

Cancer, chronic obstructive pulmonary disease and ischaemic heart disease in Ontario, Canada workers exposed to diesel engine exhaust

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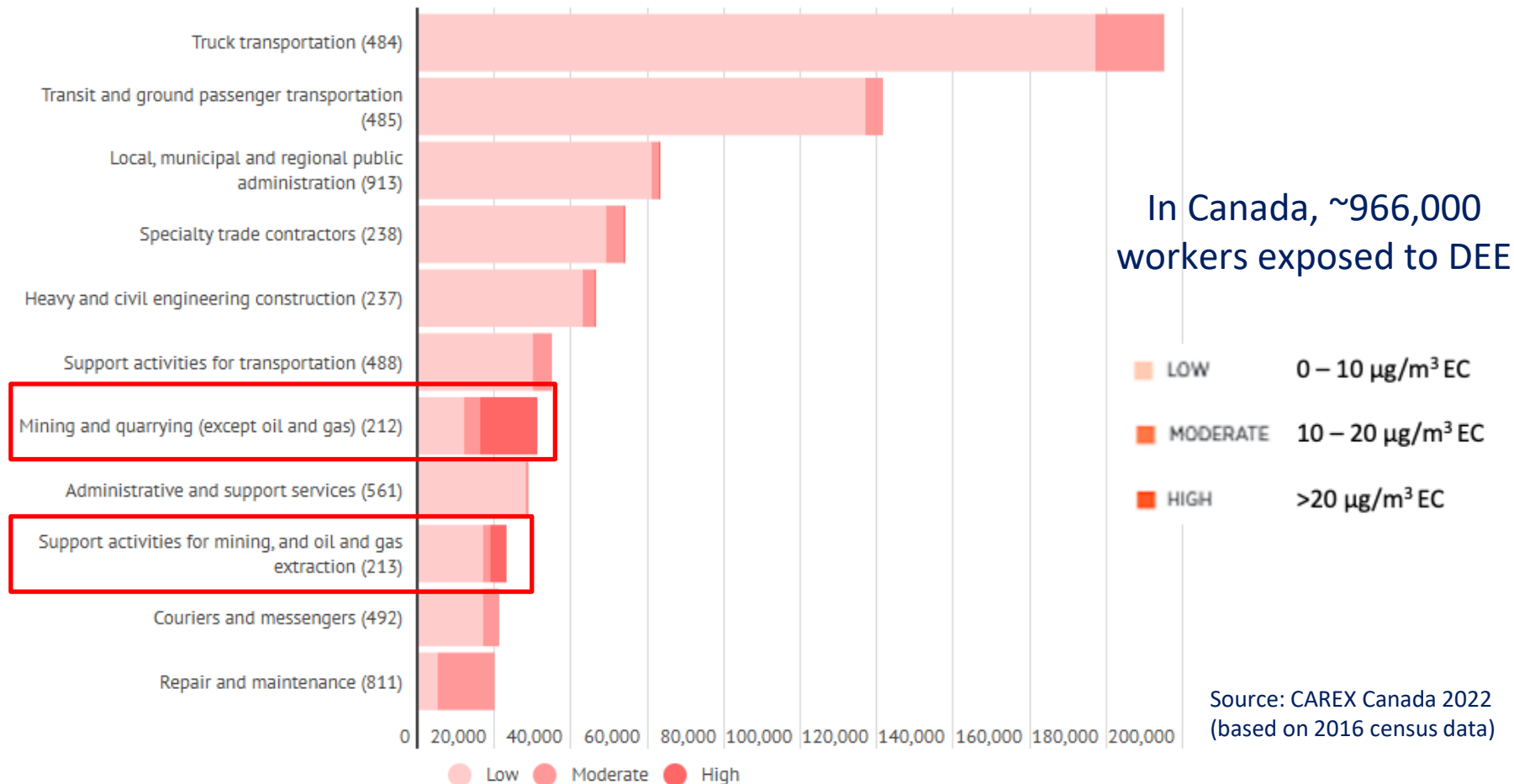


What is diesel engine exhaust (DEE)?

