Crosswalk methods for a diesel exhaust job-exposure matrix and impacts on lung cancer risk

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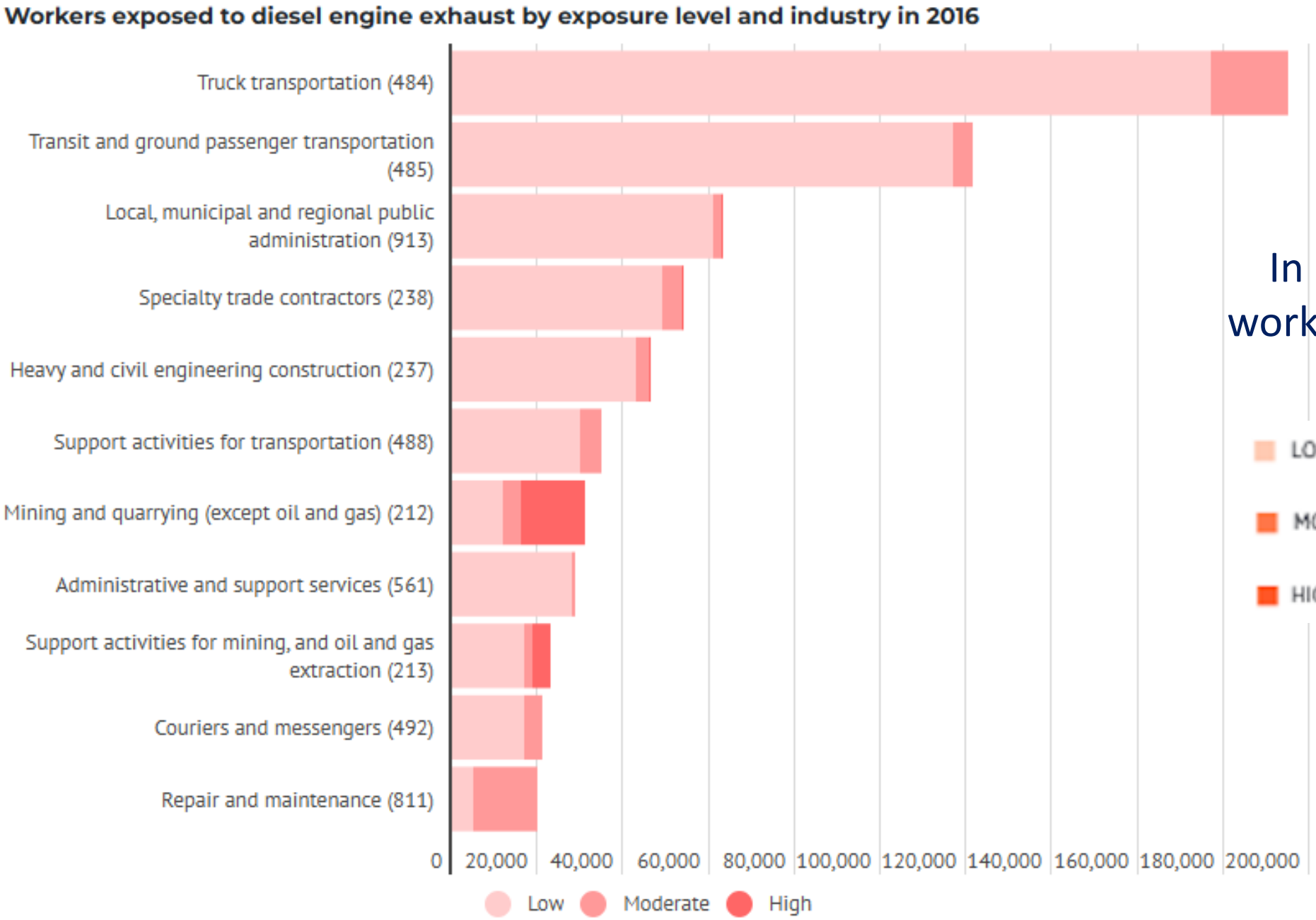
What is diesel engine exhaust (DEE)?

- Complex mixture of gases & particulates
  - By-product of combustion of diesel fuel
- Gases: CO, CO_2, NO, NO_2, PAHs, formaldehyde, naphthalene, low molecular weight HCs and derivatives, SOx compounds
- Particulates: PM ($PM_{2.5}$, UFP, EC, OC), sulfates, PAHs and nitro-PAHs, metals, trace compounds

https://en.wikipedia.org/wiki/Exhaust_gas

IARC 2012



In Canada, ~966,000 workers exposed to DPM

LOW 0 – 10 µg/m³ EC

MODERATE 10 – 20 µg/m³ EC

HIGH >20 µg/m³ EC

Source: CAREX Canada 2022 (based on 2016 census data)

Acute Health Effects

- Acute myocardial infarction
- Irritation of the eyes, throat, and bronchi
- Exacerbating allergic responses
- Nausea
- Phlegm
- Coughing

Wils et al 2025, IARC 2012, Bassig et al 2017, Wang et al 2019, Carvalho-Oliveira et al 2020

Poll Question 1

In 2012, the International Agency for Research on Cancer classified diesel engine exhaust as:

A. Group 1 – Carcinogenic to humans
B. Group 2a – Probably carcinogenic to humans
C. Group 2b – Possibly carcinogenic to humans
D. Group 3 – Not classifiable as to carcinogenicity in humans

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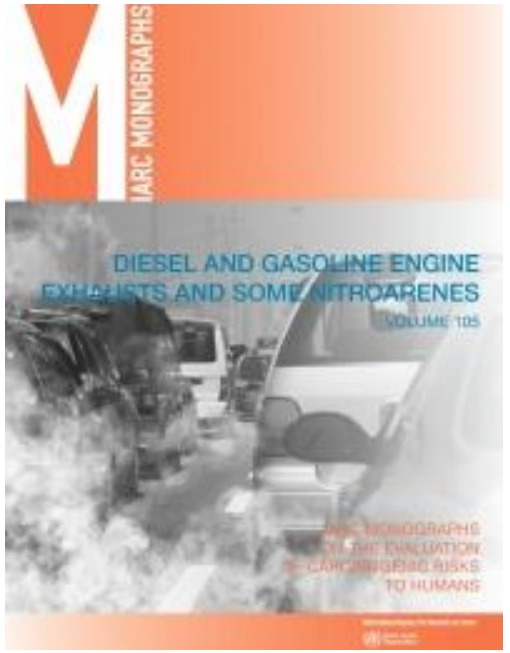
Chronic Health Effects

- Cancer
  - Lung cancer (sufficient evidence)
  - Bladder cancer (limited evidence)
    - Sufficient animal evidence for cancer from PM component
    - Estimated annual burden: 560 lung & 200 bladder cancer cases
- Non-cancer
  - Respiratory disease
  - Cardiovascular disease



Garshick et al 2012, Steenland et al 1998, IARC 2012, Boffetta & Silverman 2001, Koutros et al 2023, Grahn et al 2021, Hart et al 2013, Demers 2020 report on work-relatedness of cancer

Exposure Assessment Challenges

- Exposure assessment methods in epidemiology must balance exposure assignment specificity with practicality and feasibility.
- Exposure measurements are often unavailable (especially for DEE), so other exposure assessment tools are used.
  - Job-exposure matrix (JEM) – systematically assigns exposures to workers by industry and/or occupation codes
- Standardized occ. & ind. classification systems of a JEM & study population may not match.
  - **Crosswalks** may be required for translating codes.

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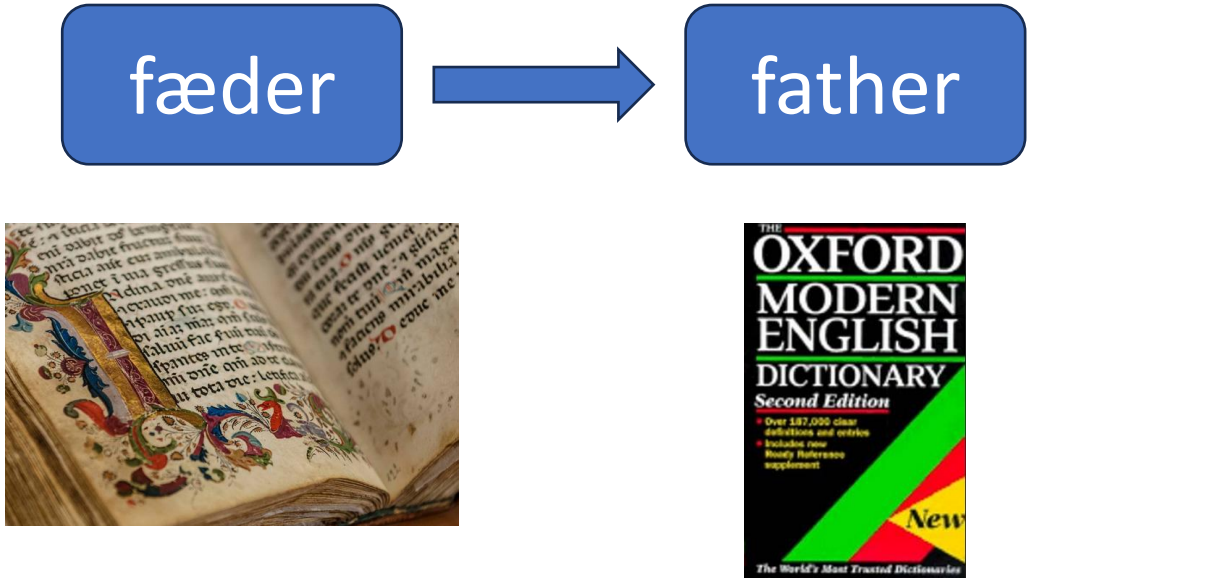
Crosswalk

