BURDEN OF OCCUPATIONAL CANCER IN CANADA

Major Workplace Carcinogens and Prevention of Exposure

SEPTEMBER 2019

PRODUCED BY THE OCCUPATIONAL CANCER RESEARCH CENTRE

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Occupational Cancer Research Centre

CAREX CANADA

Canadian Cancer Society
Société canadienne du cancer

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FOREWORD

The Occupational Cancer Research Centre (OCRC), established in 2009 and located at Cancer Care Ontario, is one of the few centres in the world dedicated to understanding the causes, surveillance, prevention and burden of occupational cancer. In 2012, the OCRC embarked on a multi-year study to characterize the extent to which workplace exposure to carcinogenic substances contributes to cancer in Canada. This report presents the findings of this study and provides an in-depth assessment of the occupational exposures found in Canadian workplaces that contribute to a large cancer burden both nationally and by province. Policy recommendations that can reduce or prevent workplace exposures to carcinogens are a core component of this report. These recommendations are directed to all levels and multiple sectors of government, as well as members of Canada's occupational health and safety system, employers, and non-governmental organizations. This diverse audience reflects the need for multiple strategies across different sectors around a shared purpose of prevention.

The Burden of Occupational Cancer in Canada Study was funded through a team grant from the Canadian Cancer Society. The team was led by the OCRC and included scientists from across the country. Lesley Rushton and Sally Hutchings, the lead scientists of the United Kingdom Occupational Cancer Burden Study, served as advisors over the four years of the Canadian study.

This report was produced by the OCRC with input from experts across Canada on scientific content and policy recommendations. The scientific information presented in this report is based on many years of occupational cancer research in Canada, much of it led and produced by the OCRC.

We hope that you find this report a compelling call to action on preventing occupational cancer in Canada.

Sincerely,

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This report was prepared at the Occupational Cancer Research Centre by Cathy Slavik, Ela Rydz, Chaojie (Daniel) Song and Paul A. Demers.

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EXECUTIVE SUMMARY

WHAT ARE THE OBJECTIVES OF THE REPORT?

The objectives of this report are to:

- **Describe and quantify occupational exposure and burden estimates by industry and/or province for the most important occupational cancer risk factors in Canada.**
- **Present policy recommendations and workplace-based opportunities for reducing exposure to occupational carcinogens.**

This knowledge is needed to prioritize and target efforts as well as to develop informed policy recommendations to prevent occupational exposures to carcinogens and ultimately reduce the risk of occupational cancer.

WHAT IS PRESENTED IN THE REPORT?

Over 100 occupational exposures have been classified as definite or probable human carcinogens by the World Health Organization's International Agency for Research on Cancer. The Occupational Cancer Research Centre has estimated the cancer burden for 44 of these. Although many of these carcinogens are found in Canadian workplaces, this report focusses on the 13 occupational carcinogens that contribute the most to the cancer burden in Canada. These carcinogens are: arsenic, asbestos, benzene, chromium (VI) compounds, diesel engine exhaust, second-hand smoke, nickel compounds, polycyclic aromatic hydrocarbons (PAHs), radon, night shift work, silica (crystalline), solar ultraviolet radiation, and welding fumes.

The report summarizes the number of cancer cases that could be prevented by removing exposure to these 13 occupational carcinogens. Exposure estimates from CAREX Canada are provided by industry and level of exposure to emphasize where exposure may be reduced now in order to prevent future cancer. Occupational cancer burden estimates are summarized by industry or province. Workplace and/or policy exposure reduction recommendations are also presented.

HOW WAS THE OCCUPATIONAL CANCER BURDEN ESTIMATED?

The researchers estimated the burden of occupational cancer in Canada in 2011 using methods adapted from a major study in the United Kingdom (1). The estimates incorporated information on (a) workers' exposures to specific occupational carcinogens between 1961 to 2001, the time period of exposure which would have been expected to contribute to the cancer burden in 2011, (b) the strength of the association between the exposure and cancer outcome, (c) changes in the working population over time, and (d) statistics on the number of cancer cases and cancer deaths by cancer site, by province and by sex.

WHAT IS THE OCCUPATIONAL CANCER BURDEN IN CANADA?

In 2011, approximately 252,000 cancers were diagnosed in Canada (2). Of those cases, 9,700 to 10,400 (3.9 and 4.2%) occur due to past occupational exposure (3), illustrating that workplace exposure to carcinogens contributes substantially to the cancer burden in Canada. Exposure to the 13 carcinogens included in this report account for the bulk of these. Solar ultraviolet radiation is the most common occupational exposure in Canada and contributes to the largest number of cancers (4,600 non-melanoma skin cancers). While workplace asbestos exposure has decreased over time, it is still responsible for an estimated 2,400 cancers, including lung, mesothelioma, laryngeal, and ovarian cancers. Diesel engine exhaust is another key exposure found in many Canadian workplaces and leads to an estimated 560 lung cancers, and 200 suspected bladder cancers. Industries with particularly high burdens of occupational cancer include the construction and manufacturing sectors. Table 1 provides a full summary of the exposure and burden estimates. Maps presenting the occupational cancer burden by province demonstrate that the provinces with the largest absolute burden based on populations (e.g., Ontario, Quebec) do not have the highest attributable fraction (i.e., proportion of cancer cases caused by the occupational exposure) in many instances. For example, while nearly a third of the total non-melanoma skin cancers caused by occupational solar radiation are diagnosed in Ontario each year, Saskatchewan has the highest attributable fraction of cases of all non-melanoma skin cancers.

WHAT POLICY ACTION CAN BE TAKEN TO REDUCE OCCUPATIONAL EXPOSURE?

Although this project focussed on the burden of cancer arising from exposures that occurred between 1961 and 2001, exposure to these carcinogens continues today. To prevent future cases of workplace-related cancers, efforts must be taken to reduce exposure now. This report highlights the types of policy action that could be taken to reduce workplace exposure to these carcinogens and include the following: strengthening occupational exposure limits across all Canadian jurisdictions so they are up-to-date, rigorous, and evidence-based; reducing or eliminating the use of cancer-causing substances with workplace-specific toxic use reduction policies; and, creating registries of workplace exposures to occupational carcinogens that will facilitate the tracking of exposures over time. In addition, the report proposes specific policies that target some of the individual carcinogens.

WHAT ARE THE NEXT STEPS?

This report highlights potential gaps in current policies and initiatives where deliberate action may be taken to reduce the burden of occupational cancer and to create healthy workplaces. The evidence-based policy recommendations in this report have been developed with all levels and multiple sectors of government in mind, as well as members of Canada's occupational health and safety system, employers and non-governmental organizations – and are intended to encourage the various levels of governments and these organizations to take further action to reduce exposure to occupational carcinogens. Collaboration between federal, provincial, and local governments will be imperative to ensure adequate and consistent protection for workers across Canada.

TABLE 1: Annual burden of occupational cancer in Canada, by carcinogen

CARCINOGEN	IARC EVALUATION FOR CARCINOGENICITY	NUMBER OF CANADIAN WORKERS EXPOSED	NUMBER OF CANCERS ATTRIBUTABLE TO OCCUPATIONAL EXPOSURE (PROPORTION OF ALL CANCER CASES DUE TO OCCUPATIONAL EXPOSURE)
Solar ultraviolet radiation	Definite	1,476,000	4,600 non-melanoma skin (6.3%)
Asbestos	Definite	152,000	1,900 lung (8.0%) 430 mesothelioma (80.5%) 45 larynx (3.7%) 15 ovarian (0.5%)
Diesel engine exhaust	Definite	897,000	560 lung (2.4%) 200 bladder (2.7%)
Silica (crystalline)	Definite	382,000	570 lung (2.4%)
Welding fumes[a] Nickel compounds Chromium (VI)	Definite Definite Definite	333,000 117,000 104,000	310 lung (1.3%) 170 lung (0.7%) 50 lung (0.2%)
Radon	Definite	188,000	190 lung (0.8%)
Second-hand smoke	Definite	520,000	130 lung (0.6%) 35 pharynx (2.4%) 20 larynx (1.6%)
Night shift work	Probable	1.9 million	470-1,200 breast (2.0-5.2%)
Polycyclic aromatic hydrocarbons (PAHs)	Definite, probable, possible, unclassifiable	350,000	130 lung (0.6%) 80 bladder (1.1%) 50 skin (0.07%)
Arsenic	Definite	25,000	60 lung (0.3%)
Benzene	Definite	374,000	20 leukemia (0.5%) 5 multiple myeloma (0.2%)

[a] Since workers may be exposed to both nickel compounds and chromium (VI) compounds through welding fumes, we have grouped these three carcinogens together. Exposure estimates for nickel compounds and chromium (VI) compounds include welders, burden estimates for exposures to nickel compounds and chromium (VI) compounds do not include welders.

RÉSUMÉ

QUELS SONT LES OBJECTIFS DU RAPPORT?

Ce rapport vise à :

- **Décrire et quantifier les estimations de l'exposition en milieu de travail et du fardeau, par industrie ou province, pour les principaux facteurs de risque de cancers professionnels au Canada.**
- **Formuler des recommandations en matière de politiques et de mesures à adopter en milieu de travail pour réduire l'exposition aux substances cancérogènes d'origine professionnelle.**

Ces connaissances sont nécessaires pour prioriser et cibler les efforts ainsi que pour formuler des recommandations éclairées en matière de politique visant à prévenir les expositions aux substances cancérogènes en milieu de travail et, à terme, réduire le risque de cancer professionnel.

QUE CONTIENT LE RAPPORT?

Le Centre international de recherche sur le cancer de l'Organisation mondiale de la Santé a classé plus de 100 types d'expositions professionnelles comme étant des substances cancérogènes pour l'homme dans les catégories « certaine » ou « probable ». Le Centre de recherche sur le cancer professionnel a évalué le fardeau du cancer de 44 de ces substances. Bien qu'un grand nombre de ces substances cancérogènes soient présentes dans les milieux de travail canadiens, ce rapport se concentre sur les 13 substances cancérogènes professionnelles qui contribuent le plus au fardeau des cancers au Canada. Ces substances cancérogènes sont : l'amiante, l'arsenic, le benzène, les composés du chrome (VI), les gaz d'échappement des moteurs au diesel, la fumée secondaire, les composés du nickel, les hydrocarbures aromatiques polycycliques (HAP), le radon, le travail de nuit, la silice (cristalline), les rayons ultra-violets du soleil et les fumées de soudage.

Le rapport présente un résumé du nombre de cas de cancer qui auraient pu être évités en éliminant l'exposition à ces 13 substances cancérogènes en milieu de travail. Les estimations sur l'exposition de CAREX Canada sont classées par industrie et par niveau d'exposition afin de mettre en évidence les domaines où l'exposition pourrait être réduite dès aujourd'hui afin de prévenir les futurs cas de cancer. Des estimations sur le fardeau des cancers professionnels par industrie ou par province sont également présentées. Le rapport contient également des recommandations sur la réduction de l'exposition en milieu de travail et sur l'élaboration de politiques en la matière.

COMMENT LE FARDEAU DES CANCERS PROFESSIONNELS A-T-IL ÉTÉ ESTIMÉ?

L'équipe de recherche a estimé le fardeau des cancers professionnels au Canada en 2011 à l'aide de méthodes adaptées d'une importante étude réalisée au Royaume-Uni (1). Les estimations comprenaient des renseignements sur 1) les expositions des travailleuses et travailleurs à certaines substances cancérogènes professionnelles entre 1961 et 2011, période d'exposition qui aurait contribué au fardeau des cancers de 2011, 2) l'importance de la corrélation entre l'exposition et l'incidence ces cancers, 3) les changements dans la population active au fil du temps, et 4) les statistiques sur le nombre de cas de cancer et de décès imputables à cette maladie, par siège de cancer, par province et par sexe.

QUE REPRÉSENTE LE FARDEAU DES CANCERS PROFESSIONNELS AU CANADA?

En 2011, environ 252 000 cas de cancer ont été diagnostiqués au Canada (2). Parmi ces cas, de 9 700 à 10 400 cancers (3,9 et 4, 2 %) se sont développés suite à une exposition professionnelle (3), ce qui indique que l'exposition en milieu de travail aux substances cancérogènes contribue considérablement au fardeau du cancer au Canada. L'exposition aux treize substances carcinogènes indiquées dans ce rapport représente la majeure partie de ces cas. Les travailleurs canadiens sont exposés à de nombreux agents cancérogènes, toutefois, les rayons ultra-violets du soleil constituent l'exposition professionnelle la plus fréquente au pays et contribuent au plus grand nombre de cas de cancer (4 600 cancers de la peau sans présence de mélanome). Malgré la baisse de l'exposition à l'amiante en milieu de travail, on estime que ce type d'exposition est toujours responsable de 2 400 cas de cancer, notamment des cancers du poumon, du larynx, de l'ovaire et de mésothéliome. Le gaz d'échappement des moteurs au diesel est un autre type majeur d'exposition dans de nombreux milieux de travail au Canada. Il serait la cause de 560 cancers de cancer du poumon, et de 200 cas de suspicion de cancer de la vessie. Le fardeau des cancers professionnels est particulièrement élevé dans le secteur de la construction et le secteur manufacturier. Le Tableau 1 présente un résumé complet des estimations sur l'exposition et les résultats du fardeau.

Les cartes représentant le fardeau des cancers professionnels par province montrent que les provinces ayant le fardeau global le plus élevé selon les populations (p. ex., Ontario, Québec) ne présentent pas, dans de nombreux cas, la fraction attribuable la plus élevée (c.-à-d., la proportion de cas de cancer causés par l'exposition professionnelle). Par exemple, bien que près d'un tiers du total des cas de cancer de la peau sans présence de mélanome causés par l'exposition professionnelle aux rayons du soleil soit diagnostiqué en Ontario chaque année, la Saskatchewan présente la fraction attribuable la plus élevée de cas liés à cette maladie.

QUELLES MESURES POLITIQUES PEUVENT-ÊTRE PRISES POUR RÉDUIRE L'EXPOSITION PROFESSIONNELLE?

Bien que ce projet soit axé sur le fardeau des cancers découlant des expositions survenues entre 1961 et 2001, l'exposition à ces substances cancérogènes se poursuit aujourd'hui. Pour prévenir de futurs cas de cancers professionnels, des mesures doivent être prises afin de réduire l'exposition immédiatement. Le présent rapport met l'accent sur les types d'actions politiques qui pourraient être entreprises pour réduire l'exposition en milieu de travail à ces substances cancérogènes, notamment : renforcer les limites d'exposition en milieu de travail dans l'ensemble des provinces et territoires du Canada afin qu'elles soient actualisées, rigoureuses et fondées sur des données probantes; réduire ou éliminer l'utilisation de substances cancérogènes par le biais des politiques de réduction de l'utilisation de certaines substances toxiques en milieu de travail; et, créer des registres de l'exposition en milieu de travail aux substances cancérogènes professionnelles qui faciliteront le suivi des expositions au fil du temps. De plus, le rapport suggère l'application de politiques visant précisément certaines substances cancérogènes.

QUELLES SONT LES PROCHAINES ÉTAPES?

Le présent rapport met en lumière les lacunes potentielles des politiques et initiatives actuelles où des mesures délibérées peuvent être prises pour réduire le fardeau des cancers professionnels et créer des milieux de travail sains. Les recommandations en matière de politique du présent rapport sont fondées sur des données probantes. Elles ont été formulées en ayant à l'esprit tous les échelons et multiples secteurs du gouvernement, ainsi que les acteurs du système canadien de santé et de sécurité au travail, les employeurs et les organisations non gouvernementales. Elles visent à encourager les différents paliers gouvernementaux et ces organismes à prendre des mesures supplémentaires pour réduire l'exposition aux substances cancérogènes en milieu de travail. La collaboration entre les gouvernements fédéral, provinciaux et locaux sera essentielle pour garantir la protection adéquate et uniforme des travailleuses et travailleurs de tout le pays.

TABLEAU 1 : Fardeau annuel des cancers professionnels au Canada, par substance cancérogène

SUBSTANCE CANCÉROGÈNE	ÉVALUATION DE LA CANCÉROGÉNICITÉ DU CIRC	NOMBRE DE TRAVAILLEUSES ET TRAVAILLEURS CANADIENS EXPOSÉS	NOMBRES DE CAS DE CANCER ATTRIBUABLES À L'EXPOSITION EN MILIEU DE TRAVAIL (proportion de tous les cas de cancer dus à l'exposition en milieu de travail)
Rayons ultra-violets du soleil	Certaine	1 476 000	4 600 cas de cancer de la peau sans présence de mélanome (6,3%)
Amiante	Certaine	152 000	1 900 cas de cancer du poumon (8,0%) 430 cas de mésothéliome (80,5%) 45 cas de cancer du larynx (3,7%) 15 cas de cancer de l'ovaire (0,5%)
Gaz d'échappement des moteurs au diesel	Certaine	897 000	560 cas de cancer du poumon (2,4%) 200 cas de cancer de la vessie (2,7%)
Silice (cristalline)	Certaine	382 000	570 cas de cancer du poumon (2,4%)
Fumées de soudage[a] Composés du nickel Chrome (VI)	Certaine Certaine Certaine	333 000 117 000 104 000	310 cas de cancer du poumon (1,3%) 170 cas de cancer du poumon (0,7%) 50 cas de cancer du poumon (0,2%)
Radon	Certaine	188 000	190 cas de cancer du poumon (0,8%)
Fumée secondaire au travail	Certaine	520 000	130 cas de cancer du poumon (0,6%) 35 cas de cancer du pharynx (2,4%) 20 cas de cancer du larynx (1,6%)
Travail de nuit	Probable	1.9 million	470 à 1 200 cas de cancer du sein (2,0-5,2%)
Hydrocarbures aromatiques polycycliques (HAP)	Certaine, probable, possible, non classée	350 000	130 cas de cancer du poumon (0,6%) 80 cas de cancer de la vessie (1,1%) 50 cas de cancer de la peau (0,07%)
Arsenic	Certaine	25 000	60 cas de cancer du poumon (0,3%)
Benzène	Certaine	374 000	20 cas de leucémie (0,5%) 5 cas de myélome multiple (0,2%)

[a] Puisque les travailleuses et travailleurs peuvent être exposés à la fois aux composés du nickel et aux composés du chrome (VI) à cause des fumées de soudage, nous avons regroupé ces trois substances cancérogènes. Les estimations de l'exposition aux composés du nickel et du chrome (VI) prennent en compte les soudeurs; les estimations du fardeau des expositions aux composés du nickel et du chrome (VI) ne tiennent pas compte des soudeurs.