- Complex mixture of gases & particulates
 - By-product of combustion of diesel fuel
- Gases: CO, CO₂, NO, NO₂, PAHs, formaldehyde, naphthalene, low molecular weight HCs and derivatives, SOx compounds
- Particulates: PM, sulfates, PAHs and nitro-PAHs, metals, trace compounds



Workers exposed to diesel engine exhaust by exposure level and industry in 2016



Acute Health Effects

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



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



Knowledge Gaps

- Association between DEE exposure and bladder cancer, COPD, and IHD is less understood
 - Bladder cancer: high exposure only
 - COPD and IHD: TRAP studies common; occupational studies scarce
- Relatively few studies have assessed disease incidence or exposure-response relationships
- **Objective:** to assess potential exposure-response relationships for lung cancer, bladder cancer, COPD, and IHD in Ontario workers exposed to DEE



Background & Case Ascertainment

- ODSS: ~2.3 million Ontario workers identified through workers' compensation claims (1983-2019)
 - Occupation (CCDO), industry (SIC1970) of employment related to compensated injury or disease
- For cancer, cases identified through linkage to:
 - Ontario Cancer Registry (1964-2019)
- For COPD & IHD, cases identified through linkage to:
 - Discharge Abstract Database (2006-2020)
 - National Ambulatory Care Reporting System (2006-2020)
 - Ontario Health Insurance Plan (1999-2020)



Registry
Data



Hospital
Discharges



Emergency
Department
Visits



Physician
Billing
Records

Case Definitions

- Lung and bladder cancers: ICD 3rd revision SEER codes
 - Lung cancer (22030), bladder cancer (29010)
- COPD: ICD 9th revision 491-492, 496, ICD 10th revision J41-J44
 - ≥ 3 NACRS records on separate days within 2 years, or ≥ 3 OHIP records on separate days within 2 years, or 1 DAD record at any time among workers aged 35-65 years
- IHD: ICD 9th revision 410-414, ICD 10th revision I20-I25
 - ≥ 2 OHIP records on separate days within 1 year, or 1 DAD record at any time among workers ≥ 20 years

Sritharan 2024, Gershon 2009, Tu 2010

Case Follow-Up

- Excluded from analysis if missing:
 - Sex, birthdate, claim date, occupation/industry information, <15 years old
- 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 outcome
 - Death
 - Emigration from Ontario
 - Worker turned 85 years old (65 years for COPD)
 - End of study period (31 Dec 2019 for cancer, 31 Dec 2020 for non-cancer)



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

- Semi-quantitative JEM based on expert assessment and published exposure data (elemental carbon, EC)
- Axes of industry-occupation intersections (NAICS 2002–NOC-S 2006)
 - Updated with published literature [Ziembicki et al. 2024]
 - Crosswalked to SIC-1970-CCDO intersections & validated [Ziembicki et al. 2026]
- Prevalence is proportion of exposed workers within an intersection
 - $\geq 25\%$ threshold for exposed cases

Exposure Levels and Values of DEC-JEM

Exposure Level	Exposure Range ($\mu\text{g}/\text{m}^3$ EC)	Midpoint ($\mu\text{g}/\text{m}^3$ EC)
Unexposed	0	0
Low	>0 & <10	5
Moderate	≥ 10 & <20	15
High	≥ 20 & <40	25
Very high	≥ 40	70

Statistical Analysis

- Cox-proportional hazards models to estimate HRs & 95% CIs
 - Adjusted for age, birth year, sex
 - Analyses:
 - Exposed/unexposed
 - Categorical exposure level (unexposed, low, moderate, high, very high)
 - Sex
 - Major industry
- Test for trend with exposure level midpoints
- Tests for interaction by sex and major industry

Results

	Lung Cancer Cases	Bladder Cancer Cases	COPD Cases	IHD Cases
N	39,743	12,528	77,124	302,876
% Male	71%	87%	68%	74%
Median years of follow-up (males, females)	18 years, 18 years	21 years, 18 years	8 years, 7 years	7 years, 7 years

