIMETRY**

exposed how  
much, and for  
how long



## **SUSCEPTIBILITY**

genetics, DNA  
repair,  
infection...



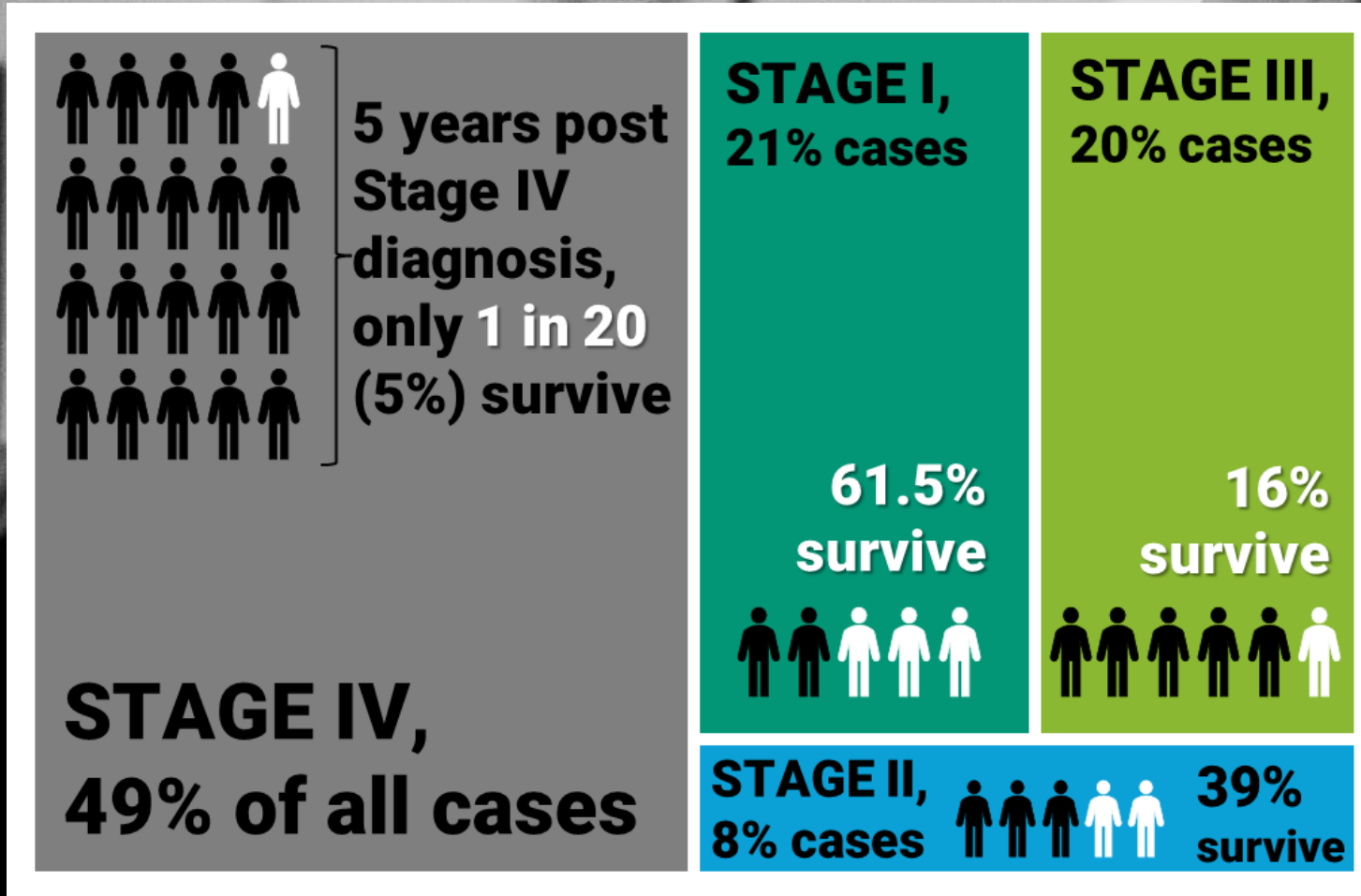
## **BEHAVIOUR**

lifestyle,  
diet, fitness,  
occupation...

# EXPOSURES ARE CONNECTED



# WHY IS THIS IMPORTANT?





**HOW CAN WE (ALL)  
RESPOND?**



# LEARN and **COMMUNICATE**





# **RADON (and PM<sub>2.5</sub>)** **BASICS**

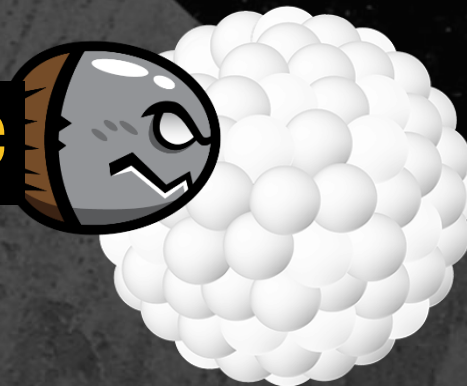
# RADON = PARTICLE RADIATION



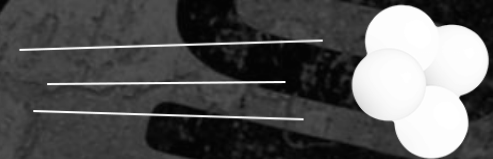
**Rn**  
radon



Moves at **15,000 km/sec**



Alpha particle



# RADON GAS ENTRY INTO RESIDENTIAL BUILDINGS

Radon diluted into atmosphere (low levels)

Radon retained within indoor air (to potentially high levels)



Vents  
Cracks  
Fittings  
Furnace  
Footings

Radon in Surface-Level Soil

Well

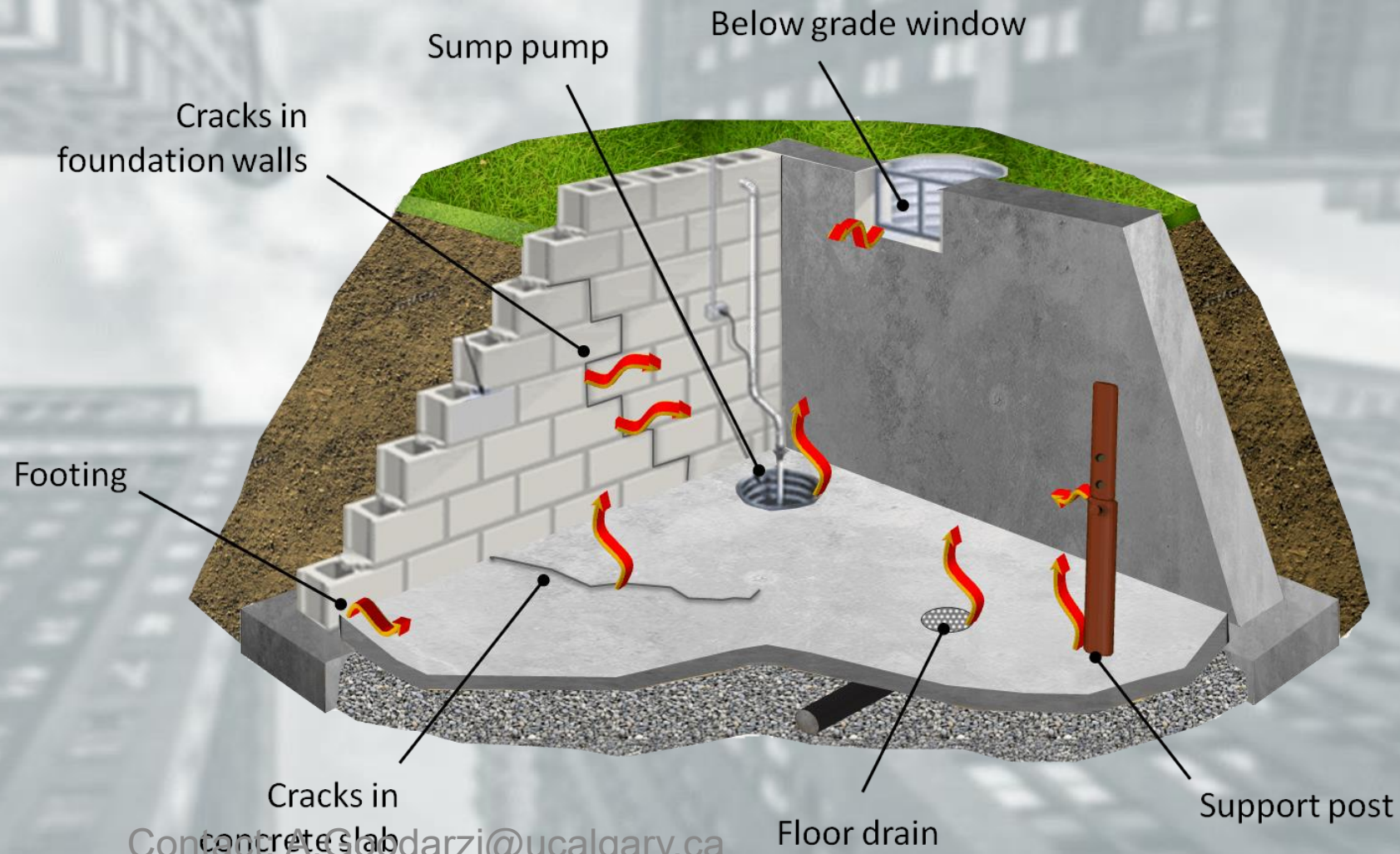
Geologic Sources of Radon Gas



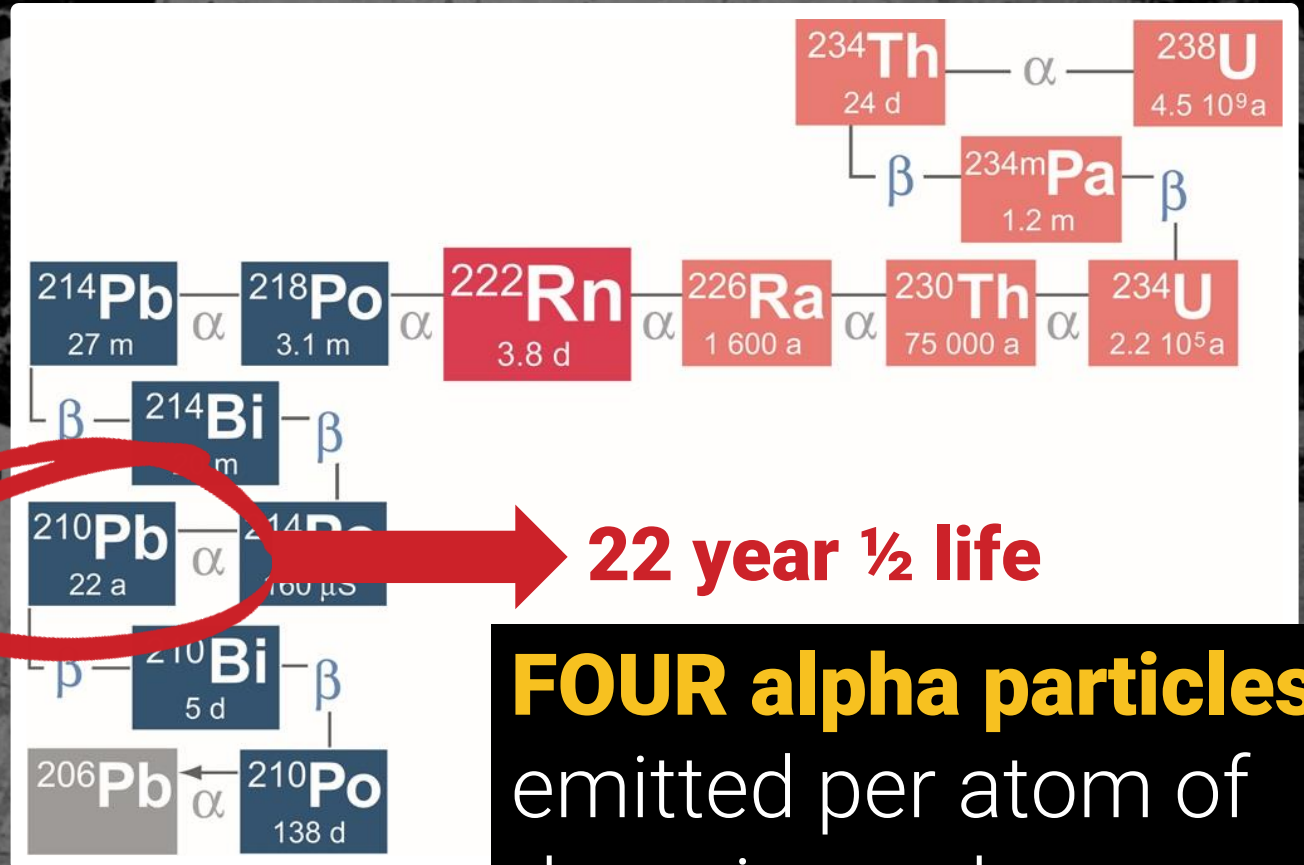
CROSS-CANADA  
RADON SURVEY



# RADON ENTRY



# Radon Decay Products **Precipitate**



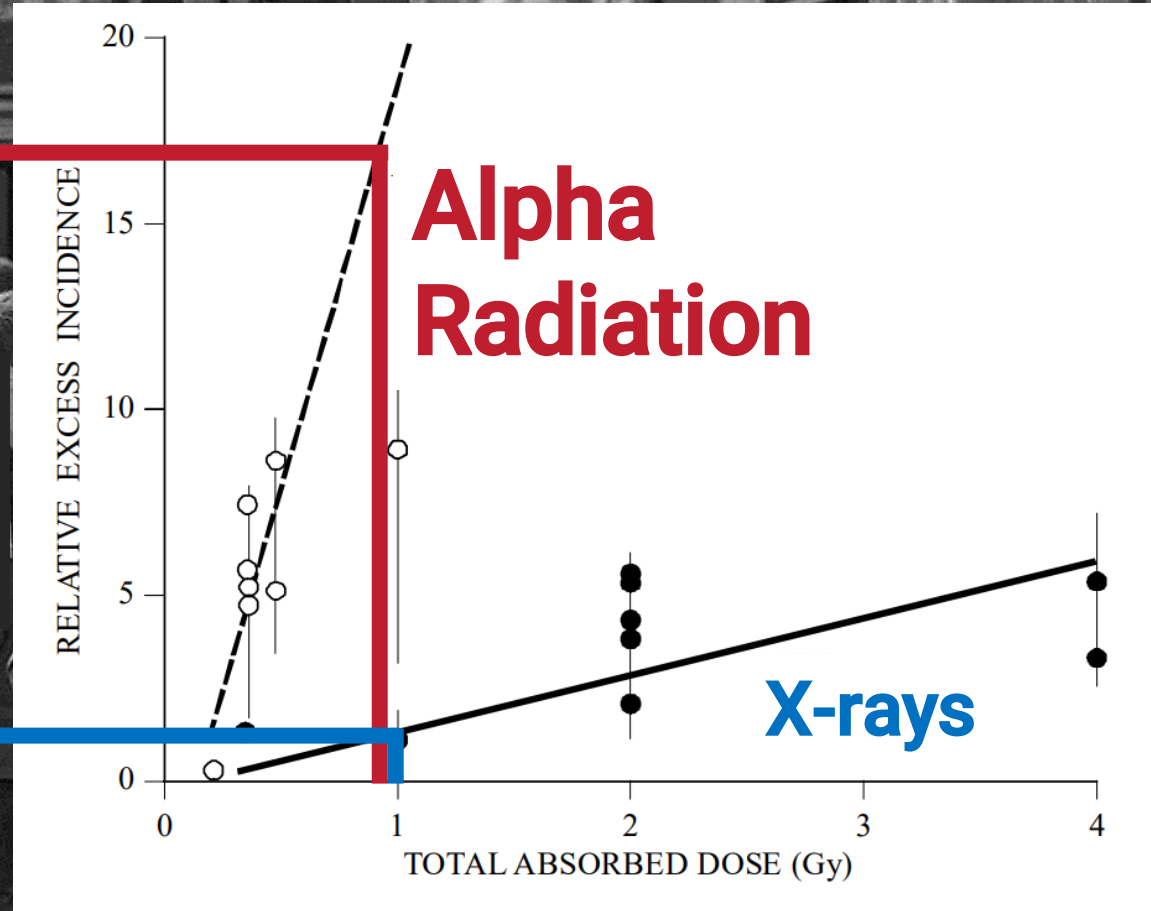
**22 year ½ life**

**FOUR alpha particles** are emitted per atom of decaying radon

# WHY SO **CANCER** causing?

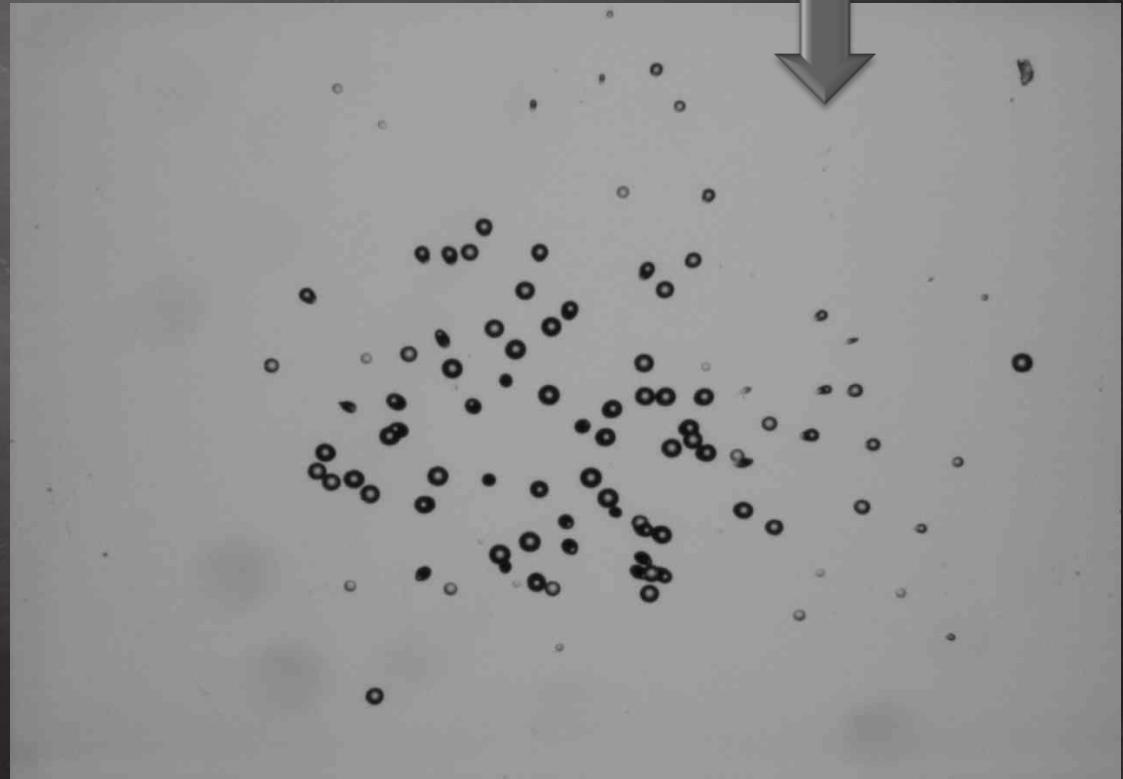
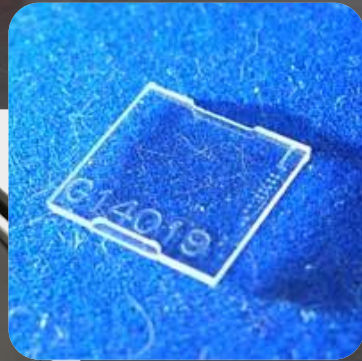
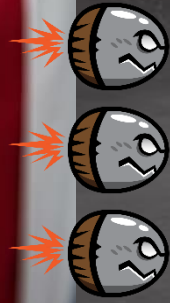


**CANCER RISK**

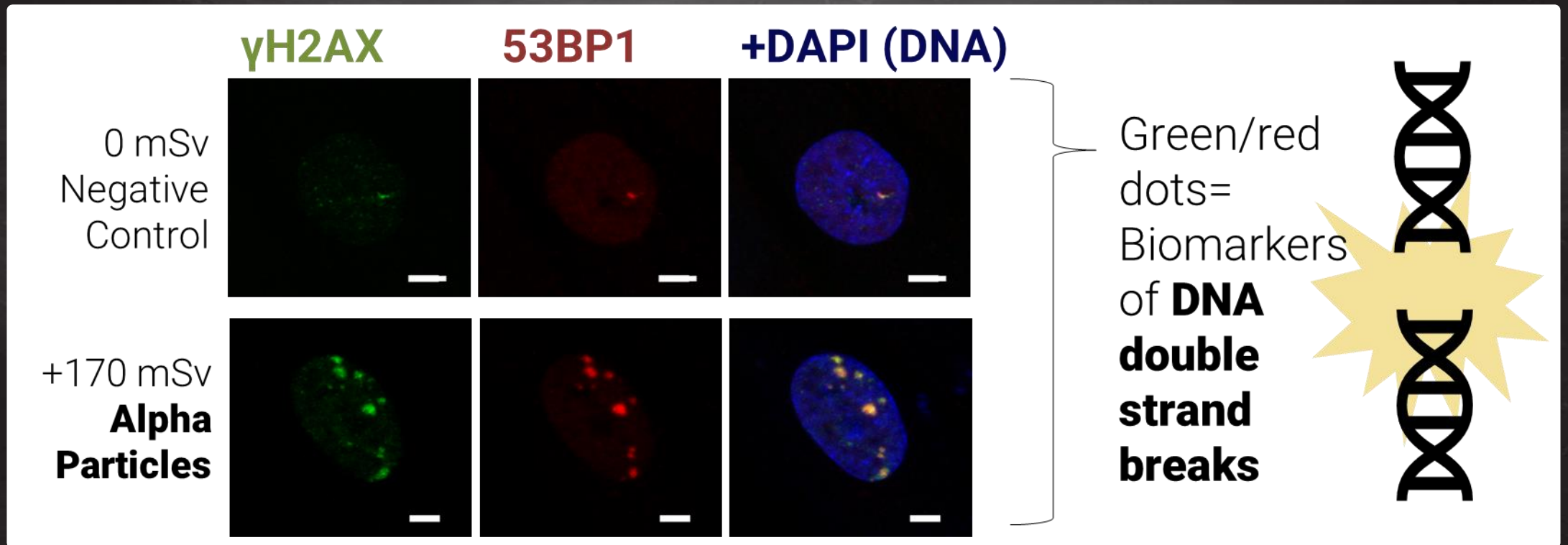


**RADIATION DOSE**

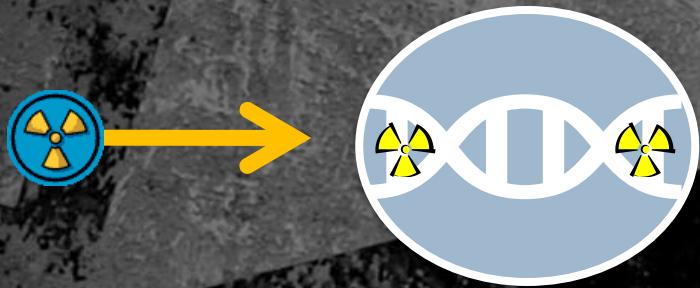
Measured in **Becquerels (Bq)/m<sup>3</sup>**



# Alpha particles impact **DNA**

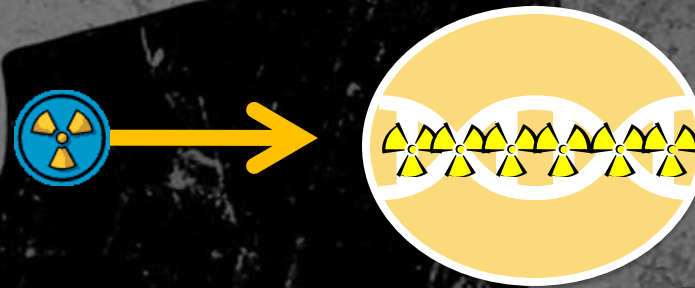


# WHY SO **CANCER** causing?



**Photon**

(e.g. x-ray, gamma-ray)



**Particle**

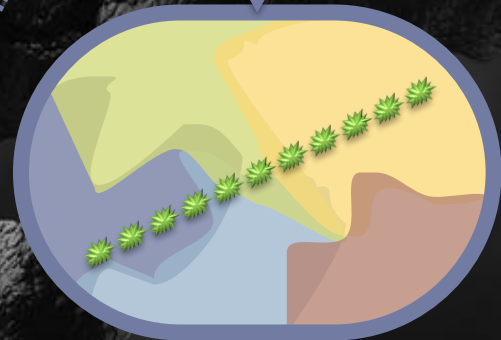
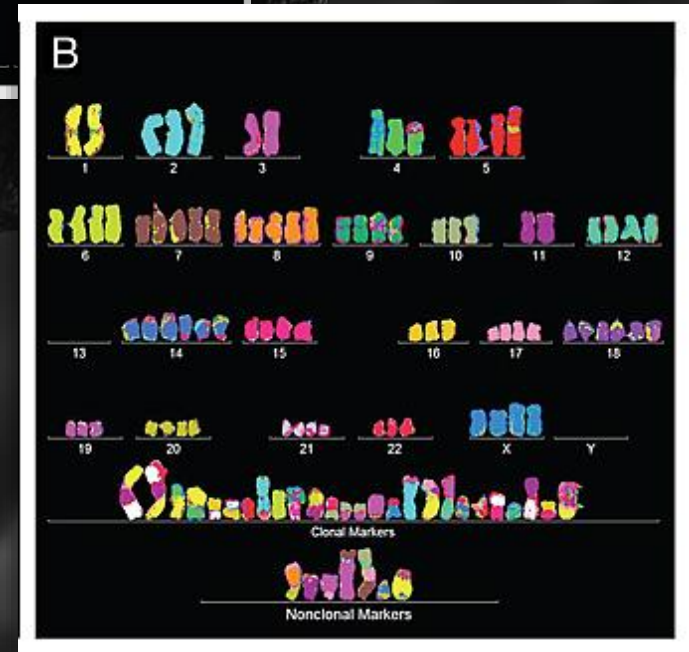
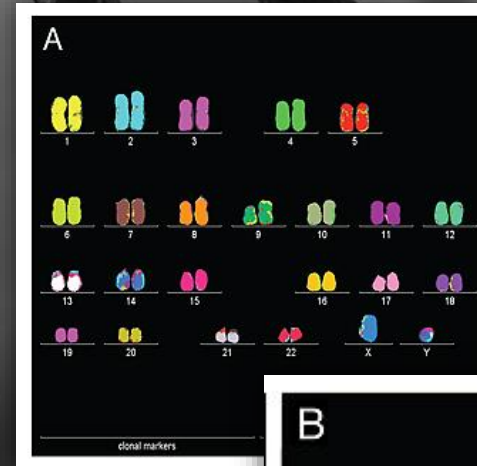
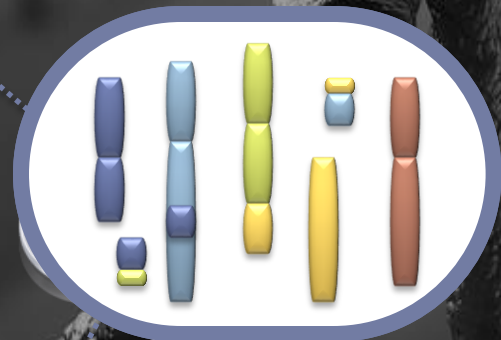
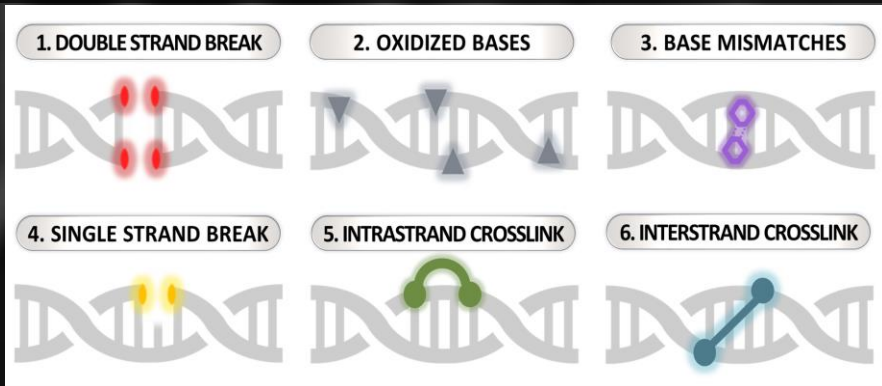
(e.g. from radon)