INTRODUCTION

WHY FOCUS ON OCCUPATION FOR CANCER PREVENTION?

An estimated 206,000 cancer cases, excluding non-melanoma skin cancer, were diagnosed in Canada in 2017 (4). While survival rates are increasing, cancer is still responsible for over 80,000 deaths annually in Canada, making it the leading cause of mortality in the country (5). Cancer is a complex disease and while some causes and risk factors are known, evidence for others is limited or inconsistent.

Workplaces are important settings to target for cancer prevention efforts because workplace exposures tend to be higher than in the general environment and because Canadians spend a significant portion of their days at work. On average, one-third of Canadians' waking time is spent at work (6). Therefore, reducing or eliminating certain occupational exposures that have been linked to cancer represents an important avenue to reduce the number of cancers diagnosed in Canada. In addition, workplaces are required to comply with legally enforceable policies and regulations, amendments to which have the potential to impact large portions of the population (7, 8).

WHAT IS CURRENTLY KNOWN ABOUT THE BURDEN OF OCCUPATIONAL CANCER?

In this report, the term "burden" refers to the number and proportion of cancer cases that could be prevented by limiting occupational exposure to known and suspected carcinogens. While workers' compensation systems collect information on accepted cancer claims, these data are limited due to under-reporting of occupational disease, limited information on the causes of cancer, and the under-recognition of occupational cancer by many workers' compensation systems. No other systems or organizations collect data related to the number of cancer cases caused by exposure to specific occupational carcinogens in Canada, nor the economic impact of these cancers.

WHAT ARE THE OBJECTIVES OF THIS REPORT?

The objectives of this report are to:

1) Describe and quantify occupational exposure and burden estimates by industry and/or province for the most important occupational cancer risk factors in Canada

2) Present policy recommendations and workplace-based opportunities for reducing exposure to occupational carcinogens in Canada

WHAT FORMED THE BASIS OF THIS REPORT?

Modelling approaches have been used to estimate the number of cancer cases linked to occupational exposures. The attributable fraction method is a commonly accepted approach used worldwide, which approximates the proportion of total cancer cases that are due to occupational exposures. In 2012, scientists in the United Kingdom (UK) applied the attributable fraction method and estimated that the percentage of all current cancers as a result of occupational carcinogen exposures in Great Britain was 5.3% (1).

While the UK and other studies had estimated that the burden of occupational cancer ranges from 2% to 10% (1, 9-13), the impact of occupational exposure on Canadian workers to cancer-causing substances was unknown. To address this knowledge gap, the Occupational Cancer Research Centre (OCRC) embarked on a four-year study to estimate the burden of occupational cancer in Canada in collaboration with a national team of experts.

In 2017, occupational cancer burden estimates for Ontario were summarized in “Burden of Occupational Cancer in Ontario: Major Workplace Carcinogens and Prevention of Exposure”. The Ontario report was well received and spurred the creation of this report, which summarizes national occupational cancer burden estimates and highlights policy recommendations to reduce occupational exposure to 13 carcinogens.

WHAT DOES THIS REPORT INCLUDE?

This report includes occupational exposure estimates from CAREX Canada and cancer burden results for 2011 for Canada. Findings are presented by major industry and by province. The OCRC used the following criteria to select occupational carcinogens for inclusion in this report:

- Number of Canadian workers occupationally exposed in 2006: at least 25,000
- Strength of evidence of carcinogenicity: priority carcinogens were those classified as definite (Group 1) or probable (Group 2) human carcinogens by the International Agency for Research on Cancer
- Potential for prevention: carcinogens associated with 25 or more newly diagnosed cancer cases per year

Thirteen carcinogens are included in this report: arsenic, asbestos, benzene, chromium (VI) compounds, diesel engine exhaust, second-hand smoke, nickel compounds, polycyclic aromatic hydrocarbons (PAHs), radon, night shift work, silica (crystalline), solar ultraviolet radiation, and welding fumes. All of these, except for night shift work (probable carcinogen) and PAHs (which describe a group of compounds that have been classified as definite, probable, possible, or unclassifiable carcinogens), are definite carcinogens.

This report also includes general policy, as well as carcinogen-specific, recommendations designed to reduce the burden of occupational cancer in Canada. Many of these recommendations are geared towards federal and provincial Ministries of Labour and Health, but some may involve additional ministries (such as Environment, Transportation, Infrastructure) as well as cooperation from other agencies and local governments. To enable and empower employers, employees, organized labour, and joint Health and Safety committees, practical workplace-based recommendations are included along with the systemic changes that the recommended policies can achieve.

Additional information on the burden of occupational cancer by other occupational exposures, more detailed occupation or industry, age, and/or exposure level, as well as the economic burden of occupational cancer by cancer site are available but have not been included in this report. If you are interested in accessing these more detailed data, please refer to our scientific publications and website (3, 14-20).

HOW CAN THIS REPORT BE USED?

This report highlights opportunities to reduce and prevent carcinogenic workplace exposures that are responsible for the largest number of occupational cancers. This report can be used to raise awareness, encourage discussion, create change and, most importantly, to drive the prevention of future occupational cancers in Canada using evidence-based information and recommendations.

APPROACH

The burden of occupational cancer in Canada was estimated using methods that were adapted from the approach previously used in the UK (1). In the OCRC study, a total of 44 known and suspected occupational carcinogens and 27 associated cancer sites were included, based on evaluations conducted by the International Agency for Research on Cancer (IARC) Monographs program (3). This section of the report describes the general methods used to estimate the occupational cancer burden in Canada.

The year 2011 was selected as the target year for the burden estimates because it was the most recent census year available. Because the time between workplace exposure to carcinogens and the diagnosis of cancer can be up to several decades, we assumed that the period of exposure that could contribute to newly diagnosed solid tumour cancers (e.g., lung cancer) in 2011 was between 1961 and 2001. This 40-year period was called the "risk exposure period". For lymphatic and hematopoietic tumours (e.g., leukemia), which can develop more quickly than solid tumours, we used a 20-year risk exposure period from 1991 to 2011 (Figure 1).

In this study, the burden of cancer was defined as the attributable fraction (AF), which is the proportion of total cancers that could have been prevented if occupational carcinogen exposures were eliminated. Calculating the AF for each cancer and its associated occupational carcinogens involved three major steps:

1. Selecting an appropriate estimate of the risk, or the strength of the relationship between exposure and cancer

2. Assessing how many Canadians are exposed to specific carcinogens in the workplace (i.e., the prevalence of exposure)

3. Modelling the total working population, as well as the working population exposed to specific carcinogens included in the study

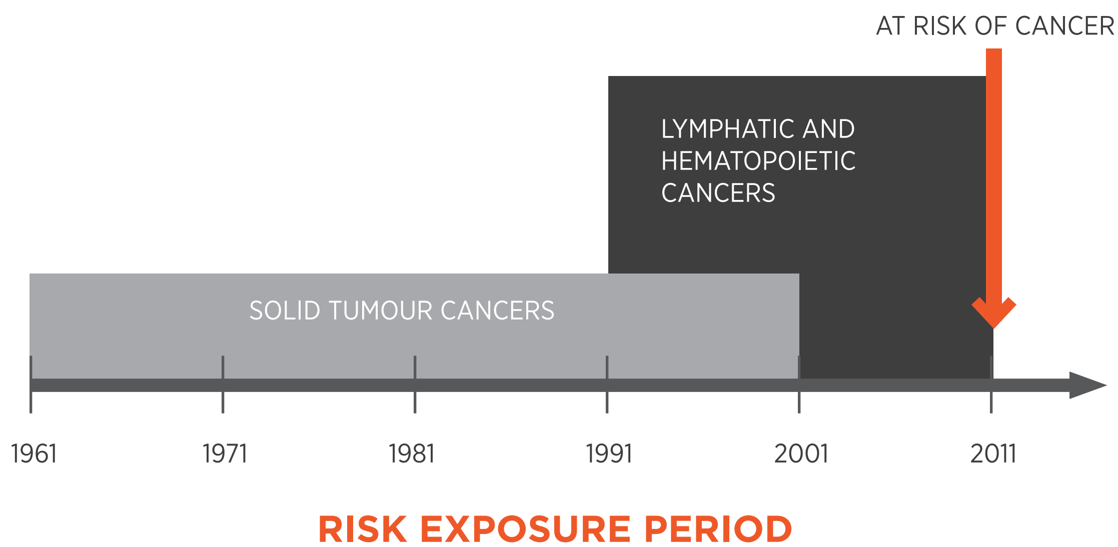


Figure 1. The risk exposure period

SELECTING AN APPROPRIATE ESTIMATE OF THE RISK

The scientific literature was reviewed to identify epidemiological studies that studied the relationship between occupational carcinogen exposure and cancer. For each exposure, the quality of the studies was assessed and the risk estimates from a single study were selected for use. Priority was given to studies that applied to the Canadian context in terms of industrial activities, combined the results from multiple studies to increase sample sizes, studied how level of exposure affects risk, and controlled for important confounders. Exposure groups in the burden study were matched closely to the exposure categories used in the study.

ESTIMATING THE PREVALENCE OF EXPOSURE

The prevalence of exposure was mostly based on estimates previously developed by CAREX Canada. CAREX Canada, funded by the Canadian Partnership Against Cancer (CPAC), is a multi-institution research project that aims to provide a body of knowledge about Canadians' exposures to known and suspected carcinogens. CAREX Canada estimated the prevalence of Canadians' workplace exposure to 45 carcinogens in 2006 by incorporating national workforce information with evidence about the proportion of workers exposed to individual carcinogens. A detailed description of CAREX Canada's methods can be found in Peters et al., 2015 (21). Workers were, for the most part, assigned to different exposure levels based on exposure measurement data from the Canadian Workplace Exposure Database, a database that consolidates regulatory exposure measurement data from six provincial and territorial jurisdictions (22). CAREX Canada estimates were used to estimate burden for all substances presented in this report except for asbestos, welding fumes, and second-hand smoke. CAREX Canada's exposure estimates were used for calculating the radon burden estimates; however, different cut-points for exposure were used. For example, CAREX Canada estimates only consider workers with greater than 200 Bq/m^3 as exposed, while the burden estimates considered a worker exposed if levels exceeded 0 Bq/m^3.

Since CAREX Canada assessed occupational carcinogen exposures for the year 2006, historical trends estimated as part of CANJEM, a Canadian job-exposure matrix, were combined with CAREX Canada data to account for changes in the prevalence of exposure over the risk exposure period (i.e., 1961 to 2001) for certain carcinogens (23). There were also a few carcinogens that warranted a separate and unique exposure assessment approach from the CAREX method. These are asbestos, radon, second-hand smoke, and welding fumes.

MODELLING THE WORKING POPULATION

The number of workers ever exposed during the risk exposure period was calculated by counting the number of all exposed workers in the first year of the risk exposure period (i.e., 1961 or 1991, depending on cancer type) and the number of exposed new hires in each subsequent year (i.e., 1962–2000 or 1992–2010); the survival of all of these workers was then followed to the target year (i.e., 2011). The population model was built using data from multiple Canadian censuses, labour force surveys and life tables.

Canadian Cancer Statistics for the year 2011 were used to determine the number of newly diagnosed cancers from exposure to each occupational carcinogen (2). This number was determined by multiplying the AF with the total number of incident cancers, by cancer type.

More information about the burden study can be found at:

- Occupational Cancer Research Centre: https://www.occupationalcancer.ca/burden
- CAREX Canada: https://www.carexcanada.ca/special-topics/burden-of-cancer/

Policy recommendations for this report were developed using two approaches. First, searches were conducted for published regulations and policies that have been proposed, developed, or enacted by governments in Canada and other jurisdictions. Then, a Policy Advisory Committee was assembled to provide input on recommendations. The membership of this Policy Advisory Committee reflected diverse areas of expertise in occupational health and safety, policy, and cancer and chronic disease prevention.

GUIDANCE FOR UNDERSTANDING THE RESULTS

HOW TO INTERPRET THE OCCUPATIONAL CARCINOGEN EXPOSURE ESTIMATES

This report presents the most recent estimate of workplace exposure in Canada for each carcinogen. In interpreting the estimates, it is important to remember that many of these estimates were generated by CAREX Canada using 2006 labour force estimates. CAREX Canada is currently in the process of updating their estimates to 2016. For some carcinogens in this report, information about the estimated level of exposure (i.e., low, moderate, high) is available. Some of these estimates are quantitative, based on exposure concentration thresholds relevant to workplace exposure limits and cancer health outcomes. Others have been qualitatively assessed. The most recent estimates, along with further details on the methods for estimating occupational exposure to the specific carcinogens, can be found at CAREX Canada's website.

HOW TO INTERPRET THE OCCUPATIONAL CANCER BURDEN ESTIMATES

In this report, the burden of occupational cancer is presented in two different ways:

1. The number of newly diagnosed cancers each year in Canada that are due to occupational exposure to carcinogens and could have been prevented by eliminating workplace exposure.

2. The attributable fraction, which is the percent of all cancer cases due to occupational exposure to a specific carcinogen. For example, 4,600 non-melanoma skin cancers are due to solar ultraviolet radiation, which is 6.3% of all non-melanoma skin cancers diagnosed in a year.

To assist in the interpretation of the findings, maps displaying cancer burden estimates and attributable fractions for the priority carcinogens for each province have been created. As would be expected, provinces with a larger population will have a larger number of occupational cancers. The attributable fractions by province are more variable because of inter-provincial differences in the composition of the labour force.

FRAMEWORK FOR WORKPLACE-BASED EXPOSURE REDUCTION MEASURES

The hierarchy of hazard controls (Figure 2) provided the framework for this report's recommendations on workplace-based exposure reduction measures. The hierarchy ranks controls from most effective to least effective. Eliminating a hazard by physically removing it from a workplace or substituting a hazard by replacing it with a safer alternative are among the most effective hazard controls. The next level of the hierarchy is engineering controls, which work by reducing potential exposure to hazards (e.g., by isolating people from the hazard, or increasing ventilation). Administrative controls, which reduce potential workplace exposures by changing how or when work is completed (e.g., incorporating regular maintenance of equipment into operations), and personal protective equipment are the least effective methods of preventing occupational exposures to hazards.

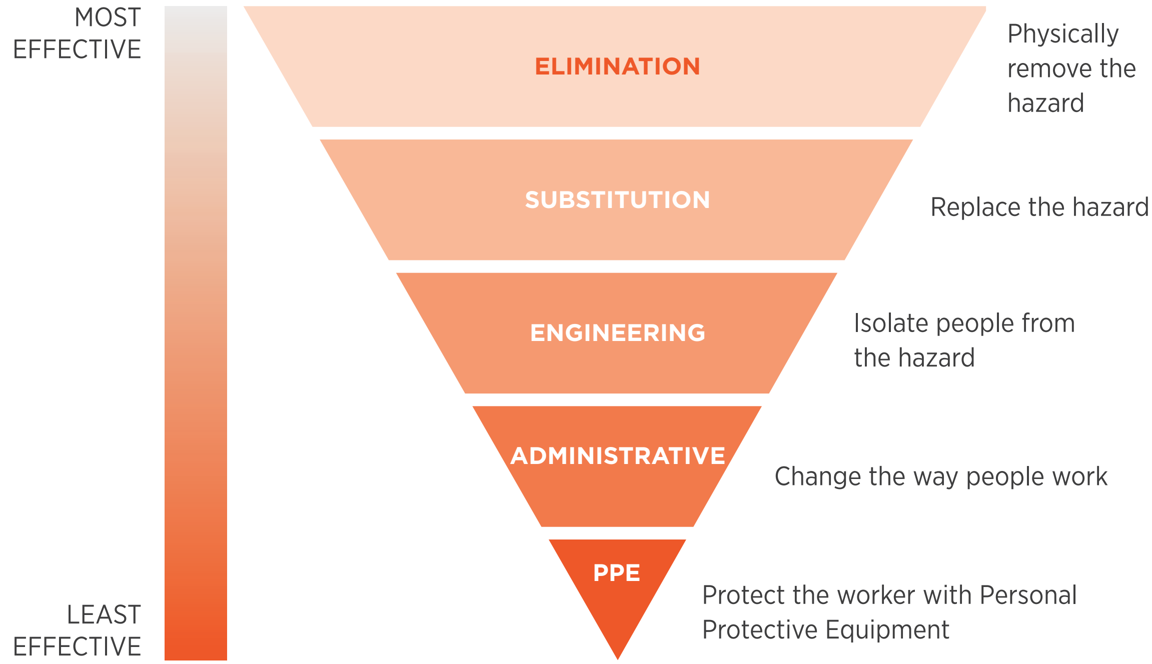


Figure 2. Hierarchy of hazard controls (24)

This report prioritizes more effective controls over less effective controls. As a consequence, details on PPE are not included. The use of PPE as a control measure shifts the burden of protection onto workers, presents challenges around availability, selection, fit, maintenance and comfort, and relies on workers' compliance. They should only be used as a last resort or as a temporary approach to reducing hazardous workplace exposures. However, it is important to note that at times, PPE may be the only option available. For example, PPE is particularly important for mobile workers who do not have control of their surroundings, or where the installation of permanent controls is more challenging.

POLICY RECOMMENDATIONS

This report presents some policy recommendations that were the result of consultations with a Policy Advisory Committee specifically convened to provide feedback on the findings. The general policy recommendations are meant to be applied to all carcinogens in this report.