Results by exposure status

Disease Exposure Status	Cases	Workers	HR (95% CI)
Lung Cancer			
Unexposed	34,466	2,185,478	Ref.
Exposed	4,832	179,461	1.33 (1.29 to 1.37)
Bladder Cancer			
Unexposed	10,416	2,185,250	Ref.
Exposed	1,604	179,444	1.19 (1.13 to 1.26)
COPD			
Unexposed	68,624	1,780,891	Ref.
Exposed	8,499	146,636	1.34 (1.31 to 1.37)
IHD			
Unexposed	270,004	1,783,083	Ref.
Exposed	32,861	146,872	1.15 (1.13 to 1.16)



Lung and bladder cancers by exposure category

Exposure Level	Lung Cancer			Bladder Cancer		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Unexposed	34,466	2,185,478	Ref.	10,416	2,185,250	Ref.
Low	4,306	163,508	1.32 (1.28-1.37)	1,452	163,481	1.21 (1.14-1.28)
Moderate	160	7,420	1.25 (1.07-1.46)	44	7,424	0.90 (0.67-1.22)
High	82	2,671	1.39 (1.12-1.73)	23	2,671	1.07 (0.71-1.62)
Very high	284	5,862	1.52 (1.35-1.71)	85	5,868	1.21 (0.97-1.50)
<i>Test for trend</i>			<i>P<0.0001</i>			<i>P<0.0001</i>

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Test for
trend

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COPD and IHD by exposure category

Exposure Level	Chronic Obstructive Pulmonary Disease			Ischaemic Heart Disease		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Unexposed	68,624	1,780,891	Ref.	270,004	1,783,083	Ref.
Low	7,783	134,091	1.34 (1.31-1.37)	29,738	134,304	1.14 (1.13-1.15)
Moderate	273	5,993	1.24 (1.10-1.40)	1,097	6,000	1.16 (1.09-1.23)
High	131	2,173	1.59 (1.34-1.88)	496	2,182	1.16 (1.06-1.27)
Very high	312	4,379	1.32 (1.18-1.47)	1,530	4,386	1.26 (1.20-1.33)
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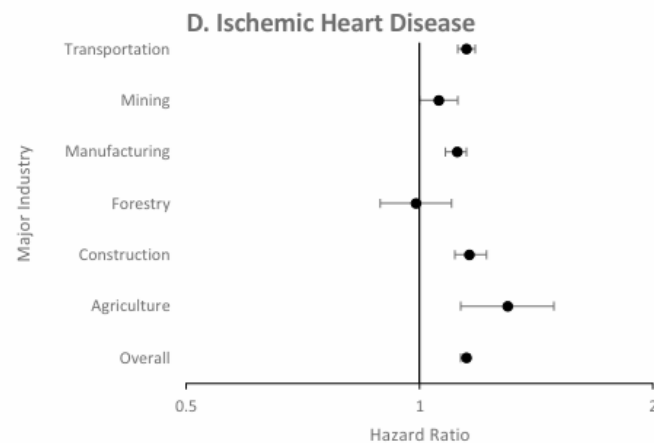
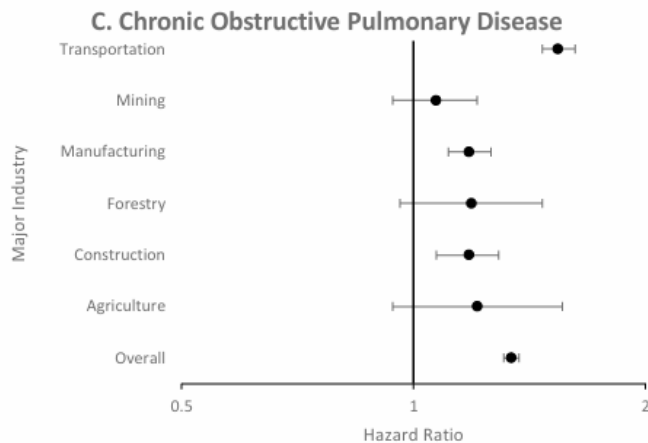
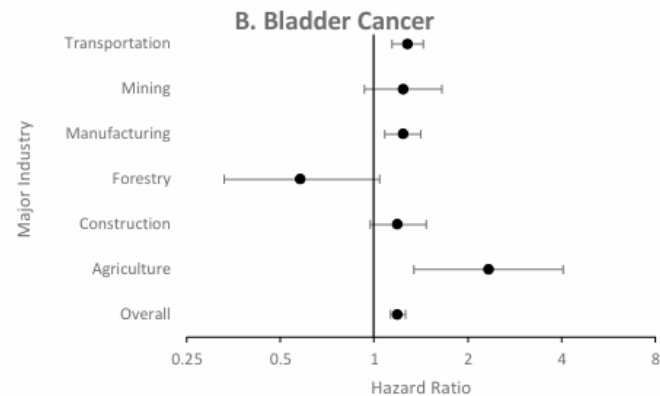
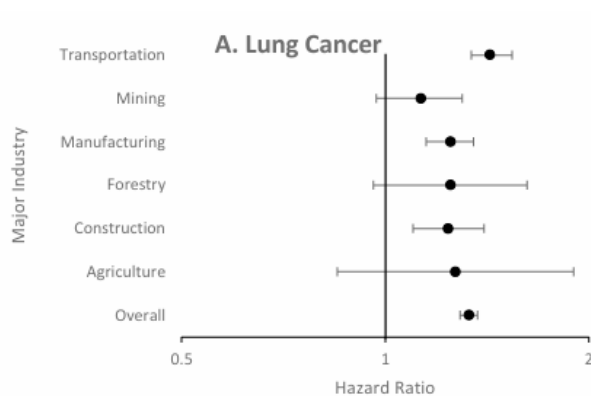
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Sex-Stratified Results