# DNA damage **CLUSTERING** effects

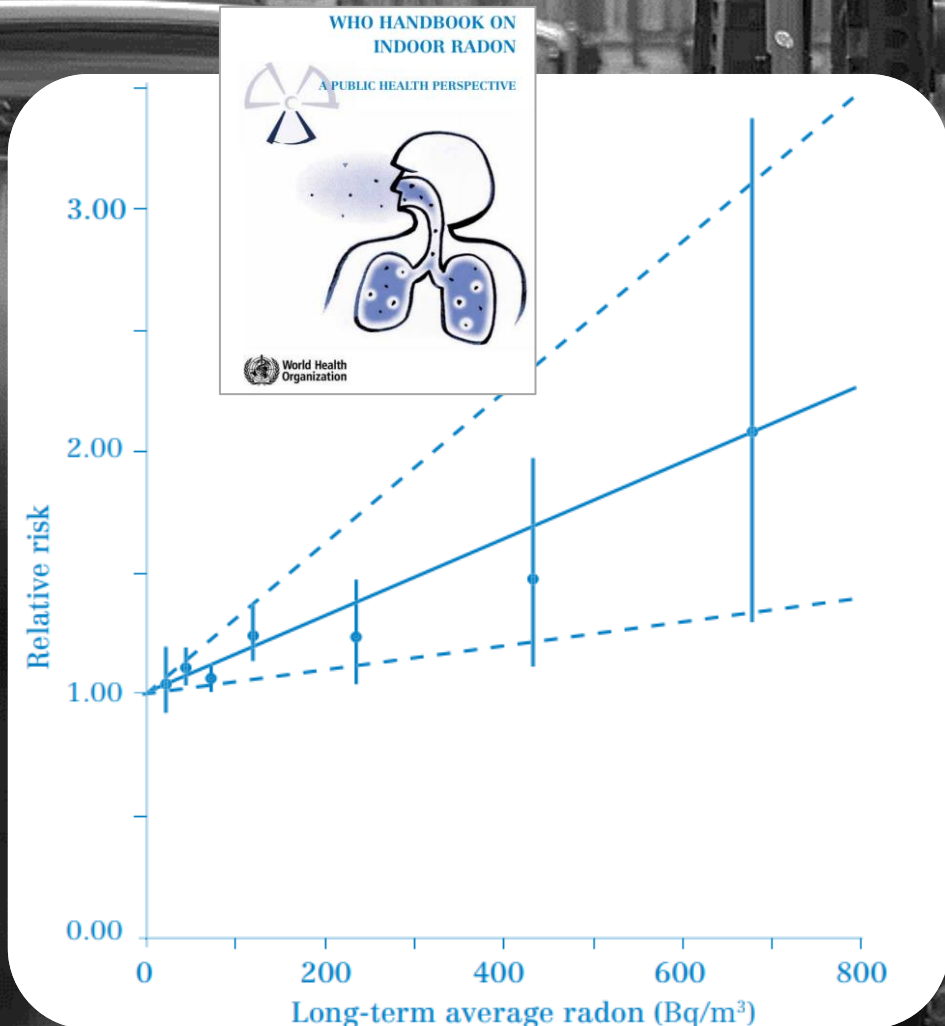
Relatively straight-forward **repair**



# DNA damage **CLUSTERING** effects



# RADON = LUNG CANCER



**Residential Radon and Risk of Lung Cancer**  
*A Combined Analysis of 7 North American Case-Control Studies*

Daniel Krewski,<sup>\*</sup> Jay H. Lubin,<sup>†</sup> Jan M. Zielinski,<sup>\*\*</sup> Michael Alavanja,<sup>‡</sup> Vanessa S. Catalan,<sup>§</sup> R. William Field,<sup>\*\*\*</sup> Judith B. Klotz,<sup>††</sup> Ernest G. Létourneau,<sup>‡‡</sup> Charles F. Lynch,<sup>†</sup> Joseph I. Lyon,<sup>§§</sup> Dale P. Sandler,<sup>||</sup> Janet B. Schoenberg,<sup>††</sup> Daniel J. Steck,<sup>¶¶</sup> Jan A. Stolwijk,<sup>\*\*\*</sup> Clarice Weinberg,<sup>†††</sup> and Homer B. Wilcox<sup>††</sup>

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**Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies**

S Darby, D Hill, A Auvinen, J M Barros-Dios, H Baysson, F Bochicchio, H Deo, R Falk, F Forastiere, M Hakama, I Heid, L Kreienbrock, M Kreuzer, F Lagarde, I Makeläinen, C Muirhead, W Oberaigner, G Pershagen, A Ruano-Ravina, E Ruosteenoja, A Schaffrath Rosario, M Tirmarche, L Tomášek, E Whitley, H E Wichmann, R Doll

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*Int. J. Cancer*: 109, 132–137 (2004)  
 © 2003 Wiley-Liss, Inc.

**UICC** Publication of the International Union Against Cancer

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**RISK OF LUNG CANCER AND RESIDENTIAL RADON IN CHINA: POOLED RESULTS OF TWO STUDIES**

Jay H. LUBIN<sup>1,\*</sup>, Zuo Yuan WANG<sup>2</sup>, John D. BOICE JR<sup>4</sup>, Zhao Yi XU<sup>5</sup>, William J. BLOT<sup>4</sup>, Long De WANG<sup>3</sup> and Ruth A. KLEINERMAN<sup>1</sup>

<sup>1</sup>Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rockville, Maryland, USA  
<sup>2</sup>Laboratory of Industrial Hygiene, Ministry of Health, Beijing, China  
<sup>3</sup>Ministry of Health, Beijing, China  
<sup>4</sup>International Epidemiology Institute  
<sup>5</sup>Liaoning Center for Disease Control and Prevention, Shenyang, China

**+16% to life lung cancer risk per 100 Bq/m³**



**I**NTERNATIONAL  
**A**GENCY FOR  
**R**ESEARCH ON  
**C**CANCER

International Agency for Research on Cancer



[www.iarc.fr](http://www.iarc.fr)

**CLASSIFICATIONS**

GROUP  
**1**

**ABSOLUTELY**

GROUP  
**2A**

**PROBABLY**

GROUP  
**2B**

**POSSIBLY**

GROUP  
**3**

**UNSURE**

GROUP  
**4**

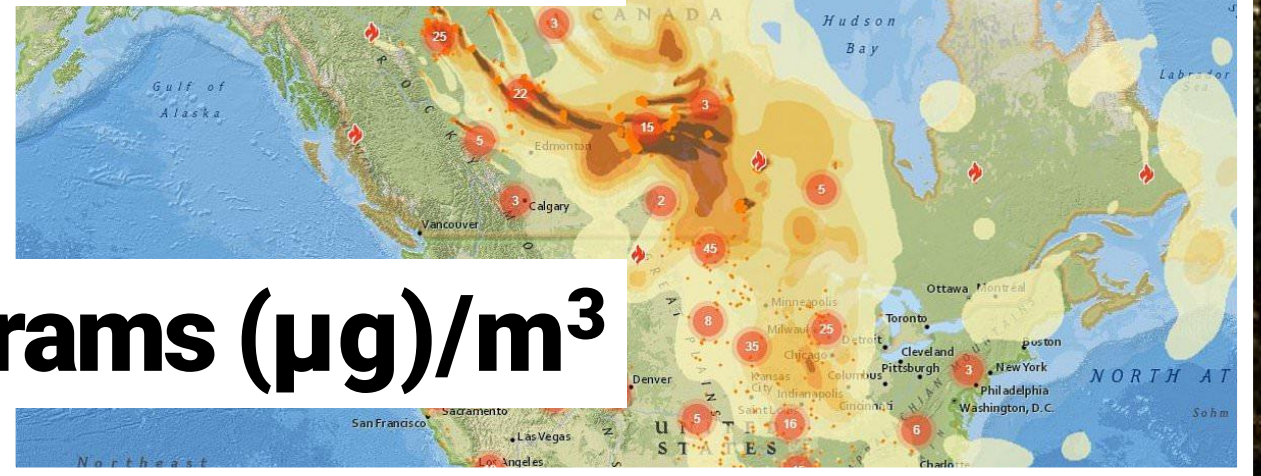
**LIKELY NOT**

# COMBUSTION PARTICULATES

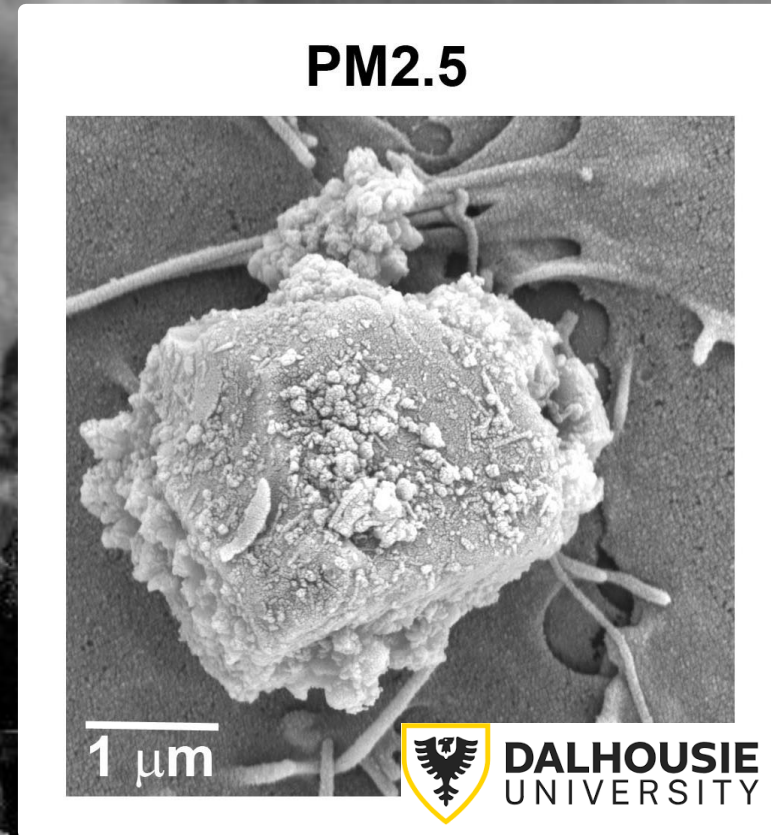
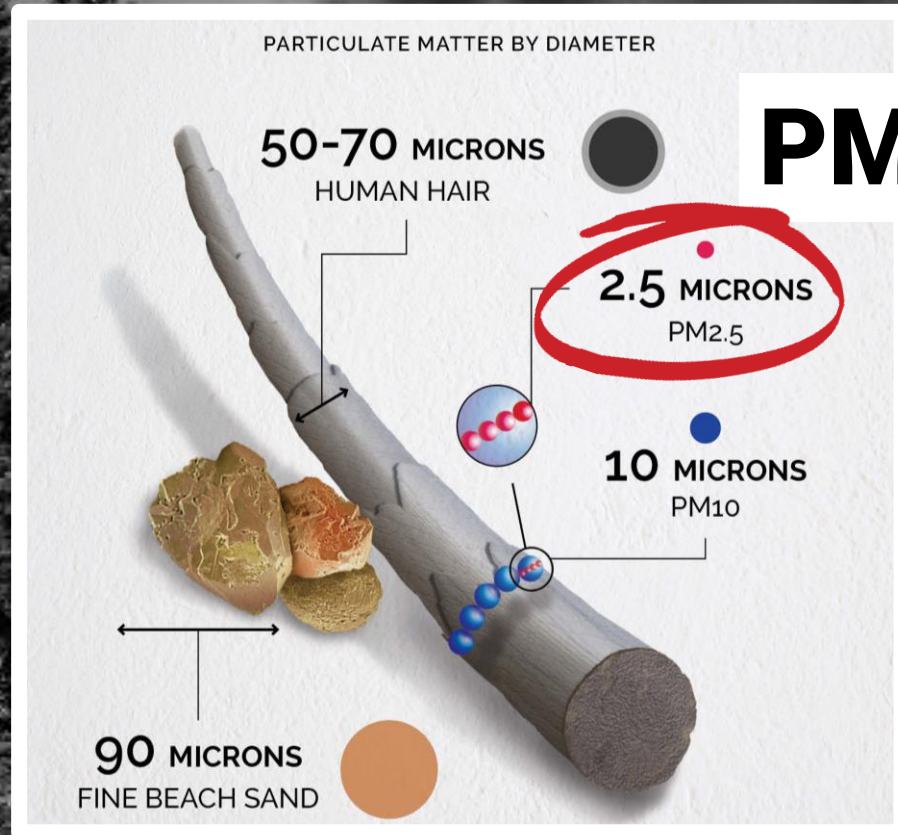


**COMBUSTION PARTICULATES - FROM THE AIR TO THE GROUND (TO OUR LUNG CELLS)**

Measured in **micrograms ( $\mu\text{g}$ )/m<sup>3</sup>**

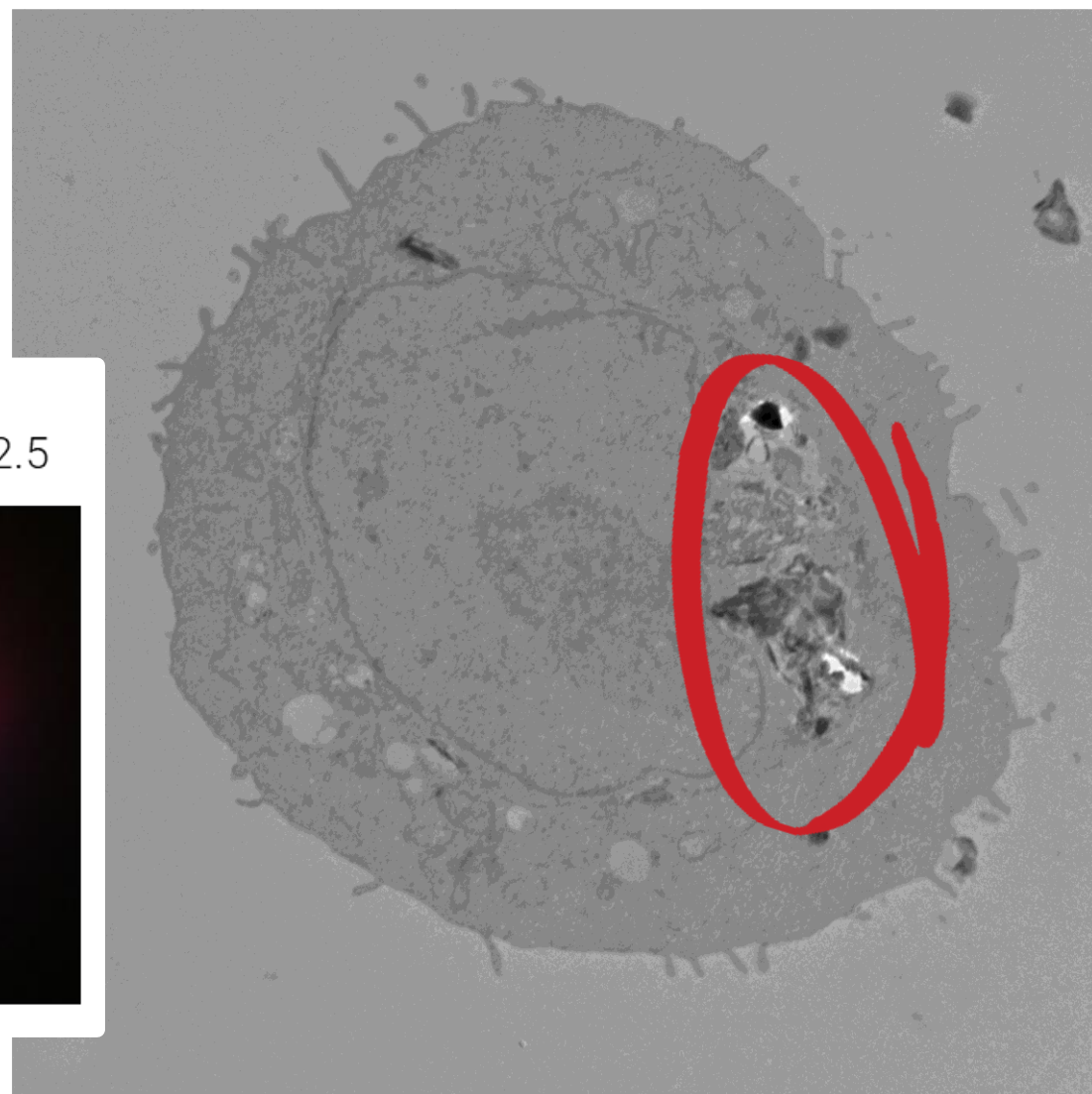
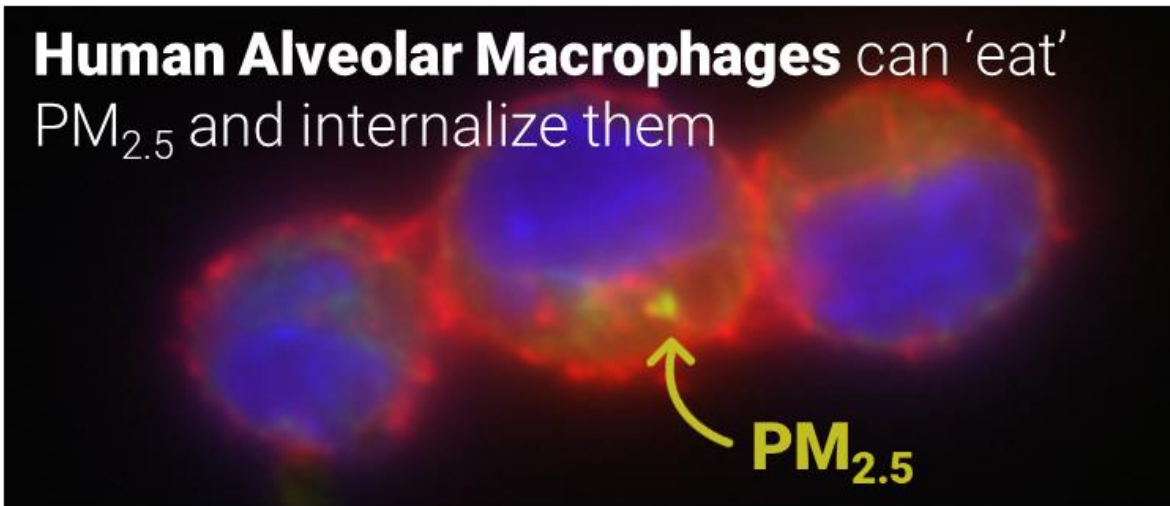


# PARTICULATE MATTER



 Tubulin  DAPI (DNA)  PM<sub>2.5</sub>

**Human Alveolar Macrophages** can 'eat'  
PM<sub>2.5</sub> and internalize them



pm2 50ug 24hr 05C.tif  
PM 50ug 24hr  
11:55:31 6/12/2024  
TEM Mode: Imaging

# COMBUSTION PARTICULATES

**PM2.5**

1  $\mu\text{m}$

**Toxic Metalloids**

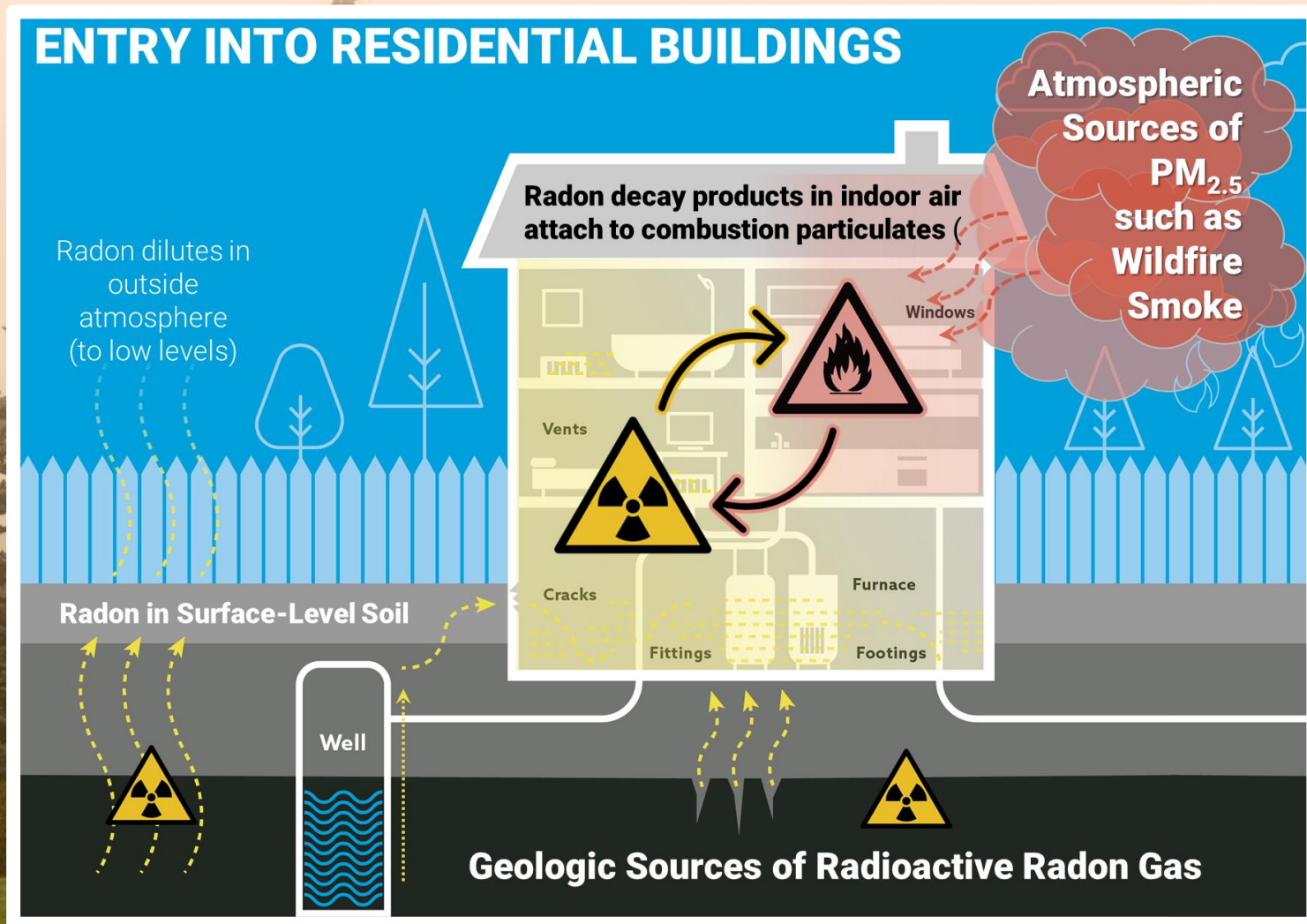
- Aluminum
- Arsenic
- Lead
- Cadmium
- Mercury

**HEAVY METAL TOXINS**

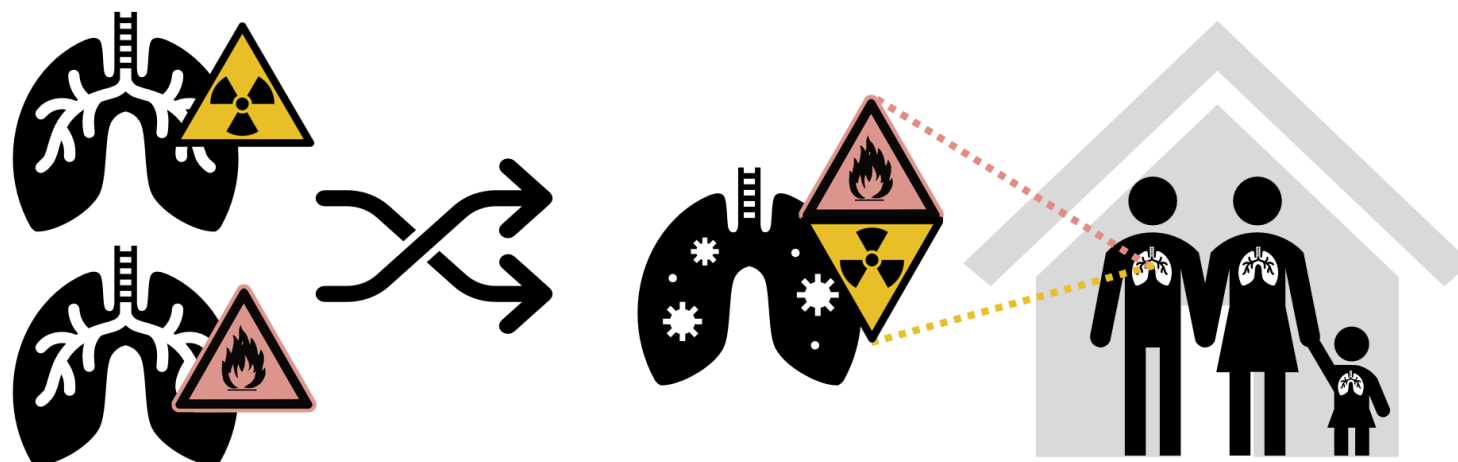
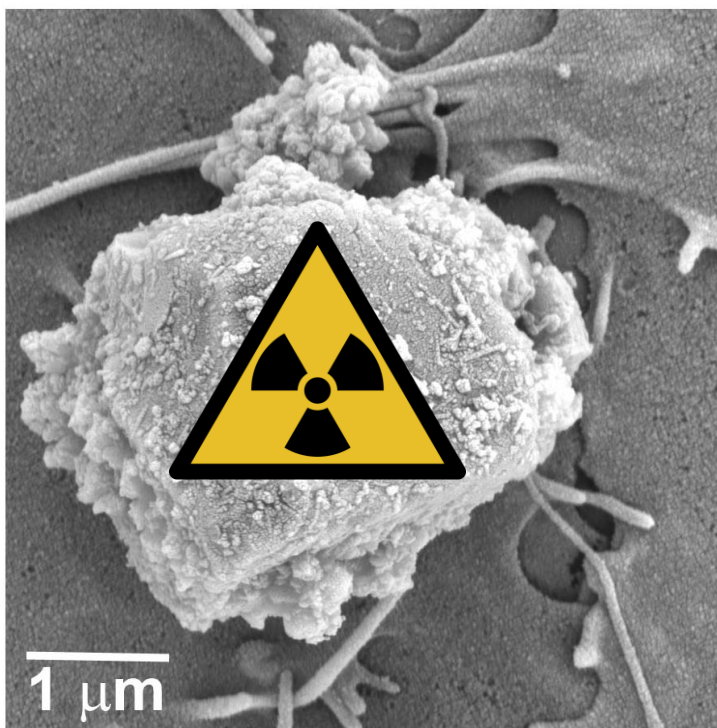
**Volatile Organics**