RESULTS

SOLAR ULTRAVIOLET (UV) RADIATION

The sun is the main source of exposure to broad spectrum UV radiation (25). Solar UV radiation includes wavelengths in the electromagnetic spectrum between 100 and 400 nanometres. It comprises UVA, UVB and UVC radiation, all of which cause skin cancer (however, solar UVC is entirely filtered out by the Earth's atmosphere and is not a concern for human exposure) (26). Solar UV radiation can cause melanoma and non-melanoma skin cancers (NMSC), depending on the exposure patterns. Intermittent non-occupational sun-intensive activities, such as sunbathing and holidays, are associated with melanoma skin cancer and to a certain extent basal cell carcinoma (a sub-type of non-melanoma skin cancer). Cumulative exposure, such as long-term occupational exposure, is strongly linked to NMSC, including basal cell carcinoma, and in particular, the squamous cell carcinoma sub-type (27). Associations have also been observed between solar UV radiation and cancers of the lip, and in or around the eye (27). Other health effects associated with exposure to solar UV radiation include sunburn, reduced immune function, retinal injury and cataracts (28).

EXPOSURE

Solar UV radiation is the second most common occupational carcinogen exposure in Canada, after shiftwork, with nearly 1.5 million workers exposed. While all outdoor workers are at risk of solar UV radiation exposure, the largest industrial groups exposed include: agriculture, forestry, fishing and hunting; construction; and transportation and warehousing (e.g., truck transportation, postal service, public transit) (Figure 3). When examining exposures to solar UV radiation by province, the largest number of exposed workers in Alberta, British Columbia, Ontario and Quebec were employed in the construction industry. However, in Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Prince Edward Island and Saskatchewan, the largest number of UV-exposed workers were employed in the agriculture industry.

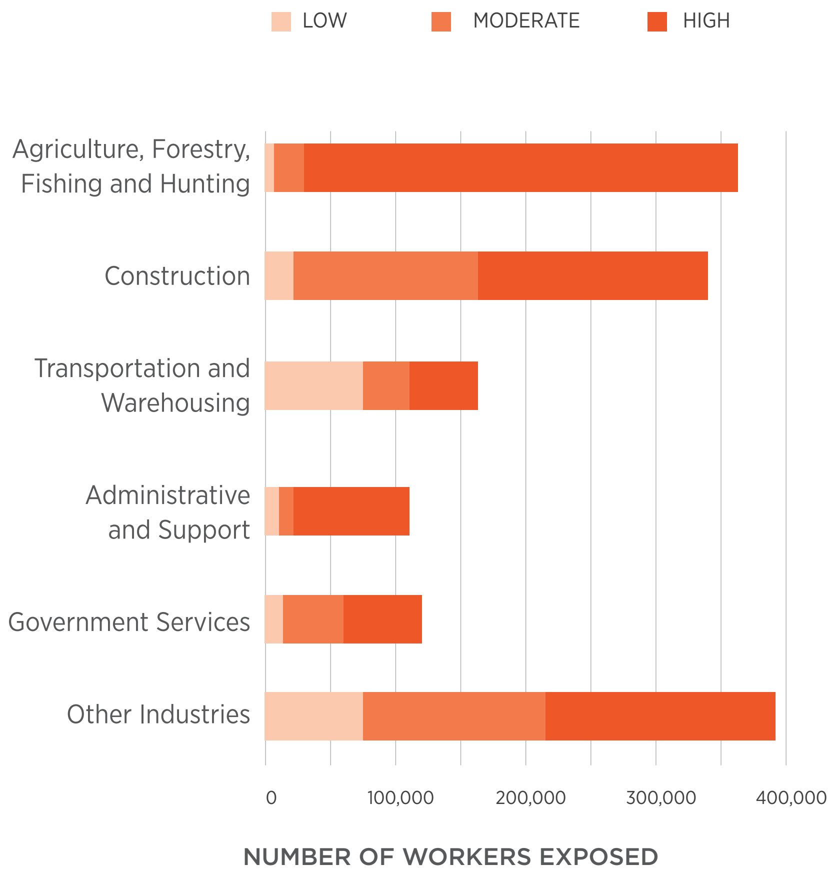
Not all workers are exposed to the same levels of UV radiation. Of the nearly 1.5 million total workers exposed in Canada, 13% are exposed to low levels, 26% to moderate levels and 61% to high levels.

- Low-level exposure occurs in jobs where some outdoor work is expected (>2 hours per day, or 25% of the time), such as among truck drivers and courier service drivers.
- Moderate-level exposure occurs in occupations that entail a mix of indoor and outdoor work, but where workers are outdoors less than 75% of the workday, such as heavy equipment operators.
- High-level exposure occurs in occupations where workers are expected to be outside for at least 75% of the workday, including landscapers, construction workers and farmers.

Overall, the largest occupational groups exposed in Canada are farmers and farm managers (149,000 workers), construction trades helpers and labourers (125,000 workers) and landscaping and ground maintenance labourers (114,000 workers).

BURDEN

Annually, approximately 4,600 NMSC diagnoses are caused by occupational solar UV radiation exposure in Canada (Figure 4). This accounts for 6.3% of the estimated total NMSCs diagnosed each year. Looking at the distribution of cancers by industry, the greatest burden of NMSC is found in the agricultural and construction industries (Figure 4). “Other industries” where an excess of NMSC is observed include: forestry and logging, mining, and fishing and hunting.



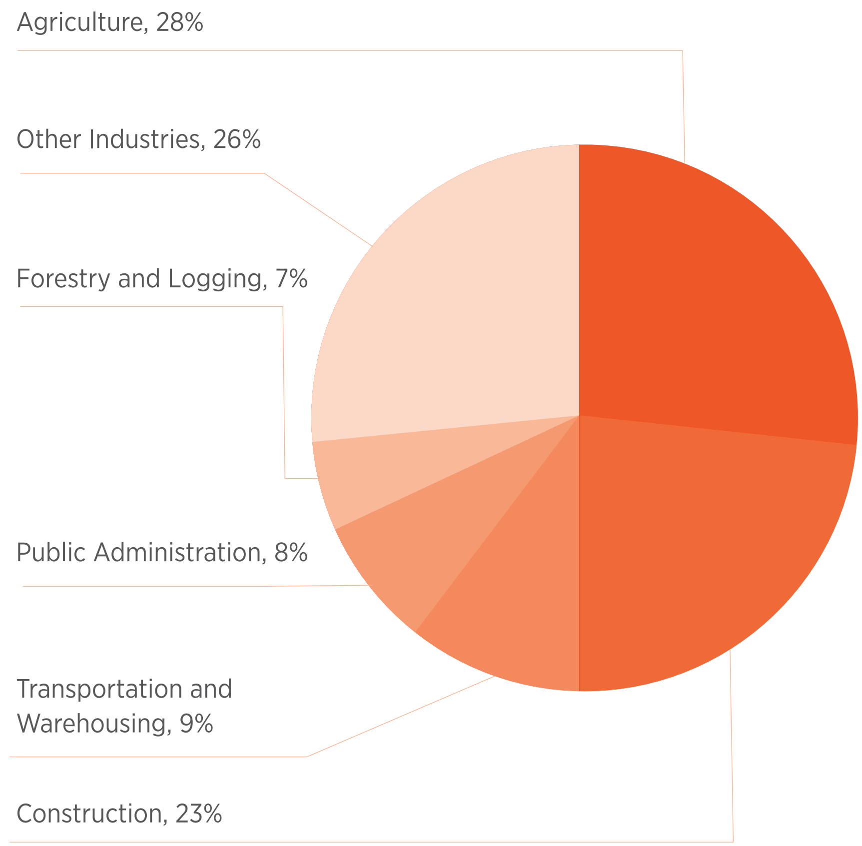


Figure 3. Number of workers occupationally exposed to solar UV radiation by level of exposure and industry in Canada in 2006.

Figure 4. Industry breakdown of total non-melanoma skin cancers (NMSCs) attributed to occupational solar ultraviolet (UV) radiation exposure in 2011.

4,600
Non-melanoma skin cancers
AF = 6.3%

Figure 5 presents the occupational burden of non-melanoma skin cancers (NMSCs), by province. The provinces with the highest attributable fractions are Saskatchewan and Prince Edward Island, where 12.9% and 12.0% of the estimated total NMSCs diagnosed each year are caused by occupational solar radiation exposure, respectively (Figure 5). The attributable fraction in Newfoundland and Labrador was also among the highest at 10.0%.

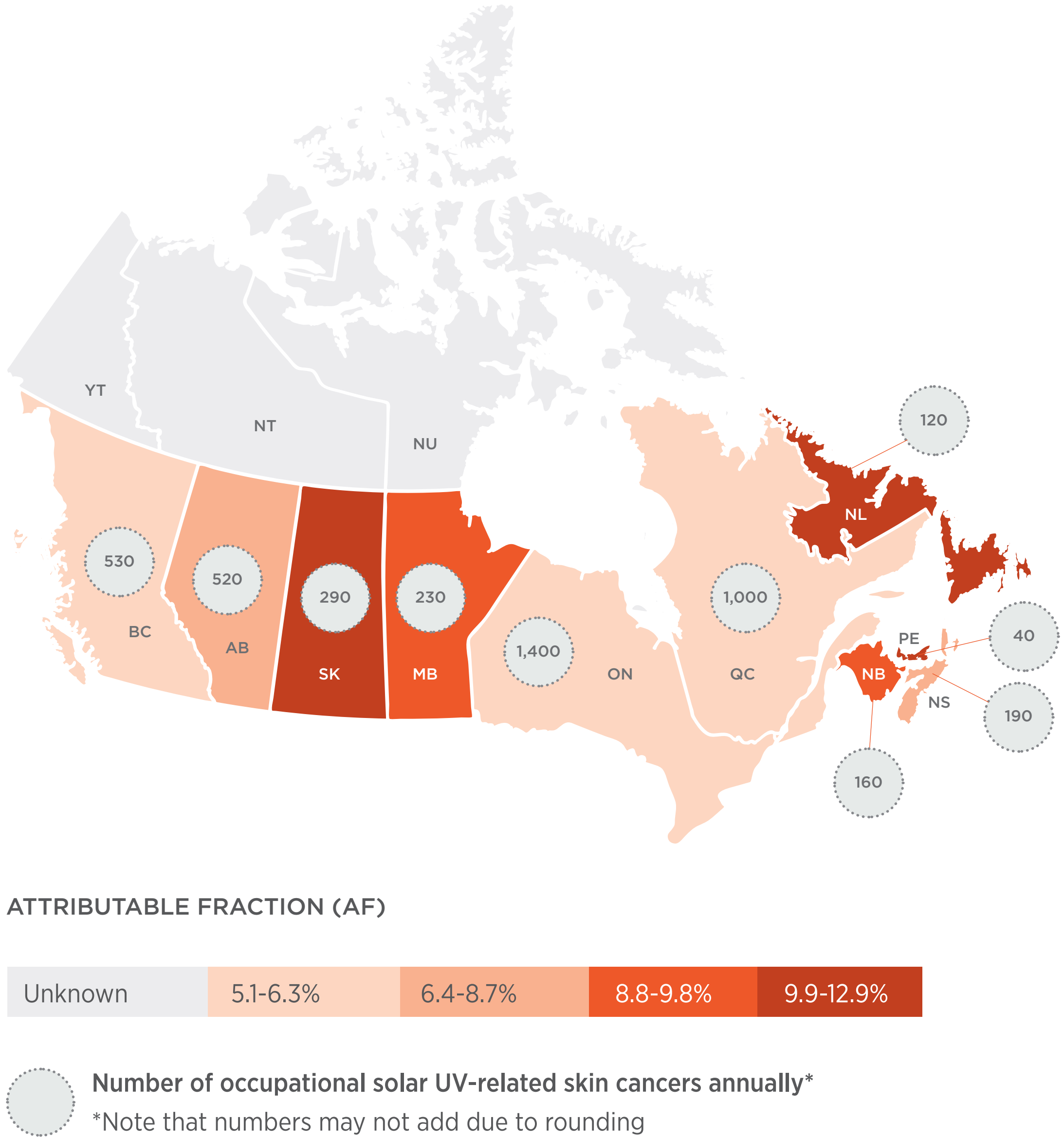


Figure 5. Provincial breakdown of total non-melanoma skin cancers (NMSCs) attributed to occupational solar ultraviolet (UV) radiation exposure in 2011.

EXPOSURE REDUCTION STRATEGIES

Providing shade is the best way to protect workers from solar UV radiation. If no natural sources of shade are available, shade structures that are designed, placed and utilized to maximize protection can be built (29-31). The UV protection factor rating for shade materials should be at least 40 for maximum protection (29). Other engineering controls include modifying reflective surfaces and tinting windows on vehicles (30, 31). Administrative controls – such as scheduling shifts to minimize time spent in the sun during peak UV hours (i.e., between 11 am and 3 pm) and distributing outdoor and indoor tasks across workers to minimize individual exposure – can have a significant impact on daily exposure (32). Sun awareness training should also be implemented in workplaces to raise awareness of the risks associated with solar UV exposure and available protective measures such as full-coverage clothing and water-resistant sunscreen with a sun protection factor of 30 or higher (30, 31). Sun Safety at Work Canada provides resources to assist small and large workplaces to develop and implement sun safety programs (29).

POLICY RECOMMENDATIONS FOR SOLAR UV RADIATION

The general, overarching policy recommendations, presented later in this report, can be applied to solar UV radiation in addition to the following specific recommendation:

Require all workplaces with workers that work outdoors for part or all of the day to develop a comprehensive, multi-component sun safety program.

This recommendation is in line with the Cancer Council of Australia's position on sun protection in the workplace (33). Sun safety programs include a risk assessment to identify workers at high risk of exposure and scenarios of potential high exposure by reviewing worker tasks and assessing how any current control measures can be improved to reduce the risks identified.

Sun safety programs should also include the implementation of effective sun protection control measures identified in the risk assessment, and sun protection training and education to ensure workers are aware of the risks of sun exposure to facilitate the management of solar UV radiation risk (29).

ASBESTOS

Asbestos is the commercial term for six different types of related mineral fibres (34). Known for its heat resistance, tensile strength, insulation and friction properties (25), asbestos was widely used as insulation in buildings and as a fireproofing agent from the 1930s to the 1980s (35). In 1990, its use as insulation in buildings was no longer permitted (35).

Until 2012, when the last asbestos mines in Canada were closed, Canada had historically been a major global producer and exporter of asbestos (36). In 2016, the Canadian government committed to a government-wide asbestos strategy, including an asbestos ban in 2018 (37). However, asbestos still exists in the insulation and other building materials in many older buildings (e.g., roof shingles, tiles, cement) (35) and in newly imported asbestos-containing products (38). Asbestos can also be found in a number of legacy products in the manufacturing, construction and commercial sectors, such as in friction materials (e.g., brake linings, automobile clutch pads (25, 39).

There is well-established scientific evidence that all forms of asbestos cause lung cancer and mesothelioma, a rare but aggressive form of cancer of the lining of the lungs and other organs (40). Asbestos also causes cancer of the larynx and ovary and there is some evidence that has linked it to an increased risk of colorectal, pharyngeal and stomach cancers (40). Smokers who are occupationally exposed to asbestos have a greatly increased risk of developing lung cancer (25). Asbestos-related cancers have a long latency and, as a result, some cancers diagnosed today are the result of exposure that took place up to 50 years ago (41). In addition to cancer, asbestos causes asbestosis, an incurable condition characterized by the formation of scar tissue in the lungs (42).

EXPOSURE

Occupational asbestos exposure occurs from inhaling fibres released from asbestos-containing products and building materials (43). Para-occupational, or "take-home" exposure, occurs when a family member is exposed to asbestos-contaminated clothing brought home by the worker. Para-occupational exposure levels can put family members at increased risk of mesothelioma and other asbestos-related diseases (44).

CAREX Canada estimates that approximately 152,000 workers are occupationally exposed to asbestos in Canada annually (42). Most occupational exposure (89%) occurs in construction, primarily due to the maintenance, renovation and modification of existing public, residential and commercial buildings. Other workers that may be exposed include: brake repair workers in the automotive repair and maintenance sector, and people who repair and maintain ships in the transportation equipment manufacturing industry.

BURDEN

In Canada, approximately 1,900 lung cancers, 430 mesotheliomas (including 20 cases attributed to para-occupational exposure), 45 laryngeal cancers and 15 ovarian cancers are caused by occupational asbestos exposure each year (Figure 6). These cancers account for 8% of lung cancers, 81% of mesotheliomas, 4% of laryngeal cancers and 0.5% of ovarian cancers diagnosed annually across Canada. The remaining mesothelioma cases are likely due to environmental asbestos exposure. There are additional cancers of the colon, rectum, stomach and pharynx that are likely due to asbestos, but it was not possible to estimate the number of possible cases.

More than half (55%) of lung cancers and mesotheliomas caused by occupational asbestos exposure are diagnosed among workers who were employed in the manufacturing and construction sectors (Figure 6). Approximately 11% of these cancers occur in the transportation and storage sector and in government services. Cancers diagnosed in government service sector workers are likely due to the extensive use of asbestos in many government buildings, particularly those built before the 1980s. The remaining cancers caused by occupational asbestos exposure occur in industries such as communication and other utilities, trade, educational services and mining.