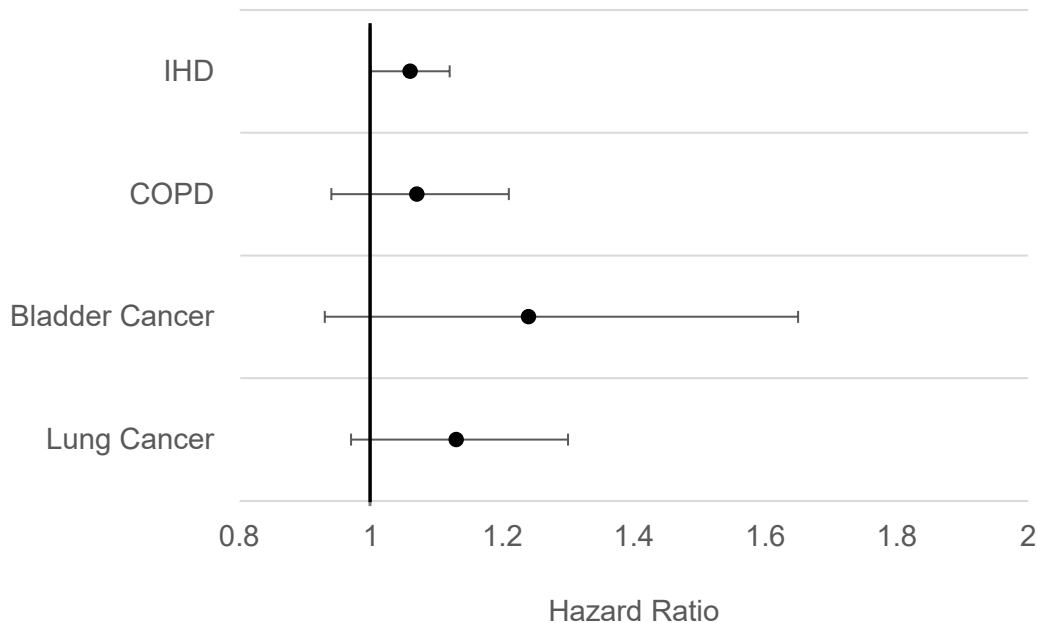
Disease Exposure Status	Males			Females		
	Cases	Workers	HR (95% CI)	Cases	Workers	HR (95% CI)
Lung Cancer						
Unexposed	23,304	1,361,026	Ref.	11,162	824,452	Ref.
Exposed	4,614	167,631	1.31 (1.27-1.35)	218	11,830	1.55 (1.36-1.77)
Bladder Cancer						
Unexposed	8,947	1,360,742	Ref.	1,469	824,508	Ref.
Exposed	1,575	167,610	1.19 (1.12-1.25)	29	11,163	1.64 (1.13-2.39)
COPD						
Unexposed	44,490	1,146,413	Ref.	24,134	634,478	Ref.
Exposed	7,937	138,023	1.31 (1.28-1.34)	562	8,613	1.63 (1.50-1.77)
IHD						
Unexposed	193,708	1,147,788	Ref.	76,296	635,295	Ref.
Exposed	31,738	138,249	1.15 (1.13-1.16)	1,123	8,623	1.14 (1.08-1.21)