- Benzo[a]pyrene
- Dibenzo[a,]pyrene
- 7,12-dimethylbenz[a]anthracene

# MIXED EXPOSURE



# MIXED EXPOSURE

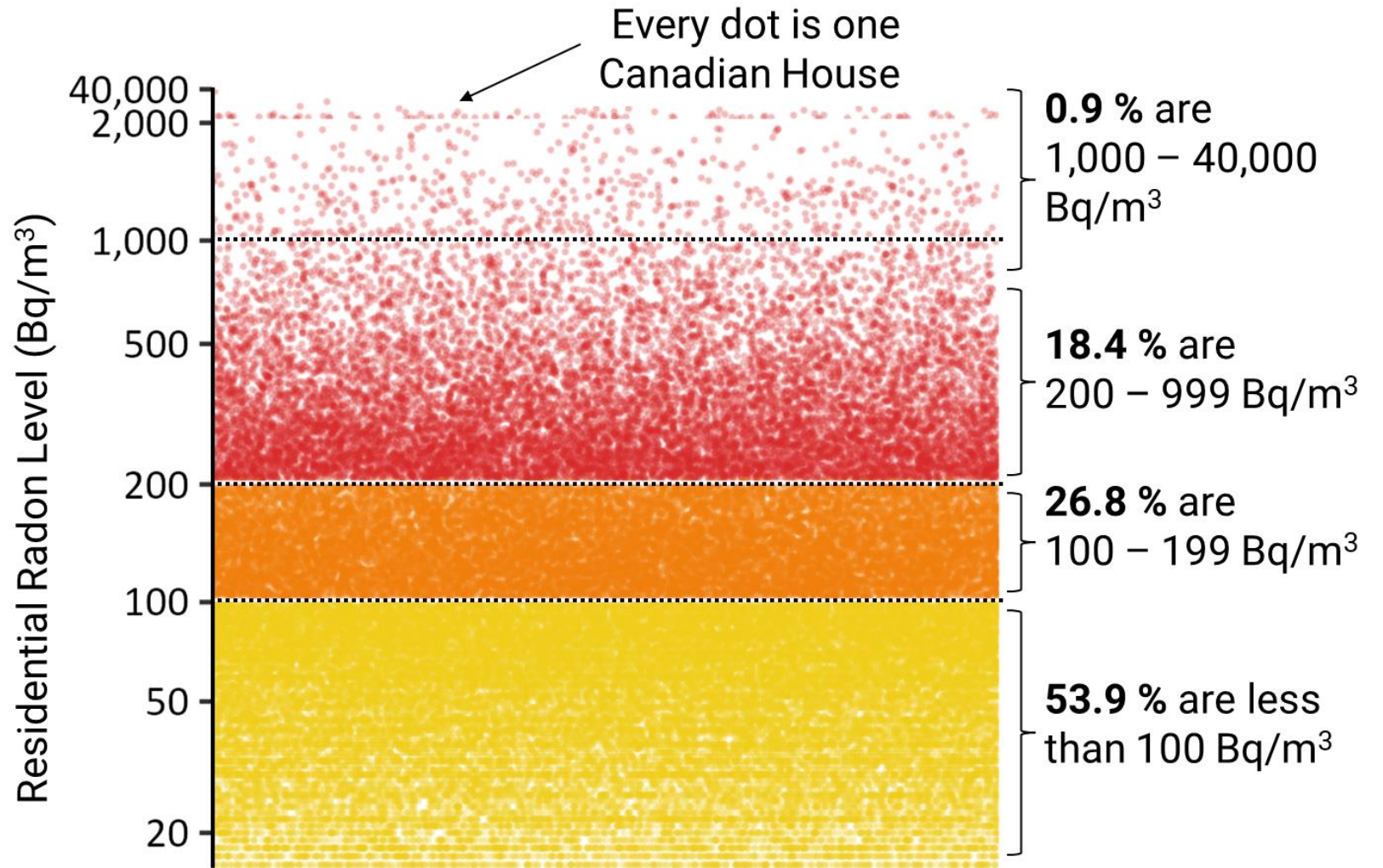


*In INDOOR AIR, most radon decay products will attach to airborne particulates, many forming **radioactive PM<sub>2.5</sub> containing <sup>210</sup>Pb***



**RADON** in our  
Built Environment

# Analysing Residential Radon in **CANADA**



**RESIDENTIAL RADON GAS**  
levels in 21<sup>st</sup> Century Canada

# INGREDIENTS of a radon problem



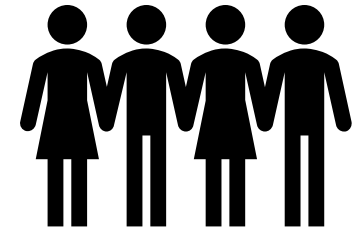
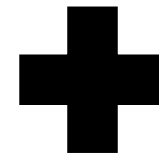
**LOCATION**

(REGION, COMMUNITY)



**BUILT**

**ENVIRONMENT**



**DEMOGRAPHICS**

**+BEHAVIOUR**





 **CROSS-CANADA  
RADON SURVEY**

[Voir en français](#)

[Cross-Canada Radon Survey](#)

**Read the 2024 Cross-Canada Survey  
of Radon and learn how it may  
affect you.**

[DOWNLOAD FULL REPORT](#)

[CONTACT US](#)

[Executive Summary](#)  
[Introduction to Radon](#)  
[History of Radon](#)  
[Purpose](#)  
[Radon Levels for Canada  
and by Building Type](#)  
[Radon Levels in Canada, by  
Urban to Rural  
Community](#)

## **CROSS-CANADA SURVEY OF RADON EXPOSURE IN RESIDENTIAL BUILDINGS OF URBAN AND RURAL COMMUNITIES**

*Made possible by funding from:* Canadian Institutes of Health Research - Healthy Cities Research Initiative; Health Canada's National Radon Program; the Alberta Real Estate Foundation; and the Canadian Cancer Society.

*Report prepared and published by the:* [Evict Radon National Study team](#) (including researchers at the British Columbia Cancer Agency, the Arnie Charbonneau Cancer Institute at the University of Calgary, University of Saskatchewan, and Dalhousie University) in collaboration with the staff and researchers at [Health Canada](#), [CAREX Canada](#), and the [British Columbia Centre for Disease Control](#).

## **Cross-Canada Survey of Radon Exposure in the Residential Buildings of Urban and Rural Communities**



**2024 REPORT**

Version 1.1 (CCSR.24.1.1), released October, 2024  
[crosscanadaradon.ca](http://crosscanadaradon.ca)



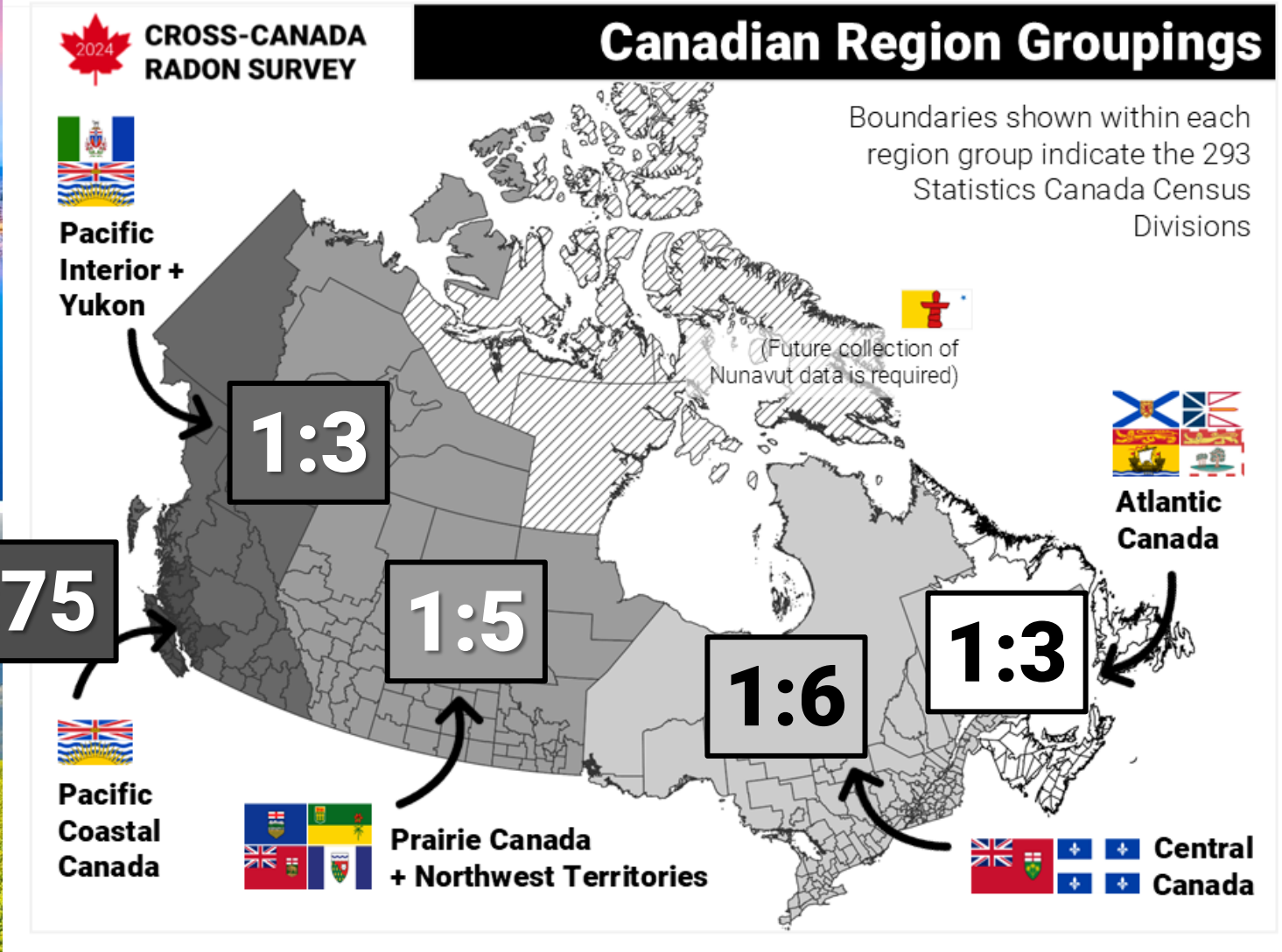
**Made possible by funding from:** Canadian Institutes of Health Research - Healthy Cities Research Initiative; Health Canada's National Radon Program; the Alberta Real Estate Foundation; and the Canadian Cancer Society.

**Report prepared and published by the:** Evict Radon National Study team (including researchers at the British Columbia Cancer Agency, the Arnie Charbonneau Cancer Institute at the University of Calgary, University of Saskatchewan, and Dalhousie University) in collaboration with the staff and researchers at Health Canada, CAREX Canada, and the British Columbia Centre for Disease Control.

**58.1%**  
<100 Bq/m<sup>3</sup>

**24.2%**  
100-199 Bq/m<sup>3</sup>

**17.8%**  
≥200 Bq/m<sup>3</sup>

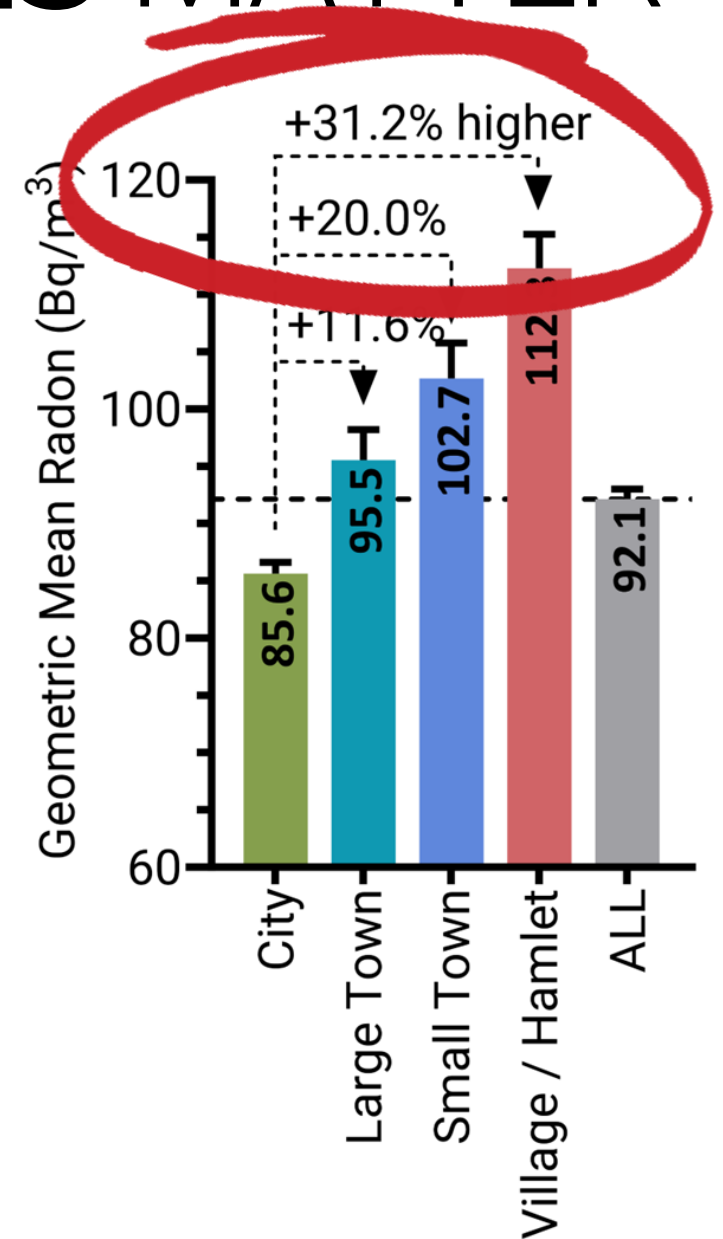


# COMMUNITIES MATTER

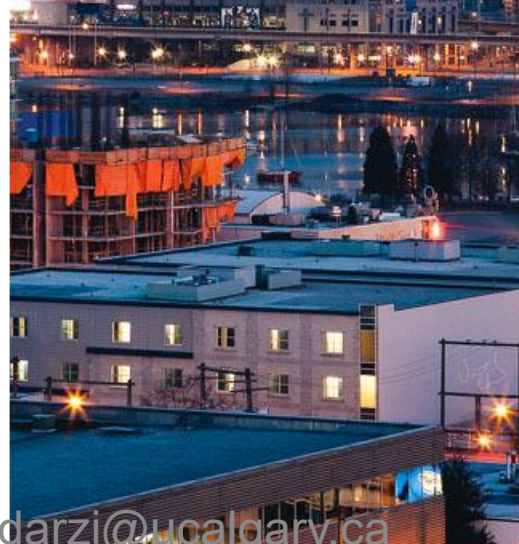
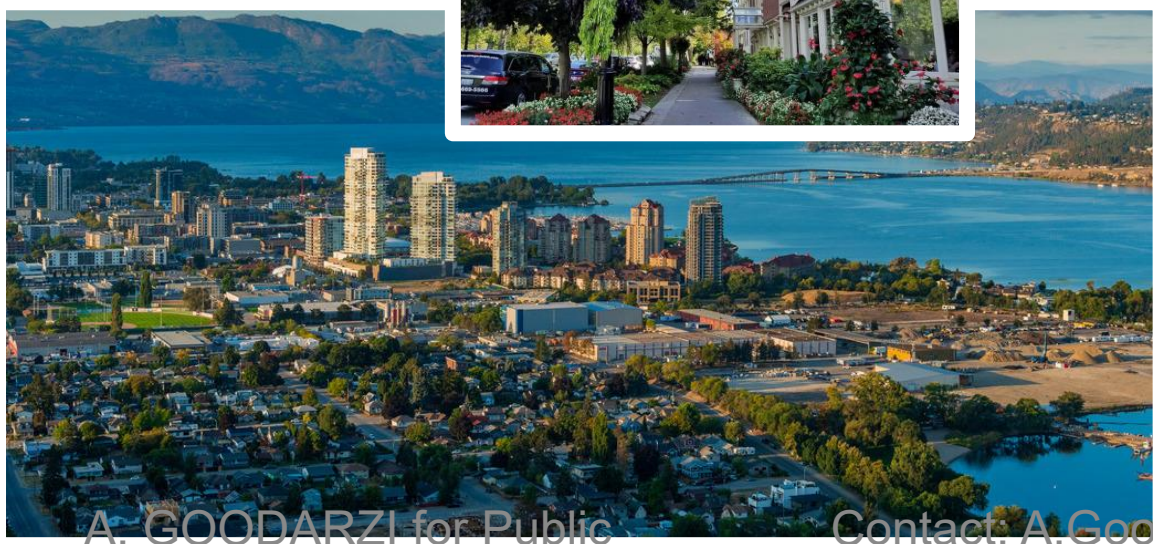


More **'URBAN'** communities ← → More **'RURAL'** communities

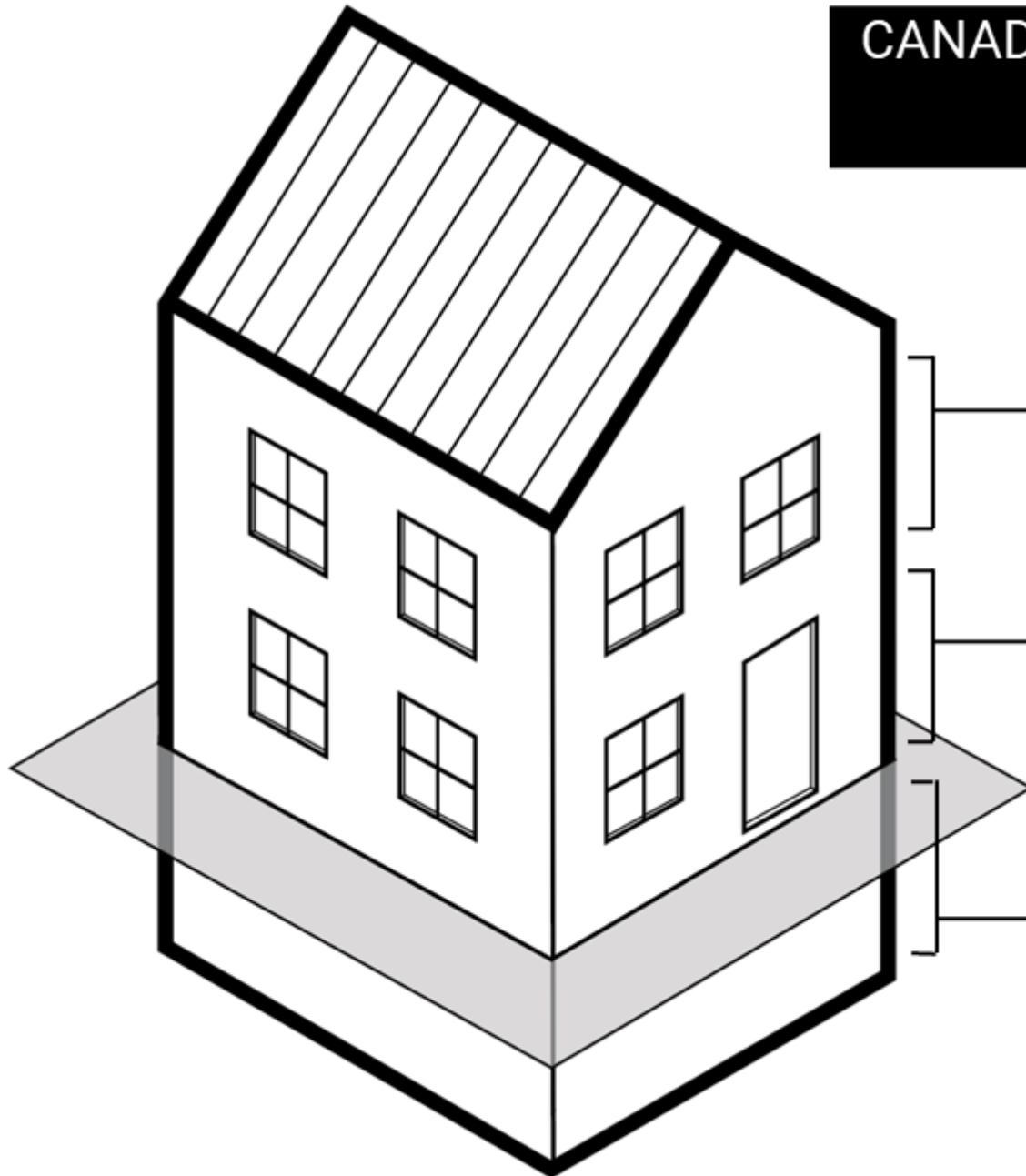
|  |   |   |   |
|--|---|---|---|
| <p>Large Urban<br/>Population Centre =<br/><b>100,000+ people</b></p> <p><b>'CITY'</b> with dense urban core and suburban sprawl zone</p> <p>E.G., Vancouver (BC), Calgary (AB), Regina (SK), Winnipeg (MB), Toronto (ON), Ottawa (ON), Montreal (QC), Halifax (NS)...</p> | <p>Medium<br/>Population Centre =<br/><b>30,000-99,999 people</b></p> <p><b>'LARGE TOWN'</b></p> <p>E.G., Airdrie (AB), Moose Jaw (SK), Chatham (ON), Charlottetown (PEI), Kanata (ON), Moncton (NB)...</p> | <p>Small<br/>Population Centre =<br/><b>1,000-29,999 people</b></p> <p><b>'SMALL TOWN'</b></p> <p>E.G., Yellowknife (NWT), Tofino (BC), Martensville (SK), Whitehorse (YK), Lunenburg (NS), Iqaluit (NU)...</p> | <p>Rural<br/>Population Area =<br/><b>1-999 people</b></p> <p><b>'VILLAGE, HAMLET'</b><br/>(and isolated properties)</p> <p>E.G., Bragg Creek (AB), Rocky Lake (MB), Big Beaver (SK), Tewksbury (QC)...</p> |
|--|---|---|---|



# BUILDINGS MATTER



# CANADIAN RESIDENTIAL RADON LEVELS BY FLOOR OF TESTING



FLOORS THAT ARE AT  
LEAST ONE STOREY  
ABOVE GROUND

Avg. Radon: 54.4 Bq/m<sup>3</sup>

FLOORS FULLY OR PARTLY  
LEVEL WITH THE GROUND

Avg. Radon: 68.8 Bq/m<sup>3</sup>

FLOORS THAT ARE  
ENTIRELY BELOW GROUND  
(basements, cellars)

Avg. Radon: 89.9 Bq/m<sup>3</sup>

+20.9%

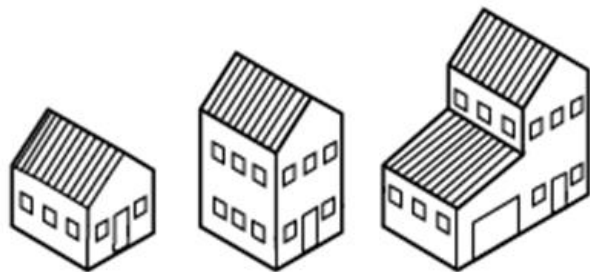
+23.5%



**CROSS-CANADA  
RADON SURVEY**

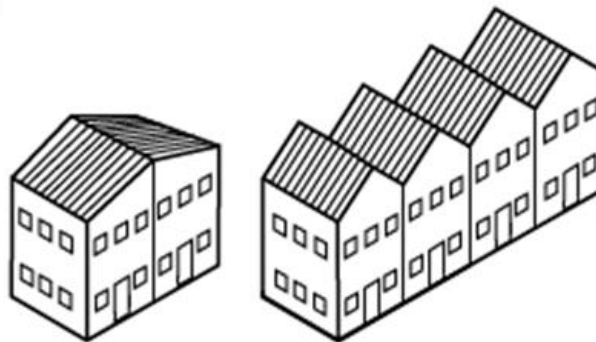
# BUILDINGS MATTER

## Single-Detached



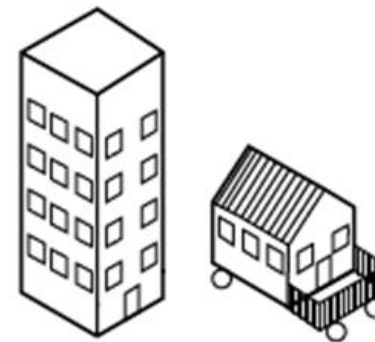
Bungalow    Multi-Storey    Split-Level

## Semi-Detached



Duplex    Row House

## Other



Apartment Building    Mobile Home

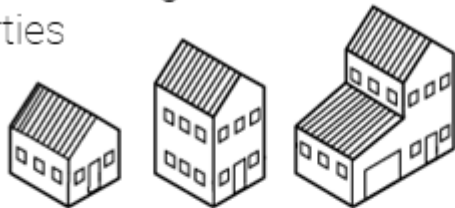


## CROSS-CANADA RADON SURVEY

## CANADIAN RESIDENTIAL RADON LEVELS BY BUILDING TYPE

### SINGLE-DETACHED

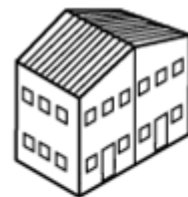
53% of residential buildings in Canada are single-detached properties



**1 in 5 (20.4%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 93.4 Bq/m<sup>3</sup>**

### SEMI-DETACHED

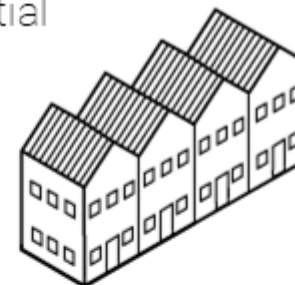
10% of residential buildings in Canada are semi-detached properties such as duplexes



**1 in 9 (11.1%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 61.5 Bq/m<sup>3</sup>**

### ROW-STYLE

7% of residential buildings in Canada are row-style (attached) properties



**1 in 13 (7.9%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 51.8 Bq/m<sup>3</sup>**



**Cross-Canada Survey of Radon Exposure in the Residential Buildings of Urban and Rural Communities**

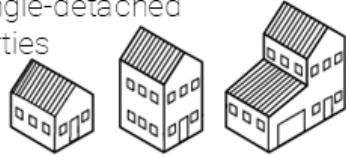
2024 REPORT  
Version 1.1 (CORS-24.1.1), released October, 2024  
crosscanadaradon.ca



Made possible by funding from: Canadian Institutes of Health Research - Healthy Cities Research Initiative; Health Canada; National Radon Program; The Clara Lee Estate Foundation and the Canadian Cancer Society.  
Report prepared and published by the: Cross-Canada National Study team (including researchers at the British Columbia Cancer Agency, the Arnie Charbonneau Cancer Institute at the University of Calgary, University of Saskatchewan, and Dalhousie University) in collaboration with the staff and researchers at Health Canada, CAPEX Canada, and the British Columbia Centre for Disease Control.