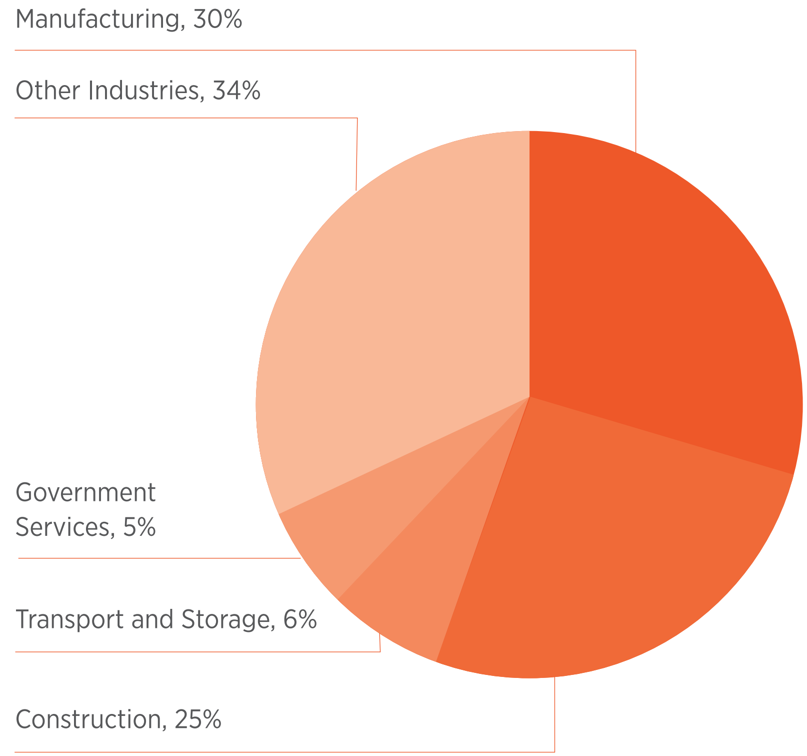


Figure 6. Industry breakdown of total lung cancers and mesotheliomas attributed to occupational asbestos exposure in 2011.

*Total count of cases of mesothelioma includes 20 cases attributed to para-occupational asbestos exposure.

1,900 Lung cancers (AF = 8.0%)

430 Mesothelioma* (AF = 80.5%)

45 Laryngeal cancers (AF = 3.7%)

15 Ovarian cancers (AF = 0.5%)

Figure 7 presents the occupational burden of lung cancers and mesothelioma, by province. Approximately two thirds of lung cancers and mesotheliomas caused by occupational asbestos exposure are diagnosed in Ontario and Quebec. This is consistent with the majority of Canada's asbestos mines being historically located in those two provinces. The provinces with the highest attributable fractions of lung cancer are Saskatchewan and Quebec, where 11.5% and 9% of the estimated total lung cancers diagnosed each year are caused by occupational asbestos exposure, respectively (Figure 7).

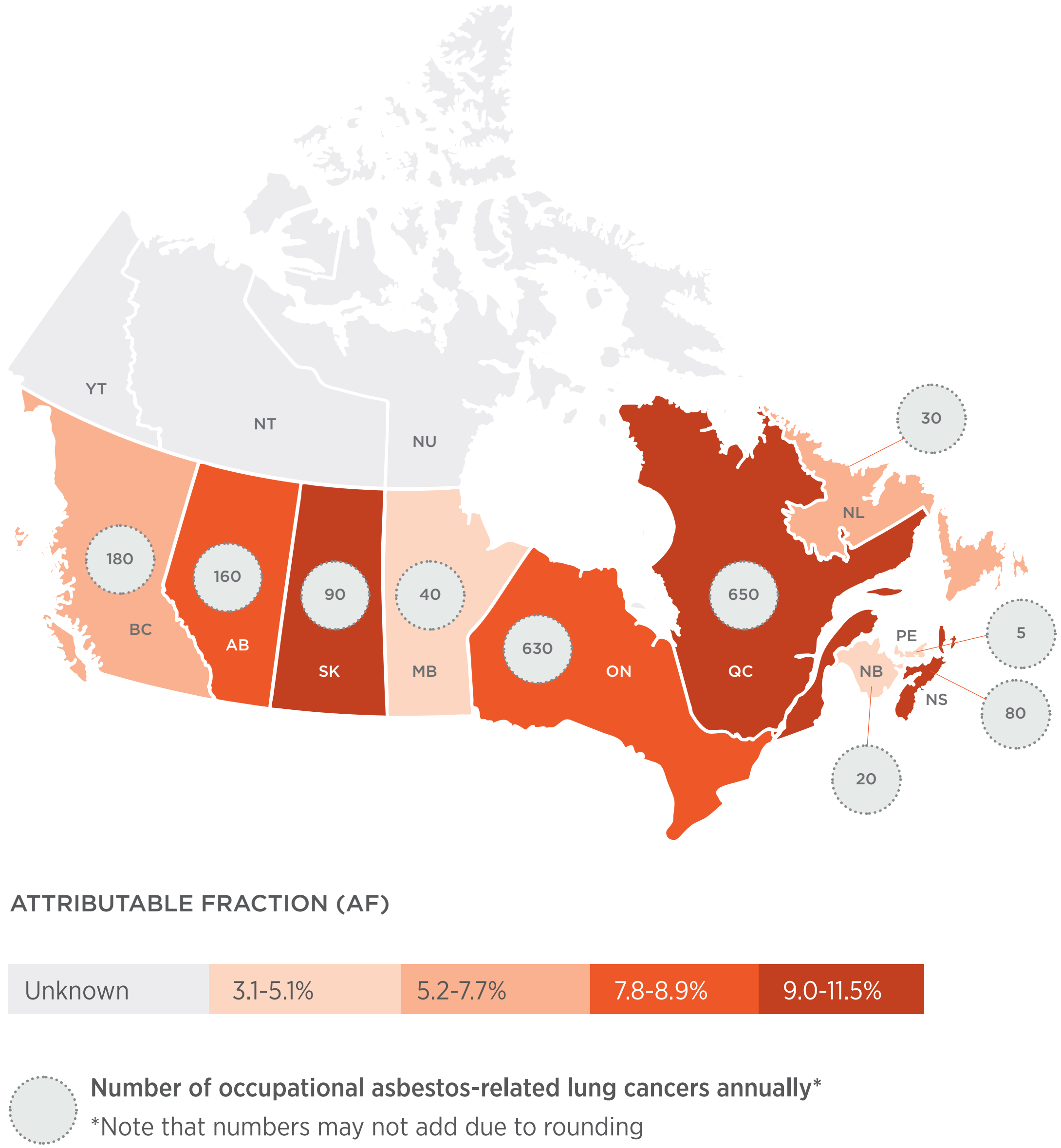


Figure 7. Provincial breakdown of total lung cancers attributed to occupational asbestos exposure in 2011.

EXPOSURE REDUCTION STRATEGIES

On December 30, 2018, the federal government's legislation prohibiting asbestos in Canada came into force. The regulation, called Prohibition of Asbestos and Products Containing Asbestos Regulations (SOR/2018-196), prohibits the use, sale, import of asbestos and the manufacture, import, sale and use of products containing asbestos under the authority of the Canadian Environmental Protection Act, 1999 (45). In addition, the export of all forms of asbestos is now prohibited to most countries to ensure Canada is compliant with its export obligations under international conventions such as the Rotterdam Convention. There are also plans to expand the registry of federal buildings containing asbestos and remove all references to asbestos from the National Building Code of Canada (46).

In 2017, the federal government lowered the exposure limit for airborne chrysotile asbestos from 1 fibre per cubic centimetre (f/cc) to as close to zero as is reasonably possible, but not exceeding 0.1 f/cc, which is in line with the majority of Canadian provinces. The revised exposure limit is also in alignment with the American Conference of Governmental Industrial Hygienists' (ACGIH) recommended limits (47).

The handling and remediation of asbestos are regulated and controlled tasks that require trained individuals to use a combination of engineering and administrative controls in combination with appropriate PPE. There are numerous exposure reduction strategies that can be adopted by workplaces to reduce occupational exposure to all forms of asbestos. Engineering controls for people who must work with asbestos include using a vacuum equipped with a high-efficiency particulate air (HEPA) filter and brush attachment and using wet processes. Administrative controls include: prohibiting eating, drinking or smoking in areas where asbestos is present; and, providing showers, lockers, change rooms and laundering facilities at the worksite, which can also help reduce para-occupational (take-home) exposures among family members of asbestos-exposed workers (48, 49). While these exposure reduction strategies play an important role in reducing occupational diseases related to the exposure to asbestos in the workplace, only a comprehensive asbestos ban and eventual removal from all building components and other sources over time will completely eliminate exposure to asbestos.

POLICY RECOMMENDATIONS FOR ASBESTOS

The general, overarching policy recommendations, presented later in this report, can be applied to asbestos in addition to the following specific recommendations:

Create a public registry of all public buildings and workplaces that contain asbestos.

A public registry would inform the public and workers about where asbestos (all forms) currently exists in buildings (50). This recommendation adds to existing legislation in provinces like Ontario and British Columbia, which already mandate that employers assess the risk of exposure to asbestos on construction and demolition projects, in buildings and in repair operations, and help to identify buildings that require regular inspection (51, 52). Developing both a provincial and a national registry would be beneficial. A provincial registry will facilitate the enforcement of occupational health and safety regulations, which occurs at the provincial level, while a national registry will ensure consistency in data collection across provinces.

Saskatchewan is the only Canadian province with a mandatory online public building registry. This registry, maintained by the Labour Relations and Workplace Safety Ministry, includes all buildings owned by the provincial government, health regions, crown corporations and public schools (53). A similar federal registry includes all buildings owned or leased by Public Services and Procurement Canada, and has recently expanded to include all federal buildings owned or leased by other government departments (54). The federal registry also requires buildings that contain asbestos-containing material to have an Asbestos Management Plan, which contains all of the information related to the management of asbestos in that facility and communicates processes for working with asbestos-containing materials (55). It is recommended that public registries include all workplaces, particularly those built before 1980, when asbestos was widely used in building construction. A public registry should also contain information about current measures and plans to remediate or control asbestos exposure in buildings.

Establish provincial inter-ministerial working groups to develop an implementation framework for the asbestos ban and related exposure monitoring and reporting.

Preventing occupational exposure to asbestos (all forms) is a complex issue that necessitates a coordinated approach by multiple government agencies. A working group led by a central agency with representation from multiple other agencies (including provincial Ministries of Labour, Environment, Health, and Infrastructure) and key stakeholders (including organized labour and employer groups) is necessary to address all of the diverse issues associated with asbestos. These include: occupational health and safety, safe disposal, public health, and building renovation and abatement. An inter-ministerial working group, which will engage with the federal government and various stakeholders to support the implementation of Canada's recent asbestos ban, has already been established in British Columbia and may be used as a model (56).

Develop a mandatory national standard and regulatory framework for asbestos disposal.

While the asbestos ban was key to preventing exposure to new sources of asbestos, an important part of reducing future exposure to asbestos will require the development of a national standard and regulatory framework for the safe and consistent disposal of existing asbestos across Canada. This mandatory standard should be based on best practices in asbestos disposal that ensure the protection of workers and the public during asbestos remediation and disposal. The standard must provide supports to employers and residents with older buildings and homes to help them address asbestos in a healthy and safe manner while minimizing exposure during disposal. The standard should also mandate that consideration of proper asbestos remediation and disposal procedures be required during the planning and tendering phases of all major construction projects. Ongoing inspection and enforcement of workplaces with asbestos-containing materials is needed to ensure compliance with existing provincial regulations on asbestos management and disposal in the interim. In addition, the development of consistent education and training materials as part of a broader certification process for workers conducting asbestos removal and disposal would ensure that workers are provided with the skills necessary to conduct asbestos remediation and disposal safely across Canada. In Australia, anyone who removes asbestos must hold a license that is issued after undergoing a mandated certification and training program with their local state or territorial workplace health and safety regulator (57).

Remove any remaining exemptions from the ban.

Currently Canada's asbestos ban includes exemptions to allow military, nuclear and chlor-alkali plants to continue using asbestos. In the case of chlor-alkali plants, the industry has until the end of 2029 to phase out the import and use of asbestos in their production processes. Exemptions currently also exist for road infrastructure that was produced prior to the ban coming into force, allowing for asbestos in road mounds and noise barriers to be reused in road infrastructure (58). The development of new technology should be promoted to facilitate the phasing out of asbestos to address these remaining exemptions moving forward (e.g. through providing innovation grants).

DIESEL ENGINE EXHAUST

Diesel engine exhaust (DEE) is a complex mixture of gases and particulates produced from the combustion of diesel fuel (43). Diesel engines are used in vehicles on-road and off-road (e.g., trucks, trains, ships) and in industrial equipment (e.g., in mining, construction) (59). DEE has been classified as a known carcinogen based on evidence that it causes lung cancer (60). There is also limited, but growing, evidence that DEE causes bladder cancer (60, 61). DEE exposure has also been associated with respiratory effects (e.g., increased airway resistance, respiratory inflammation) and adverse cardiovascular health outcomes (62).

EXPOSURE

The primary route of exposure to DEE is via inhalation (43). CAREX Canada estimates that approximately 897,000 Canadian workers, or about 5% of the working population, are occupationally exposed to DEE. The majority of workers occupationally exposed to DEE in Canada are drivers of diesel engine vehicles or heavy equipment (Figure 8) (63). Elemental carbon measurements are often used as a surrogate for capturing the carcinogenic effects of DEE since concentrations of elemental carbon (EC) can be accurately measured at low levels and DEE is a significant source of EC in the air (64).

The majority of affected workers are exposed to low levels of DEE (approximately 87%), compared to moderate or high levels (11% and 2%, respectively) (63). Workers are exposed to low levels of DEE if they work above ground, work near traffic-related sources of diesel exhaust or are bystanders (i.e., working near, but not operating, diesel equipment). Truck drivers are the primary group exposed to low levels, but low-level exposures also occur in transit drivers, school bus drivers, heavy equipment operators and firefighters, among others. Generally, exposure levels for truck, bus and taxi drivers range from 1 to 10 µg/m^3 EC (65).

Workers are exposed to moderate levels if they repair or maintain diesel-powered equipment; for example, mechanics are exposed to concentrations of approximately 20 to 40 µg/m^3 EC (65). High levels of exposure occur primarily in people who work in underground mines, where diesel-powered equipment is commonly used and ventilation can be poor. Exposure concentrations typically range from 30 to 660 µg/m^3 EC in underground mines (65). Although there are relatively few workers exposed to high levels of DEE compared to workers exposed to low and moderate levels, from a health standpoint, these exposures are significant because cancer risk increases with level of exposure. This increased risk is reflected in the burden estimates.

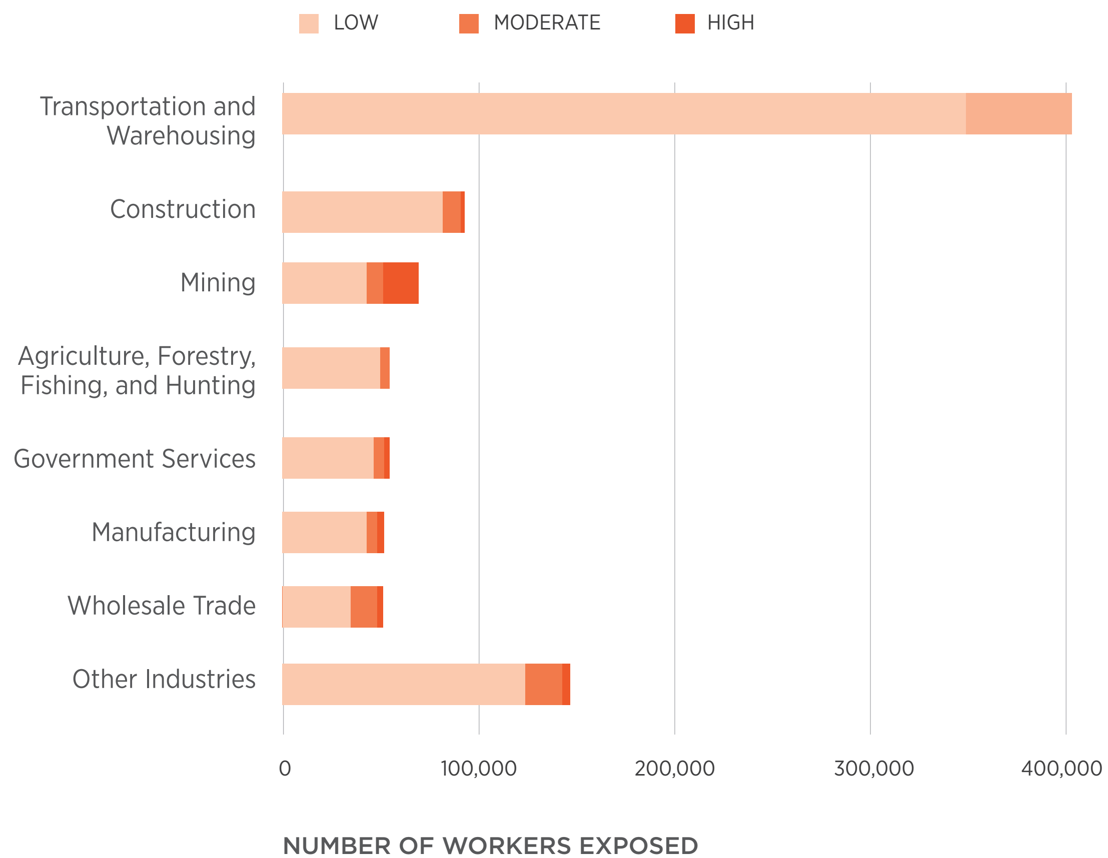
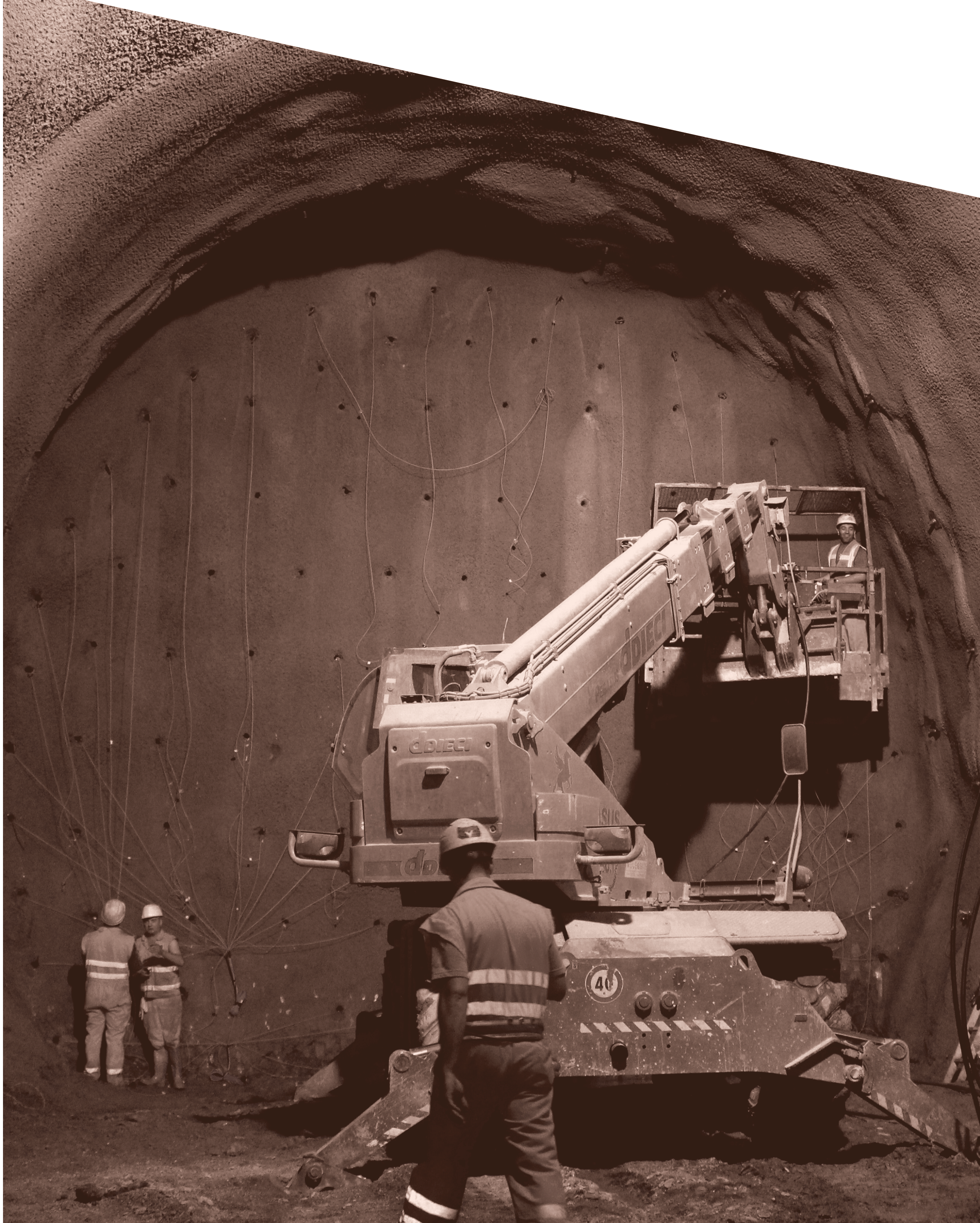