- Mapping between equivalent codes in different classification systems
- Standardized systems of occupation and industry code information
  - Industry examples: NAICS 2002, NAICS 2012, SIC 1970, SIC 1980
  - Occupation examples: NOC-S 2006, NOC 2011, CCDO 1971, ISCO 1968, ISCO 2008
- Translate occupation and/or industry codes in an exposure assessment tool and disease dataset

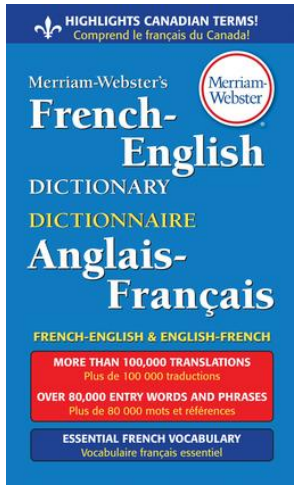
Crosswalk Example: Update a job coding system

E.g., translating a word from old English to modern English



Crosswalk Example: Crosswalk to a different system

E.g., translating a word from French to English



ancien →

ancient
former
old
antique
past
elder
late
vintage
antiquarian
bygone
antiquated
quondam
oldster
one-time
old-fashioned
old-timer
ex-

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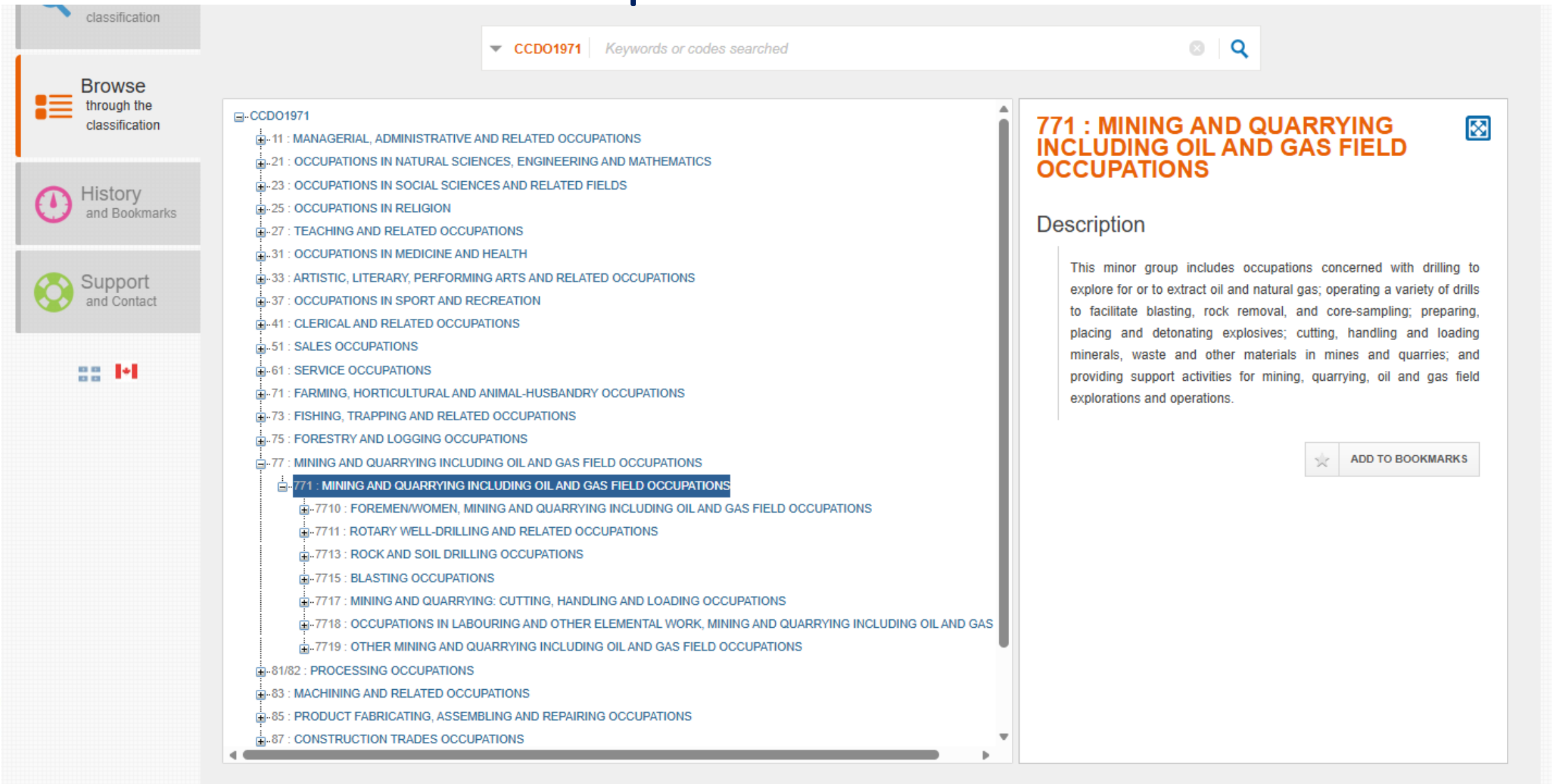
Crosswalking Tools

- Expert judgement traditionally used to code crosswalks manually
- Concordance tables and crosswalk assistants identify matches between two classification systems
- Examples:
  - CAPS Canada
  - Concordance tables from Statistics Canada

Koeman et al 2013, Wan et al 2023, Burstyn et al 2014, Remen et al 2018.

Example: CAPS Canada



A	B	C	D
sic7(	SIC_desc	naic	NAICSDESC
031	Logging	1133	Logging
031	Logging	1153	Support activities for forestry
031	Logging	4831	Deep sea, coastal and great lakes water transportation
031	Logging	4832	Inland water transportation
031	Logging	4842	Specialized freight trucking
031	Logging	4883	Support activities for water transportation
039	Forestry services	1131	Timber tract operations
039	Forestry services	1132	Forest nurseries and gathering of forest products
039	Forestry services	1150	Support activities for farms (1151 to 1152)
039	Forestry services	1153	Support activities for forestry
039	Forestry services	4812	Non-scheduled air transportation
039	Forestry services	4879	Scenic and sightseeing transportation, other
039	Forestry services	5413	Architectural, engineering and related services
039	Forestry services	7139	Other amusement and recreation industries
041	Fishing	1110	Farms (1111 to 1129)
041	Fishing	1141	Fishing
041	Fishing	1153	Support activities for forestry
045	Fishery services	1110	Farms (1111 to 1129)
045	Fishery services	5417	Scientific research and development services
045	Fishery services	8113	Commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance
045	Fishery services	9112	Other federal government public administration (9112 to 9119)
047	Hunting and trapping	1142	Hunting and trapping
051-052	Gold mines	2122	Metal ore mining
057	Uranium mines	2122	Metal ore mining
058	Iron mines	2122	Metal ore mining
058	Iron mines	2123	Non-metallic mineral mining and quarrying
059	Miscellaneous metal mines	2122	Metal ore mining
061	Coal mines	2121	Coal mining
064	Crude petroleum and natural gas industry	2111	Oil and gas extraction
071	Asbestos mines	2123	Non-metallic mineral mining and quarrying
072	Peat extraction	2123	Non-metallic mineral mining and quarrying
073	Gypsum mines	2123	Non-metallic mineral mining and quarrying
079	Miscellaneous non-metal mines	2123	Non-metallic mineral mining and quarrying
083	Stone quarries	2123	Non-metallic mineral mining and quarrying
087	Sand pits or quarries	2123	Non-metallic mineral mining and quarrying

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087	Sand pits or quarries	2123	Non-metallic mineral mining and quarrying

Challenges in Crosswalking

- No two classification systems are 100% equivalent
- A code in the original system matches to many codes in the other system ("one-to-multiple" mapping)
- Multiple codes can match to a single occ/ind code in the second system, often with different exposure values attached (including unexposed job matches)
- Expert judgement traditionally used to code crosswalks manually
  - Subjective, time-consuming, prone to human error
  - Potential exposure misclassification
- Exposure information from all possible matches may be important to limit misclassification.