## SINGLE-DETACHED

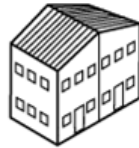
74.8% of residential buildings are single-detached properties



**1 in 5 (19.0%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 84.0 Bq/m<sup>3</sup>**

## SEMI-DETACHED

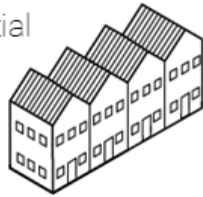
15.5% of residential buildings are semi-detached properties such as duplexes



**1 in 10 (9.7%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 60.2 Bq/m<sup>3</sup>**

## ROW-STYLE

9.8% of residential buildings are row-style (attached) properties



**1 in 15 (6.6%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 48.9 Bq/m<sup>3</sup>**



## CROSS-CANADA RADON SURVEY

## RESIDENTIAL RADON LEVELS FOR CENTRAL CANADA

CENTRAL REGION POPULATION = 22,725,775  
(based on 2021 Canada Census)



### OVERALL

**1 in 6 (16.4%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 76.9 Bq/m<sup>3</sup>**

### URBAN COMMUNITIES

64.6% of residential buildings are in urban communities

**1 in 7 (14.3%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 72.4 Bq/m<sup>3</sup>**

### RURAL COMMUNITIES

35.4% of residential buildings are in rural communities

**1 in 5 (20.2%)  $\geq 200$  Bq/m<sup>3</sup>**  
**Avg. Radon = 85.1 Bq/m<sup>3</sup>**

### BY PROVINCE



#### ONTARIO:

- 1 in 8 (12.4%)  $\geq 200$  Bq/m<sup>3</sup>
- Avg. Radon = 71.9 Bq/m<sup>3</sup>

#### QUEBEC:

- 1 in 6 (16.7%)  $\geq 200$  Bq/m<sup>3</sup>
- Avg. Radon = 77.7 Bq/m<sup>3</sup>

# COMMUNICATING IS IMPORTANT





stuffashleedoes Calgary, Alberta  
 476 likes

dezeighh Calgary, Alberta  
 443 likes

stuffashleedoes Five years ago we moved into our home. I was a new mom and I heard about high levels of radon gas in our area. I read an article about a lady dying of lung cancer and I became obsessed with researching more about this. I had our home tested, I shared this information with my friends and family and today I want to share this with you.

dezeighh Hey guys announce that I'm a partner many of how much I try to co awareness and rese lost important peopl cancer.  
 @evictradon is found researchers at the U Calgary. By ordering kit, you are enrolled radon study at Univ

#CBC | MENU

NEWS Top Stories Local Climate World Canada Politics Indigenous

Calgary

### Radon levels in new Canadian homes now 467% higher than in homes in Sweden, U of C study finds

Canadian and Swedish homes found to have comparable levels in the 1980s

Hannah Kost - CBC News - Posted: Nov 24, 2021 7:04 PM MT | Last Updated: February 4

# SUNDAY STAR

WEATHER HIGH 16 C | A FEW SHOWERS | MAP A16

SUNDAY, MAY 2, 2021

> TORONTO STAR/IJB INVESTIGATION

## The invisible threat inside your home: Canadians at risk from radon exposure

### Growing number of houses show dangerous levels of cancer-causing gas

**ROBERT CRIBB**  
TORONTO STAR

**DECLAN KEOGH AND PALEAH MOHER**  
INVESTIGATIVE JOURNALISM BUREAU

The prevalence of deadly radon gas is rising across Canada as lax building codes allow dangerously high levels to be trapped inside newly built homes.

Radon is an invisible, odourless radioactive gas that is naturally emitted from uranium in soil and enters homes, where it can concentrate. When radon is inhaled, it can damage DNA in the lungs and cause cancer.

The carcinogen is the second-leading cause of lung cancer in Canada, estimated to be responsible for more than 3,000 deaths a year — more than deaths from motor vehicle collisions.

The scale of the problem has been captured in six years' worth of test results from 30,000 homes across Canada, believed to be the largest and most detailed body of results collected in this country.

The data was shared exclusively with the Toronto Star and the Investigative Journalism Bureau (IJB), and the findings are being publicly reported here for the first time.

Canada has some of the highest measured rates in the world, with an estimated new case of radon-induced lung cancer diagnosed each day in the hardest-hit provinces.

One in five homes — 5,600 of the 30,000 tested nationwide — showed radon levels exceeding Health Canada's guideline of 200 becquerels per cubic metre (Bq/m<sup>3</sup>), according to data gathered by researchers from the University of Calgary collaborating with this investigation.

**3,000** Estimated lung cancer deaths in Canada each year caused by radon exposure

**19%** of homes tested nationwide exceed Health Canada safety guideline

RADON continued on A4

GLOBALNEWS.CA

### Radon Awareness | Watch News Videos Online

Watch Radon Awareness Video Online, on GlobalNews.ca

ICI TÉLÉ

À la une Émissions Horaire Cinéma Blogue télé Recettes U Applications mobiles Participer ou assister aux émissions

## LA FAC+URE

ACCUEIL ÉMISSION REPORTAGES CAPSULES NOUS JOINDRE AUTRES SAISONS COVID-19

MARDI 10 MARS 2020

### LE RADON : UNE MENACE TROP SOUVENT IGNORÉE

mardi 19 h 30 - 20 h 30 HA  
jeudi 13 h 30, samedi 12 h 30

VOIR LES ÉPISODES  
ICI TOUJOURS

bonjour québec

L'exposition au radon, un gaz incolore, inodore et invisible, est la première cause de cancer du poumon chez les non-fumeurs. Pourtant, au Canada, la concentration de radon n'a été testée que dans 7 % des maisons. Des résidents de Bédouin, en Montérégie, ont fait l'exercice. Ils ont été surpris de découvrir des concentrations de radon plus élevées que le seul recommandé par Santé Canada. Et pourtant, leurs résidences ont été construites récemment.

IJB. UNIVERSITY OF TORONTO  
DALLA LANA SCHOOL OF PUBLIC HEALTH

about projects people networks

Investigative Journalism Bureau.

## Journalism for the future.

A. GOODARZI for Public Health Ontario Boards

Contact: A.Goodarzi@ucalgary.ca for permissions



 **CROSS-CANADA  
RADON SURVEY**

[Voir en français](#)

Cross-Canada Radon Survey

Read the 2024 Cross-Canada Survey  
of Radon and learn how it may  
affect you.

[DOWNLOAD FULL REPORT](#)

[CONTACT US](#)

Executive Summary

Introduction to Radon

History of Radon

Purpose

Radon Levels for Canada  
and by Building Type

Radon Levels in Canada, by  
Urban to Rural

Community  
A. GOODARZI for Public Health Ontario  
Rounds

**CROSS-CANADA SURVEY OF RADON EXPOSURE IN  
RESIDENTIAL BUILDINGS OF URBAN AND RURAL  
COMMUNITIES**

*Made possible by funding from:* Canadian Institutes of Health Research - Healthy Cities Research Initiative; Health Canada's National Radon Program; the Alberta Real Estate Foundation; and the Canadian Cancer Society.

*Report prepared and published by the:* [Evict Radon National Study team](#) (including researchers at the British Columbia Cancer Agency, the Arnie Charbonneau Cancer Institute at the University of Calgary, University of Saskatchewan, and Dalhousie University) in collaboration with the staff and researchers at [Health Canada](#), [CAREX Canada](#), and the [British Columbia Centre for Disease Control](#).

**Cross-Canada Survey of Radon  
Exposure in the Residential  
Buildings of Urban and Rural  
Communities**



**2024 REPORT**

Version 1.1 (CCSR.24.1.1), released October, 2024  
[crosscanadaradon.ca](http://crosscanadaradon.ca)



**Made possible by funding from:** Canadian Institutes of Health Research - Healthy Cities Research Initiative; Health Canada's National Radon Program; the Alberta Real Estate Foundation; and the Canadian Cancer Society.

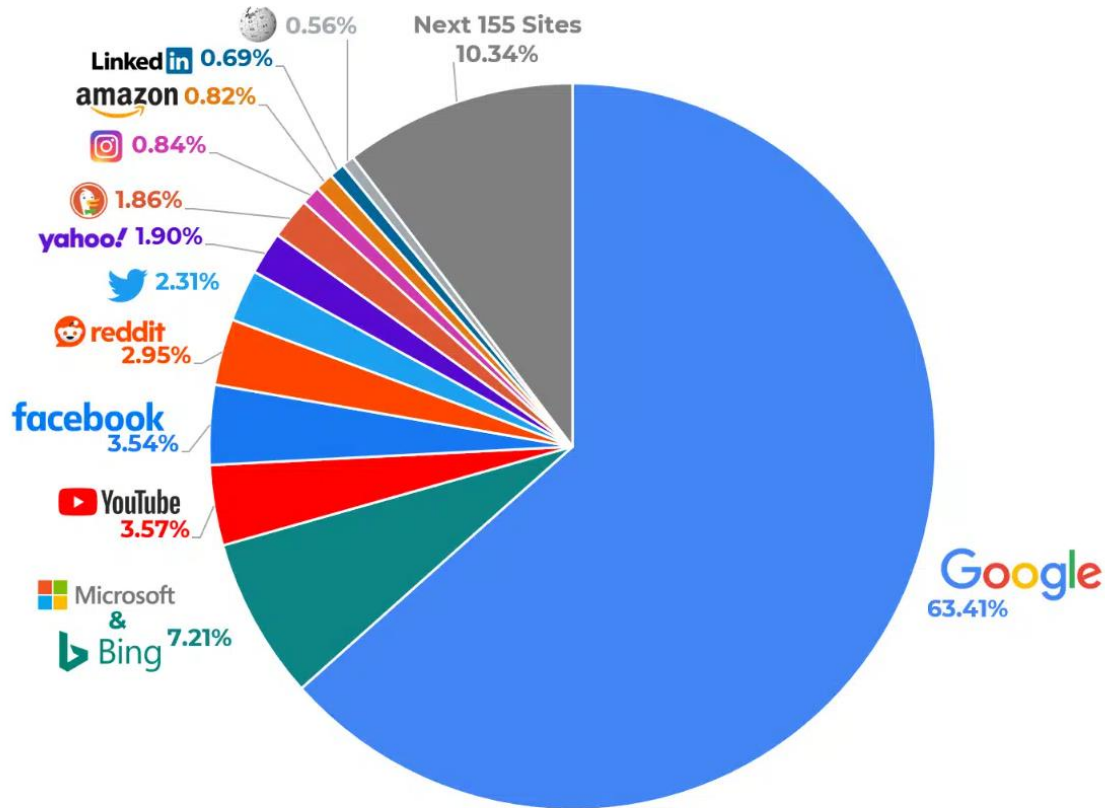
**Report prepared and published by the:** Evict Radon National Study team (including researchers at the British Columbia Cancer Agency, the Arnie Charbonneau Cancer Institute at the University of Calgary, University of Saskatchewan, and Dalhousie University) in collaboration with the staff and researchers at Health Canada, CAREX Canada, and the British Columbia Centre for Disease Control.

Contact: [A.Goodarzi@ucalgary.ca](mailto:A.Goodarzi@ucalgary.ca) for permissions

# GOOGLE search TRENDS

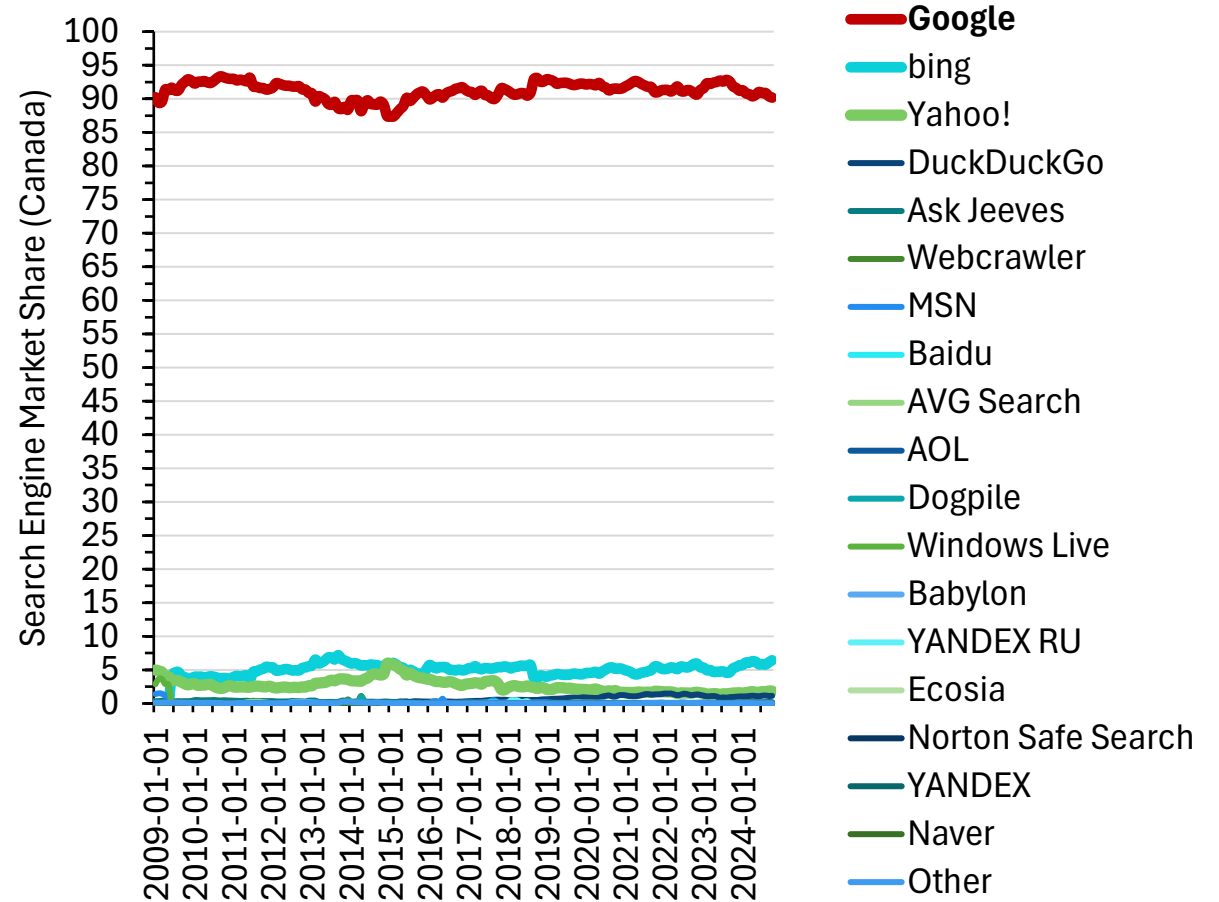
## The Web's Largest Traffic Referrers Jan. 2024

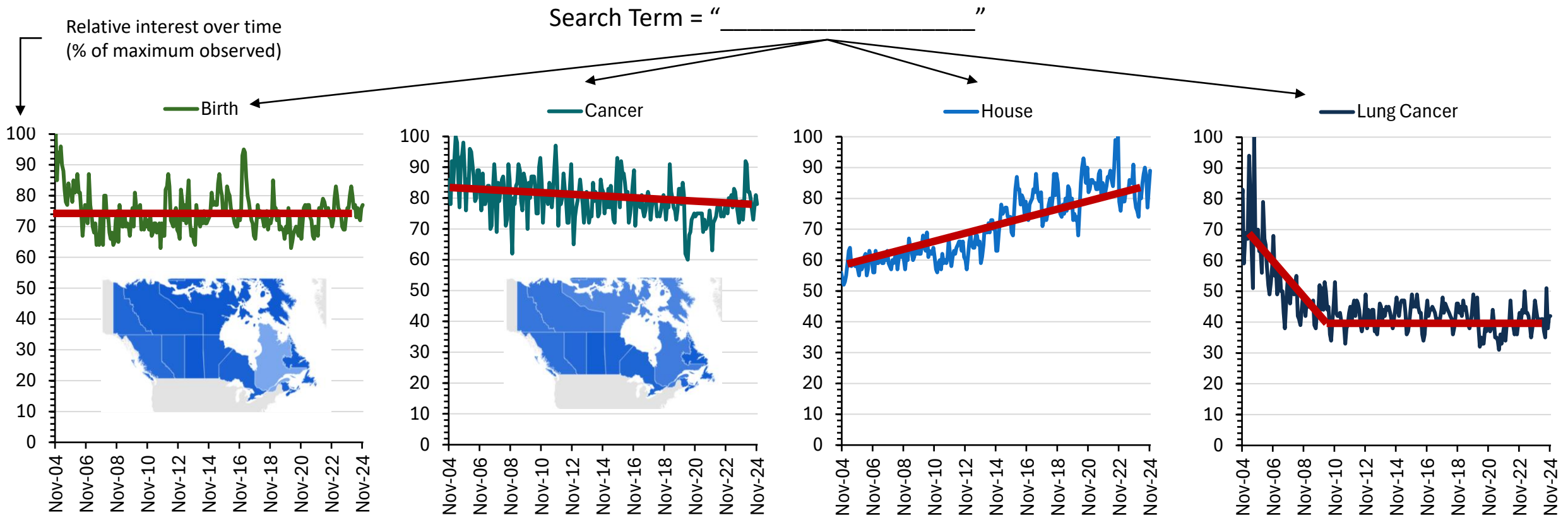
(as a percent of traffic sent by the top 170 traffic-referring domains to all sites on the web | Source: Datas)



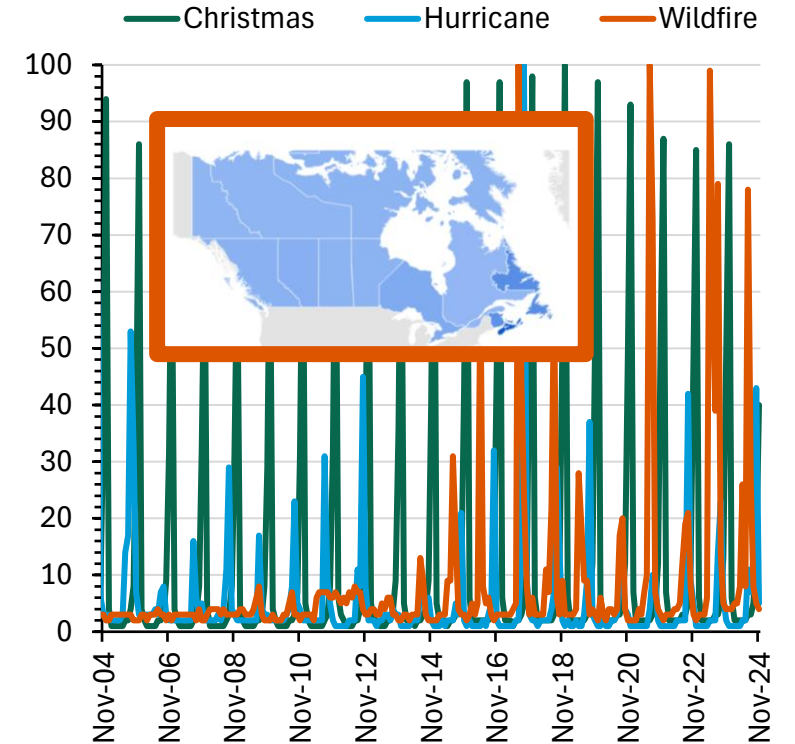
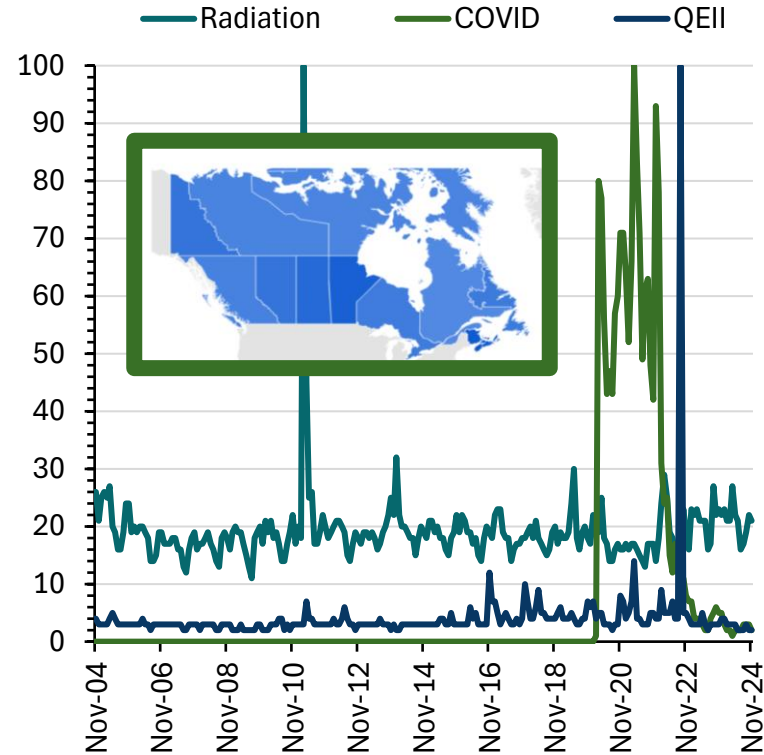
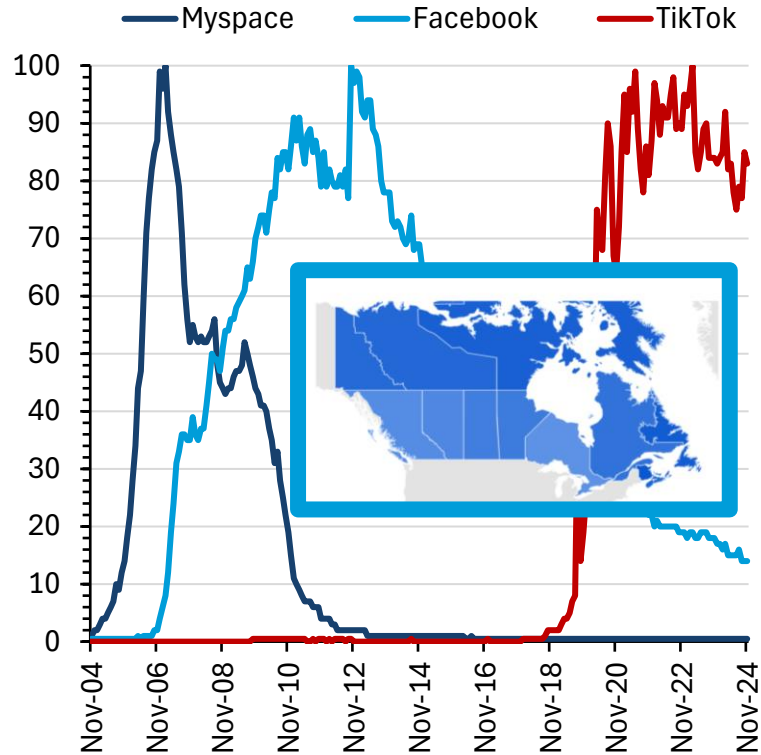
\*\* Sites with a single owner that pass referrals via multiple entities have been grouped (e.g. Twitter.com, Twimg.com, and T.co; Live.com, Bing.com, MicrosoftOnline.com, Office.com, and Office365.com; etc.)

Datos SparkToro

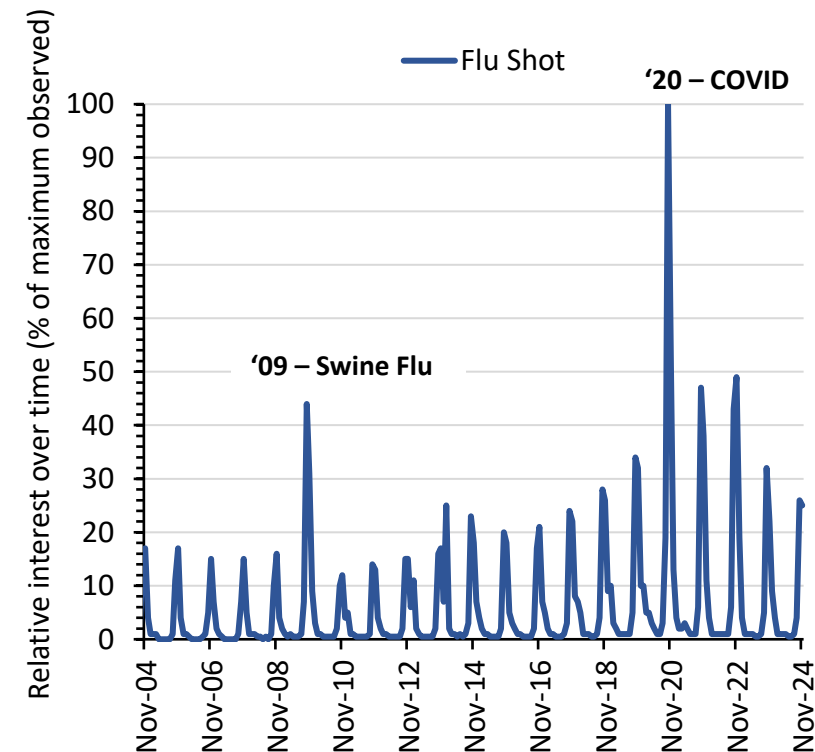
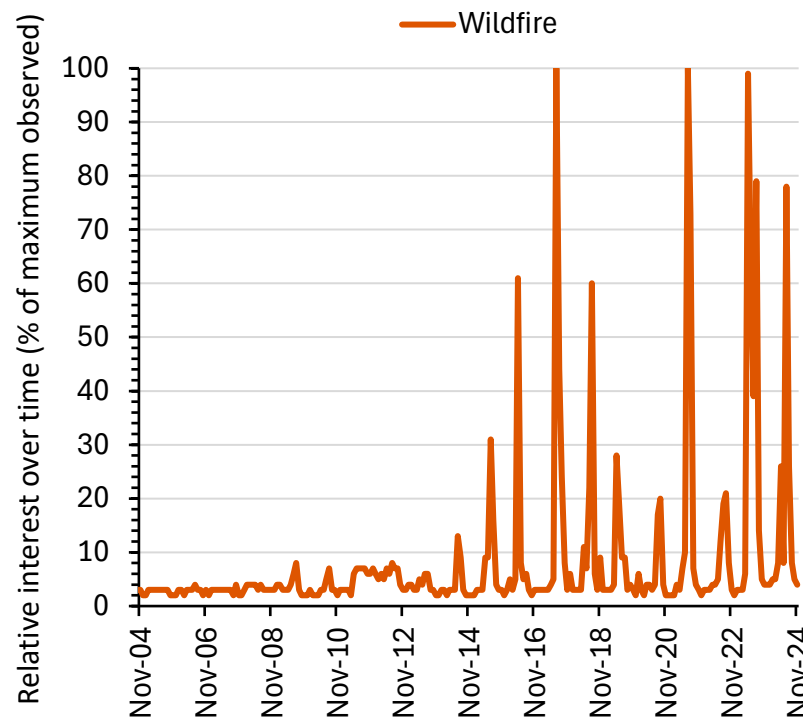
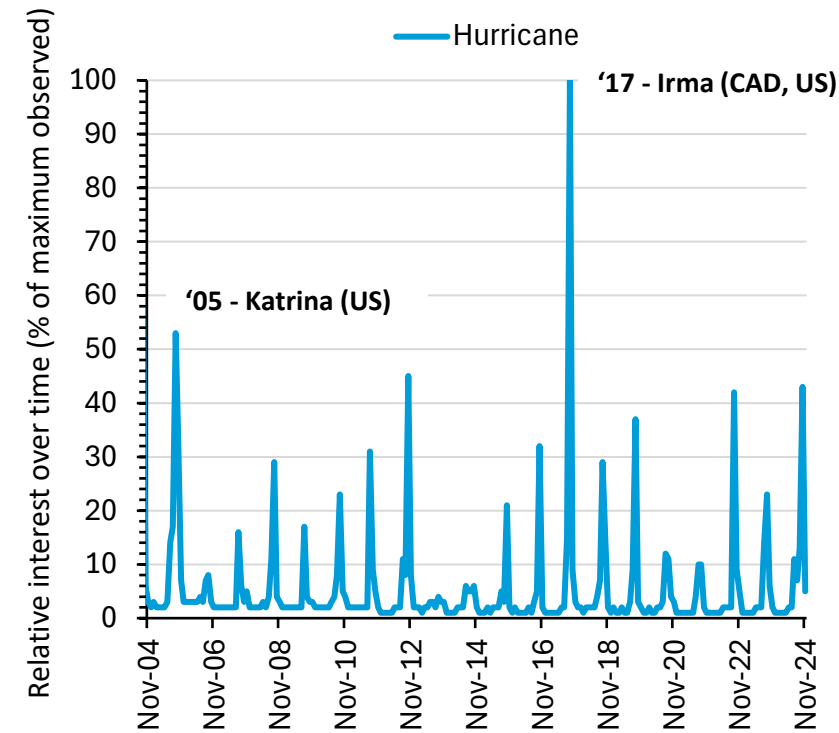