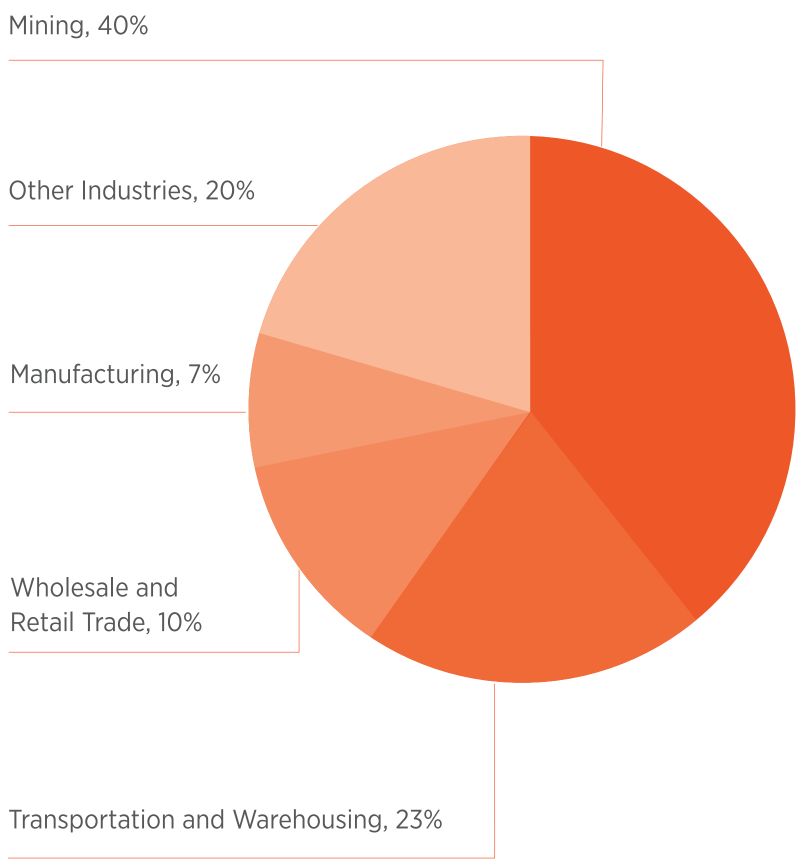
Figure 8. Number of workers occupationally exposed to DEE by level of exposure and industry in Canada in 2006.

BURDEN

Approximately 560 cases of lung cancer diagnosed annually in Canada are from occupational exposure to DEE (Figure 9). This accounts for 2.4% of the estimated total lung cancers diagnosed each year. The burden of lung cancer is highest in mining, where workers are exposed to high levels of DEE, as well as in transportation and warehousing, where the largest number of workers are exposed of any industry, though at lower levels.

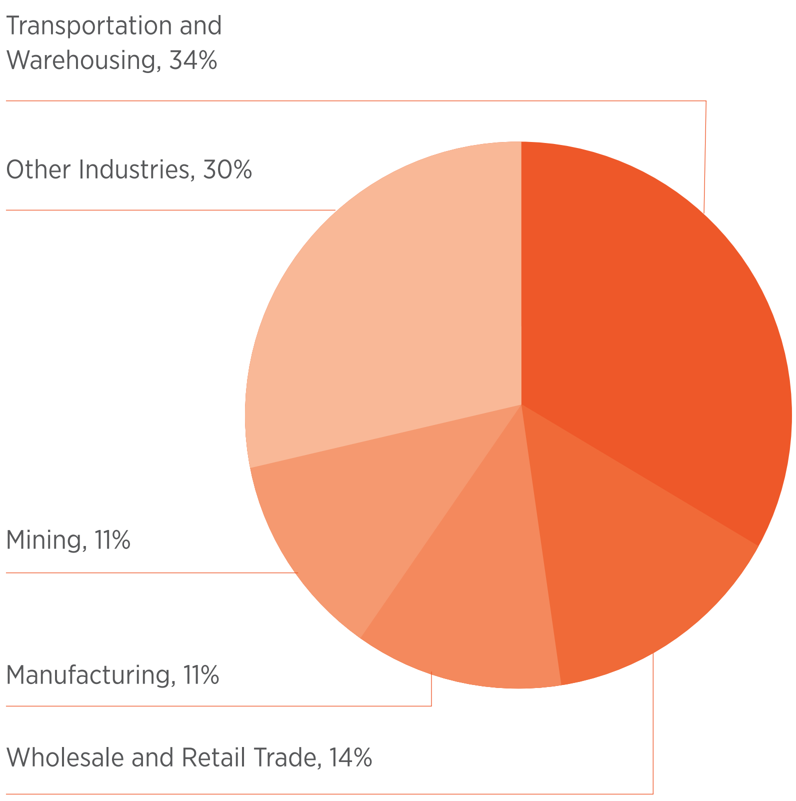
In addition, approximately 200 cases of bladder cancer diagnosed annually in Canada may be from occupational exposure to DEE (or 2.7% of the estimated total annual bladder cancers) (Figure 10), with most cases occurring in the transportation and warehousing industries. The burden of bladder cancer appears highest among transport and equipment operators.





560
Lung cancers
AF = 2.4%

Figure 9. Industry breakdown of total lung cancers attributed to occupational diesel engine exhaust (DEE) exposure in 2011.



200
Bladder cancers
AF = 2.7%

Figure 10. Industry breakdown of total bladder cancers attributed to occupational diesel engine exhaust (DEE) exposure in 2011.

Figure 11 presents the occupational burden of lung cancers associated with DEE exposure, by province. The provinces with the highest attributable fractions of lung cancer caused by DEE are all located in Atlantic Canada. They include New Brunswick, Nova Scotia, and Newfoundland and Labrador, where 3.4%, 4.1% and 5.1% of the estimated total lung cancers diagnosed each year are caused by exposure to DEE, respectively (Figure 11).

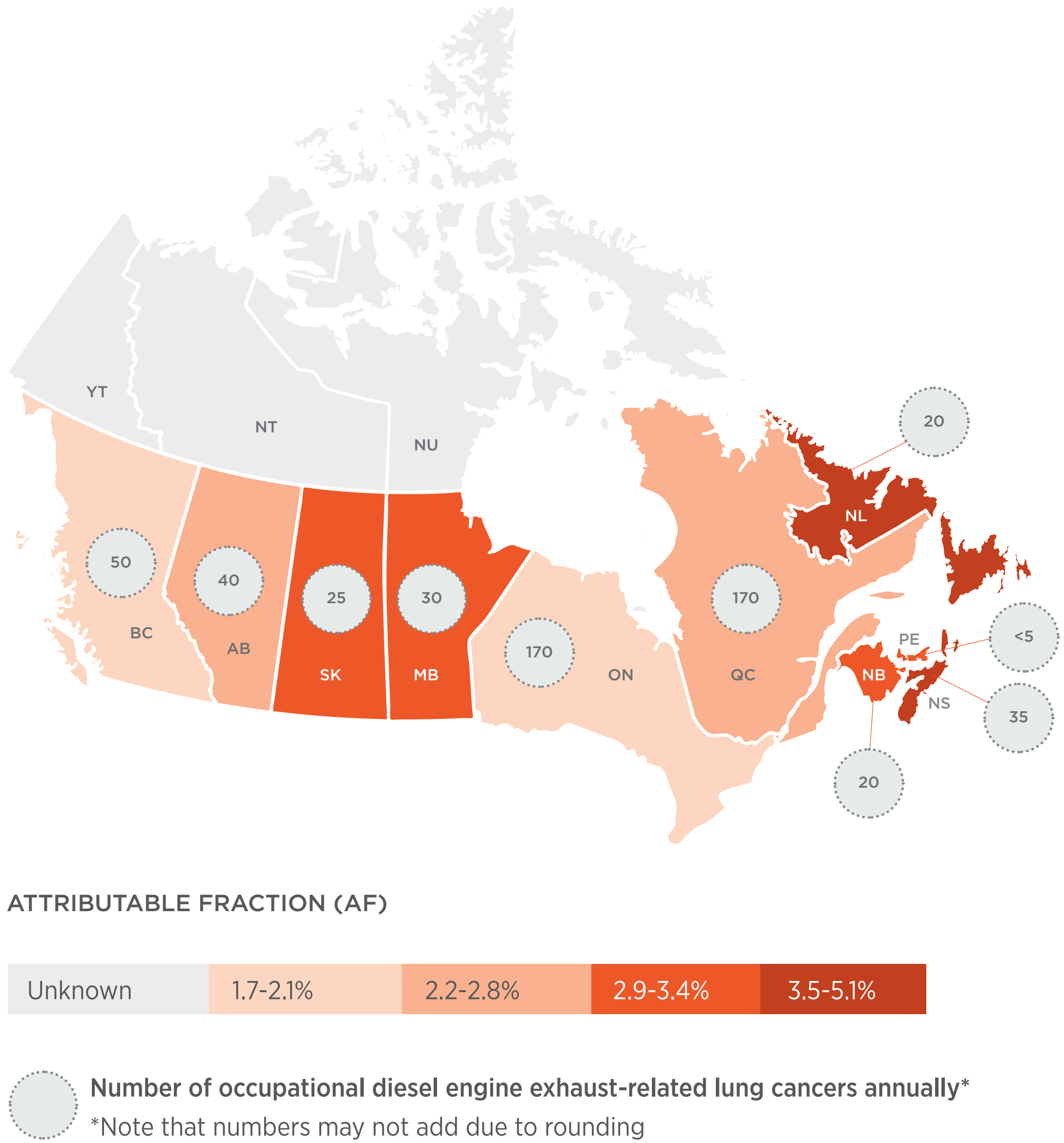


Figure 11. Provincial breakdown of total lung cancers attributed to occupational diesel engine exhaust (DEE) exposure in 2011.

EXPOSURE REDUCTION STRATEGIES

Exposure to DEE occurs in many Canadian workplaces. Preventing and controlling occupational exposure (e.g., by reducing emissions from trucks and buses) will also have the side benefit of reducing environmental emissions that affect the general population.

Options for controlling exposure through substitution include: using alternatives to diesel fuel, such as natural gas, propane, electricity and hydrogen fuel cells (66); replacing old engines with low-emission diesel engines or rebuilding old engines and performing regular engine maintenance (67); using reformulated diesel (i.e., diesel made with lower ratios of its hazardous constituents) or biodiesel fuel (68); or using low sulfur diesel fuel, which has been shown to reduce carbon-containing particulate emissions (69, 70).

A range of engineering controls can be implemented to reduce DEE exposure, including: installing pipe exhaust extenders and using enclosed pressurized cabs equipped with HEPA filters to better isolate workers from the exhaust (68); implementing exhaust treatment systems (e.g., tailpipe filters, oxidation catalytic converters) to help to reduce the overall amount of harmful exhaust being released into the air (68); and implementing technology to automatically turn off idling vehicles (67). Indoor areas should be adequately ventilated with positive pressure ventilation to keep diesel out of the indoor work environment and/or exhaust extraction devices should be used to remove diesel engine exhaust from the indoor work environment (e.g., tail pipe exhaust extraction systems used in fire halls) (68, 71). Provincial mining regulations mandate some engineering requirements related to controlling DEE, such as requirements for adequate air flow (72).

Available administrative controls include: reducing engine idling, maintaining engines and vehicle bodies regularly; running engines outdoors; and implementing job rotation or scheduling work to minimize the number of workers near a diesel engine in operation (68, 70).

More information on controlling exposure to DEE in mining can be found in the United States Department of Labor’s “Practical Ways to Reduce Exposure to Diesel Exhaust in Mining—A Toolbox” (70).

POLICY RECOMMENDATIONS FOR DIESEL ENGINE EXHAUST

The general, overarching policy recommendations, presented later in this report, can be applied to DEE in addition to the following specific recommendations:

Adopt occupational exposure limits of 20 μg/m³ and 5 μg/m³ (8-hour time-weighted average, based on elemental carbon) for the mining industry and other workplaces, respectively and continue to work towards limits that reflect the current science.

Occupational exposure limits exist for various components of diesel engine exhaust (e.g., formaldehyde, benzene, 1,3-butadiene) across the provinces. However, outside of the mining industry, no occupational exposure limits currently exist for elemental carbon in any province, which is considered the best surrogate for capturing the carcinogenic effects of DEE (64). As of 2019, only Ontario has proposed to introduce a new occupational exposure limit for diesel particulate matter (160 μg/m³ total carbon). Several jurisdictions, including Finland, have implemented standards of 100 μg/m³ elemental carbon (73). However, the Finnish Institute for Occupational Health recommends occupational exposure limits of 20 μg/m³ elemental carbon for the mining industry and 5 μg/m³ elemental carbon for other workplaces (74), based on evidence of health effects and feasibility considerations. While our recommendation is in line with these limits recommended by the Finnish Institute for Occupational Health, other jurisdictions have recommended more ambitious health-based limits. For example, the Health Council of the Netherlands has proposed two health-based limits - a prohibition risk level of 1.03 μg/m³ elemental carbon and a target risk level of 0.011 μg/m³ elemental carbon (75). Setting an aspirational health-based limit as well as strengthening interim limits during a transition period would be one way of presently driving down occupational exposures to DEE until compliance with the health-based limit is achievable.

Upgrade or replace old on-road and off-road trucks and diesel engines.

Since engine replacement and/or the installation of engineering controls are better able to reduce overall DEE emissions than other controls, mandating the transition to upgraded off-road and on-road engines within five years could result in significant decreases in exposure to DEE. Such regulations have been implemented in other jurisdictions such as California (76). Though upgrading old engines or vehicles may be costly, regulations could be rolled out incrementally and accompanied with financial supports for companies affected (e.g., through financial awards or tax credits) (77). In the interim, mandatory emissions testing targeting aged trucks and diesel engines could set priorities for the upgrade and replacement of these vehicles. Municipalities may also have a role to play in encouraging vehicle upgrades of trucks and diesel engines, as many municipalities require specific vehicles to pass inspections as a condition of licensing. For example, the City of

Toronto requires tow truck owners to undergo mechanical inspections through the Ontario Ministry of Transportation at the time of license application and renewal prior to receiving a permit to operate in the city (78).

SILICA (CRYSTALLINE)

Silica is a common mineral found in soil, sand and rock (25). Crystalline silica can be used for various purposes, including as an abrasive, insulator, and filler. However, a variety of industrial processes (e.g., cutting, grinding, drilling, etc.) result in a dust containing fine crystalline silica particles. This fine particulate is found in a number of industries, including construction, glass and ceramics, electronics and optical components (40).

There is strong and consistent evidence that exposure to fine crystalline silica dust causes lung cancer. Occupational exposure to silica also causes silicosis, an incurable non-cancerous condition that causes lung tissue to scar, thicken and stiffen (79). Other non-cancer health effects include autoimmune and chronic kidney disease, and chronic obstructive pulmonary disease (79, 80).

EXPOSURE

Inhalation of silica is the only route of exposure that is linked to cancer and other health outcomes. CAREX Canada estimates that there are 382,000 workers occupationally exposed to silica in Canada (81). Of these, approximately 48% are exposed to low levels of silica, 38% to moderate levels and 14% to high levels (81).