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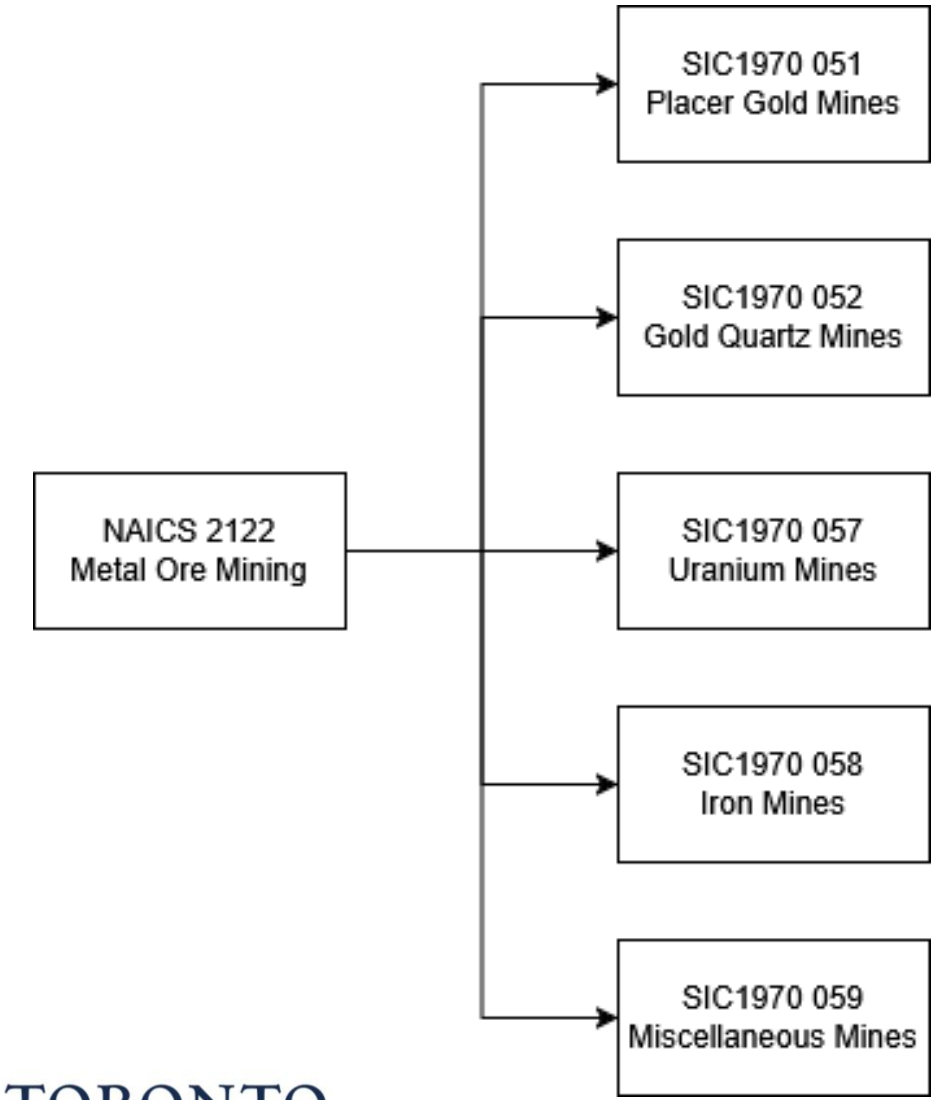
Koeman et al 2013, Wan et al 2023, Burstyn et al 2014.


NAICS 2122
Metal Ore Mining
SIC1970 051
Placer Gold Mines
SIC1970 052
Gold Quartz Mines
SIC1970 057
Uranium Mines
SIC1970 058
Iron Mines
SIC1970 059
Miscellaneous Mines

Knowledge Gaps

- Discussions about crosswalks for exposure assessment and impacts on disease risk estimation are often only briefly mentioned or absent.
- Little research exists on resolving the one-to-multiple match challenge of crosswalks for exposure assessment.

Koeman et al 2013, Wan et al 2023, Burstyn et al 2014, Peters et al 2021.

Burstyn et al 2014 study

Liberal Method

Assigned exposed to JEM cells if any of the one-to-multiple matches were exposed

Intermediate Method

Assigned exposed to JEM cells if >20% of one-to-multiple matches were exposed

Conservative Method

Omitted all observations that were one-to-multiple matches from analysis

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Burstyn I, Slutsky A, Lee DG, Singer AB, An Y, Michael YL. Beyond crosswalks: reliability of exposure assessment following automated coding of free-text job descriptions for occupational epidemiology. Ann Occup Hyg. 2014 May;58(4):482–92.

Study Objective

This study investigates the effect of three crosswalk methods of the Diesel Exhaust in Canada Job-Exposure Matrix (DEC-JEM) on lung cancer risk among Ontario workers.

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Occupational Disease Surveillance System (ODSS)

- ~2.3 million workers identified through workers' compensation claims (1983-2020)
  - Occupation & industry of employment related to compensated injury/disease
- Death or emigration from Ontario captured through linkage to Registered Persons Database (1990-2022)
  - Records for all publicly insured persons in Ontario
- Industry information coded in 3-digit SIC 1970
- Occupation information coded in 4-digit CCDO 1971

Diesel Exhaust in Canada Job-Exposure Matrix (DEC-JEM)

- Semi-quantitative JEM based on expert assessment and published exposure data (EC)
- Axes of industry-occupation intersections (NAICS 2002–NOC-S 2006)
  - Industry information coded in 4-digit NAICS 2002
  - Occupation information coded in 4-digit NOC-S 2006
- Updated with published literature [Ziembicki *et al.* 2024]

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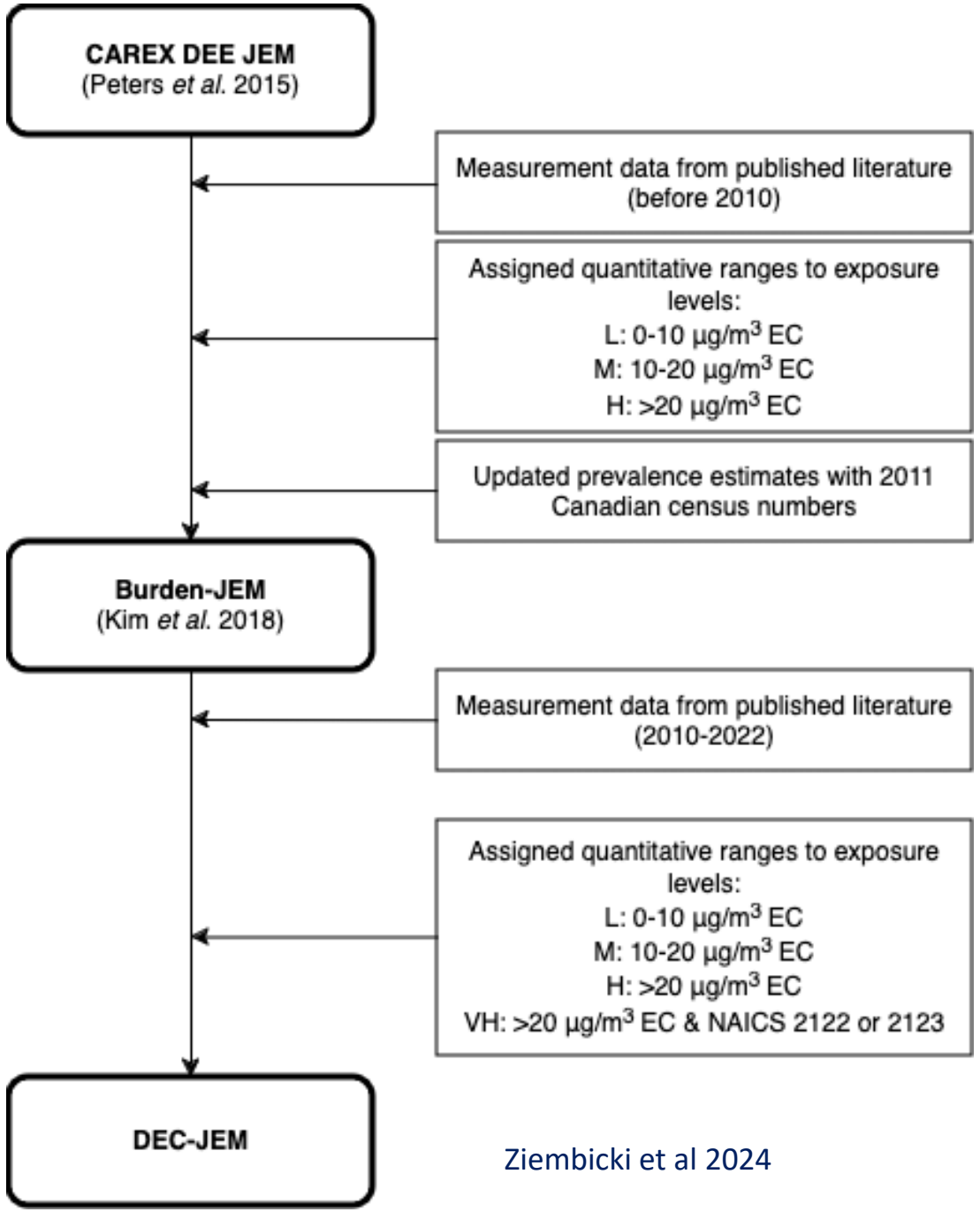
Development of DEC-JEM

- Exposure seems to have been underestimated in previous versions
  - Exposures for 66% of identified job groups increased
  - Increased exposures for 12.5% of DEC-JEM & 15.8% DEE-exposed workers



Ziembicki et al 2024

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Exposure Levels and Values of DEC-JEM

Exposure Level	Exposure Range (µg/m^3 EC)	Midpoint (µg/m^3 EC)
Unexposed	0	0
Low	>0 & <10	5
Moderate	≥10 & <20	15
High	≥20 & <40	25
Very high	≥40	70

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For DEC-JEM$_2$ & DEC-JEM$_3$ only:

Step 1. All NAICS$_{2002}$-NOC-S$_{2006}$ intersections were identified in a dataset.

Step 2. DEC-JEM exposure & exposure prevalence estimates were applied to the dataset of all NAICS$_{2002}$-NOC-S$_{2006}$ intersections.

- For matched cells: DEC-JEM estimates were applied.
- For unmatched cells: zero exposure & 0% exposure prevalence were applied.

For all DEC-JEM methods:

Step 3. Statistics Canada concordance tables were applied to DEC-JEM intersections.

- All SIC$_{1970}$ matches were merged to each NAICS$_{2002}$ code in DEC-JEM.
- All CCDO matches were merged to each NOC-S$_{2006}$ code in DEC-JEM.