Major industry HRs for all outcomes



Mining HRs for all outcomes



Conclusions

- Improves understanding of incident DEE-associated diseases
 - More diseases associated with DEE besides lung cancer
- Potential exposure-response relationships
- Increased risk in females



Strengths & Limitations

- Large sample size, particularly for females
- Agent-specific exposure assessment
- DEC-JEM recently updated and validated
- Administrative linked data
- Incident risk vs mortality
- Many co-exposures possible
- No smoking data
- Exposure misclassification
- Exposure based on one timepoint
- Non-differential misclassification of full work history

Prevention & Policy Implications

- Develop targeted prevention measures that reduce DEE exposure & disease burden
 - Especially for high risk industries
- Inform development of OELs for DEE
- Benefit future worker compensation practices for occupational disease
- Improve awareness efforts



Research Implications

Table 3: Primary causal agent for accepted cancer claims in Ontario (2009-2018)

Table 1: Burden of occupational cancer in Ontario

Carcinogen	Annual cancers in Ontario (Note 1)	Currently exposed (Note 2)
Solar UV at work	1400 non-melanoma skin	449,000
Asbestos	630 lung, 140 mesothelioma, 15 laryngeal, <5 ovarian, <i>additional colorectal and stomach</i>	52,000
Diesel exhaust	170 lung, 45 bladder	301,000
Crystalline silica	200 lung	142,000
Welding fumes	100 lung	169,000
Nickel	80 lung	48,000
Chromium VI	25 lung	39,000
Second-hand smoke at work	50 lung, 10 pharyngeal, 5 laryngeal (Note 3)	125,000
Radon	60 lung	34,000
Arsenic	20 lung	8,000
Benzene	10 leukemia, <5 multiple myeloma	147,000
PAHs	60 lung, 15 skin, 30 bladder	134,000
Shiftwork	180-460 breast	833,000
Artificial UV Radiation	5 ocular	48,000
Wood dust	<5 sinonasal, <5 nasopharyngeal	92,000
Formaldehyde	<5 leukemia, <5 sinonasal, <5 nasopharyngeal	63,000

Agent	Cases
Asbestos	1291
Crystalline silica	23
Benzene	21
Defoliants and herbicides	38
Solar & ultraviolet radiation	24
Coal Tar	14
Foundry emissions	13
Coke oven emissions	11
Nickel & sinter plant emissions	18
Welding fumes	9
Uranium (radon)	8
Exhaust gases - diesel	7
Rubber chemicals	6
Ultraviolet radiation	6
Solvents	6
Aluminum powder	6
Trichloroethylene	5
Ionizing radiation	5
Aromatic hydrocarbons	5
Other and unspecified agents	172

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