**What do they reflect, and how are they useful?**



**Drift, Short-term Interest, Seasonality**



## Notable Event Severity, Call-to-Action Effectiveness

# GOOGLING “RADON”

All 393 Questions 31 Attributes 42 Brands 0

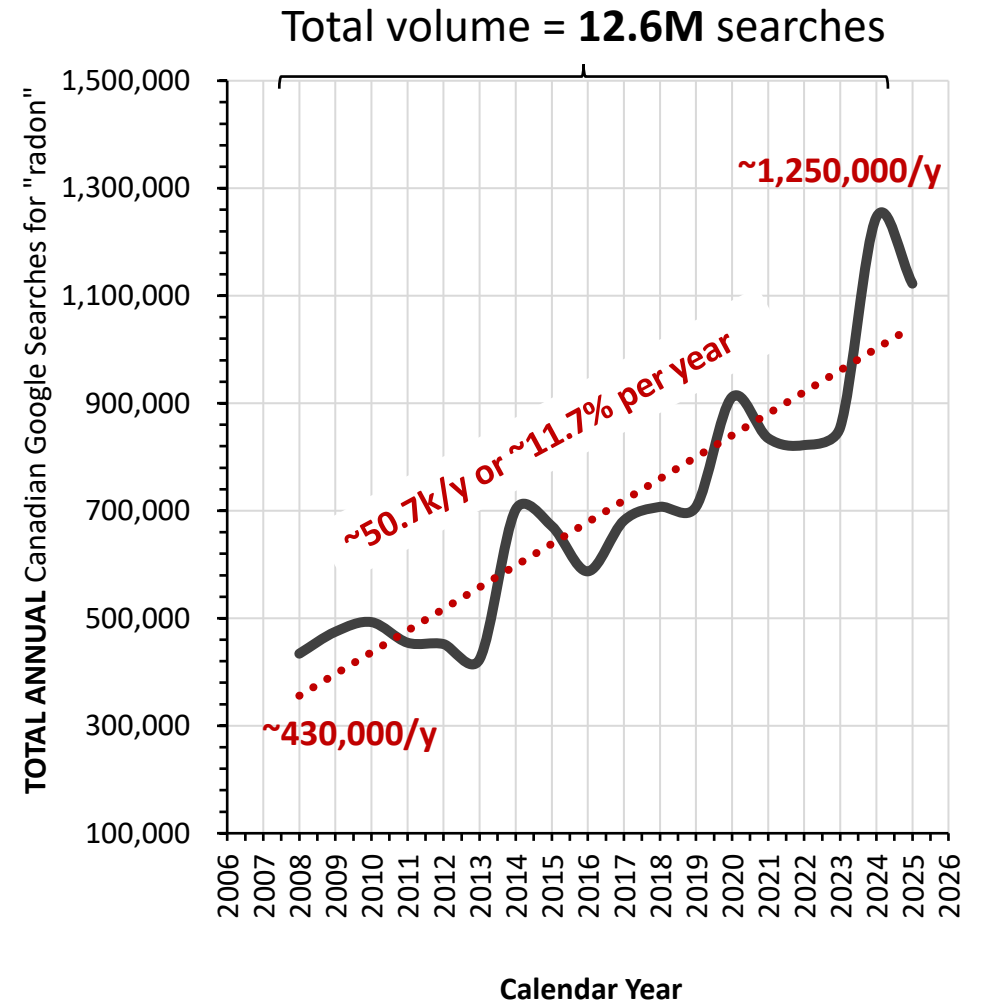
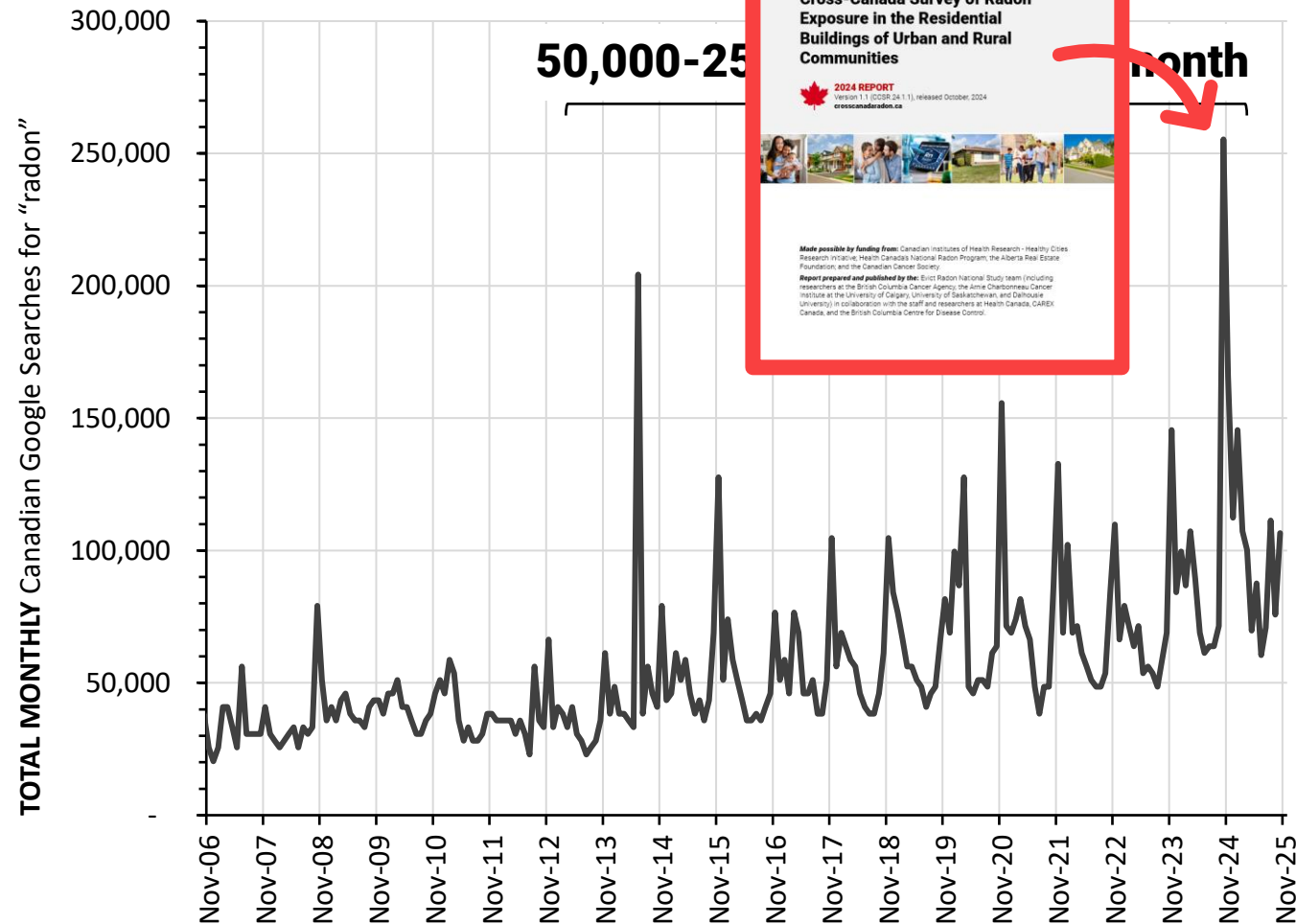
|                    |                          |
|--------------------|--------------------------|
| radon gas          | radon mitigation system  |
| radon test kit     | radon reduction system   |
| radon detect       | radon vent               |
| radon detector     | radon ventilation system |
| radon test         | radon gas symptoms       |
| radon tester       | radon levels             |
| radon abatement    | radon acceptable levels  |
| radon gas detector | radon canada map         |
| radon mitigation   | radon detector canada    |

All 393 Questions 31 Attributes 42 Brands 0

|   |
|---|
| how to test for radon                   |
| how to get rid of radon                 |
| is radon dangerous                      |
| is radon gas dangerous                  |
| is radon heavier than air               |
| is radon radioactive                    |
| are radon detectors accurate            |
| are radon levels higher in the basement |
| are radon mitigation systems effective  |

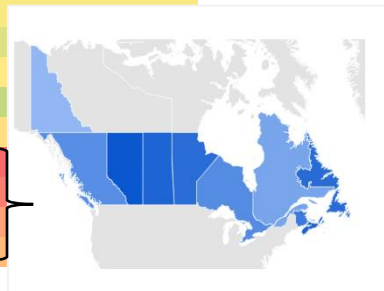
Top Questions

# GOOGLING "RADON" OVER TIME



## Example – The 2024 Cross Canada Radon Survey released October 23<sup>rd</sup>, 2024 (>50x articles)

| WEEK       | % of MAX Searches | Searches | Search Change relative to 5y Avg. |
|------------|-------------------|----------|-----------------------------------|
| 2024-08-31 | 18.27             | 10763.3  | -1488.10                          |
| 2024-09-07 | 21.92             | 12915.9  | 664.55                            |
| 2024-09-14 | 20.09             | 11839.6  | -411.78                           |
| 2024-09-21 | 18.27             | 10763.3  | -1488.10                          |
| 2024-09-28 | 21.92             | 12915.9  | 664.55                            |
| 2024-10-05 | 18.27             | 10763.3  | -1488.10                          |
| 2024-10-12 | 29.23             | 17221.2  | 4969.86                           |
| 2024-10-19 | 182.67            | 107632.8 | 95381.38                          |
| 2024-10-26 | 82.20             | 48434.7  | 36183.36                          |
| 2024-11-02 | 60.28             | 35518.8  | 23267.43                          |
| 2024-11-09 | 45.67             | 26908.2  | 14656.81                          |



**NATIONAL POST**  
 Home / News / Canada  
**Is an invisible gas in your home giving you lung cancer? What Canadians should know about radon**  
 A new study suggests the number of Canadians with lung cancer from radon gas has more than doubled since 2000.  
 By Kenn Oliver  
 Published Oct 27, 2024 Last updated Oct 27, 2024 4 min

**CBC**  
 Top Stories Local Climate World Canada Politics Indigenous  
**Calgary**  
**National radon study shows higher levels, exposure to radioactive gas in homes**  
 An estimated 10.3 million Canadians live in homes with radon levels that are higher than recommended.  
 Bill Graveland · The Canadian Press  
 Posted: Oct 23, 2024 11:09 AM M

**CTV NEWS**  
 Trump's Tariffs Election 2025 Local Download Our App  
**Calgary | News**  
**More than 10 million Canadians living in homes with 'high radon,' report says**  
 By Michael Franklin  
 Published: October 23, 2024 at 8:59AM EDT

Two long-term electrometer ion chambers used for radon measurement. (Wikimedia Commons)

A new study released this week indicates that radon exposure is a significant public health concern across Canada, adding to concern about its link to lung cancer.

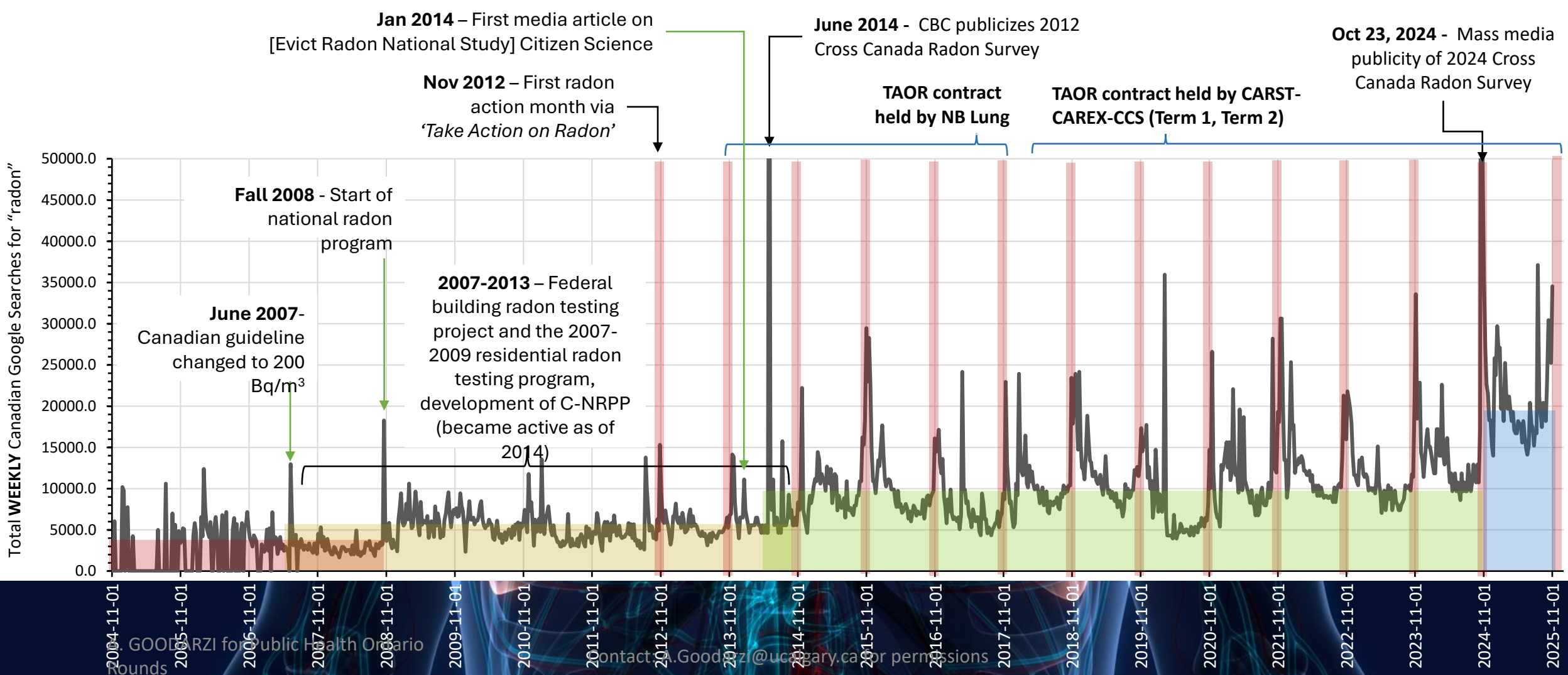
Radon gas, a radioactive element, seeps into homes from the ground. (Public Health Ontario)

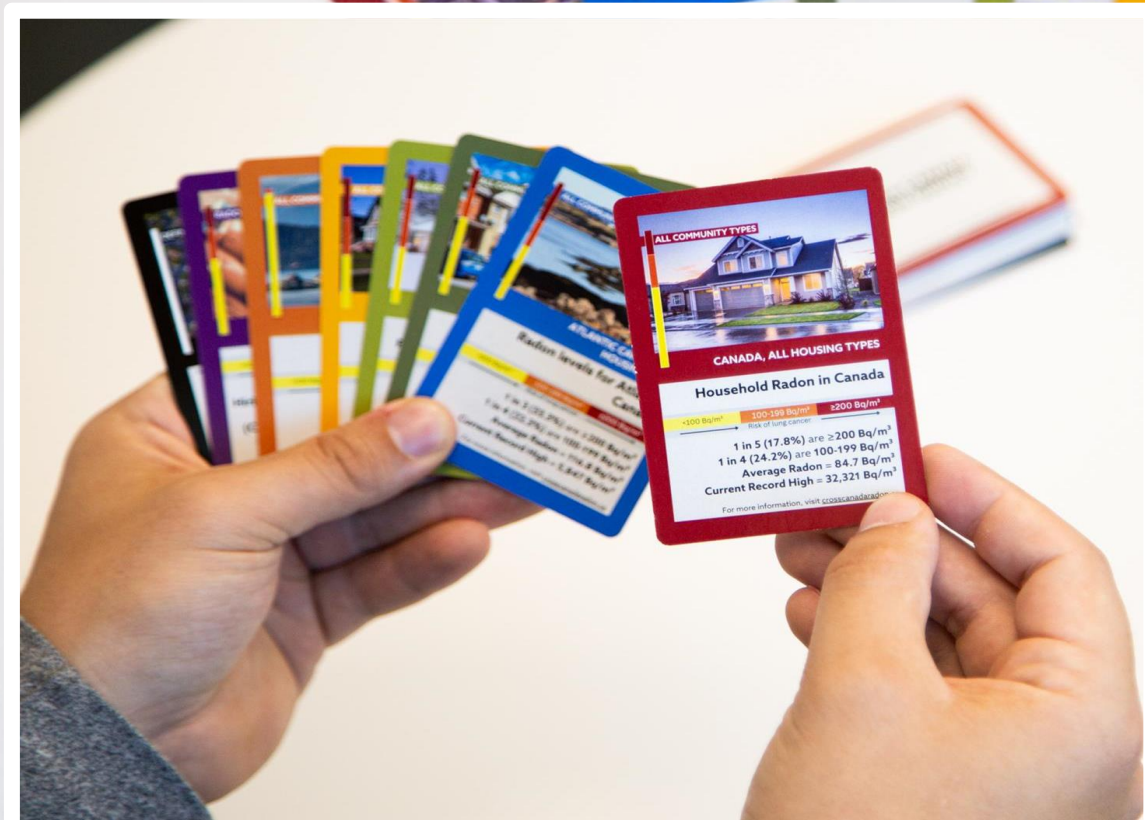
A nationwide study says radioactive radon gas in homes is a public health concern.

The study, released Wednesday, is the first to show that radon exposure is a significant public health concern across Canada.

A new study out of Alberta is sharing new concerning data about radon levels inside homes that could be deadly. Adrian Ghorbali reports.

A new report suggests that Canadians' exposure to a radioactive gas is increasing, putting millions of people at a higher risk of lung cancer.







April 17, 2023

**She found out she'd been breathing a cancer-causing gas for over a decade. So why won't Canada's health-care system let her get her lungs tested?**

Toronto Star

[Read the article](#)



December 9, 2022

**Les maisons canadiennes tuent de plus en plus de non-fumeurs**

La Maison du 21<sup>e</sup> siècle

[Read the article](#)



November 21, 2022

**De l'aide pour les propriétaires qui installent des mesures d'atténuation du radon**

Radio-Canada - Saskatchewan

[Read the article](#)



November 18, 2022

**Radon mitigation reimbursements available for Sask. homeowners**

CBC - Saskatchewan

[Read the article](#)



November 17, 2022

**Financial relief coming to help Canadians reduce risk from radon gas**

Take Action on Radon

[Read the article](#)

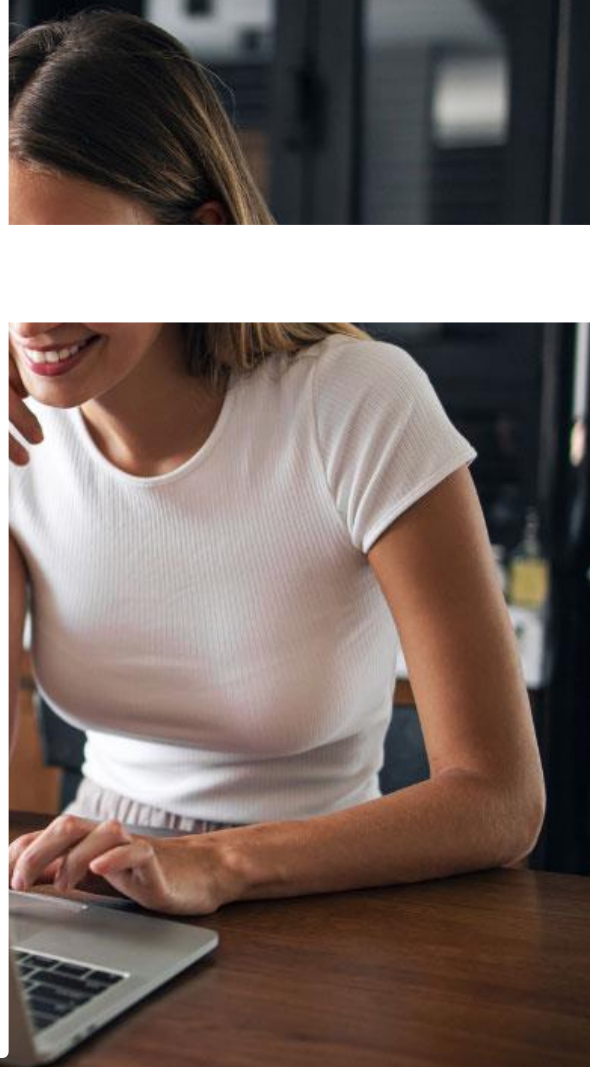


November 16, 2022

**Chilliwack brother and sister wage war against radon**

The Chilliwack Progress

[Read the article](#)



## De l'aide pour les propriétaires qui installent des mesures d'atténuation du radon



Selon une représentante de l'Association pulmonaire de la Saskatchewan, la province fait partie des endroits qui comptent le plus haut taux de radon dans le monde. (Archives)  
PHOTO: RADIO-CANADA / ROBERT SHORT



February 26, 2024

### A Closer Look At Residential Radon Exposure Disparities in Canada

[Read the article >](#)



April 25, 2023

### How Working from Home May Increase Your Radon Exposure

[Read the article >](#)



March 29, 2023

### Things to Consider Before Renovating Your Home to Keep Your Family Safe from Radon

[Read the article >](#)



February 28, 2023

### Radon: Is It High in Your Area?

[Read the article >](#)



January 30, 2023

### 5 Causes of Lung Cancer

[Read the article >](#)



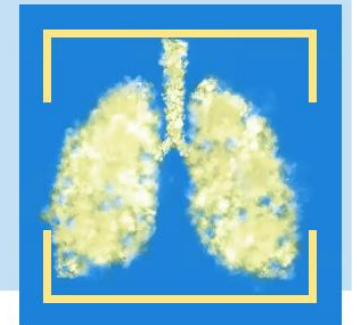
January 16, 2023

### Safe (& What to Do If It Isn't)

[Read the article >](#)

January 30, 2023

## 5 Causes of Lung Cancer



#### Summary of Key Points:

- Lung cancer is expected to be the leading cause of cancer death in Canada in 2023, with radon gas being a leading cause of lung cancer in Canada, particularly for people who do not smoke tobacco. However, there are several other major causes of lung cancer people should be aware of in order to reduce their risk.
- Smoking tobacco products is the single largest cause of lung cancer in Canada, contributing to nearly 85% of all lung cancer deaths. Combined exposure to radon gas and tobacco smoke make the chances of lung cancer much more likely.
- Radon is a soil gas produced when minerals containing uranium, thorium or radium break down. It creates a significant risk of lung cancer when it becomes concentrated in buildings, which is why we urge homeowners to test the radon levels in their homes.
- PM2.5 ("particulate matter of 2.5 microns in size") is a kind of air pollution caused by hydrocarbon combustion, and can be produced by automobiles, forest fire smoke, solid fuel burning, as well as other natural and industrial processes. Since exposure to PM2.5 increases your risk of lung cancer, it's advised to reduce your exposure to environments where these dangerous particles are present in high concentration.
- Arsenic is a naturally occurring heavy metal that is found in natural abundance in some areas of Canada, and can also be produced in large amounts by industry. Long-term exposure to arsenic in water and water vapours increases your risk of lung cancer via lung fibrosis and bronchitis. It is recommended to test your drinking water for arsenic and use a filtration system to reduce its levels if necessary.
- Severe and/or ongoing (chronic) lung inflammation from infections such as tuberculosis or pneumonia, or diseases such as COPD are also linked to an increased risk of lung cancer. Taking steps towards avoiding severe lung infection outcomes, either through changes in behaviour, hygiene, vaccination, and/or timely medication may help you avoid this."

scientific reports

OPEN **Consequences of changing Canadian activity patterns since the COVID-19 pandemic include increased residential radon gas exposure for younger people**

Natasha L. Cholowsky<sup>1,3</sup>, Myra J. Chen<sup>1,3</sup>, Ghozilane Selouani<sup>1</sup>, Sophie C. Pett<sup>1</sup>, Dustin D. Pearson<sup>1</sup>, John M. Danforth<sup>2</sup>, Shelby Fenton<sup>2</sup>, Ela Rydz<sup>2</sup>, Matthew J. Ditzeljan<sup>1</sup>, Cheryl E. Peters<sup>4,5</sup>, & Aaron A. Goodarz<sup>1,6\*</sup>

The COVID-19 pandemic has profused widespread behaviour changes that shifted how people split their time between different environments, altering health risks. Here, we report an update of North American activity patterns before and after pandemic onset, and implications to radioactive radon gas exposure, a leading cause of lung cancer. We surveyed 4000 Canadian households home to people of varied age, gender, employment, community, and income. While overall time spent indoors remained unchanged, time in primary residence increased from 66.4 to 77% of life (1862 h/y) after pandemic onset, increasing annual radiation doses from residential radon by 1.5%. Disproportionately greater changes were experienced by younger people in properties with more occupants, and/or those employed in managerial, administrative or health care occupations. Microinfluencer-based public health messaging that behaviour amongst highly impacted, younger groups by 50%. This work sets environmental health risks modified by still-changing activity patterns.

The 2003 National Human Activity Pattern Study demonstrated that the typical American adult spent ~60% of life (6018 h/y) inside a residential building, and ~17% of life spent in a primary residence (at home), different residential buildings (e.g., offices, schools, hotels, factories, shopping centres, etc.), and outdoors in highly functional environments that differ by age, health status, job, lifestyle variables, and can change seasonally or over a lifetime. Behaviourally driven determinants of health, such as the amount of time that people spend within the duration of exposure to numerous indoor- and outdoor environmental toxicants. This is very important in the case of indoor air quality, which can vary substantially generally an unavoidable exposure of occupying (i.e., breathing) an environment and lethal human diseases driven by exposure to indoor air toxicants in lung cancer. In a cancer-related study in North America and Europe, the addition to tobacco a function of exposure to carcinogenic triggers such as radioactive radon gas, passive and active, as well as modifiers such as history of inflammatory lung disease, tuberculosis, emphysema, diet, fitness, and genetics<sup>1-4</sup>.

scientific reports

OPEN **Rural communities experience higher radon exposure versus urban areas, potentially due to drilled groundwater well annuli acting as unintended radon gas migration conduits**

Selim M. Khan<sup>1,2,3</sup>, Dustin D. Pearson<sup>1,4</sup>, Evangelina L. Eldridge<sup>5</sup>, Tiago A. Moraes<sup>1</sup>, Marvin L. C. Achanonu<sup>6</sup>, M. Cathryn Ryan<sup>1,5</sup>, Joshua M. Taroni<sup>1,5</sup>, & Aaron A. Goodarz<sup>1,2,3,4\*</sup>

Repetitive, long-term inhalation of radioactive radon gas is one of the leading causes of lung cancer, with exposure differences being a function of geographic location, both environment, personal demographics, activity patterns, and decision-making. Here, we examine radon exposure disparities across the urban-to-rural landscape, based on 42,051 Canadian residential properties in 2024 distinct communities. People living in rural, lower population density communities experience as much as 31.2% greater average residential radon levels relative to urban equivalents, equating to an additional 24.7 Bq/m<sup>3</sup> excess in geometric mean indoor air radon, and an additional 1 mSv/year in excess alpha radiation exposure dose rate to the lungs for occupants. Pairwise and multivariate analyses indicate that community-based radon exposure disparities are, in part, explained by increased prevalence of larger floorplan basements in rural areas, but that a majority of the effect is attributed to proximity to, but not water use from, drilled groundwater wells. We propose that unintended radon gas migration in the annulus of drilled groundwater wells provides radon migration pathways from the deeper subsurface into near surface materials. Our findings highlight a previously under-recognized determinant of radon-induced lung cancer risk, and support a need for targeted radon testing and reduction in rural communities.