Example: NAICS-NOCS to SIC-CCDO expansion

2122-I214 (Metal mines – Mine labourers) – Very High exposure

2122 matches to 5 SIC codes:

- 051 - Placer Gold Mines
- 052 - Gold Quartz Mines
- 057 - Uranium Mines
- 058 - Iron Mines
- 059 - Misc Metal Mines

I214 matches to 4 CCDO codes:

- 7715 - Blasting
- 7717 - Mining/quarrying: cutting, handling, loading
- 7718 - Mining/quarrying labouring
- 7719 - Mining/quarrying n.e.c.

2122-I214 expands to 20 SIC-CCDO intersections (all Very High exposure):

051-7715	052-7715	057-7715	058-7715	059-7715
051-7717	052-7717	057-7717	058-7717	059-7717
051-7718	052-7718	057-7718	058-7718	059-7718
051-7719	052-7719	057-7719	058-7719	059-7719

Step 4. Exposure categories were replaced with numeric exposure values for each observation to allow for averaging of one-to-multiple matches.

Qualitative Exposure	µg/m^3 EC
Unexposed	0
Low	5
Moderate	15
High	25
Very High	70

Step 5. The exposure level & exposure prevalence for each SIC$_{1970}$-CCDO intersection was averaged.

- *For **DEC-JEM$_1$ & DEC-JEM$_2$***: All SIC$_{1970}$-CCDO intersections were weighted equally.
- *For **DEC-JEM$_3$***: SIC$_{1970}$-CCDO intersections were weighted by **crosswalk strength**.

$$Crosswalk\ strength\ for\ NAICS-NOCS\ intersection = \frac{1}{N\ SIC\ matches} + \frac{1}{N\ CCDO\ matches}$$

$$Example:\ 2122\text{-}I214 = \frac{1}{5} + \frac{1}{4} = \frac{9}{20} = 0.45$$

Step 6. Exposure levels were converted back into categorical exposure levels by EC ranges.

µg/m^3 EC	Final Exposure
0	Unexposed
>0 & <10	Low
≥10 & <20	Moderate
≥20 & <40	High
≥40	Very High

Methods

3 methods were used to **crosswalk DEC-JEM** to the codes in the ODSS:

1. Unexposed matches **ex**cluded, average of one-to-multiple matches
2. Unexposed matches included, average of one-to-multiple matches
3. Unexposed matches included, **weighted** average of one-to-multiple matches

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For all DEC-JEM methods:

Step 3. Statistics Canada concordance tables were applied to DEC-JEM intersections.

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- All CCDO matches were merged to each NOC-S$_{2006}$ code in DEC-JEM.

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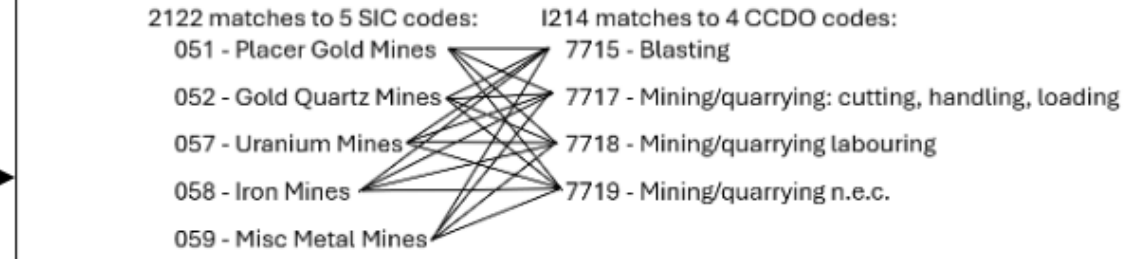
2122-I214 (Metal mines – Mine labourers) – Very High exposure



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051-7715	052-7715	057-7715	058-7715	059-7715
051-7717	052-7717	057-7717	058-7717	059-7717
051-7718	052-7718	057-7718	058-7718	059-7718
051-7719	052-7719	057-7719	058-7719	059-7719

Step 4. Exposure categories were replaced with numeric exposure values for each observation to allow for averaging of one-to-multiple matches.

Qualitative Exposure	µg/m^3 EC
Unexposed	0
Low	5
Moderate	15
High	25
Very High	70

Step 5. The exposure level & exposure prevalence for each SIC$_{1970}$-CCDO intersection was averaged.

- *For **DEC-JEM$_1$ & DEC-JEM$_2$***: All SIC$_{1970}$-CCDO intersections were weighted equally.
- *For **DEC-JEM$_3$***: SIC$_{1970}$-CCDO intersections were weighted by **crosswalk strength**.

$$Crosswalk\ strength\ for\ NAICS-NOCS\ intersection = \frac{1}{N\ SIC\ matches} + \frac{1}{N\ CCDO\ matches}$$

$$Example:\ 2122\text{-}I214 = \frac{1}{5} + \frac{1}{4} = \frac{9}{20} = 0.45$$

Step 6. Exposure levels were converted back into categorical exposure levels by EC ranges.

µg/m^3 EC	Final Exposure
0	Unexposed
>0 & <10	Low
≥10 & <20	Moderate
≥20 & <40	High
≥40	Very High

Crosswalk Method 1

To apply an exposure level to an intersection:

1. Application of concordance tables to DEC-JEM intersections.

Step 3. Statistics Canada concordance tables were applied to DEC-JEM intersections.

- All SIC_{1970} matches were merged to each $NAICS_{2002}$ code in DEC-JEM.
- All CCDO matches were merged to each $NOC\text{-}S_{2006}$ code in DEC-JEM.

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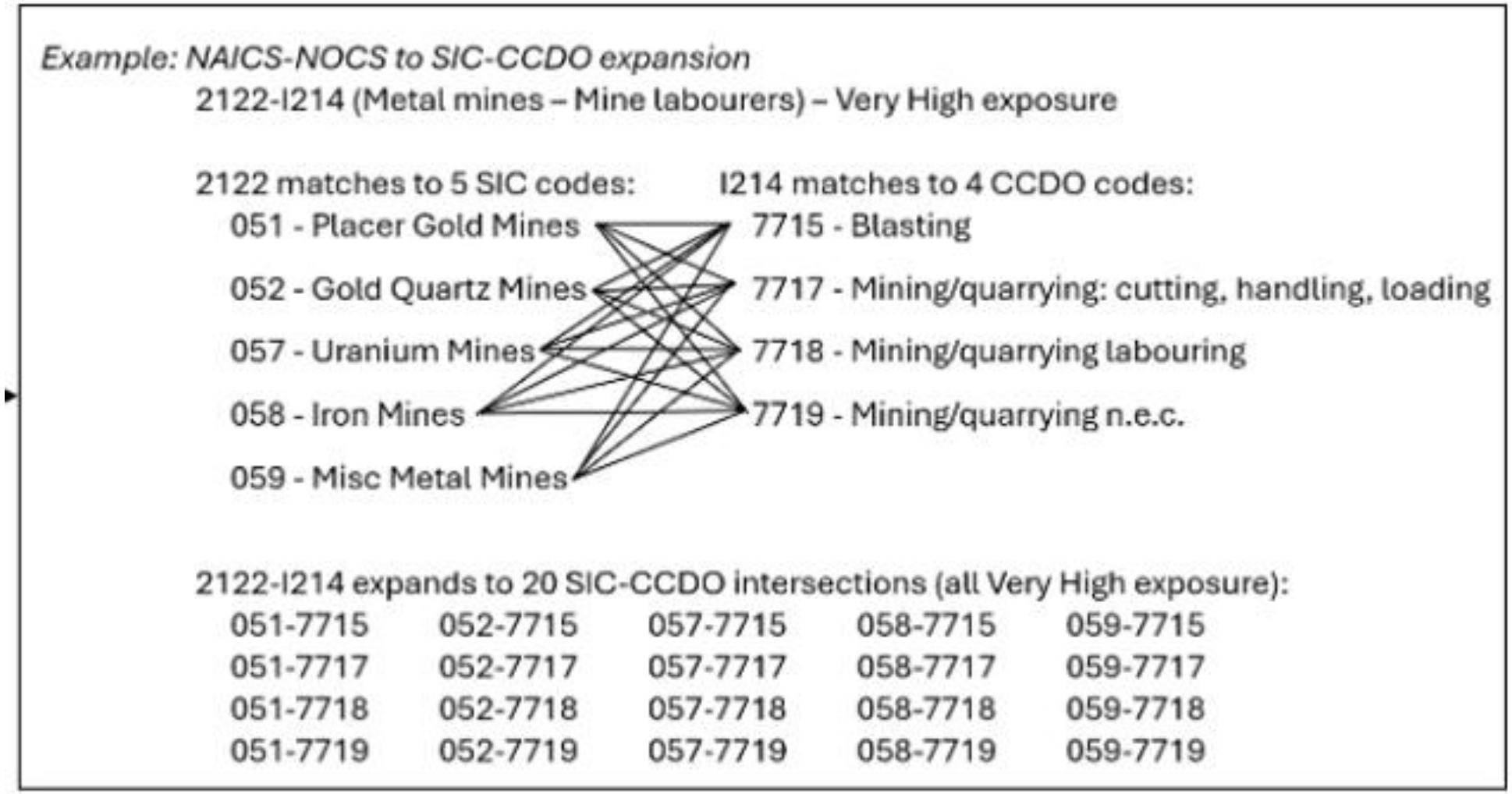
Example: NAICS-NOCS to SIC-CCDO expansion

2122-I214 (Metal mines – Mine labourers) – Very High exposure



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051-7718	052-7718	057-7718	058-7718	059-7718
051-7719	052-7719	057-7719	058-7719	059-7719

Crosswalk Method 1

2. Development of a single exposure estimate for intersections with one-to-multiple matches.

Step 4. Exposure categories were replaced with numeric exposure values for each observation to allow for averaging of one-to-multiple matches.