Because silica is ubiquitous in many common materials and industrial processes, exposure occurs in a large number of diverse occupations during activities that release fine silica dusts, such as grinding, cutting, drilling or chipping (82, 83). The majority of exposures occur at low and moderate levels in the construction industry, particularly among construction tradespersons and helpers, plumbers, plasterers and bricklayers (Figure 12). Another major group in which exposure occurs is heavy equipment operators, who are employed across multiple industry sectors. Over half of the workers with high exposures work in the manufacturing sector. Workers in the underground mining industry are particularly susceptible to exposure due to confined work locations.

BURDEN

Occupational silica exposure causes approximately 570 cases of lung cancer each year in Canada. The majority of these lung cancers (56%) are diagnosed in workers in the construction industry, followed by the manufacturing and mining industries (21% and 14%, respectively) (Figure 13). These cancers amount to 2.4% of all lung cancers diagnosed annually in Canada.

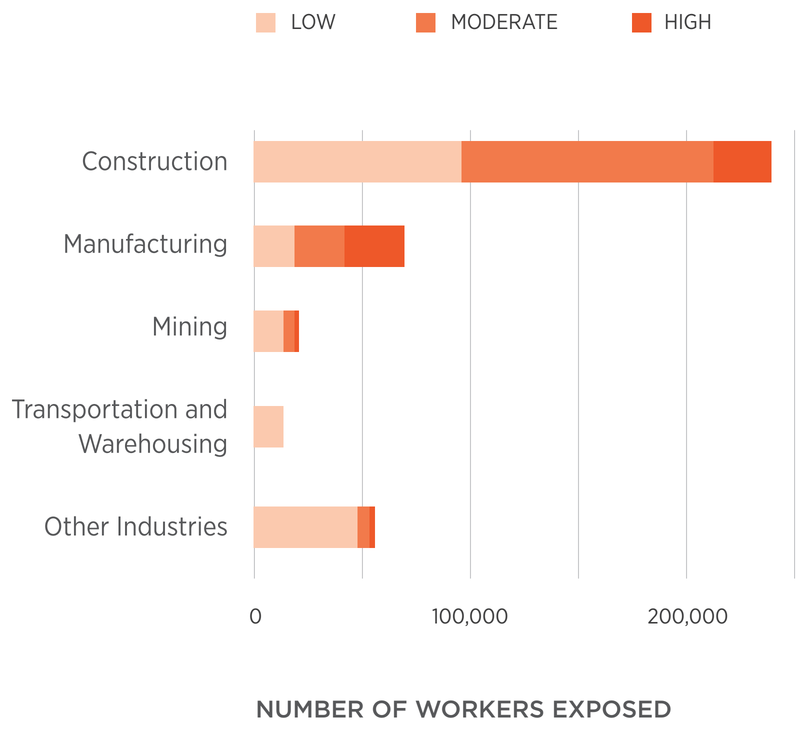


Figure 12. Number of workers occupationally exposed to crystalline silica by level of exposure and industry in Canada in 2006.

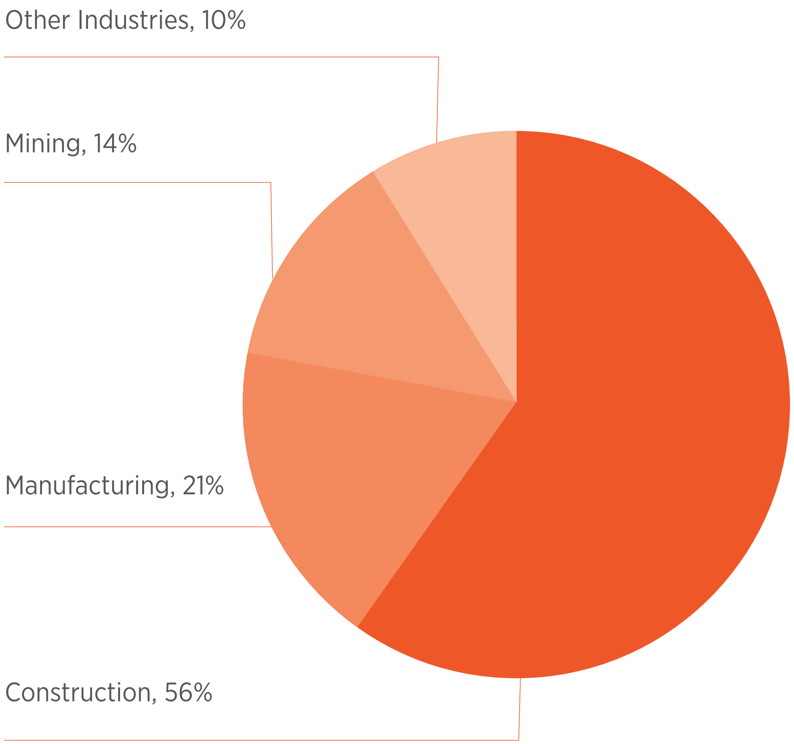


Figure 13. Industry breakdown of total lung cancers attributed to occupational crystalline silica exposure in 2011.

570
Lung cancers
AF = 2.4%

Figure 14 presents the occupational burden of lung cancers associated with occupational silica exposure, by province. The province with the highest attributable fraction of lung cancer caused by silica exposure is Newfoundland and Labrador (4.0%), followed by Nova Scotia and New Brunswick (2.9% each) (Figure 14).

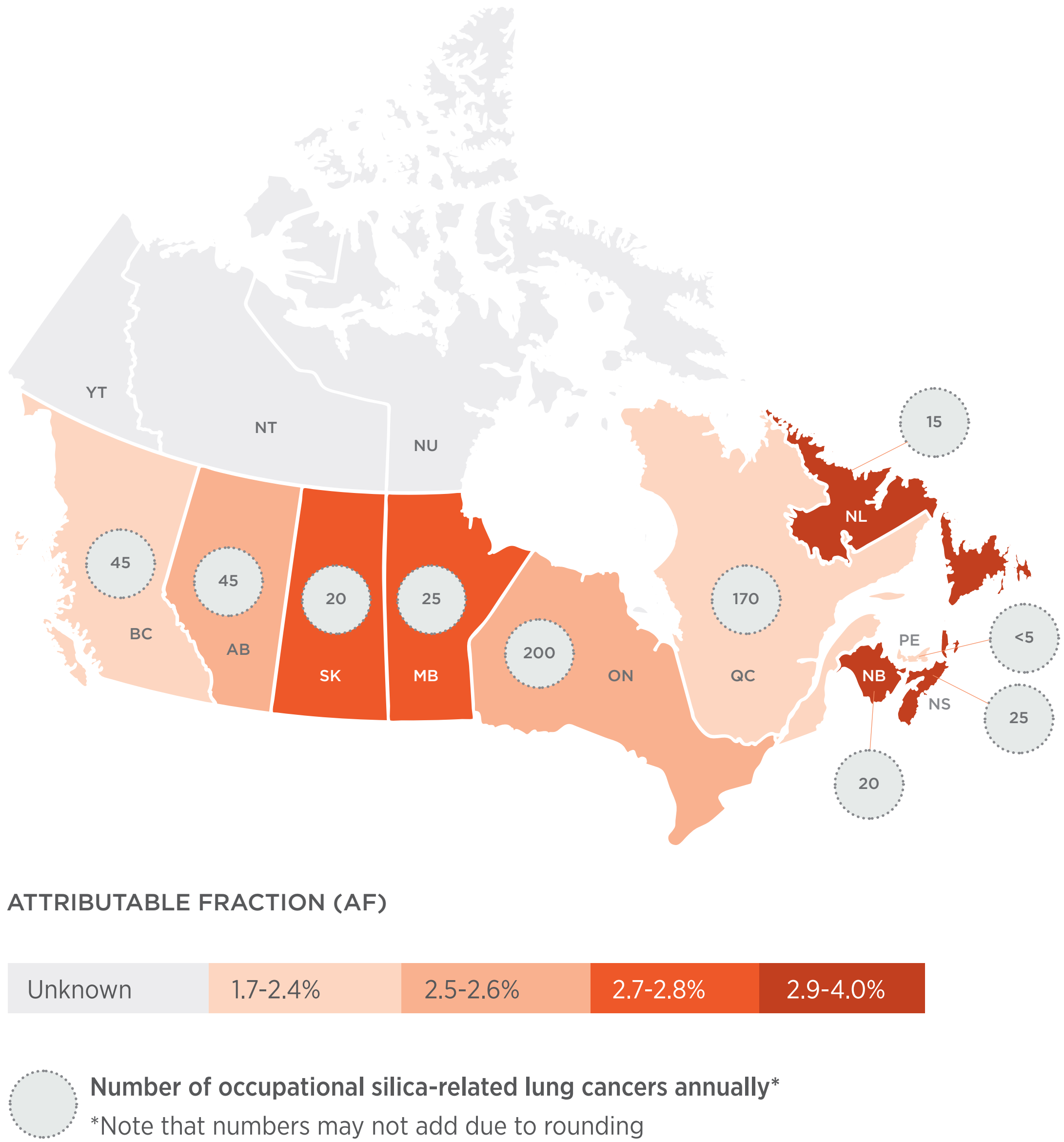


Figure 14. Provincial breakdown of total lung cancers attributed to occupational silica exposure in 2011.

EXPOSURE REDUCTION STRATEGIES

To reduce occupational exposure to silica, the use of safer alternatives for silica-containing products should be considered. For example, silica in sand-blasting operations may be replaced by garnet, alumina, cereal husks and/or high pressure water (84). Sandstone grinding wheels can be replaced with aluminum oxide wheels, and silica bricks in furnaces can be replaced with magnesite or aluminum oxide bricks (84). Where elimination of silica-containing materials is not possible, processes that generate respirable crystalline silica (i.e., silica that can be deposited deep within the respiratory tract) could potentially be eliminated or adapted. For example, creating a smooth surface while pouring concrete reduces the need to grind rough concrete, which in turn would reduce silica exposures.

Where silica substitution or process changes are not available, engineering controls provide the next best level of protection. Examples include: using local exhaust ventilation with dust collectors and filters (80), process enclosure to prevent the release of dusts into the workplace and during the disposal of waste from vacuums and ventilation systems (85), mechanized processes (80) and placing workers in enclosed cabs with filtration systems (86). In addition, workers should be trained to select processes (e.g., wet cutting) and tools that are the least likely to generate respirable dusts (84).

Administrative controls that can be employed to reduce occupational silica exposures include: maintaining good housekeeping practices (e.g., using HEPA-filtered vacuums and wet sweeping methods instead of dry sweeping or cleaning with compressed air), maintaining dust control equipment, removing excess dust from clothing and skin, and removing work clothes at the work site (80).

The use of an online tool and resources can assist employers in implementing exposure controls and safe work practices. For example, the BC Construction Safety Alliance Silica Control Tool houses data on worker exposure to respirable crystalline silica associated with different materials and work practices (87). The Silica Control Tool allows employers to conduct risk assessments and implement the degree of controls necessary to reduce crystalline silica levels to acceptable levels. The tool works by estimating the exposure level associated with specific tasks, tools and/or materials, as well as by providing information on how to control exposure and a corresponding exposure control plan.

POLICY RECOMMENDATIONS FOR SILICA

The general, overarching policy recommendations, presented later in this report, can be applied to silica in addition to the following specific recommendations:

Adopt, implement and enforce an occupational exposure limit of 0.025 mg/m^3 (8-hour time-weighted average) for respirable silica at all workplaces in Canada.

Occupational exposure limits for silica vary across Canada. In most provinces, the OEL for both quartz and cristobalite is 0.025 mg/m^3, consistent with the American Conference of Governmental Industrial Hygienists. However, the OEL for both quartz and cristobalite is 0.05 mg/m^3 in Saskatchewan, while the limits are 0.05 mg/m^3 (cristobalite) and 0.1 mg/m^3 (quartz) in New Brunswick, Quebec and Ontario. Reducing the OEL for silica to 0.025 mg/m^3 in provinces where it is currently higher, in tandem with effective enforcement, would help reduce exposures, thereby reducing the risk of lung cancer and silicosis.

Collect exposure data and monitor levels of silica in conjunction with the implementation of a silica control plan.

Preventing occupational disease due to silica exposure will also require the ongoing measurement and monitoring of exposure levels to silica. The implementation of mandatory air monitoring at work sites where workers may be exposed to respirable silica at harmful levels could help provincial governments track workplace exposures and highlight cases of overexposure that require more effective controls at the work site. The collection of exposure data and ongoing monitoring should be implemented as part of a broader silica control plan. In British Columbia, a silica exposure control plan must be developed by employers for construction projects, which sets out the employer's approach to protecting workers from silica exposure and what control measures will be selected (88). It is recommended that other provinces adopt a similar approach to developing a silica control plan.

WELDING FUMES, NICKEL COMPOUNDS AND CHROMIUM (VI) COMPOUNDS

This section examines welding fumes, nickel compounds and chromium (VI) compounds (also known as hexavalent chromium or chrome 6). Since workers may be exposed to both nickel compounds and chromium (VI) compounds through welding fumes, we have grouped these three carcinogens together for the purposes of this report. It is important to note that while exposure estimates for nickel compounds and chromium (VI) compounds include welders, burden estimates for exposures to nickel compounds and chromium (VI) compounds do not include welders because welders were already accounted for in the burden estimates for welding fumes.

WELDING FUMES

Welding fumes consist of a mixture of metallic oxides such as iron, nickel, chromium (VI), cadmium and lead. Welding fumes are formed when metals that are heated above their melting point vaporize and then condense to form fine particles (89). The composition of welding fumes depends on the metals being welded as well as the coatings or residues on the metal (90). Welding fumes as a group of compounds are known to cause lung cancer (91) and have been linked to other health effects, including irritation of the skin and respiratory systems, kidney damage and emphysema (90).

EXPOSURE

Workers are exposed to welding fumes via inhalation. CAREX Canada estimates that approximately 333,000 workers, or about 2% of the working population, are exposed to welding fumes in Canada (43). Of those, 60% are exposed to high levels, while 31% are exposed to moderate levels and 9% are exposed to low levels. Workers were considered exposed to high levels if their main job duties involve welding more often than not, moderate levels if their main job duties include welding intermittently or working in closer proximity to welding activities often, and low levels if the main route of exposure is via the bystander effect.

Welders are the primary group of workers exposed to welding fumes. However, many other workers, including construction trades helpers and labourers, automotive service technicians, machinists, and sheet metal workers, are exposed to welding fumes when welding or when working in close proximity to welders. Exposed workers are primarily employed by the manufacturing industry, followed by construction and other services industry (which includes repair and maintenance) (Figure 15). "Other industries" with exposed workers includes retail trade, transportation and warehousing, and public administration.

BURDEN

It is estimated that approximately 310 cases of lung cancer are diagnosed each year in Canada due to occupational exposure to welding fumes. Most of these lung cancer cases are diagnosed in workers from the manufacturing industry, trade, other services (e.g., metal repair shops) and construction sectors (Figure 16). On average, these cases amount to 1.3% of all lung cancer cases diagnosed annually in Canada.

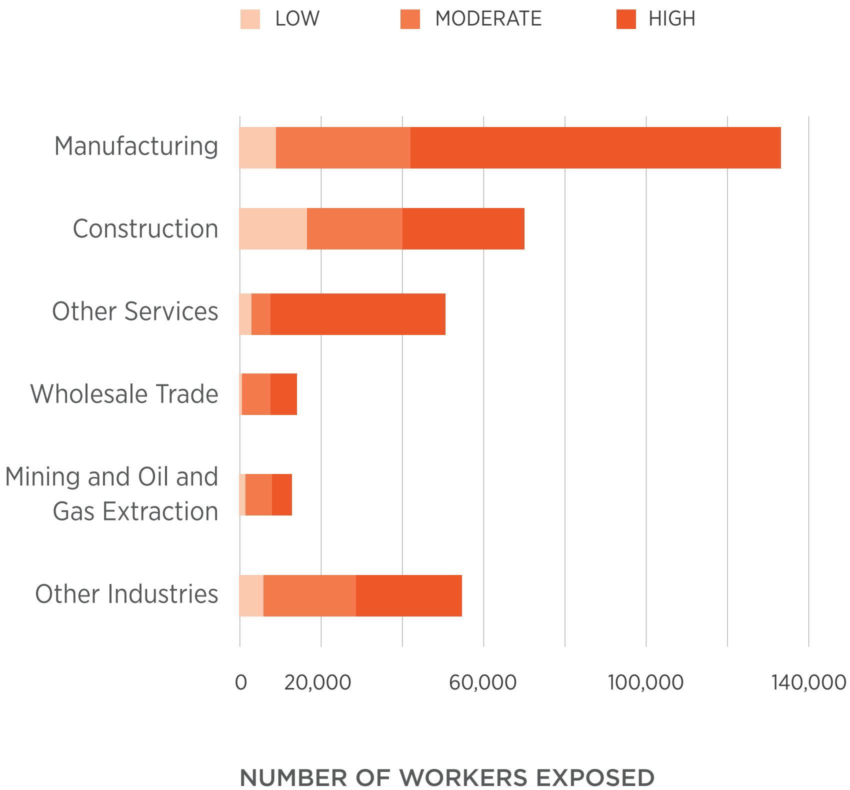


Figure 15. Number of workers occupationally exposed to welding fumes by level of exposure and industry in Canada in 2006.