Radioactive radon (<sup>222</sup>Rn) exposure is an indoor air environmental carcinogen that is among the most prevalent non-tobacco causes of lung cancer, alongside 2.5 micron particulate matter (PM<sub>2.5</sub>) air pollutants, arsenic, nitrobenzene, and severe lung inflammation from infectious disease and/or silica exposure<sup>1-4</sup>. The inhalation of gaseous radon and its solid radioactive progeny increases the relative lifetime risk of lung cancer by emitting alpha particles that damage lung epithelial cell DNA, raising the likelihood of cancer-causing genetic mutations<sup>5-8</sup>. Radioactivity from decaying radon progeny in indoor air is measured in Becquerels (Bq), equating with one alpha particle emission per second, per cubic metre (m<sup>3</sup>) of air, with a total of four alpha particle emissions occurring as <sup>222</sup>Rn decays into stable <sup>206</sup>Pb over time<sup>9</sup>. For large populations, there is a 16% increase in relative lifetime risk of lung cancer per 100 Bq/m<sup>3</sup> of radon exposure that, based on the documented activity patterns of a typical North American adult, equates to an absorbed dose of ~4 millirems (mSv) per year (mSv) of particle radiation<sup>10</sup>. Understanding excess radon exposure is important because a substantial number of people diagnosed with lung cancer do not meet current inclusion criteria for early

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Vera-Chang et al. *Clinical Epigenetics* (2022) 13:174  
<https://doi.org/10.1186/s13148-023-01564-z>

RESEARCH **Profound DNA methylomic differences between single- and multi-fraction alpha irradiations of lung fibroblasts**

Marilyn N. Vera-Chang<sup>1</sup>, John M. Danforth<sup>2</sup>, Marilnye Stuart<sup>3</sup>, Aaron A. Goodarz<sup>1</sup>, Marjorie Brand<sup>4,5</sup> and Richard B. Richardson<sup>1,6\*</sup>

**Abstract**  
**Background** Alpha (α)-radiation is a ubiquitous environmental agent with epigenotoxic effects. Human exposure to α-radiation at potentially harmful levels can occur repeatedly over the long term via inhalation of naturally occurring radon gas that accumulates in enclosed spaces, or as a result of a single exposure from a nuclear accident. Alterations in epigenetic DNA methylation (DNAm) have been implicated in normal aging and cancer pathogenesis. Nevertheless, the effects of alterations in the methylene of human lung cells following exposure to single or multiple α-irradiation events on these processes remain unexplored.

**Results** We performed genome-wide DNAm profiling of human embryonic lung fibroblasts from control and irradiated cells using anomicam. 341 α sources. Cells were irradiated in quadruplicate to seven doses using two exposure regimens, a single-fraction (SF) where the total dose was given at once, and a multi-fraction (MF) method, where the total dose was given in two fractions that SF irradiation.

scientific reports

OPEN **A novel method for assessing postmortem interval using radon radioisotopic decay – an internal radon ‘time of death clock’**

Behnam Ashrafkhan<sup>1</sup>, Armin Tabesh<sup>1</sup>, Fredrik Tanssens<sup>2,3</sup>, Aaron A. Goodarz<sup>1</sup>, Martin Tondel<sup>4,5</sup>, Robert Ian Thompson<sup>1</sup>, & Michael E. Wieser<sup>1\*</sup>

Estimating the postmortem interval (PMI)—the time since death—remains a longstanding challenge in forensic and biological sciences due to the complex influence of environmental and physiological variables. Here, we present a novel computational framework that leverages the physical principles of radioactive decay to estimate PMI using the relative isotope abundances of radon progeny (<sup>218</sup>Pb, <sup>214</sup>Pb, and <sup>210</sup>Pb) in biological tissue. Our approach models the decay chain of inhaled <sup>222</sup>Rn and solves the associated system of differential equations to determine PMI based on isotope ratio dynamics. A key innovation is the use of paired measurements taken at two postmortem time points to capture the time-derivative of the decay curve, enhancing solution uniqueness, reducing dependence on prior exposure history, and therefore minimizing error. Monte Carlo simulations were employed to assess model performance. A validated empirically, this approach lays the groundwork for a physics-based method for PMI estimation with potential applications in forensic science and radiology biology.

The amount of time that has elapsed since the death of an individual and discovery of their corpse is known as the postmortem interval (PMI) and, as it is typically very important for investigators to get an estimation of how long the person has been dead, it is a challenging problem in forensic science<sup>1</sup>. Indeed, the earliest documented study of PMI dates to the 19<sup>th</sup> century, with controlled scientific studies commencing in the 19<sup>th</sup> century<sup>2</sup>. Since then, a large number of methods have been explored, with an exponential increase in publications since the 1970s. Resulting PMI methods have largely been based on physical, biological, and biochemical indicators<sup>3</sup>. However, all PMI tools we have are subject to varying degrees of uncertainty that make it difficult to determine PMI with accuracy. Our PMI estimate reflects the actual time of death and/or fraction (i.e., PMI estimate are consistent between corpses with same time of death<sup>4</sup>). Current information used to estimate PMI can be broadly divided into three groups based on the various information: circumstantial evidence, environmental indicators, and body changes.

Circumstantial evidence such as when the deceased was last seen alive, etc., can certainly be helpful to narrow down PMI, but certainly not universal to all cases, and can be confounded by many variables influencing body changes; as this is not part of forensic per se, we will not comment on the use of circumstantial evidence any further. Environmental indicators of PMI include external processes such as forensic entomology, the study of insects such as flies that paralyze dead tissue<sup>5</sup>. In that case, insects may lay eggs on various membranes such as eyes or mouth, which later develop into larvae, by studying eggs and larvae, an entomologist may estimate the earliest time that egg laying occurred that, under ideal circumstances, can suggest the minimum PMI. However, maximum PMI cannot be estimated using this approach, which is also confounded by environmental temperatures that influence egg hatching and larva development, and are precluded if the corpse exists in an environment with few to no insects.

Postmortem bodily changes are perhaps the best studied and most useful way to estimate PMI that we have today, and refer to how a corpse is impacted by different physical, biochemical, and biological processes<sup>6</sup>. The

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Environment International xxx (xxxx) xxx

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Full length article

**Quantitative assessment of the radon (<sup>222</sup>Rn) decay product <sup>210</sup>Pb in human toenails as a sensitive measure of personalized long-term radon gas exposure history**

Kerri A. Miller<sup>1,2,3,4</sup>, Dustin D. Pearson<sup>1,2,3,4</sup>, Sophie C. Pett<sup>1,2,3,4</sup>, Michael E. Wieser<sup>1,2,3,4,5</sup>, Aaron A. Goodarz<sup>1,2,3,4,5\*</sup>

<sup>1</sup>Department of Physics and Astronomy, Faculty of Science, University of Calgary, Alberta, Canada. <sup>2</sup>Department of Biochemistry & Molecular Biology, Cumming School of Medicine, University of Calgary, Alberta, Canada. <sup>3</sup>Amie Charbonneau Cancer Institute, Cumming School of Medicine, University of Calgary, Alberta, Canada.

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Multiple collector inductively coupled mass spectrometry  
Isotope dilution mass spectrometry  
Bulk environment

ABSTRACT

Lung cancer mortality can be lowered through early-diagnostic screening of people demonstrating a ≥1.5 % 6-year risk of tumor development. However, many who develop lung cancer are ineligible for screening (~40 % of Canadian patients) as they have insufficient tobacco smoking history. Tools to assess individual lung cancer risk based on exposure to other prevalent environmental carcinogens such as radon (<sup>222</sup>Rn) gas are lacking. Here, we explore ultra-sensitive quantification of the <sup>222</sup>Rn decay product <sup>210</sup>Pb in toenails (n = 30) as an indicator of personalized, long-term radon exposure history. Toenail cartilage from adults inhaling elevated indoor radon in their primary home (average radon = 354.9 Bq/m<sup>3</sup>) over a mean of 26.5y (equating to 427 mSv radiation dose) contained 0.298 femtomograms of <sup>210</sup>Pb per nanogram of stable Pb. By contrast, only 0.075 femtomograms <sup>210</sup>Pb per nanogram Pb were detected in toenails from low radon exposure controls (28.4 Bq/m<sup>3</sup> over 22.5y equating to 22.8 mSv) – a 397 % difference. Notably, elevated radon decay products (0.245 femtomograms of <sup>210</sup>Pb per nanogram Pb) persisted in toenails from highly radon-exposed people (545.6 Bq/m<sup>3</sup> over 18.5y equating to 283 mSv) who, up to 6 years prior to toenail collection, had mitigated their primary residence to reduce radon (post-mitigation radon = 28.1 Bq/m<sup>3</sup>). No differences were detected on the basis of sex, age, tobacco smoking history, or <sup>210</sup>Pb-rich game meat consumption. These data suggest that toenail <sup>210</sup>Pb/Pb isotope (amount) ratios show promise for evaluating individualized retrospective radon dosimetry history – an approach that may become helpful to assess non-tobacco lung cancer risk in the future.

1. Introduction

Radioactive radon (<sup>222</sup>Rn) gas that is inhaled repeatedly and at high levels within the indoor air of buildings is a prevalent environmental cause of lung cancer, impacting people across the world (Corrales et al., 2020; Lorenzo-Gonzalez et al., 2019; Gogna et al., 2019; Chen, 2019; Gaskin et al., 2018; Grundy et al., 2017; Stanley et al., 2019; Stanley et al., 2017). Exposure to large amounts of radon over time increases risk of lung cancer because, as <sup>222</sup>Rn undergoes radioactive decay, it emits alpha particle radiation that ionizes the DNA of nearby lung cells, damaging genetic material in a way that introduces mutations that

increase the probability of the impacted cell becoming cancerous (Pearson and Goodarz, 2016; Moore et al., 2014). Lung cancer risk from radon exposure is prevalent globally (Kang et al., 2019; LaPico et al., 2024) and, at the individual level, is a function of local geological sources of radon, the person's built environment that dictates actualized radon levels within indoor air, and behavioural variables that influence how much time per year the person spends breathing that air (Khan et al., 2021; Simms et al., 2021; World Health Organization, 2009; Irvine et al., 2022). In some regions of high geologic radon potential, such as Canada, more recent residential building practices have unintentionally worsened radon exposure (Stanley et al., 2019; Khan et al., 2021), whilst

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Full length article

**Quantitative assessment of the radon ( $^{222}\text{Rn}$ ) decay product  $^{210}\text{Pb}$  in human toenails as a sensitive measure of personalized long-term radon gas exposure history**

Kerri A. Miller<sup>a,c,1</sup>, Dustin D. Pearson<sup>b,c,1</sup>, Sophie C. Pett<sup>b,c</sup>, Michael E. Wieser<sup>a,c,1</sup>, Aaron A. Goodarzi<sup>b,c,1</sup>

<sup>a</sup> Department of Physics and Astronomy, Faculty of Science, University of Calgary, Alberta, Canada  
<sup>b</sup> Department of Biochemistry & Molecular Biology, Cumming School of Medicine, University of Calgary, Alberta, Canada  
<sup>c</sup> Author Contribution: [View this email in your browser](#)

Thursday 16 October 2025

ARTICLE IN PRESS

**nature briefing cancer**

IN THE NEWS

- Toenail clippings can reveal whether people have been exposed to radon, an odorless and invisible gas that can accumulate in buildings and contributes to lung cancer. (ScienceAlert) Reference: *Environment International* paper (2025)

1. Introduction

Radioactive radon ( $^{222}\text{Rn}$ ) gas that is inhaled repeatedly and at high levels within the indoor air of buildings is a prevalent environmental cause of lung cancer, impacting people across the world (Corrales et al., 2020; Lorenzo-Gonzalez et al., 2019; Gogna et al., 2019; Chen, 2019; Gaskin et al., 2018; Grundy et al., 2017; Stanley et al., 2019; Stanley et al., 2017). Exposure to large amounts of radon over time increases risk of lung cancer because, as  $^{222}\text{Rn}$  undergoes radioactive decay, it emits alpha particle radiation that ionizes the DNA of nearby lung cells, damaging genetic material in a way that introduces mutations that increase the probability of the cell becoming cancerous (Pearson and Goodarzi, 2016; WHO, 2024) and, at the individual level, sources of radon, the person's building radon levels within indoor air, and how much time per year the person spends in that space (Stanley et al., 2021; Simms et al., 2021; Yip et al., 2022). In some regions of Canada, more recent residential construction has worsened radon exposure (Stanley et al., 2022).

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**Toenails tell toxic tale of radon gas for U of C scientists**

*A five-year pilot study involving 40 subjects found a higher-exposure to radon corresponds to a greater level of radioactive lead in their toenails*

By Bill Kaufmann  
 Published Oct 08, 2025 Last updated Oct 08, 2025 3 minute read



Dr. Dustin Pearson and Dr. Aaron Goodarzi, researchers at the University of Calgary's Cumming School of Medicine, were photographed in their lab on Wednesday, October 8, 2025. They are working on a study analyzing toenail clippings to investigate environmental sources of lung cancer, such as radon gas. (Robert Calver/Postmedia)

CTV NEWS

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Calgary | News

**Calgary study seeks toenail clippings from 10,000 Canadians**

By Mark Villan  
 Published: October 08, 2025 at 11:25AM EDT



Global NEWS

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HEALTH

**10K toenail clippings needed for Canadian study on potential lung cancer risk**

By Gabby Rodrigues • Global News  
 Posted October 8, 2025 10:59 am - 2 min read




File photo: Getty Images

Scientists at the University of Calgary say they are looking for toenail clippings for a study looking into radon gas exposure and potential lung cancer risk.

CityNews Everywhere

News Watch Listen Weather Contests Community

**Calgary researchers collecting toenail clippings for cancer research**



CTV NEWS.CA

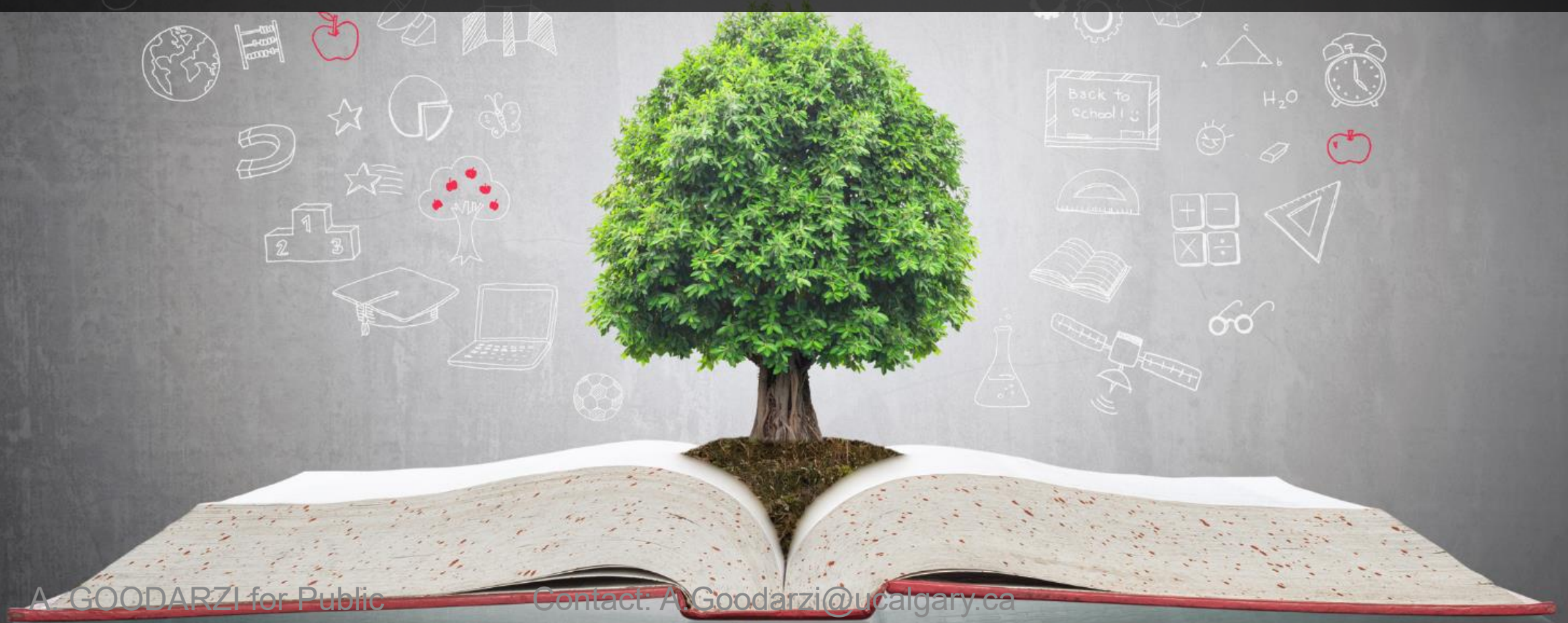


Michael Wieser, PhD, physics professor at the University of Calgary, is shown in a video call discussing his research on radon exposure and lung cancer. He is wearing a blue shirt and glasses.

**'YOU DON'T SEE TOENAILS AND RADON IN THE NEWS HEADLINES VERY OFTEN': ANALYST**

© CTV News

# KNOWLEDGE to **ACTION**



# TIME-ACTIVITY PATTERNS

**ACTIVITY PATTERN** = % of 8760 h/y (24h/d x 365 d/y) in \_\_\_\_\_ environment)



**Primary Residence**  
(sleep here)



**Different Residential Building**



**Non-Residential Building**

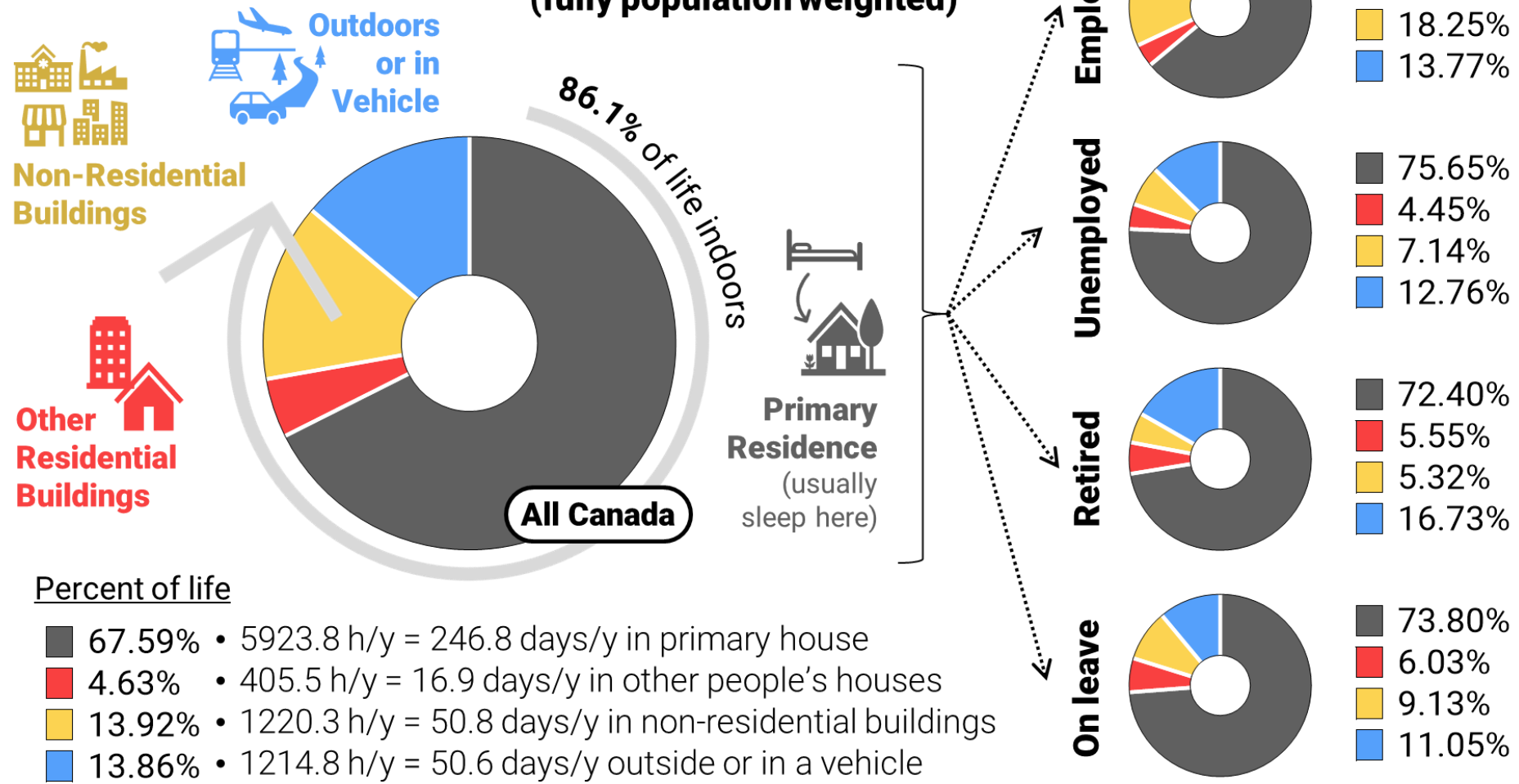


**Outdoors or in Vehicle**



# TIME-ACTIVITY PATTERNS

## AVERAGE TIME-ACTIVITY PATTERNS FOR CANADIAN ADULTS FROM SPRING 2019 TO END OF WINTER 2025 (fully population weighted)



**EVICT RADON**  
NATIONAL STUDY

WHAT IS RADON? ▾ RADON TESTING ▾ THE STUDY ▾ RESOURCES ▾ FAQ'S

# Clearing The Air Together, For Healthier Homes

Evict Radon is a publicly funded national study aimed to understand and prevent Canadian radon exposure and lung cancers.

**Promoting Action**  
We are helping Canadians take action against radon and creating safer homes.  
[TEST YOUR HOME](#)

**Empowering Communities**  
We are empowering Canadian communities by raising awareness about the dangers of radon.  
[CROSS CANADA RADON SURVEY](#)

**Educating and Prevention**  
We are providing Canadians with knowledge and tools to take preventative measures against radon.  
[KNOW YOUR RISK](#)





Radon Exposure Calculator

## Calculate the Rate and Total Dose of Alpha Particle Radiation You are Absorbing from the Radon in Your Home.



Radon Exposure  
Calculator >

News/Blogs

Our Study in the News

Real Estate Resources

### What dose of radiation are you getting from radon?

Using the latest science, the [International Commission for Radiological Protection \(ICRP\)](#) has developed a conversion formula to estimate the amount of alpha particle radiation being absorbed by your lungs from radon. To calculate this, two numbers are needed:

1. A long-term household radon level in Bq/m<sup>3</sup> or pCi/L
2. The number of hours a person spends per year breathing air in that property. This "activity pattern" is unique to a specific person depending on their lifestyle, and may not be the same for everyone living, learning or working under the same roof.

This calculator will allow you to estimate your absorbed radiation exposure based on these numbers, as an annual rate and total dose, based on the amount of time you have lived in that property.



## What dose of radiation are you getting from radon?

This calculator will allow you to estimate your absorbed radiation exposure based on how much radon is in your home and the amount of time you have lived in that property.

[RADON EXPOSURE CALCULATOR](#)

How many different houses do you consider 'home' (meaning somewhere you live and sleep for sustained periods of time) during a typical year? \*

- One house  
 I split my time between 2 or more houses

Is your time spent at home different during the days where you are working (or in school), versus the days where you are not (e.g. weekends or holidays)? \*

- Yes  
 No

\*In a typical year

What is the tested Radon in your primary residence?

- Becquerels per cubic meter (Bq/m<sup>3</sup>)  
 PicoCuries per litre (pCi/L)

Radon level in your primary home \*  
200

[Unsure of your radon levels?](#)

Number of hours spent in the house on a typical 24 hour day

Workday (in hours) \*  
16

Non-workday (in hours) \*  
22

Note: If you work in a hybrid manner (both at home and in another building) just average the number of hours per day that you are at home.

Number of years spent in your current home(s)

Years in home \*  
10

Weeks spent NOT in home(s), e.g. on vacation, away for business, during a typical year.

Number of weeks spent NOT in home(s)\*  
4

I agree to the [terms and conditions](#).



## Your Results

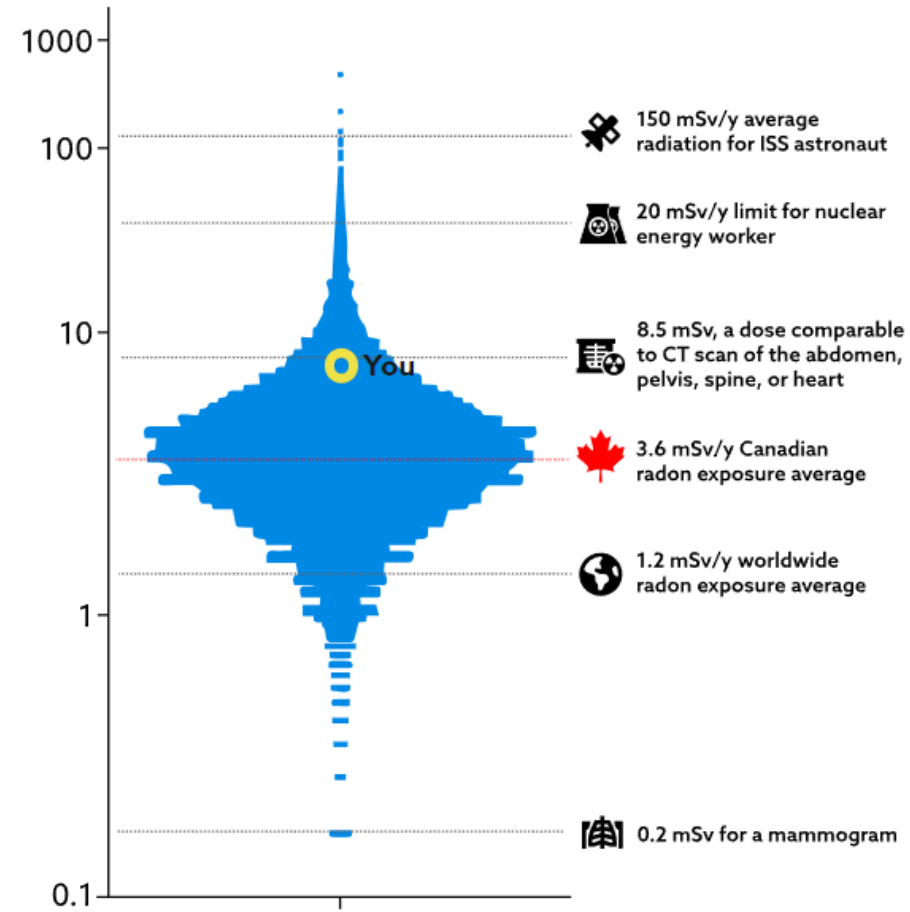
**IMPORTANT:** The estimated risks below apply to otherwise healthy adults, and are expected to be different (likely higher) for babies, children, and teens, as well as persons experiencing other lung health concerns.

Your estimated exposure is at or above where large scale studies have documented an increased lifetime risk of lung cancer due to ongoing radon inhalation. Your increased lifetime relative risk of lung cancer is **32%**

Your absorbed alpha radiation dose (to the lungs) from residential radon gas inhalation is **8 mSv/yr**, with a total exposure of **80 mSv** over the period you have lived in your current home(s).