Qualitative Exposure	µg/m^3 EC
Unexposed	0
Low	5
Moderate	15
High	25
Very High	70

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Crosswalk Method 1

Step 5. The exposure level & exposure prevalence for each SIC_{1970}-CCDO intersection was averaged.

- *For* ***DEC-JEM$_1$ & DEC-JEM$_2$***: All SIC_{1970}-CCDO intersections were weighted equally.
- *For* ***DEC-JEM$_3$***: SIC_{1970}-CCDO intersections were weighted by **crosswalk strength**.

Crosswalk Method 1

Step 6. Exposure levels were converted back into categorical exposure levels by EC ranges.

µg/m³ EC	Final Exposure
0	Unexposed
>0 & <10	Low
≥10 & <20	Moderate
≥20 & <40	High
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For DEC-JEM$_2$ & DEC-JEM$_3$ only:

Step 1. All NAICS$_{2002}$-NOC-S$_{2006}$ intersections were identified in a dataset.

Step 2. DEC-JEM exposure & exposure prevalence estimates were applied to the dataset of all NAICS$_{2002}$-NOC-S$_{2006}$ intersections.

- For matched cells: DEC-JEM estimates were applied.
- For unmatched cells: zero exposure & 0% exposure prevalence were applied.

For all DEC-JEM methods:

Step 3. Statistics Canada concordance tables were applied to DEC-JEM intersections.

- All SIC$_{1970}$ matches were merged to each NAICS$_{2002}$ code in DEC-JEM.
- All CCDO matches were merged to each NOC-S$_{2006}$ code in DEC-JEM.

Example: NAICS-NOCS to SIC-CCDO expansion

2122-I214 (Metal mines – Mine labourers) – Very High exposure

2122 matches to 5 SIC codes:

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$$Example:\ 2122\text{-}I214 = \frac{1}{5} + \frac{1}{4} = \frac{9}{20} = 0.45$$

Step 6. Exposure levels were converted back into categorical exposure levels by EC ranges.

µg/m^3 EC	Final Exposure
0	Unexposed
>0 & <10	Low
≥10 & <20	Moderate
≥20 & <40	High
≥40	Very High

Crosswalk Method 2

- A dataset of all possible NAICS 2002 – NOC-S 2006 combinations was created to identify all potentially unexposed intersections missing from DEC-JEM.
- Each NAICS 2002 code was matched to each NOC-S 2006 code, creating all NAICS 2002 – NOC-S 2006 combinations.
  - E.g., 1110-A011
    1110-A012
    1110-A013
    …..

Step 1. All $NAICS_{2002}$-NOC-S2006 intersections were identified in a dataset.

Crosswalk Method 2

Step 2. DEC-JEM exposure & exposure prevalence estimates were applied to the dataset of all $NAICS_{2002}$-NOC-S2006 intersections.

- For matched cells: DEC-JEM estimates were applied.
- For unmatched cells: zero exposure & 0% exposure prevalence were applied.

Crosswalk Method 3

Step 5. The exposure level & exposure prevalence for each SIC_{1970}-CCDO intersection was averaged.

- *For **DEC-JEM$_1$ & DEC-JEM$_2$***: All SIC_{1970}-CCDO intersections were weighted equally.
- *For **DEC-JEM$_3$***: SIC_{1970}-CCDO intersections were weighted by **crosswalk strength**.

$$Crosswalk\ strength\ for\ NAICS - NOCS\ intersection = \frac{1}{N\ SIC\ matches} + \frac{1}{N\ CCDO\ matches}$$

$$Example:\ 2122\text{-}1214 = \frac{1}{5} + \frac{1}{4} = \frac{9}{20} = 0.45$$

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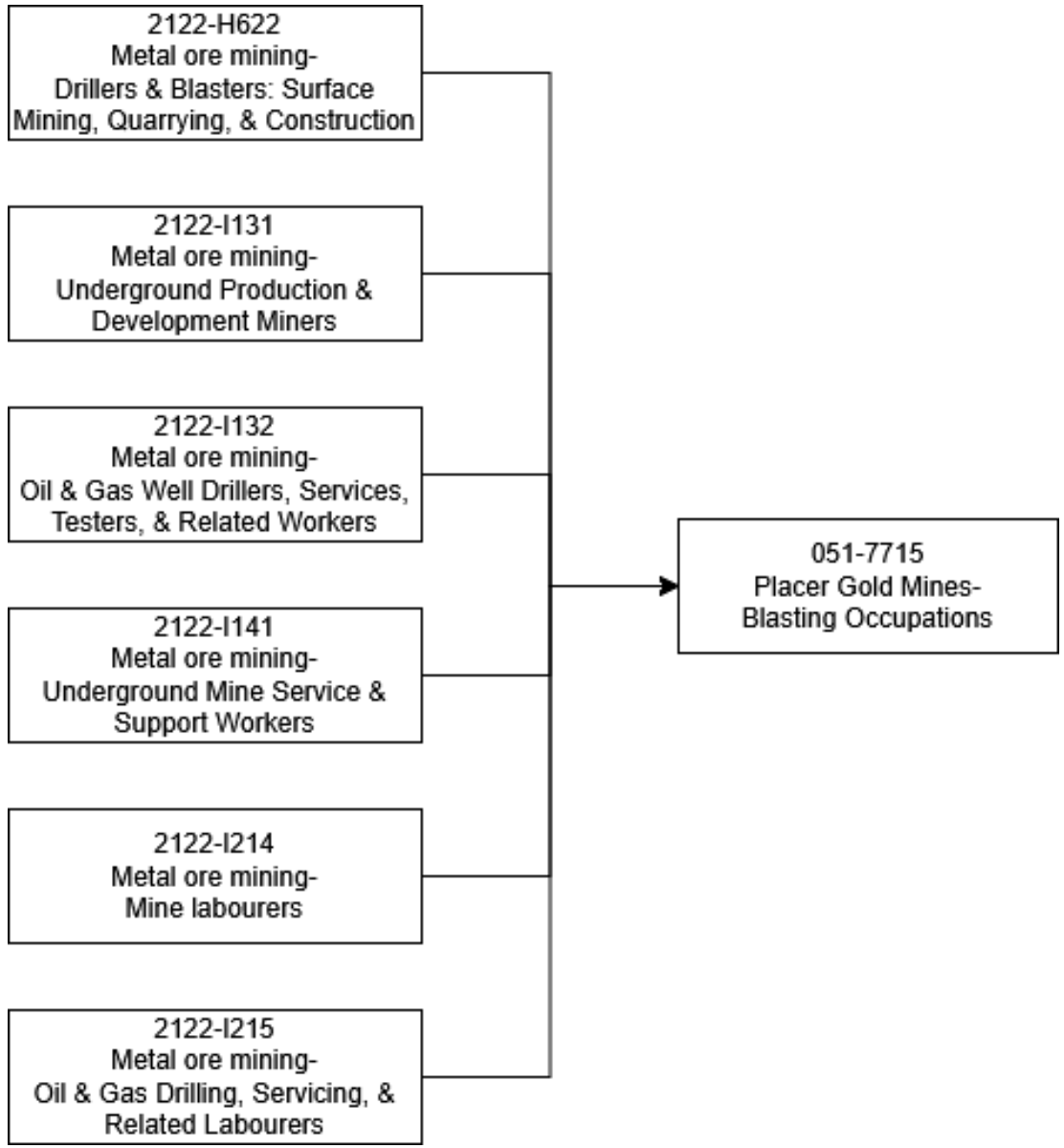
Crosswalk Method 3: Example calculation of crosswalk weighting factor applied to 051-7715



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Crosswalk Method 3: Example calculation of crosswalk weighting factor applied to 051-7715

NAICS–NOC-S	Original Qualitative Exposure Level	Original Quantitative Exposure Level (µg/m³ EC)	Original Exposure Prevalence	N CCDO Matches (Weight)	N SIC1970 Matches (Weight)	Sum of Crosswalk Weights	Crosswalk Weighted Quantitative Exposure (µg/m³ EC)	Crosswalk Weighted Qualitative Exposure	Crosswalk Weighted Exposure Prevalence
2122-H622	Very high	70	0.5	3 (0.33)	5 (0.2)	0.53	46.74	Very high	0.63
2122-I131	Very high	70	1.0	4 (0.25)	5 (0.2)	0.45			
2122-I132	Moderate	15	0.5	3 (0.33)	5 (0.2)	0.53			
2122-I141	Very high	70	1.0	6 (0.17)	5 (0.2)	0.37			
2122-I214	Very high	70	1.0	4 (0.25)	5 (0.2)	0.45			
2122-I215	Unexposed	0	0.0	3 (0.33)	5 (0.2)	0.53			

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$$\text{Crosswalk Weighted Exposure} = \frac{\Sigma\,(Exposure * Crosswalk\ Weight)}{\Sigma\,(Crosswalk\ Weight)}$$

$$= \frac{70\mu g/m^3(0.53)+70\mu g/m^3(0.45)+15\mu g/m^3(0.53)+70\mu g/m^3(0.37)+70\mu g/m^3(0.45)+\ 0\mu g/m^3(0.53)}{0.53+0.45+0.53+0.37+0.45+0.53}$$

= 46.74 µg/m³ EC

[46.74 µg/m³ EC falls in the very high exposure range (≥40µg/m³ EC)]

= Very high exposure

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Crosswalk Weighted Prevalence =

$$\frac{\Sigma\,(Exposure\ Prevalence * Crosswalk\ Weight)}{\Sigma\,(Crosswalk\ Weight)}$$

$$= \frac{0.5(0.53)+1(0.45)+0.5(0.53)+1(0.37)+1(0.45)+\ 0(0.53)}{0.53+0.45+0.53+0.37+0.45+0.53}$$

= 0.63

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Poll Question 2

Which crosswalk method includes unexposed job matches and calculates a weighted average of exposure?