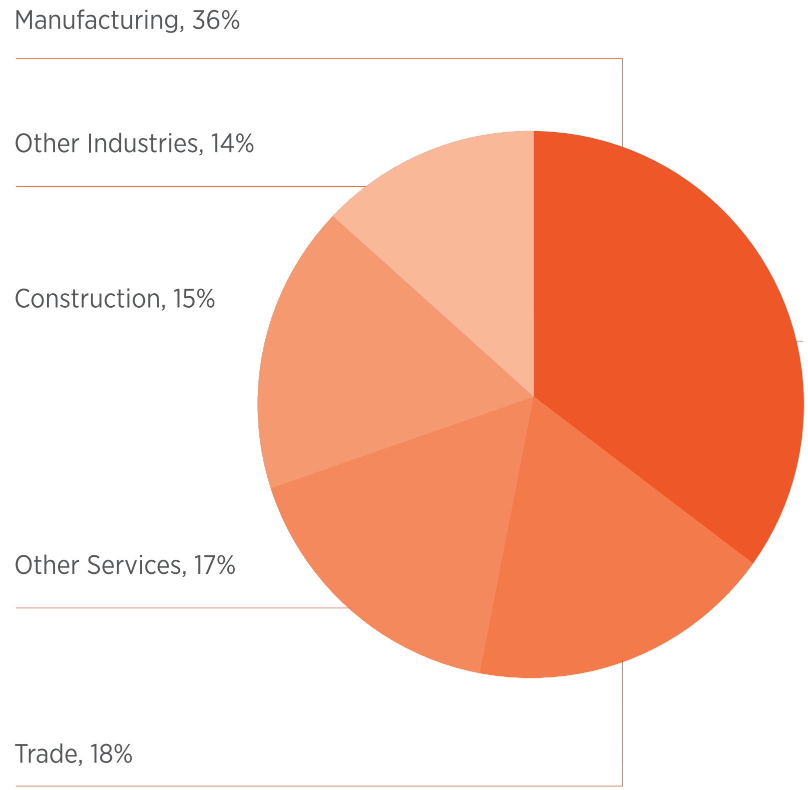


Figure 16. Industry breakdown of total lung cancers attributed to occupational welding fume exposure in 2011.

310
Lung cancers
AF = 1.3%

Figure 17 presents the occupational burden of lung cancers attributable to welding fume exposure, by province. In New Brunswick and Newfoundland and Labrador, the attributable fraction of lung cancers due to exposure to welding fumes was slightly higher at approximately 1.6% (Figure 17).

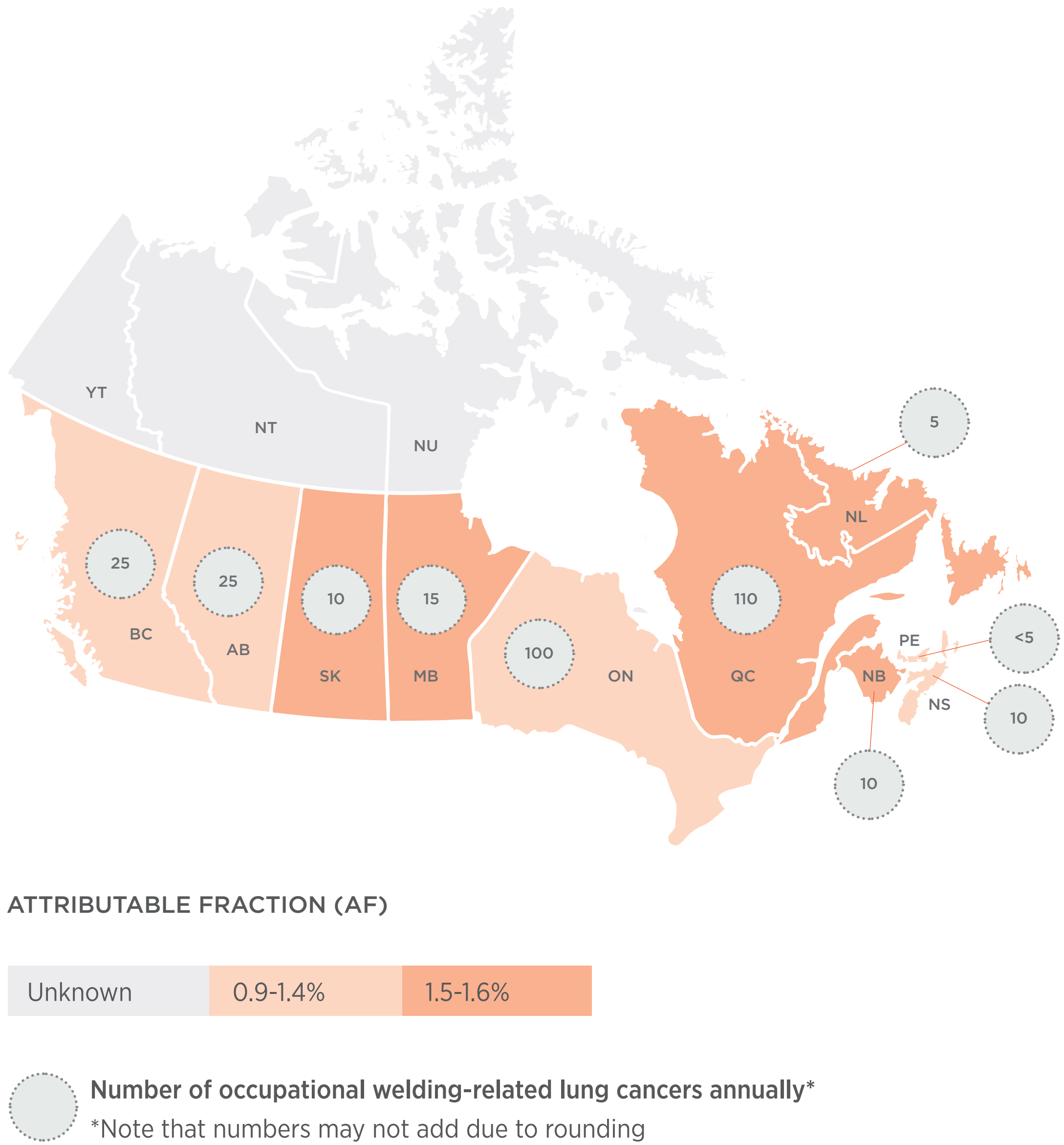


Figure 17. Provincial breakdown of total lung cancers attributed to exposure to welding fumes in 2011.

NICKEL COMPOUNDS

Nickel is a naturally occurring metal commonly used to form alloys, such as stainless steel, and in applications such as batteries, electroplating, ceramics and chemical reactions (40). There is strong evidence that nickel and its compounds cause lung, nasal and paranasal cancers (40). However, because of the small numbers of cases of nasal and paranasal cancers overall, this report will only focus on the burden of lung cancer due to occupational exposure to nickel. Nickel is also associated with chronic bronchitis, decreased lung function, and allergic skin reactions (92).

EXPOSURE

Inhalation of fumes and particles (e.g., through welding, nickel refining) and skin contact (i.e., from non-welding processes) are the primary routes of occupational exposure to nickel. Approximately 117,000 workers are exposed to nickel in Canada. Of these workers, the majority (approximately 83%) are exposed at low levels, 10% at moderate levels and 7% at high levels (Figure 18) (93). Exposure patterns for nickel are similar to exposure to chromium (VI) compounds – likely because they co-occur in some groups (i.e., welders). Welders are the single largest exposed occupational group (particularly those working with stainless steel) and they experience variable levels of exposure. High and moderate level exposures also occur in metalworkers and machine tool operators, dental technologists and metal plating operators.

BURDEN

Approximately 170 lung cancers are caused by nickel exposure in Canada each year (Figure 19), which accounts for a little under 1% of all lung cancers diagnosed annually. These results do not include the burden of cancer caused by occupational exposure to welding fumes, which have been accounted for in a preceding section of this report (see welding fumes). The largest number of cancers due to nickel exposure occur in the manufacturing industry (Figure 19). Workers with the greatest burden of lung cancer are machine operators and assemblers who process mineral ores, metal or other substances before manufacturing (e.g., smelting).

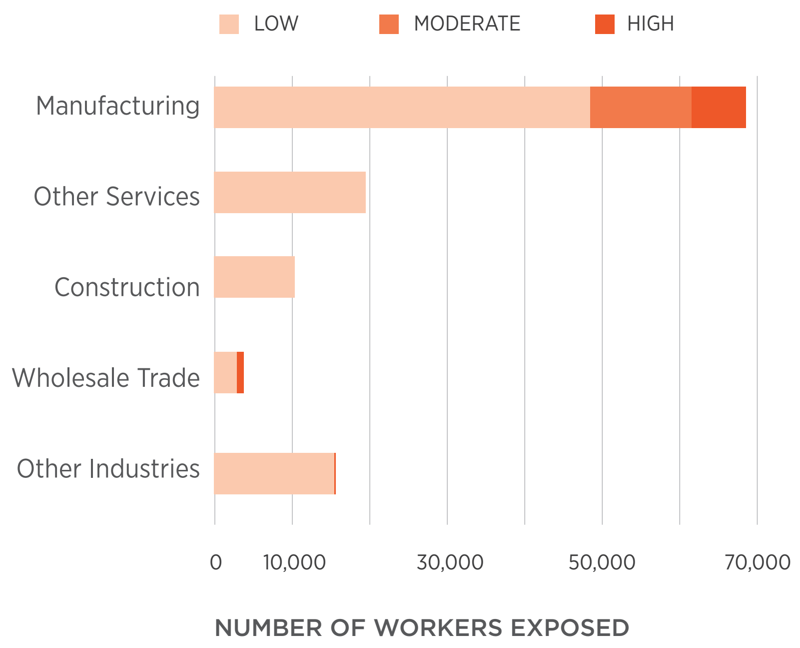


Figure 18. Number of workers occupationally exposed to nickel by level of exposure and industry in Canada in 2006.

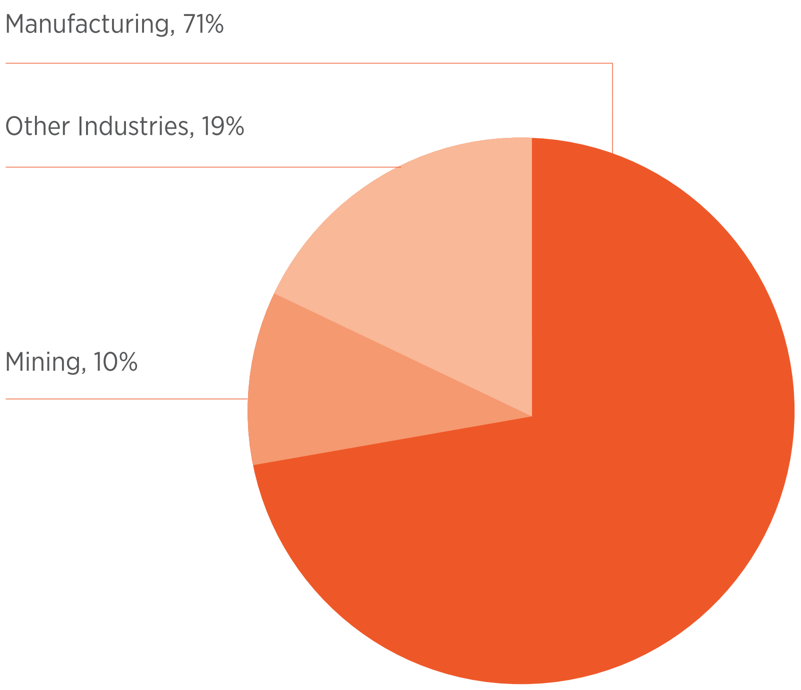


Figure 19. Industry breakdown of total lung cancers attributed to occupational exposure to nickel compounds in 2011.

170
Lung cancers
AF = 0.7%

Four Canadian provinces have active nickel mines, including Manitoba, Ontario, Quebec and Newfoundland and Labrador (93). Figure 20 presents the occupational burden of lung cancers attributable to nickel exposure, by province. The province with the highest attributable fraction of lung cancer caused by exposure to nickel compounds is Ontario, where nearly 1.0% of the estimated total lung cancers diagnosed each year are caused by occupational nickel exposure, followed by Manitoba and Quebec (0.7% each) (Figure 20). These figures are consistent with the large manufacturing base located in Ontario, where many workers are exposed to nickel and other metal products.

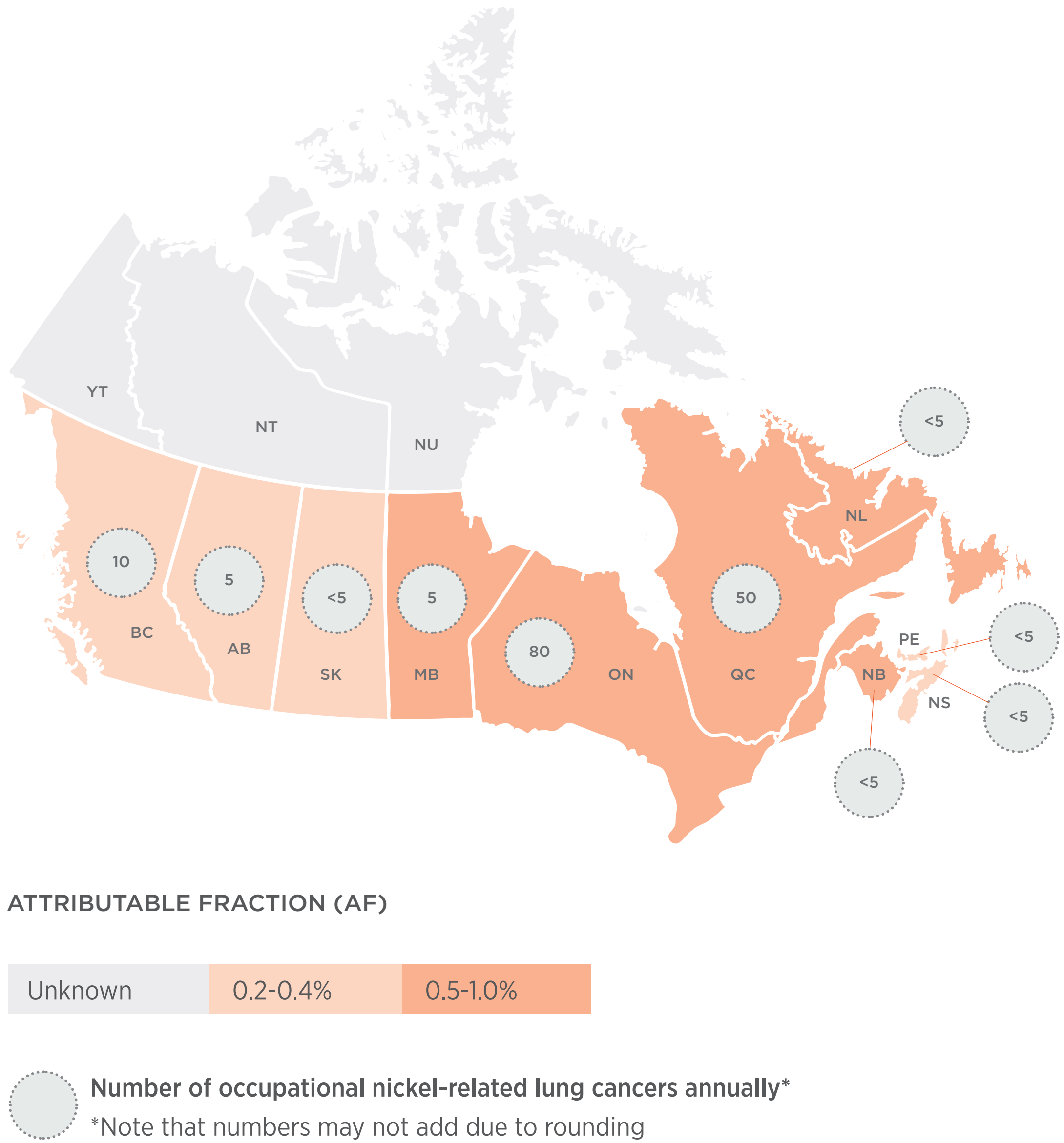


Figure 20. Provincial breakdown of total lung cancers attributed to nickel exposure in 2011.

Chromium (VI), is primarily produced as a product or by-product in manufacturing processes (40). Chromium (VI) compounds have been used as corrosion inhibitors, as well as in pigments, metal finishing, wood preservatives, catalysts and leather tanning (40, 94). There is strong evidence that it causes lung cancer, and some evidence of its potential to cause cancer of the nose and nasal sinuses. Other health effects include occupational asthma, eye irritation and damage, respiratory irritation, kidney and liver damage, pulmonary congestion and swelling, and allergic skin reactions on skin contact (95).

EXPOSURE

Inhalation (e.g., through welding) and skin contact (i.e., from non-welding processes) are the primary routes of occupational exposure to chromium (VI). The majority of Canada's 104,000 workers who are exposed to chromium (VI) are exposed to low levels (87%), while about 10% are exposed to moderate levels and 3% to high levels (Figure 21). High-level exposures occur mostly in the manufacturing sector, particularly among metalworkers and industrial painters and coaters. Moderate-level exposures occur mostly in welders. Occupations that work with forming or shaping of metal products have the largest number of workers exposed to chromium (VI) and include welders, machine operators and mechanics. Printing press operators have historically been another large exposed occupation group due to the use of chromium in pigments.

BURDEN

Approximately 50 lung cancers each year are caused by occupational exposure to chromium (VI) compounds in Canada, which accounts for 0.2% of lung cancers diagnosed annually. These results exclude the burden of cancer caused by occupational exposure to welding fumes, which have been accounted for in a preceding section of this report (see welding fumes). Due to small numbers, a figure displaying the industry breakdown of total lung cancers attributed to occupational exposure to chromium (VI) is not included in this report.

The majority of lung cancers attributable to occupational exposure to chromium (VI) occur in workers in the manufacturing industry, particularly in metal coating, auto manufacturing and metal fabrication. Workers with the greatest burden of lung cancer are machine operators and assemblers who process mineral ores, metal or other substances before manufacturing (e.g., via smelting). A map displaying the provincial breakdown of total lung cancers attributed to chromium (VI) exposure in 2011 was not produced for this report since there was very little inter-provincial variation in the attributable fractions.