**You are above the worldwide and national averages** for radon inhalation exposure.

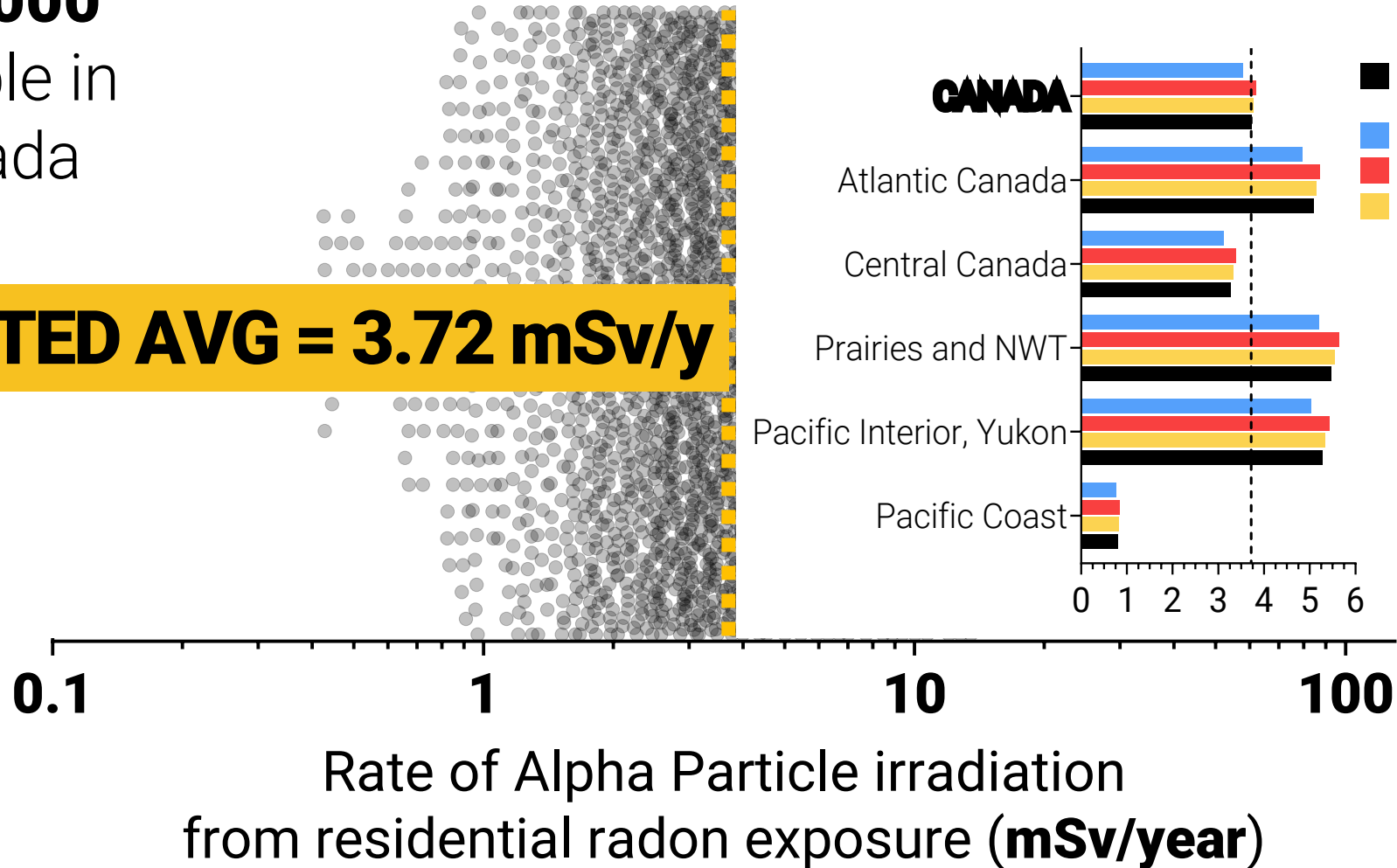
By living in your home(s) for **1.1** years, you will receive the equivalent dose of radiation from radon, as one CT scan to the abdomen, pelvis, spine, or heart



The blue in the chart above represents real radon exposure, as measured through people participating in the Evict Radon National Study. Yes, this means that there are Canadians experiencing higher radiation doses per year just from living in their homes, compared to an astronaut on the international space station.

**n > 6,000**  
people in  
Canada

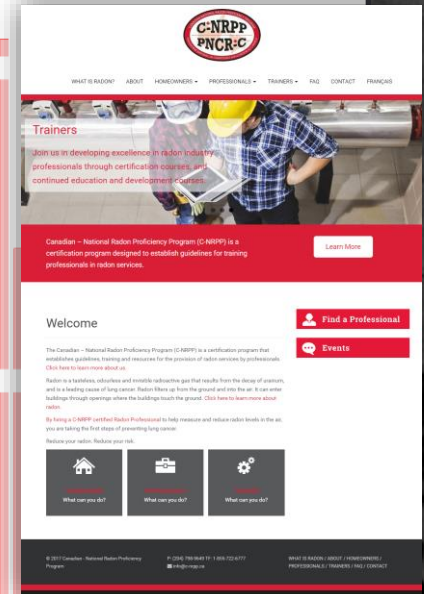
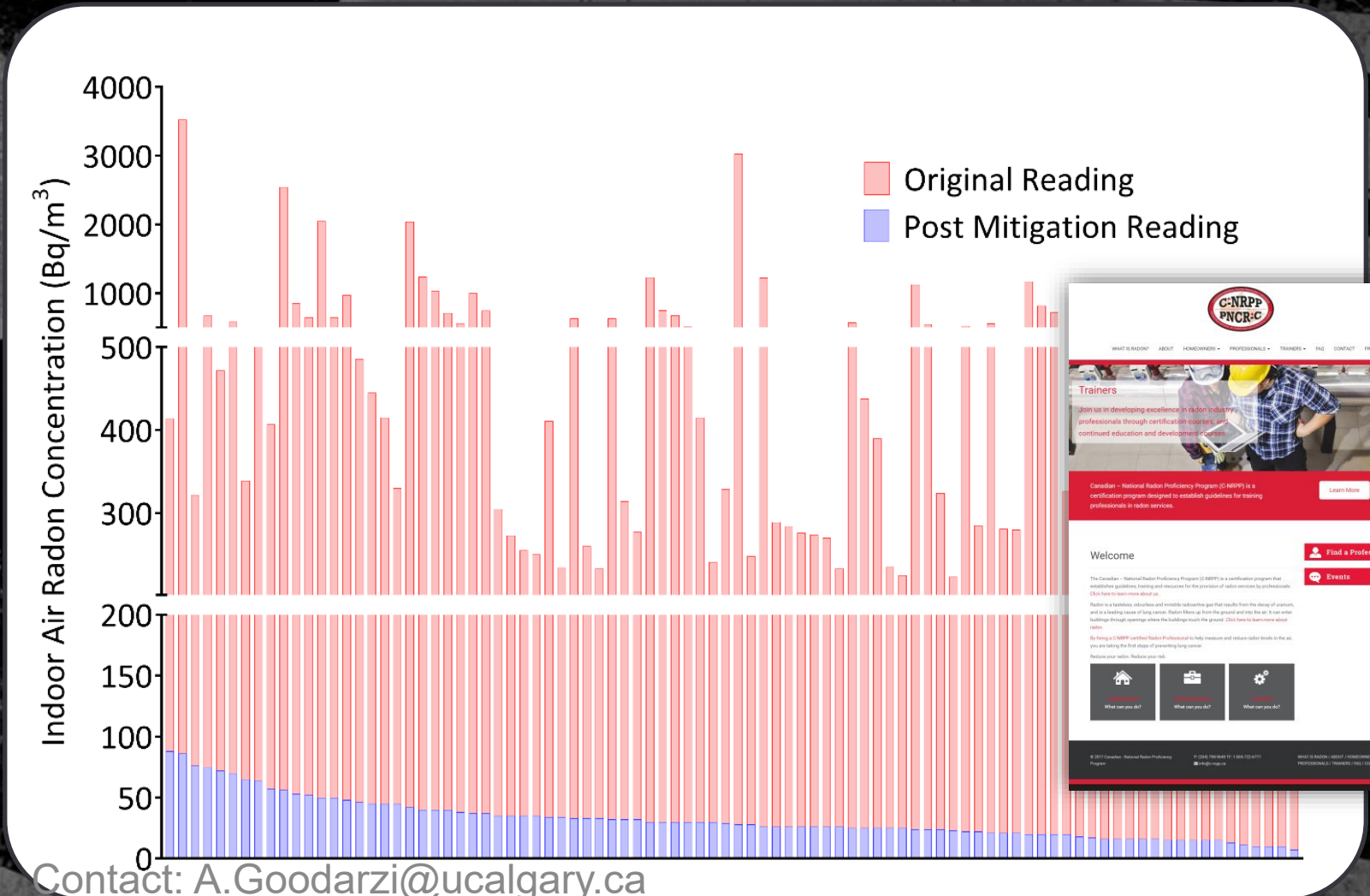
**WEIGHTED AVG = 3.72 mSv/y**



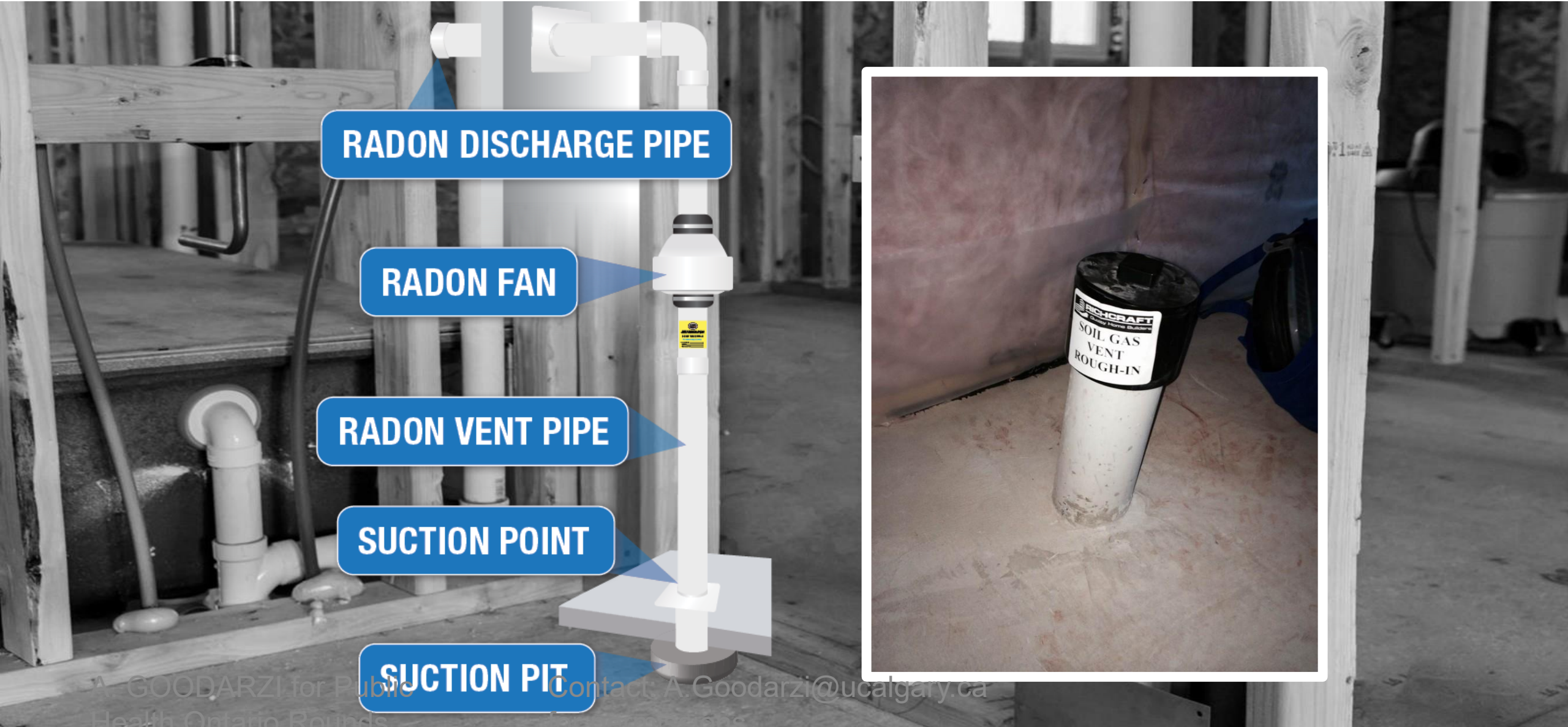


**POPULATION-LEVEL  
INTERVENTIONS**

# High radon is a **Solvable Issue**



# BUILDING CODES



**RADON DISCHARGE PIPE**

**RADON FAN**

**RADON VENT PIPE**

**SUCTION POINT**

**SUCTION PIT**

**SOIL GAS  
VENT  
ROUGH-IN**

2025-05-26

## Archived – Public review of proposed changes to the 2020 National Model Codes– Winter 2024

This national public review ran from February 27 to April 29, 2024. The Canadian Board for Harmonized Construction Codes (CBHCC) invited code users, the Codes community, and the public to participate in the winter 2024 public review of proposed changes to the 2020 editions of the National Model Codes. The National Building Code of Canada for Buildings and the National Energy Code of Canada See the public review website for comments are

### National Building Code of Canada

- Adaptable and visitable dwelling units
- Seismic hazard
- Testing of protective coverings over foamed plastic insulation
- Earthquake forces on parts and portions of structures
- Performance requirements for post-disaster buildings, High Importance Category buildings and subset of Normal Importance Category buildings
- Scope of Article 4.1.8.4.
- Simplified method applied to locations with low seismic hazard
- Structural and non-structural elements not part of seismic force resisting systems
- Airtightness
- Energy use intensity compliance path
- Operational GHG emissions
- Prescriptive compliance for Energy Performance Tier 5
- Prescriptive trade-off path in Section 9.36.
- Radon and soil gas mitigation
- Reference to new standard for asphalt core boards
- Reference to new standard for the testing of vapour barrier properties of coatings
- Reference to new standards for light-density, open-cell, spray-applied polyurethane foam
- Alteration of existing buildings

## Radon control in Canadian homes

March 25, 2019 - Ottawa, Ontario

Since 2011, the National Research Council of Canada (NRC) and Health Canada's National Radon Program have been working on a multi-year study to develop safe and cost-effective solutions to minimize the health risks from radon gas exposure in Canadian homes and to provide guidance for radon prevention and mitigation.



Radon Diffusion Test Chamber and a test sample

The intent is to:

- support the National Building Code's (NBC) standing committee to address proposed changes to the NBC,

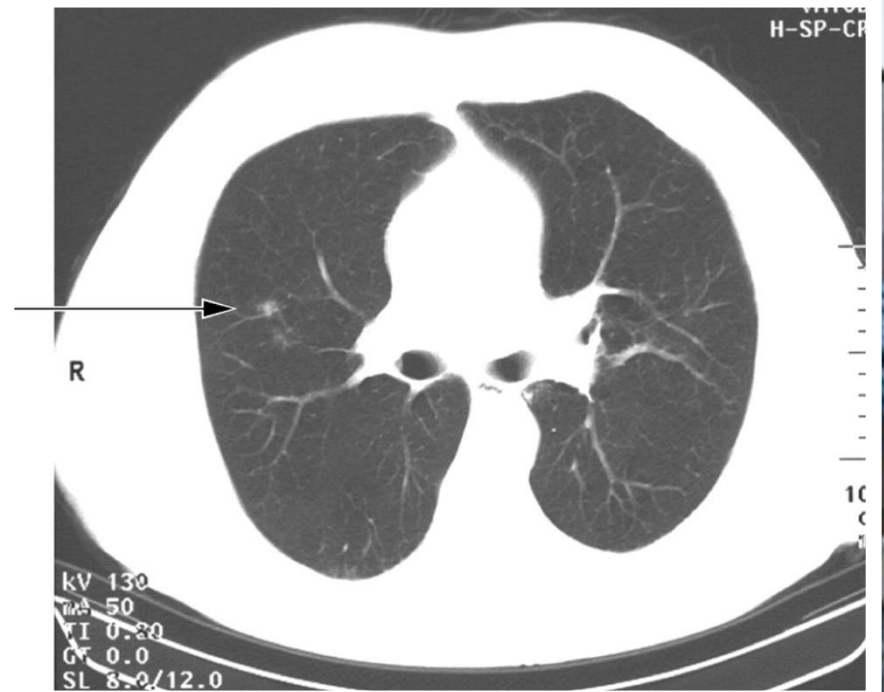


## 2025 code priorities

Canada's National Model Codes are generally developed on a five-year cycle. For each code cycle, the CBHCC establishes a work plan that guides the work of code development committees as they develop and assess potential code changes. The work plan is established to address strategic priority areas defined by the Canadian Table for Harmonized Construction Code Policy (CTHCCP).

# LUNG CANCER SCREENING

**LUNG CANCER SCREENING:**  
*What Is A Low Dose CT Scan?*



# LUNG CANCER SCREENING

## LUNG CANCER SCREENING CRITERIA

Our patients must be:

55-74  
years old



  
**CURRENTLY**  
smoke

or

**QUIT**  
in the last  
**15 YEARS**

Have at least a  
**20-30-PACK-YEAR**  
smoking history

 X  = **30**  
2 packs per day 15 years pack-year  
history



Start of compulsory education (6 years)



Start of first employment (23 years)



Leaving parental home (25.1 years)



Birth of first child (28.9 years)



Retirement (58.8 years)



Life expectancy (83.3 years)



**TEST** for 'LIFETIME' radon exposure

Start of compulsory education (6 years)



Start of first employment (22 years)



Leaving parental home (27.1 years)

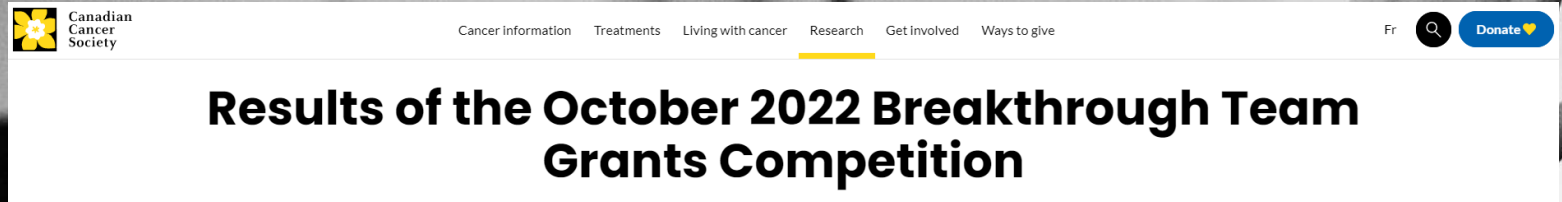


Retirement (59.4 years)



Life expectancy (77.9 years)





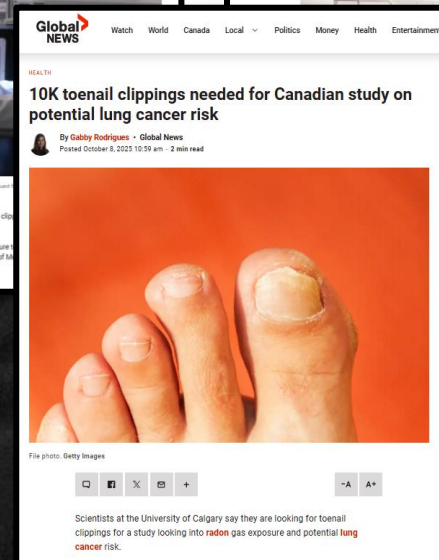
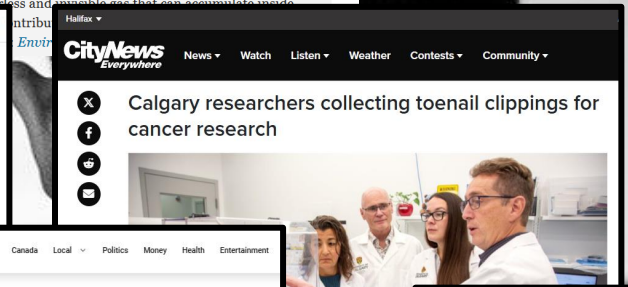
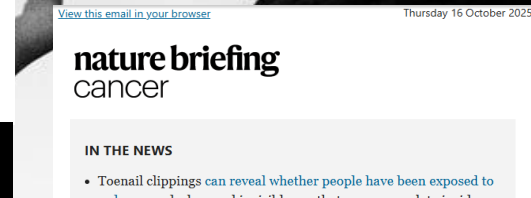
## Changing the narrative of lung cancer to improve prevention for non-smokers

A team led by Dr Robin Urquhart is examining the effects of environmental exposures in non-smokers to help detect lung cancer earlier and save lives.



A. GOODARZI for Public Health Ontario Rounds

Contact: A.Goddarzi@ucalgary.ca for permissions



No. 4890 July 20, 1963

NATURE

### Lead-210 and Polonium-210 in Human Tissues

It has recently been shown<sup>1</sup> that appreciable amounts of lead-210 and polonium-210 may occur in certain human foodstuffs as a result of deposition from the atmosphere of long-lived radon decay-products (Table 1). Absorption of these products may therefore occur by both inhalation and ingestion, but, although measurements of the activity of lead-210 in many human bone samples have been reported<sup>2-6</sup>, the ratio of polonium-210 to lead-210 in bone and the activities of these nuclides in human soft tissues have been reported in only a few samples<sup>1,3,7,8</sup>. This communication describes the results of preliminary radiochemical estimations of polonium-210 and lead-210 in human bone and soft tissue samples.

Table 1. RADON DECAY PRODUCTS

|                       | Nuclide       | Half-life (ref. 2) | Decay              |
|-----------------------|---------------|--------------------|--------------------|
| Radon                 | Rn-222 (Rn)   | 3-823 d            | $\alpha$           |
| Short-lived daughters | Po-218 (RaA)  | 3-05 m             | $\alpha$           |
|                       | Pb-214 (RaB)  | 26.8 m             | $\beta$ -          |
|                       | Bi-214 (RaC)  | 19-7 m             | $\beta$ - $\alpha$ |
| Long-lived daughters  | Po-214 (RaC') | 160 $\mu$ s        | $\alpha$           |
|                       | Pb-210 (RaD)  | 20 y               | $\beta$ -          |
|                       | Bi-210 (RaE)  | 5-0 d              | $\beta$ - $\alpha$ |
| Stable lead           | Po-210 (RaF)  | 138-4 d            | $\alpha$           |
|                       | Pb-206        | —                  | —                  |

The method used was similar to that of Black<sup>7</sup>. Up to 80 g of wet tissue were digested with nitric and perchloric acids, care being taken to keep the temperature below 200° C because of the volatility of polonium. From a final solution, 0.5 N in hydrochloric acid, polonium was electrochemically deposited on a silver disk. The activity was measured in a counter<sup>9</sup>. The specificity of the method for polonium-210 was checked by  $\alpha$ -spectrometry using the  $\alpha$ -spectrometer with a silicon detector. By low-level  $\beta$ -counting for lead-210, the activity of lead-210 was determined.

in vertebræ. This is Black<sup>7</sup> and Holtzman that the lead-210 concentration is close to the average basis, assuming an average total skeletal ash of polonium-210/lead-210 skeletal burden of lead-210.

The results of tracing human beings, summarized in Table 1, indicated that polonium-210 in soft tissues, particularly in the lower levels, the polonium-210 activity of lead-210.  $\alpha$ -spectrometry of soft tissue samples<sup>1</sup> have demonstrated that polonium-210 is in excess of other  $\alpha$ -emitters. The measurements reported here give average values for polonium-210 activity in the major soft tissues higher than those spectroscopic determinations, probably because of volatilization of polonium in the dry-ashing procedure required for the spectroscopy.

If the concentration in those types of soft tissue not measured here is comparable with that measured in skeletal muscle, the foregoing results indicate an average body burden of polonium-210 in the range 330-450 pc. with at least 20 per cent of the activity in the soft tissues. The upper and lower limits correspond to the assumptions that the more highly mineralized cortical portion of the skeleton



**CORRELATE** radon to <sup>210</sup>Pb in toenails



**INNOVATION.CA**

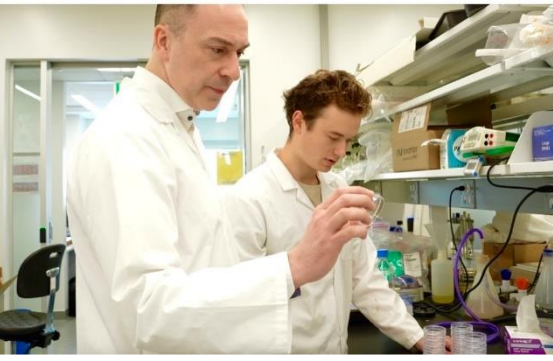
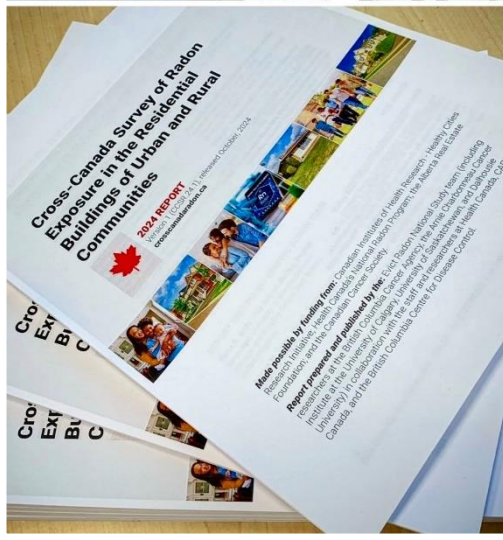
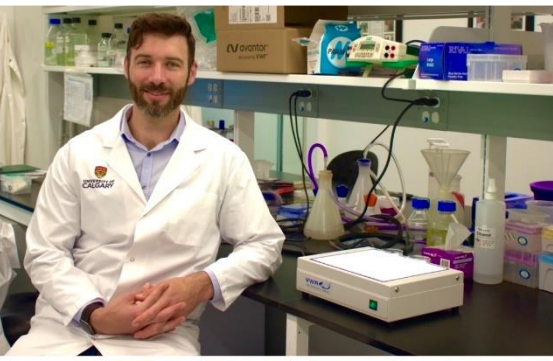
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POUR L'INNOVATION

|       |           |            |                             |
|-------|-----------|------------|-----------------------------|
| deci  | [d]       | $10^{-1}$  | = 0.1                       |
| centi | [c]       | $10^{-2}$  | = 0.01                      |
| milli | [m]       | $10^{-3}$  | = 0.001                     |
| micro | [ $\mu$ ] | $10^{-6}$  | = 0.000 001                 |
| nano  | [n]       | $10^{-9}$  | = 0.000 000 001             |
| pico  | [p]       | $10^{-12}$ | = 0.000 000 000 001         |
| femto | [f]       | $10^{-15}$ | = 0.000 000 000 000 001     |
| atto  | [a]       | $10^{-18}$ | = 0.000 000 000 000 000 001 |

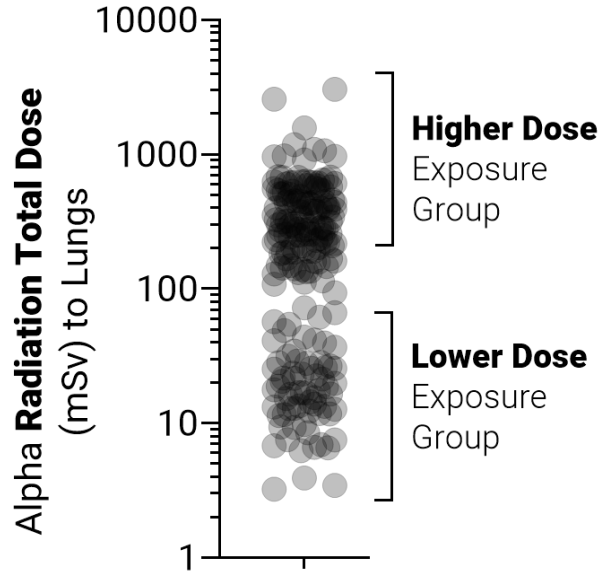
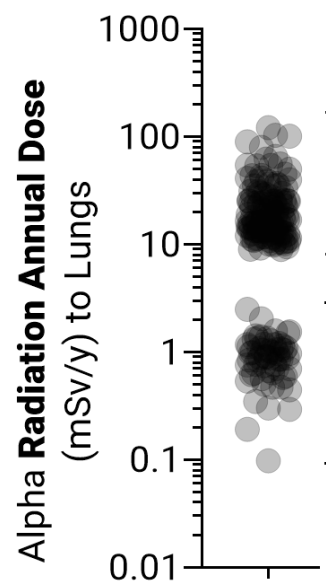
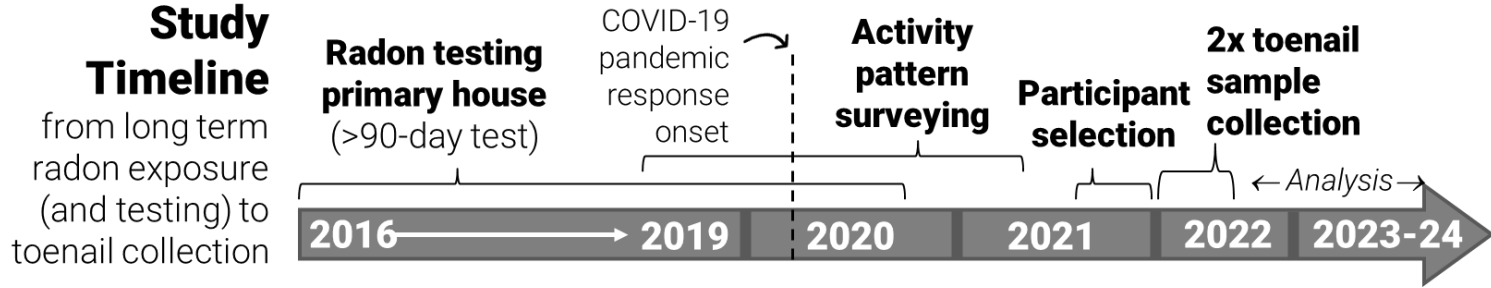
NEED **METAL FREE** LABORATORIES