A. DEC-JEM 1
B. DEC-JEM 2
C. DEC-JEM 3

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CANadian Job-Exposure Matrix (CANJEM)

- Results were compared to CANJEM
  - A JEM already coded in the destination classification system (SIC1970-CCDO)
- Exposure based on 1-5-25 mean relative intensity scale:
- Parameters:
  - Industry-occupation intersection structure
  - >5 jobs, >3 subjects
  - 1940-2005

Exposure Level	Exposure Range
Unexposed	<1
Low	1
Moderate	>1 and <5
High	≥5 and <25
Very high	≥25

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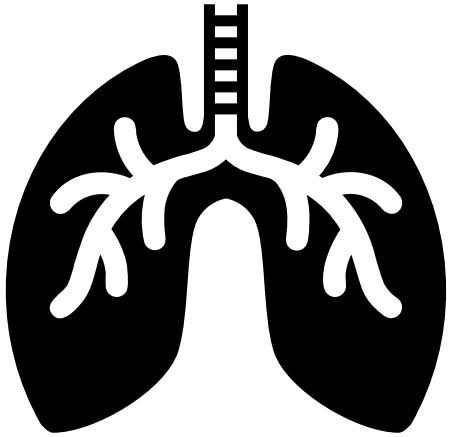
Sauvé et al 2018, Siemiatycki & Lavoué 2018

Case Ascertainment

- Linkage to Ontario Cancer Registry (1964-2019)
- ICD 3rd revision SEER code 22030



Case Follow-Up

- Follow-up began on date of first claim
  - If workers filed more than 1 claim, used 1st claim to start follow-up
- Followed until (whichever came first):
  - First primary cancer, death, emigration from Ontario, worker turned 85 years old, end of study period (31 Dec 2019)
- Excluded from analysis is missing:
  - Sex, birthdate, claim date, occupation/industry information, <15 years old

Statistical Analysis

- Cox-proportional hazards models run with 3 crosswalked DEC-JEMs and CANJEM
  - Adjusted for age, birth year, sex
- Analyses run:
  - Exposed/unexposed
  - Categorical exposure level (unexposed, low, moderate, high, very high)
  - Sex
- Analyses run at 4 exposure prevalence thresholds:
  - 5%, 25%, 50%, 75%
- Test for trend with exposure level midpoints

Results

	Lung Cancer Cases	ODSS Cohort Overall
N	39,743	2,364,427
% Male	71%	65%
Median years of follow-up	18 years	24 years
Median age at start of follow-up	49	34
Median age at end of follow-up	66	59

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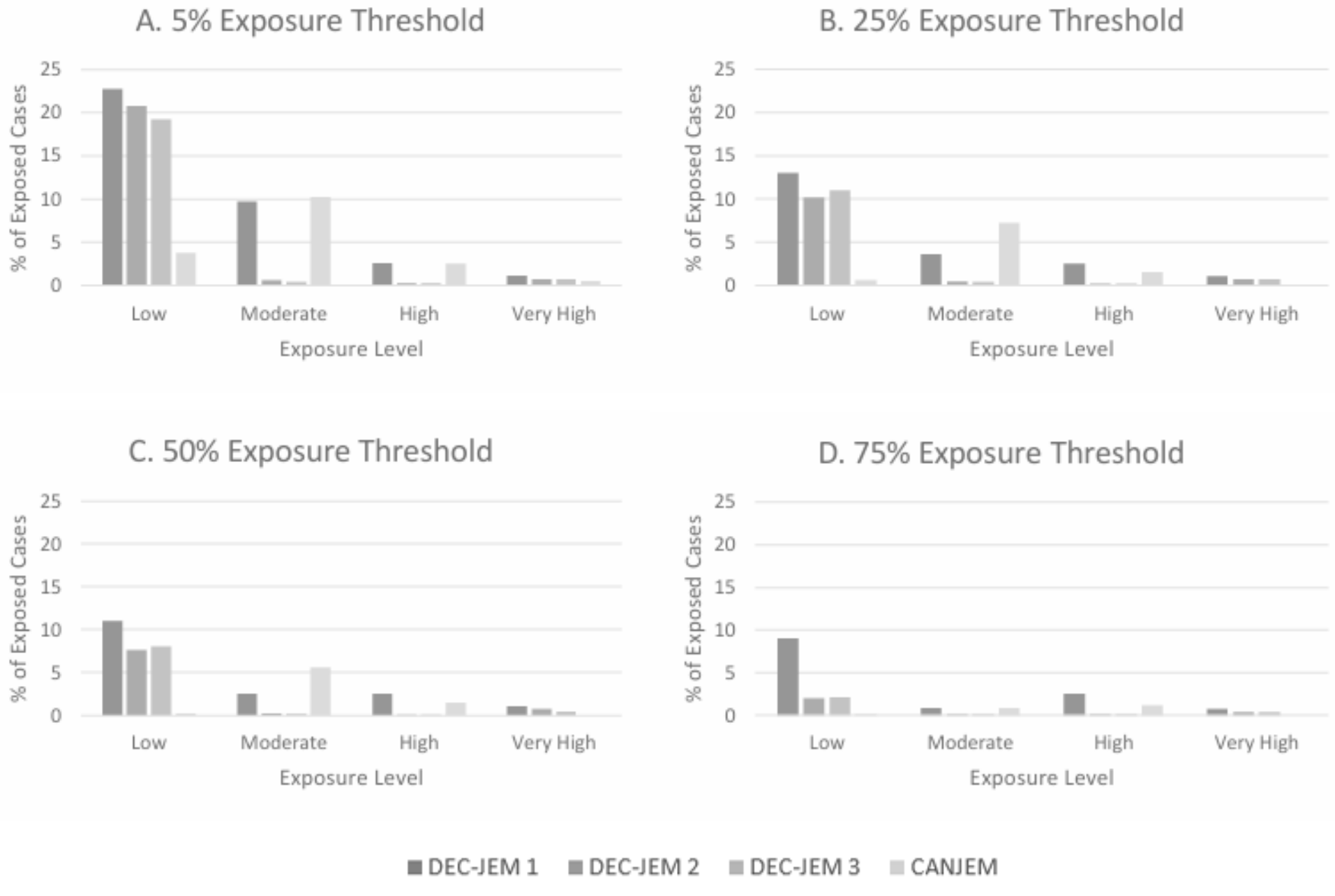
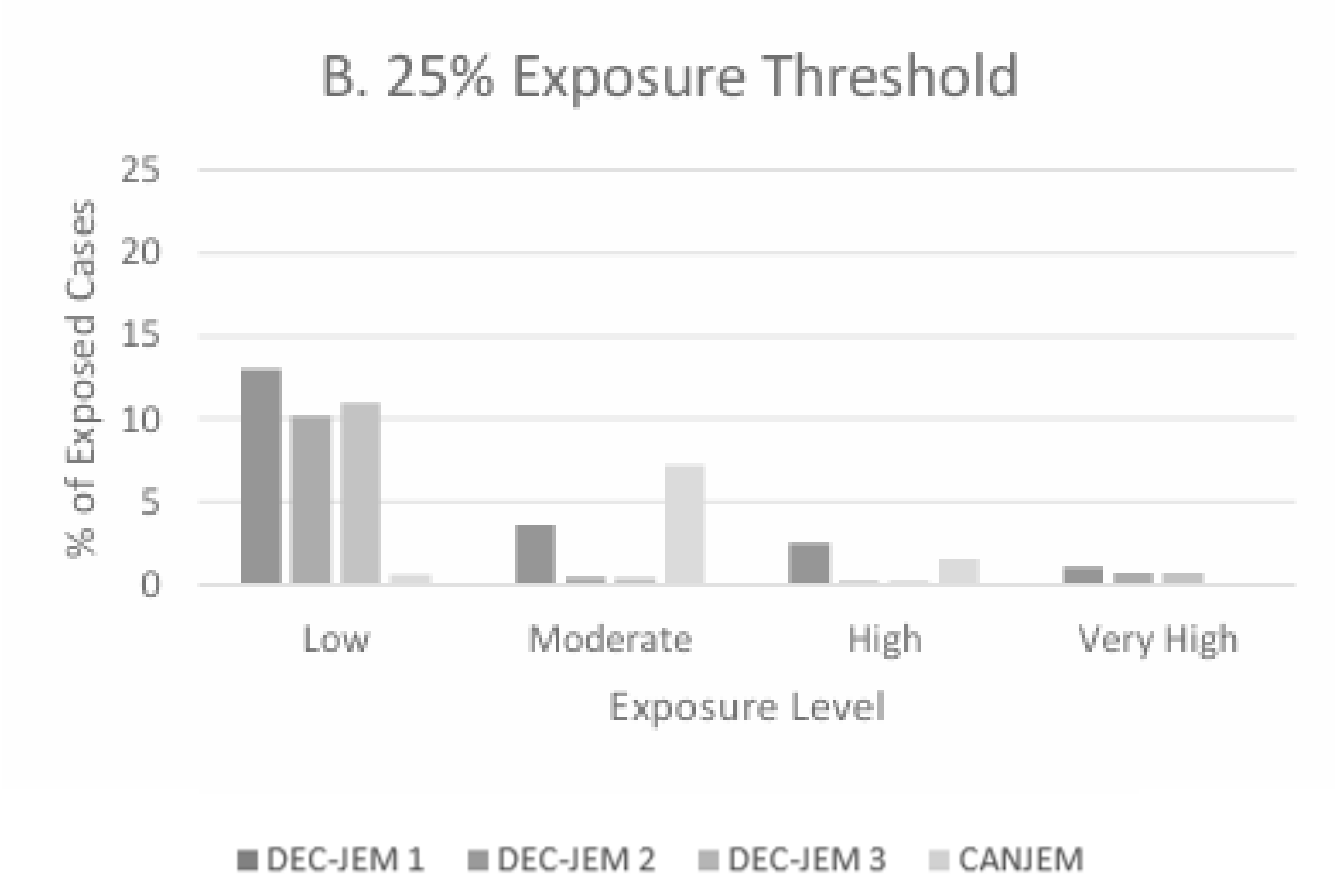
Exposure distribution among cases



Exposure distribution among cases



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Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Exposed/Unexposed									
5% threshold	14,219	716,547	**1.16 (1.14-1.19)**	8,824	399,795	**1.23 (1.20-1.26)**	8,114	353,441	**1.24 (1.21-1.27)**
25% threshold	7,954	346,529	**1.25 (1.22-1.28)**	4,539	168,240	**1.34 (1.30-1.38)**	4,832	179,461	**1.33 (1.29-1.37)**
50% threshold	6,713	282,749	**1.25 (1.22-1.29)**	3,374	113,630	**1.39 (1.35-1.45)**	3,405	117,638	**1.39 (1.34-1.44)**
75% threshold	5,118	187,968	**1.27 (1.23-1.31)**	959	31,999	**1.28 (1.20-1.37)**	1,016	34,509	**1.27 (1.19-1.35)**
Exposure Level									
Unexposed	31,344	2,018,410	Ref.	34,759	2,196,699	Ref.	34,466	2,185,478	Ref.
Low	5,098	213,855	**1.29 (1.25-1.33)**	3,992	148,569	**1.34 (1.29-1.38)**	4,306	163,508	**1.32 (1.28-1.37)**
Moderate	1,433	87,135	**1.18 (1.12-1.25)**	170	10,877	**1.20 (1.03-1.40)**	160	7,420	**1.25 (1.12-1.73)**
High	999	35,730	**1.09 (1.02-1.16)**	79	2,564	**1.26 (1.01-1.57)**	82	2,671	**1.39 (1.12-1.73)**
Very High	424	9,809	**1.49 (1.35-1.64)**	298	6,230	**1.50 (1.34-1.69)**	284	5,862	**1.52 (1.35-1.71)**

Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Exposed/Unexposed									
5% threshold	14,219	716,547	**1.16 (1.14-1.19)**	8,824	399,795	**1.23 (1.20-1.26)**	8,114	353,441	**1.24 (1.21-1.27)**
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Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Exposed/Unexposed									
5% threshold	14,219	716,547	**1.16 (1.14-1.19)**	8,824	399,795	**1.23 (1.20-1.26)**	8,114	353,441	**1.24 (1.21-1.27)**
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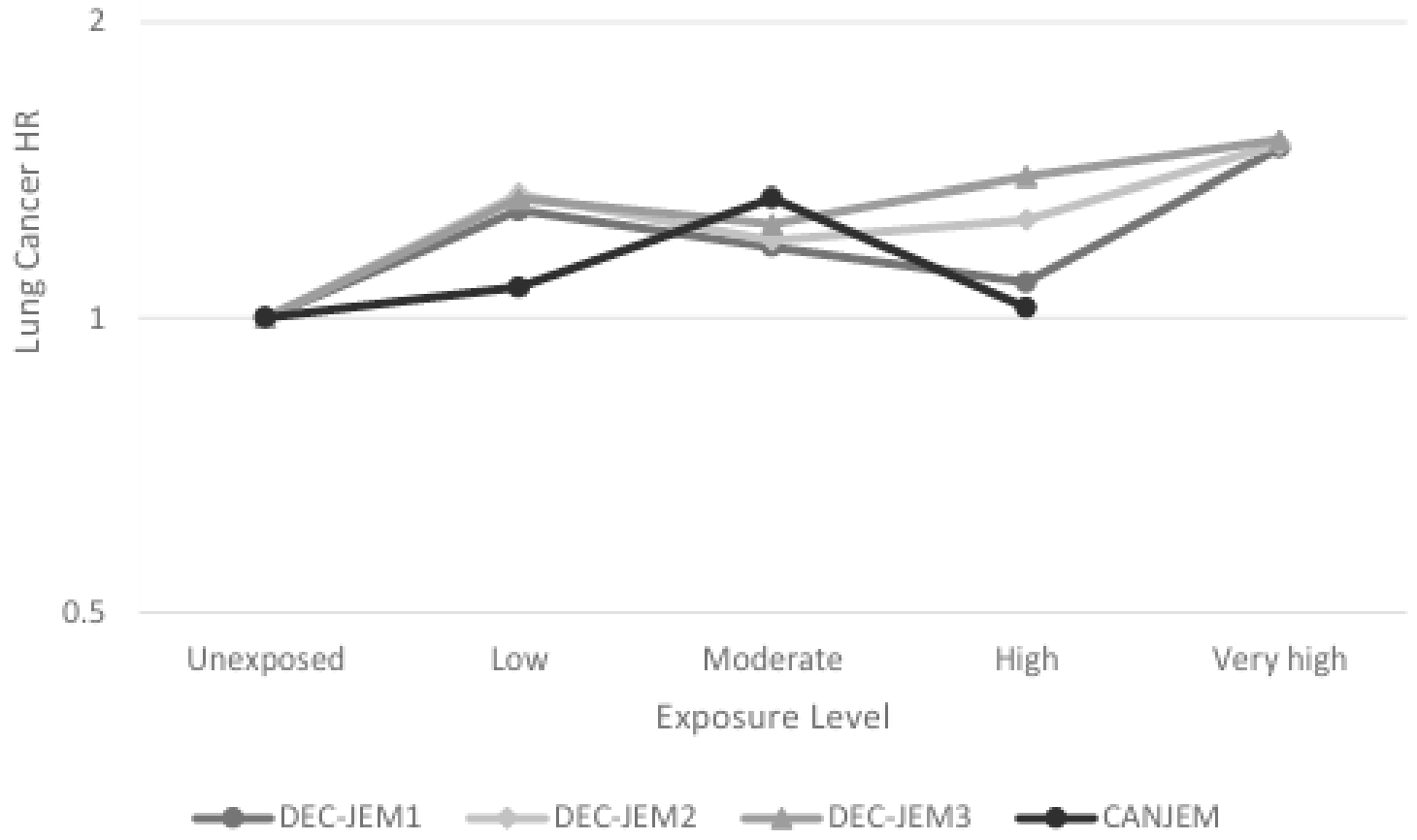
75% threshold	5,118	187,968	**1.27 (1.23-1.31)**	959	31,999	**1.28 (1.20-1.37)**	1,016	34,509	**1.27 (1.19-1.35)**
Exposure Level									
Unexposed	31,344	2,018,410	Ref.	34,759	2,196,699	Ref.	34,466	2,185,478	Ref.
Low	5,098	213,855	**1.29 (1.25-1.33)**	3,992	148,569	**1.34 (1.29-1.38)**	4,306	163,508	**1.32 (1.28-1.37)**
Moderate	1,433	87,135	**1.18 (1.12-1.25)**	170	10,877	**1.20 (1.03-1.40)**	160	7,420	**1.25 (1.12-1.73)**
High	999	35,730	**1.09 (1.02-1.16)**	79	2,564	**1.26 (1.01-1.57)**	82	2,671	**1.39 (1.12-1.73)**
Very High	424	9,809	**1.49 (1.35-1.64)**	298	6,230	**1.50 (1.34-1.69)**	284	5,862	**1.52 (1.35-1.71)**

Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Exposed/Unexposed									
5% threshold	14,219	716,547	**1.16 (1.14-1.19)**	8,824	399,795	**1.23 (1.20-1.26)**	8,114	353,441	**1.24 (1.21-1.27)**
25% threshold	7,954	346,529	**1.25 (1.22-1.28)**	4,539	168,240	**1.34 (1.30-1.38)**	4,832	179,461	**1.33 (1.29-1.37)**
50% threshold	6,713	282,749	**1.25 (1.22-1.29)**	3,374	113,630	**1.39 (1.35-1.45)**	3,405	117,638	**1.39 (1.34-1.44)**
75% threshold	5,118	187,968	**1.27 (1.23-1.31)**	959	31,999	**1.28 (1.20-1.37)**	1,016	34,509	**1.27 (1.19-1.35)**
Exposure Level									
Unexposed	31,344	2,018,410	Ref.	34,759	2,196,699	Ref.	34,466	2,185,478	Ref.
Low	5,098	213,855	**1.29 (1.25-1.33)**	3,992	148,569	**1.34 (1.29-1.38)**	4,306	163,508	**1.32 (1.28-1.37)**
Moderate	1,433	87,135	**1.18 (1.12-1.25)**	170	10,877	**1.20 (1.03-1.40)**	160	7,420	**1.25 (1.12-1.73)**
High	999	35,730	**1.09 (1.02-1.16)**	79	2,564	**1.26 (1.01-1.57)**	82	2,671	**1.39 (1.12-1.73)**
Very High	424	9,809	**1.49 (1.35-1.64)**	298	6,230	**1.50 (1.34-1.69)**	284	5,862	**1.52 (1.35-1.71)**