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Metalloomics  
Laboratory

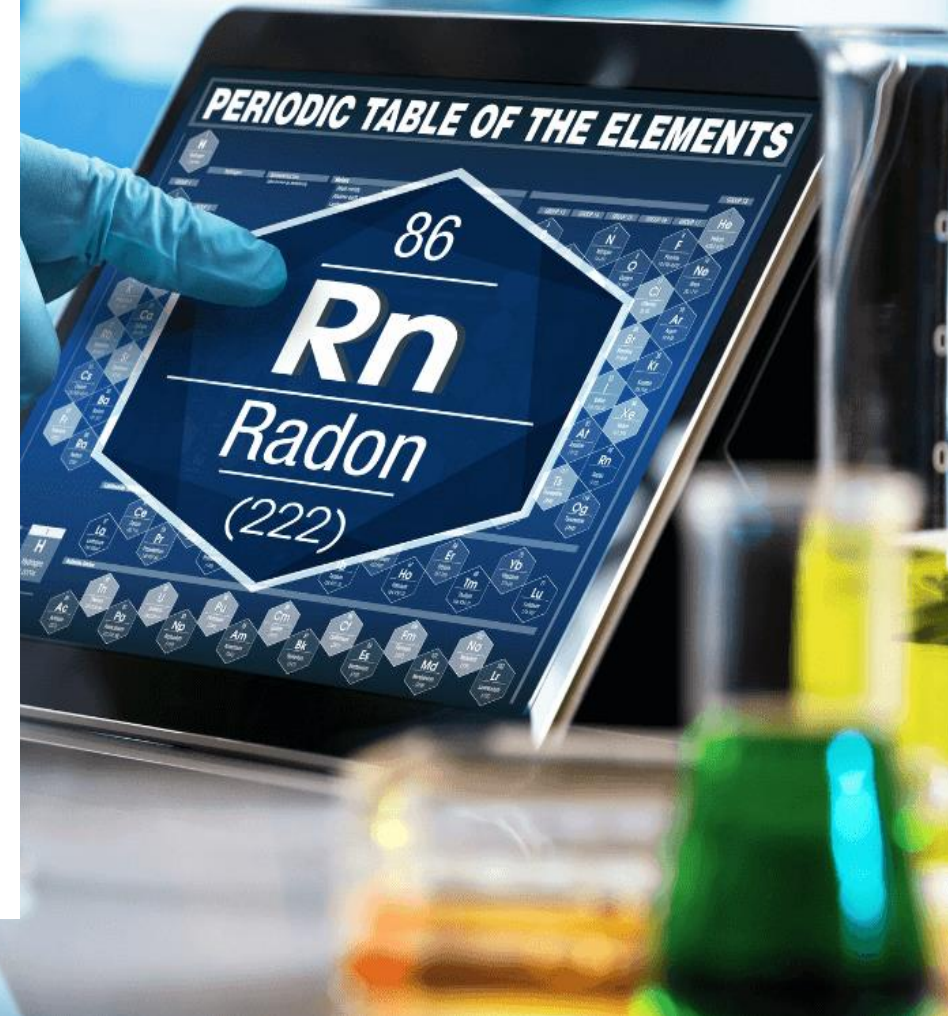


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Alpha  
Radiobiology  
Laboratory

# PERSONALIZED dosimetry

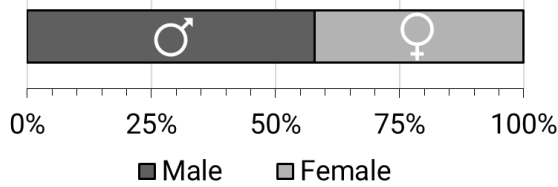


n=214 people invited to provide toenail clipping samples to assess  $^{210}\text{Pb}$  bio-accumulation as a function of estimated radiation dose from radon

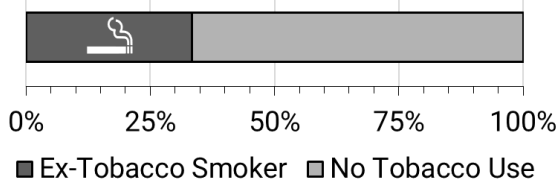


# PERSONALIZED dosimetry

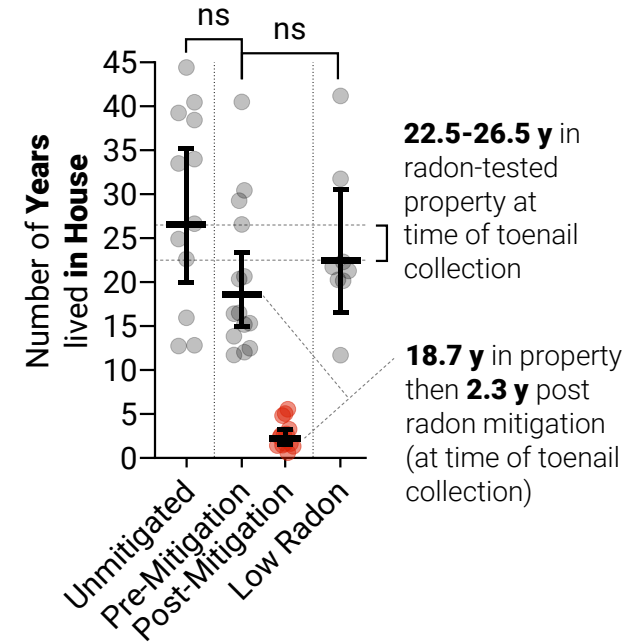
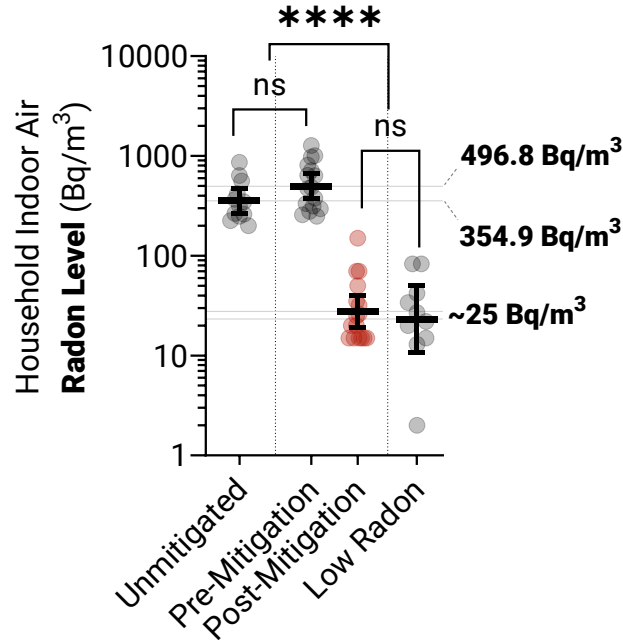
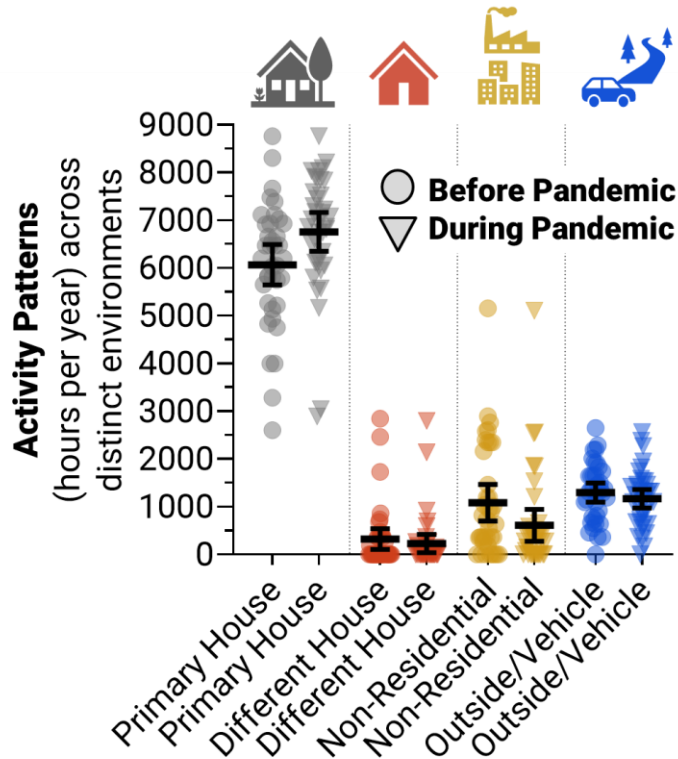
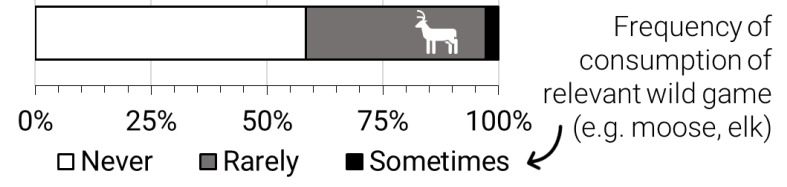
(A) Participant Sex



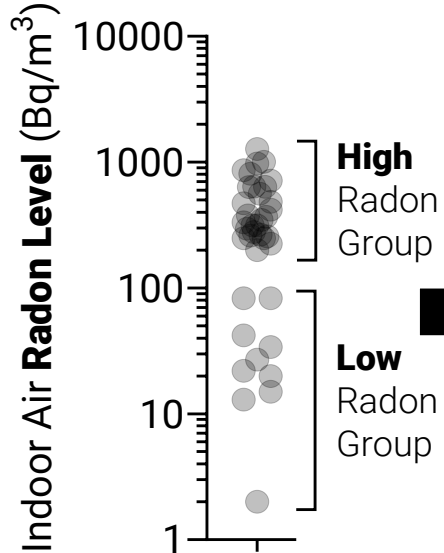
(B) Participant's Tobacco Use History



(C) Participant's diet of (<sup>210</sup>Pb-rich) game meat

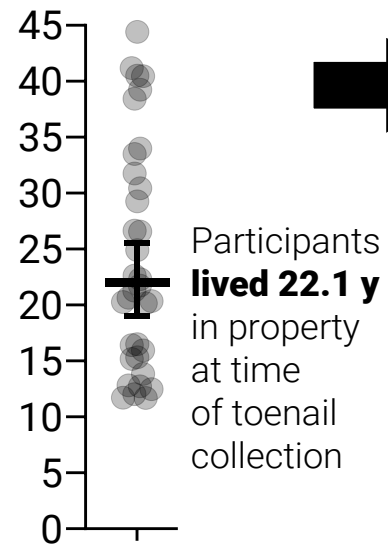


# PERSONALIZED dosimetry

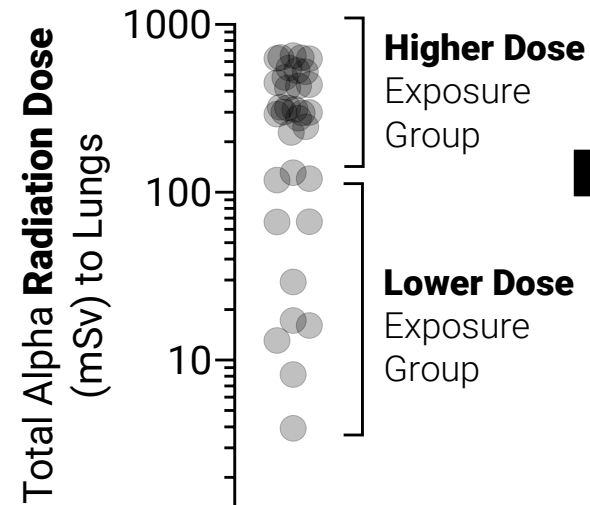


**RADON LEVEL**

Number of Years  
lived in House



**ACTIVITY+DURATION**

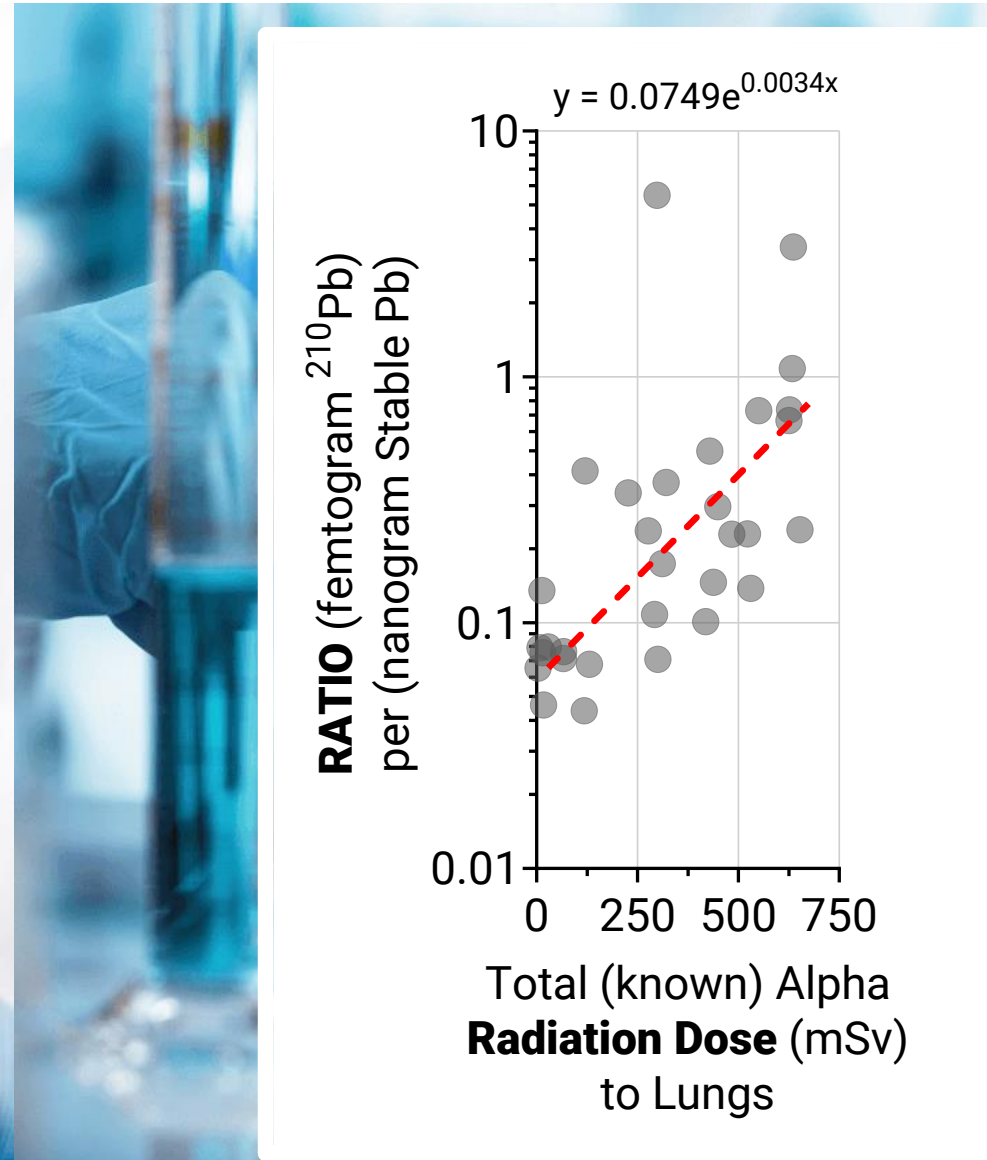
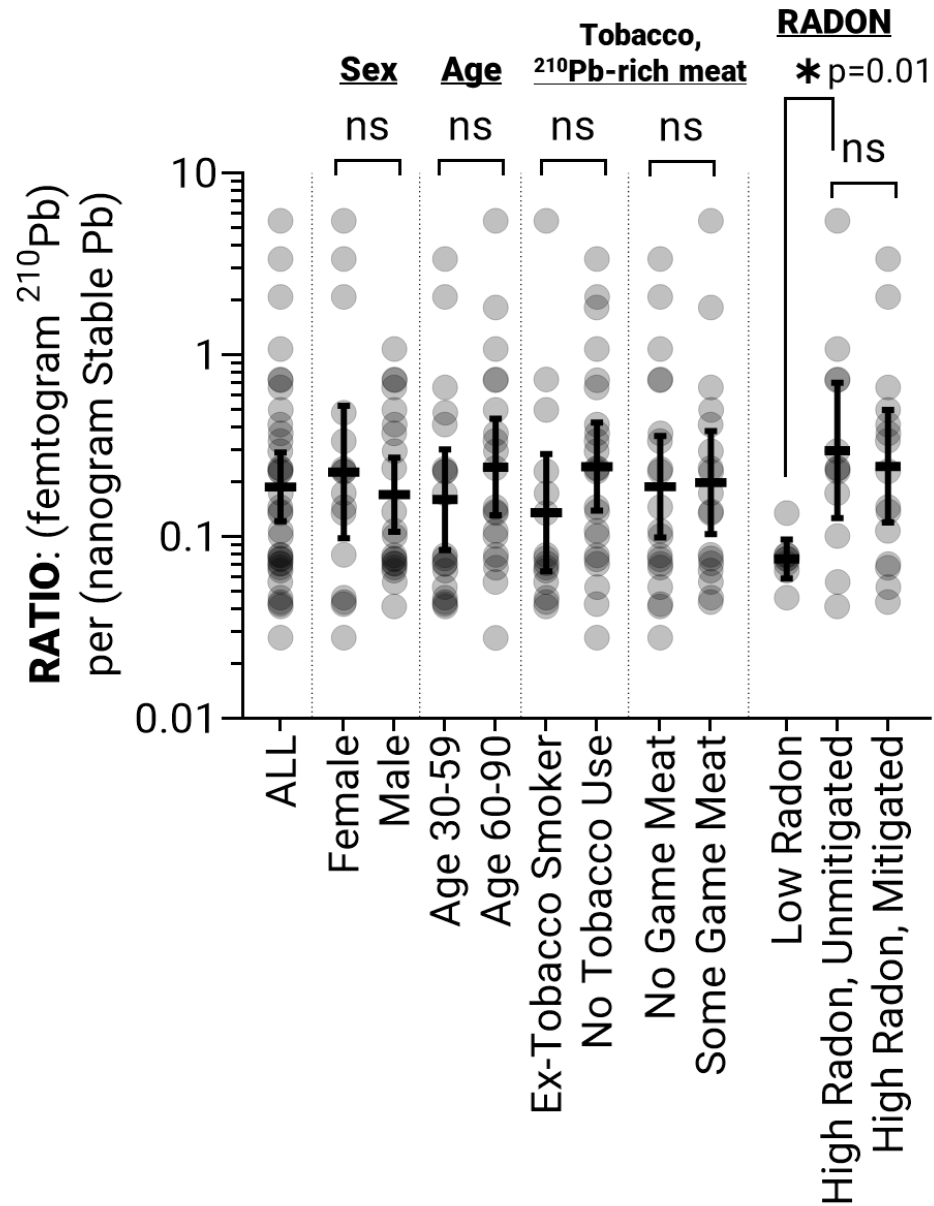


**TOTAL ABSORBED DOSE**



Cancer  
Metallomics  
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# PERSONALIZED dosimetry



## Radon Testing Study

Thank you for your interest in the Evict Radon National Study research on the biomarkers of long-term radon exposure and / or how radon impacts people living with disabilities. If you are filling out this survey response on behalf of someone else in your household, please answer the questions as if you were them.

Are you willing to perform a radon test of 120 days in duration in your primary residence, meaning the residential building in which you personally live and sleep for most of the test period? \*

- Yes  
 No

To your knowledge, has your primary residence ever been mitigated\* for radon gas by a professional or person who made modifications to your home with the specific purpose of reducing radon levels? \*

- Yes  
 No

*Radon mitigation devices vent soil gases from the foundation of the home to the exterior of the house. If you have a rough in BUT it is not connected to any exterior venting, please select "no".*

First Name \*  Last Name \*

Email \*

Enter Email

Confirm Email

In what province or territory of Canada do you primarily live? \*

Select Province/Territory

*We are asking this as we aim to recruit people of a variety of regions that, as a whole, reflect the adult population in Canada today*

## Evict Radon and Participate in the National Study

Enroll in Canada's national research study to help understand and Evict Radon from our homes.

### Become a Citizen Scientist

Become a citizen scientist and order an at-cost long-term radon test kit for \$53.99 with free shipping.

TEST YOUR HOME

### Join our Limited-Enrollment "Toenail" Study

Support Canadian scientists in exploring new ways of measuring a long-term exposure to radon.

AM I ELIGIBLE?

### Now Recruiting Participants for our "Disability" Study

Help Canadian researchers investigate how radon impacts people experiencing disability and their caregivers.

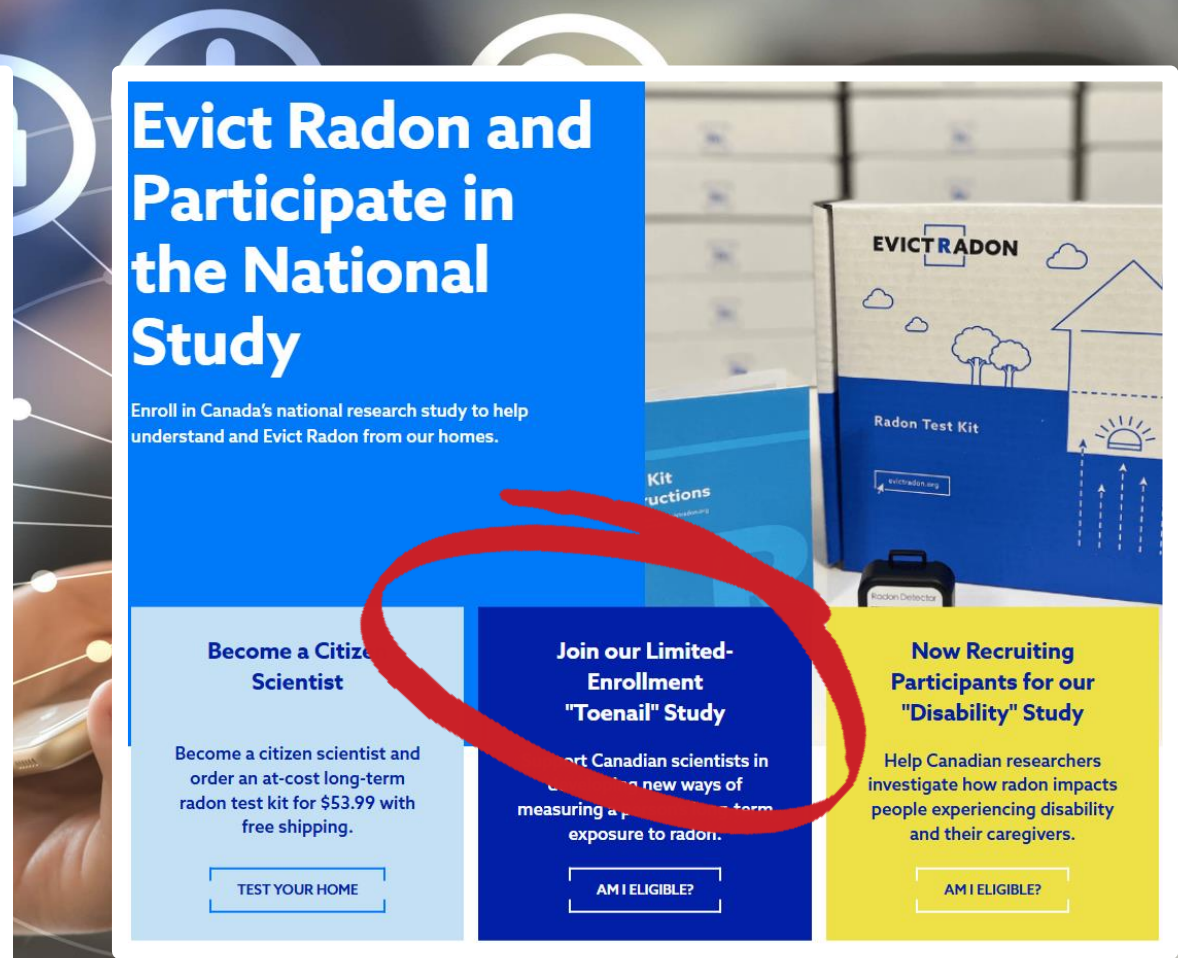
AM I ELIGIBLE?

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RCES FAQ'S



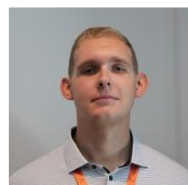
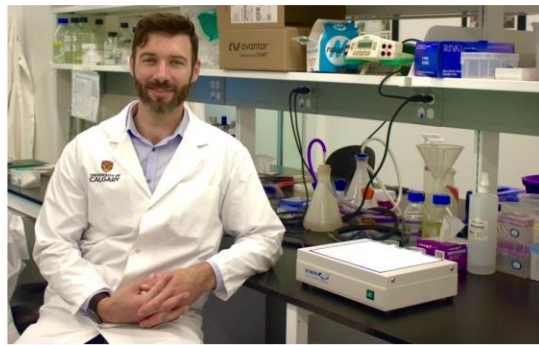
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Scientific Publications

All Evict Radon National Study Participants Contribute to Ground-Breaking Research to Help Understand Canada's Radon Problem.



October 23, 2024  
**2024 Cross-Canada Survey**  
[Read the article](#)



February 26, 2024  
**Rural communities experience higher radon exposure versus urban areas, potentially due to drilled groundwater well annuli acting as unintended radon gas migration conduits**  
 Khan & Pearson et al.  
[Read the article](#)



October 27, 2023  
**Profound DNA methylomic differences between single- and multi-fraction alpha irradiations of lung fibroblasts**  
 Vera-Chang et al.  
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**Reference Module in Biomedical Sciences: Radon (<sup>222</sup>Rn) Gas**  
 Pearson et al.  
[Read the article](#)



April 7, 2023  
**Consequences of changing Canadian activity patterns since the COVID-19 pandemic include increased residential radon gas exposure for younger people**  
 Cholowsky & Chen et al.  
[Read the article](#)



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**Reference Module in Biomedical Sciences: Ionizing radiation toxicology**  
 Danforth et al.  
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December 9, 2022  
**Characterizing occupational radon exposure greater than 100 Bq/m<sup>3</sup> in a highly exposed country**  
 Brobbay et al.  
[Read the article](#)



September 14, 2022  
**Social factors and behavioural reactions to radon test outcome underlie differences in radiation exposure dose, independent of household radon level**  
 Irvine & Simms et al.  
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July 13, 2022  
**Chromatin and the Cellular Response to Particle Radiation-Induced Oxidative and Clustered DNA Damage**  
 Danforth et al.  
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