Lung cancer HRs for DEC-JEM models & CANJEM



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Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$			CANJEM		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Exposed/Unexposed												
5% threshold	14,219	716,547	**1.16 (1.14-1.19)**	8,824	399,795	**1.23 (1.20-1.26)**	8,114	353,441	**1.24 (1.21-1.27)**	6,686	325,339	**1.15 (1.12-1.18)**
25% threshold	7,954	346,529	**1.25 (1.22-1.28)**	4,539	168,240	**1.34 (1.30-1.38)**	4,832	179,461	**1.33 (1.29-1.37)**	3,663	141,759	**1.25 (1.20-1.29)**
50% threshold	6,713	282,749	**1.25 (1.22-1.29)**	3,374	113,630	**1.39 (1.35-1.45)**	3,405	117,638	**1.39 (1.34-1.44)**	2,551	89,241	**1.30 (1.24-1.35)**
75% threshold	5,118	187,968	**1.27 (1.23-1.31)**	959	31,999	**1.28 (1.20-1.37)**	1,016	34,509	**1.27 (1.19-1.35)**	784	29,350	**1.13 (1.05-1.21)**
Exposure Level												
Unexposed	31,344	2,018,410	Ref.	34,759	2,196,699	Ref.	34,466	2,185,478	Ref.	35,635	2,223,180	Ref.
Low	5,098	213,855	**1.29 (1.25-1.33)**	3,992	148,569	**1.34 (1.29-1.38)**	4,306	163,508	**1.32 (1.28-1.37)**	226	10,653	1.07 (0.94-1.23)
Moderate	1,433	87,135	**1.18 (1.12-1.25)**	170	10,877	**1.20 (1.03-1.40)**	160	7,420	**1.25 (1.12-1.73)**	2839	104,548	**1.32 (1.27-1.38)**
High	999	35,730	**1.09 (1.02-1.16)**	79	2,564	**1.26 (1.01-1.57)**	82	2,671	**1.39 (1.12-1.73)**	598	26,558	1.02 (0.94-1.11)
Very High	424	9,809	**1.49 (1.35-1.64)**	298	6,230	**1.50 (1.34-1.69)**	284	5,862	**1.52 (1.35-1.71)**	-	-	-

Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$			CANJEM		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Sex-Stratified (Exposed/Unexposed)												
Males	7,488	315,570	**1.23 (1.20-1.26)**	4,331	156,792	**1.32 (1.28-1.36)**	4,614	167,631	**1.31 (1.27-1.35)**	3,534	133,442	**1.23 (1.19-1.28)**
Females	466	30,959	**1.38 (1.26-1.52)**	208	11,448	**1.53 (1.34-1.76)**	218	11,830	**1.55 (1.36-1.77)**	129	8,317	**1.38 (1.16-1.64)**

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Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$			CANJEM		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Sex-Stratified (Exposed/Unexposed)												
Males	7,488	315,570	**1.23 (1.20-1.26)**	4,331	156,792	**1.32 (1.28-1.36)**	4,614	167,631	**1.31 (1.27-1.35)**	3,534	133,442	**1.23 (1.19-1.28)**
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Exposure Level	DEC-JEM$_1$			DEC-JEM$_2$			DEC-JEM$_3$			CANJEM		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Sex-Stratified (Exposed/Unexposed)												
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Females	466	30,959	**1.38 (1.26-1.52)**	208	11,448	**1.53 (1.34-1.76)**	218	11,830	**1.55 (1.36-1.77)**	129	8,317	**1.38 (1.16-1.64)**

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Poll Question 3

Which crosswalk method produced the strongest association with lung cancer?

A. DEC-JEM 1
B. DEC-JEM 2
C. DEC-JEM 3

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Key Findings

- Crosswalks decisions can:
  - Change a JEM's exposure distribution
  - Determine which cases get classified as exposed
  - Influence disease risk estimates
- Coded crosswalks provide opportunities to save time and resources while improving exposure assessment
- Improves understanding of incident DEE-associated lung cancer

CAREX-Based JEMs for Estimating Risk

- Originally used to estimate exposure prevalence
- Peters et al 2016 – solar UV radiation exposure and prostate cancer
- Ziembicki et al 2026 – DEE exposure and lung cancer

Workplace

ORIGINAL ARTICLE

Occupational exposure to solar ultraviolet radiation and the risk of prostate cancer

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ABSTRACT

Objectives Preventable risk factors for prostate cancer are poorly understood; sun exposure is a possible protective factor. The goal of this study was to investigate prostate cancer risk in outdoor workers, a population with high sun exposure.

Methods Prostate cancer cases and controls from a large study (conducted between 1994 and 1997) were used for this analysis. A job exposure matrix (JEM) was used to assign solar ultraviolet radiation (UVR) at work as moderate (2 to <6 hours outside/day) or high (≥6 hours). Average daily satellite UV-B measures were linked to the latitude/longitude of the residences of each participant. Several other exposure metrics were also examined, including ever/never exposed and standard erythemal dose by years (SED×years). Logistic regression was used to evaluate the association between solar UVR exposure and the odds of prostate cancer.

Results A total of 1638 cases and 1697 controls were included. Men of Indian and Asian descent had reduced odds of prostate cancer (ORs 0.17 (0.08 to 0.35) and 0.25 (0.15 to 0.41), respectively) compared with Caucasian men, as did single men (OR 0.76 (0.58 to 0.98)) compared with married men. Overall, no statistically significant associations were observed between sun exposure and prostate cancer with 1 exception. In the satellite-enhanced JEM that considered exposure in high category jobs only, prostate cancer odds in the highest quartile of cumulative exposure was decreased compared with unexposed men (OR 0.68 (0.51 to 0.92)).

Conclusions This study found limited evidence for an association with prostate cancer, with the exception of 1 statistically significant finding of a decreased risk among workers with the longest term and highest sun exposure.

What this paper adds

- Despite being the second most common cancer in men (after skin cancer), the preventable causes of prostate cancer remain unclear. Ecological evidence suggests a possible role of sun exposure in prostate cancer prevention.
- Outdoor workers have the highest level of sun exposure, but exposure assessment methods for sun-related ultraviolet radiation are relatively crude.
- This study improves on exposure assessment methods for solar radiation in outdoor workers by including a job exposure matrix with satellite data on available sun by location, and links exposure to prostate cancer outcomes in a population-based case–control study in Canada.
- Limited evidence for a link between high solar ultraviolet radiation exposure and reduced risk of prostate cancer was found with the exception of very high long-term exposures.

INTRODUCTION

Excluding skin cancers, prostate cancer is the most common malignancy diagnosed in Canadian men.[1] Despite this, risk factors for prostate cancer remain unclear. Other than personal and genetic characteristics (older age, African ancestry, screening history, family history), consistent risk factors have not been identified.[2] The only modifiable risk factor with strong evidence for a link with prostate cancer is overweight and obesity.[3] Interest in identifying environmental causes for prostate cancer is strong,[4] both as a result of interest in cancer prevention, and for explaining varying rates by country; the incidence rates of prostate cancer vary by more than 25 times between different areas of the world.[5]

The geographical variation in cancer rates in the USA (lower in the south compared with the north) and Europe (lower in Southern Europe than Northern Europe)[5 6] prompted researchers to investigate ultraviolet radiation (UVR) exposure, and ecological studies have shown that exposure to UVR may lead to lower risks of colorectal, breast, ovarian and prostate cancers.[7–9] This was seen as plausible because of a hypothesised protective effect of vitamin D and racial differences in prostate cancer risk; darker-skinned people (especially those of African ancestry) have less ability to produce vitamin D endogenously and also have higher prostate cancer risk.[10] However, the relationship between pigmentation, vitamin D synthesis and sun protection practices in sun-sensitive individuals complicates the relationship between UVR exposure and prostate cancer.[11] As evidence of these complex relationships, several studies have not found a relationship between either sun exposure or vitamin D and prostate cancer.[12–14] Evidence also exists showing the opposite relationship, that sun exposure may increase the risk of prostate cancer, particularly in areas of high UVR.[15 16] In addition, a review on vitamin D and

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Peters et al 2016

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Strengths & Limitations

- Agent-specific exposure assessment
- Maintained exposure specificity
- Validity check with CANJEM
- DEC-JEM recently updated with quantitative measurement data
- Large sample size
- Administrative linked data
- Incident risk vs. mortality

- Many co-exposures possible
- No smoking data
- Exposure misclassification possible
- Can’t account for within job variability
- Non-differential misclassification of full work history
- Population-level approach

Future Research Directions

- Assess risk for other diseases
- Crosswalk other JEMs

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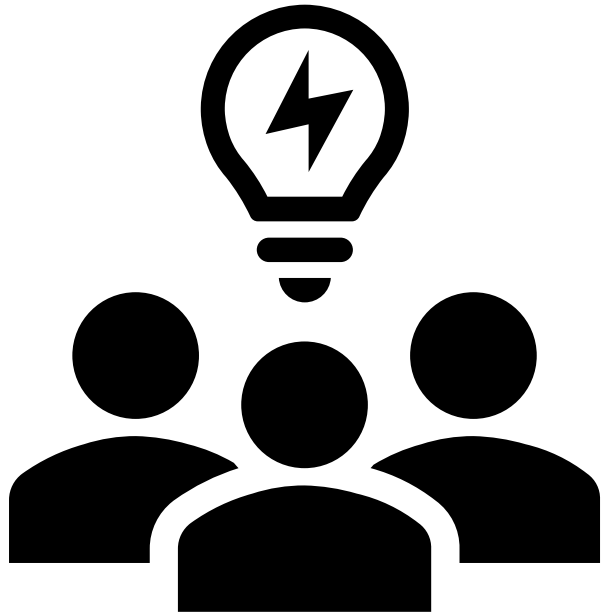
Dr. Paul Demers

Dr. Tracy Kirkham

Tanya Navaneelan



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Questions?

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