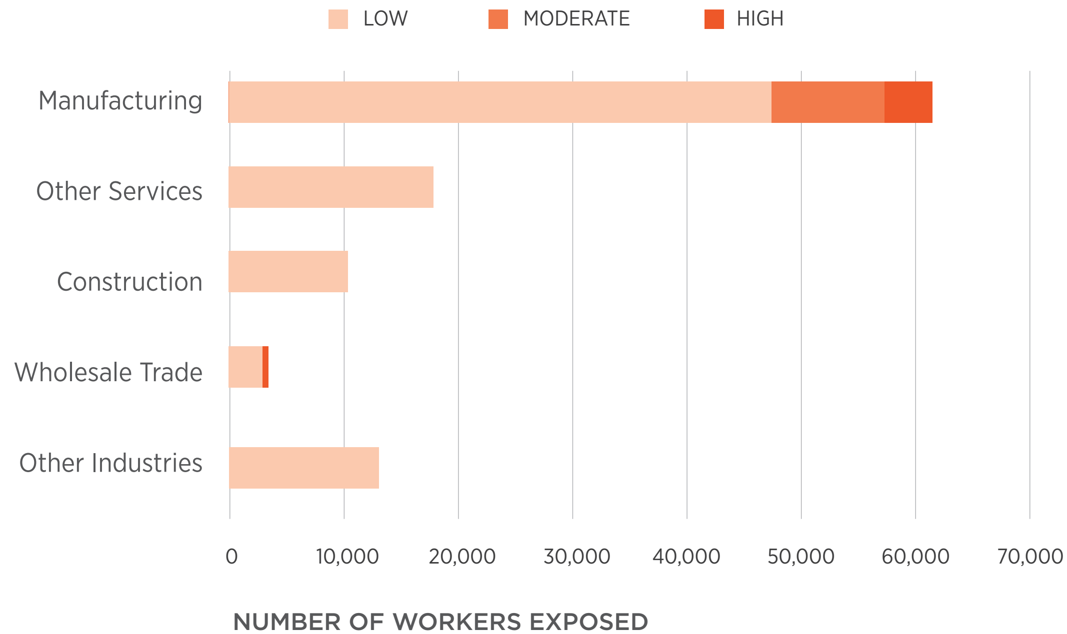


Figure 21. Number of workers occupationally exposed to chromium (VI) compounds by level of exposure and industry in Canada in 2006.

EXPOSURE REDUCTION STRATEGIES FOR WELDING FUMES, CHROMIUM (VI) COMPOUNDS, AND NICKEL COMPOUNDS

To reduce exposure to welding fumes overall, the type of welding or welding supplies that generate fewer vapours and/or fumes can sometimes be substituted for those that generate higher amounts of vapour and fumes (96). For more information on controlling exposure to welding fumes, refer to the Government of Canada's Guide to health hazards and hazard control measures with respect to welding and allied processes (97).

For reductions in exposure to chromium (VI) and nickel compounds, specific technologies can be implemented to reduce the overall generation of dusts or fumes (98, 99). These technologies include the use of chemicals to reduce the surface tension of the solution, specific tools that minimize agitation of solutions, and physical barriers to contain mists during plating (98). Other technologies can be implemented to ensure the effectiveness of exhaust ventilation. For example, in electroplating processes for chromium (VI) compounds and nickel compounds, level indicators, alarms or automatic dosing can be used to ensure that sufficient levels of solutions are maintained for the proper functioning of the local exhaust ventilation system (99, 100).

Some exposure control methods used for welding fumes are also useful to reduce occupational exposures to chromium (VI) compounds and nickel compounds. For example, ventilation and isolation of workers are common engineering controls used to reduce worker exposure to all three agents. Closed systems with properly maintained negative pressure relative to the surroundings may also be used to isolate workers (101). Local exhaust ventilation is usually more effective than general exhaust and should be used when there are specific point sources. General ventilation may be employed when emission sources are mobile (101).

Some administrative controls that can be used to reduce exposures to the three agents include: rotating employees through areas of higher production (which includes training employees to perform different tasks); proper maintenance of engineering controls (102, 103); using wet methods or HEPA filter vacuums to clean surfaces; providing and promoting the use of change rooms and washing facilities; ensuring the proper classification and disposal of waste materials; and restricting smoking, eating and drinking in work areas (102-104); and scheduling procedures that lead to the highest levels of exposure during times when the fewest employees are working (102-104).

Finally, the American Conference of Governmental Industrial Hygienists has a biological exposure index (BEI) for chromium (VI) compounds and is currently considering a BEI for nickel compounds (105). Biological exposure monitoring is the ongoing assessment and quantification of total exposure (both occupational and non-occupational) from all routes (e.g., inhalation and skin) by routinely collecting and testing biological samples (e.g., blood, urine, etc.) from individuals. Workplaces can consider implementing biological monitoring programs for workers exposed to chromium (VI) compounds and nickel compounds. It can help reduce exposures by identifying workers who are exposed above background levels and by monitoring changes in biological measures over time, which has been done for workers exposed to chromium (VI) compounds and nickel compounds in the electroplating industry (106).

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POLICY RECOMMENDATIONS FOR WELDING FUMES, NICKEL, HEXAVALENT CHROMIUM

The general, overarching policy recommendations, presented later in this report, can be applied to welding fumes, nickel, and hexavalent chromium, in addition to the following specific recommendations:

Introduce provincial regulations requiring ventilation for welding activities

Exposure to all welding fumes should be controlled. Welding fumes are now recognized as a definite (Group 1) human carcinogen by the International Agency for Research on Cancer (89) and general guidelines have been published for welding ventilation by the Standards Council of Canada (107). However, there are no mandatory standards on the implementation and use of general and local exhaust systems during welding processes. Ventilation regulations have been implemented in state and federal Occupational Safety and Health Act (OSHA) standards in the United States. For example, local exhaust is required if lead, cadmium or beryllium are being welded, and a minimum air flow is specified (108, 109). It is recommended that mandatory ventilation requirements be introduced into provincial regulations for welding activities and that training and instruction be provided to employers for the effective implementation of ventilation systems.

Develop, adopt and enforce an evidence-based OEL for welding fumes.

Occupational Exposure Limits exist for specific carcinogenic constituents of welding fumes (e.g. nickel, chromium, beryllium), but there is no OEL for welding fumes as a whole that reflects their carcinogenic effect. Most jurisdictions in Canada apply the ACGIH guideline for Particles Not Otherwise Specified (PNOS), which is 3 mg/m^3, as respirable dust, or 10 mg/m^3, as inhalable dust (105, 110). An OEL for welding fumes should be developed based on the latest scientific evidence. While the evidence for the association between welding fumes and lung cancer is strong, at this time there is relatively little data on which to base an OEL (91). One study found a small, but significant excess risk even at levels below 10 mg/m^3-years (111). This would indicate that the OEL should be lower than 1 mg/m^3 (respirable) and much lower than the ACGIH PNOS guidelines. Until an appropriate OEL is developed, levels of exposure should be kept as low as reasonably achievable (ALARA).

RADON

Radon is a radioactive gas that is produced naturally in rocks and soil when uranium and thorium decay (112). Radon can enter indoor and underground workplaces through cracks in buildings (113), and high concentrations of the gas may accumulate in confined areas or where ventilation is poor (114). Levels tend to be most concentrated in basements and underground areas due to proximity to sources and more limited ventilation (114). Radon is a known cause of lung cancer (27, 115) and tobacco smokers who are exposed to radon have roughly 25 times the increased risk of developing lung cancer compared to non-smokers (116).

EXPOSURE

Approximately 188,000 workers are occupationally exposed to radon in Canada (43). The majority of workers are exposed to low levels of radon and most radon-exposed workers are primarily found in indoor, above ground workplaces, where radon may enter through gaps in building foundations (Figure 22). The level of exposure among these workers varies based on background levels of radon and the building's characteristics (e.g., ventilation, age). Overall, about three quarters of workers occupationally exposed to radon are exposed to low levels (200 to 400 Bq/m^3), 18% to moderate levels (400 to 800 Bq/m^3), 4% to high levels (above 800 Bq/m^3) and another 4% to very high levels (i.e., underground workers susceptible to higher levels of radon exposure than general indoor workers). The majority of workers exposed in the mining industry (62%) are estimated to be exposed to very high levels. More than half of those workers exposed at very high levels in the mining industry consist of workers employed in underground production or services, where radon concentrations tend to be higher due to inadequate ventilation and greater contact with ground sources (i.e., soil and rock) (43).

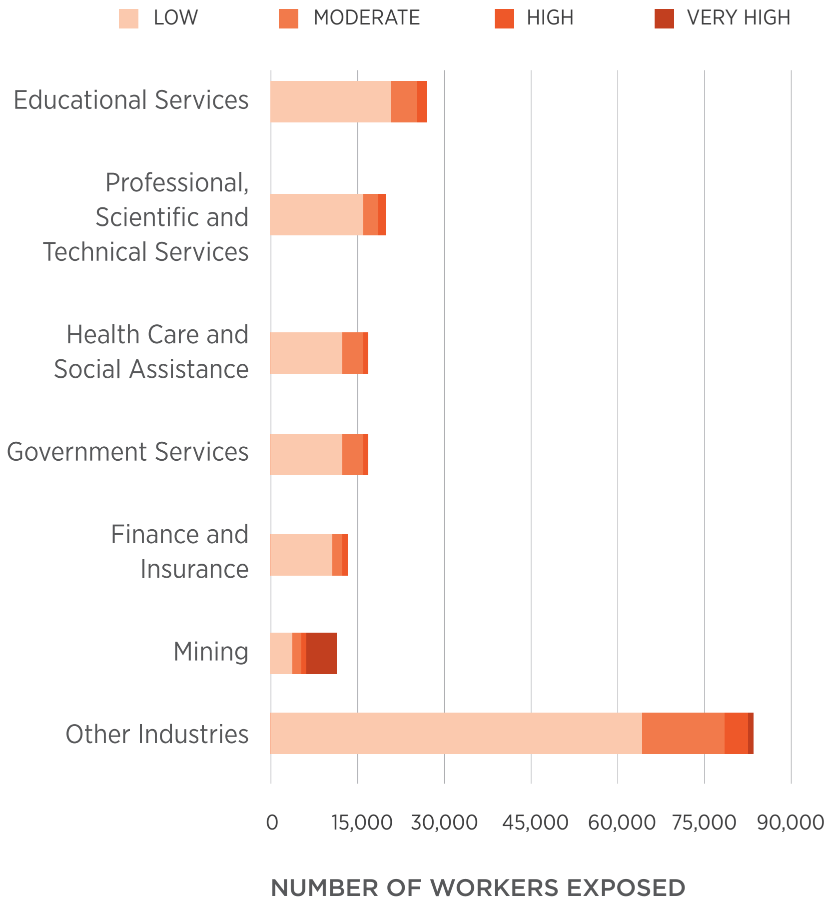

Figure 22. Number of workers occupationally exposed to radon by level of exposure and industry in Canada in 2006.

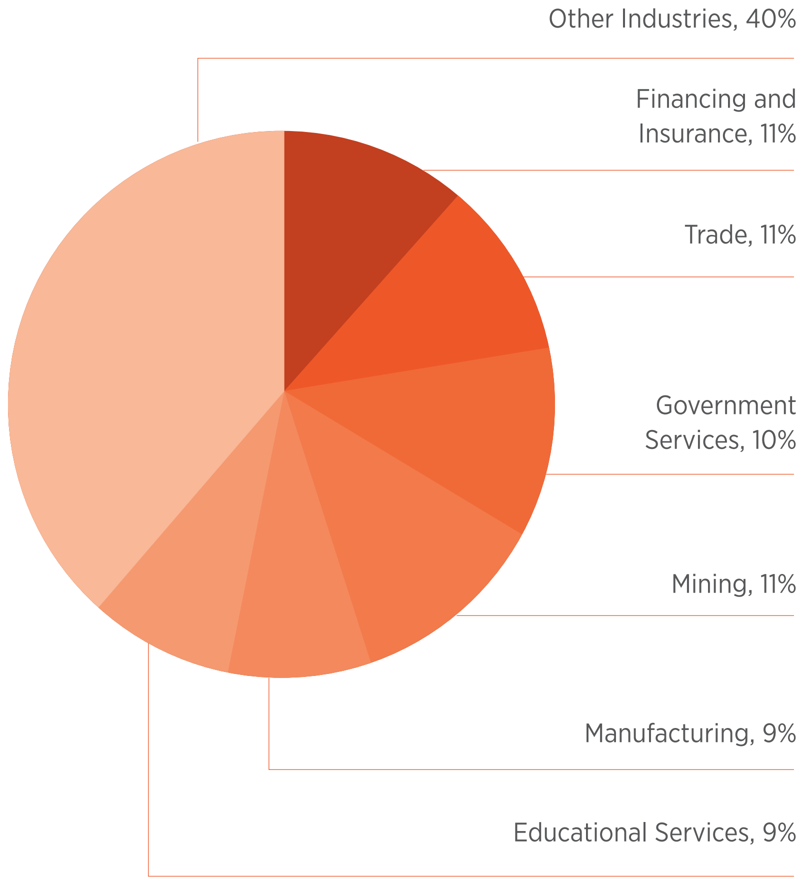

Figure 23. Industry breakdown of total lung cancers attributed to occupational radon exposure in 2011.

190
Lung cancers
AF = 0.8%

BURDEN

Approximately 190 lung cancers in Canada are caused by occupational radon exposure each year, which accounts for 0.8% of all lung cancers diagnosed annually. The burden of occupational cancer due to radon exposure is highest in finance/insurance/real estate and trade sectors, followed by government services. Mining, the industry with the highest historical levels of exposure, was responsible for about 11% of radon-related lung cancers in Canada. The remaining industries with a large occupational cancer burden due to radon exposure are summarized in Figure 23. Cancer excess in non-mining industries is associated with low to moderate levels of radon exposure and greater numbers of workers employed compared to mining. “Other industries” include professional scientific and technical services, construction, health care and others.

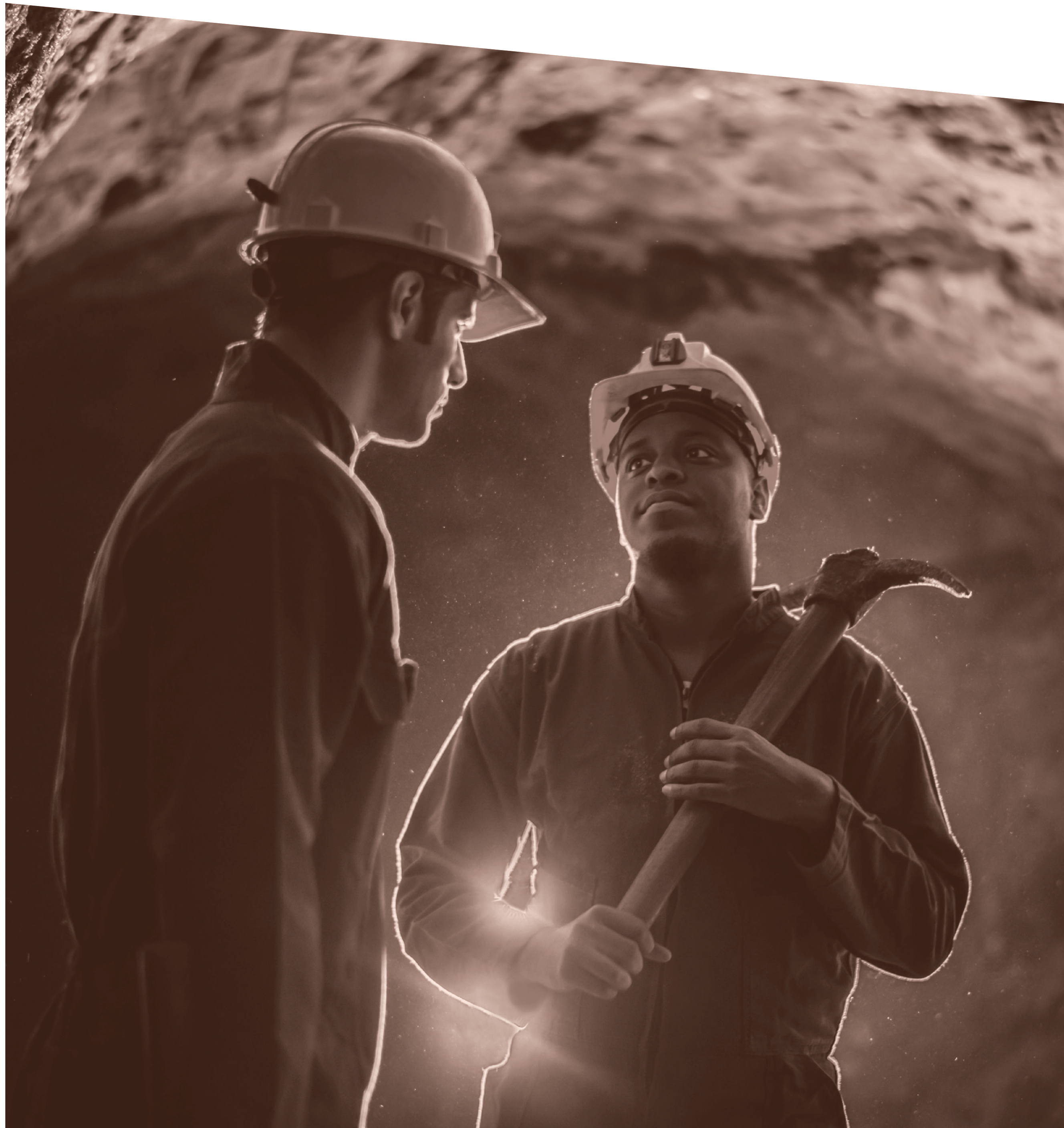

Figure 24 presents the occupational burden of lung cancer attributable to radon exposure, by province. The province with the highest attributable fraction of lung cancer caused by exposure to radon is Saskatchewan, where approximately 2.3% of the estimated total lung cancers diagnosed each year are caused by occupational radon exposure (Figure 24). Saskatchewan has some of the highest levels of radon in soil in Canada and is usually present in areas where uranium is found and mined (117). Attributable fractions were also high in Manitoba and Alberta, where approximately 1.9% and 1.1% of lung cancers diagnosed are due to occupational radon exposure, respectively.

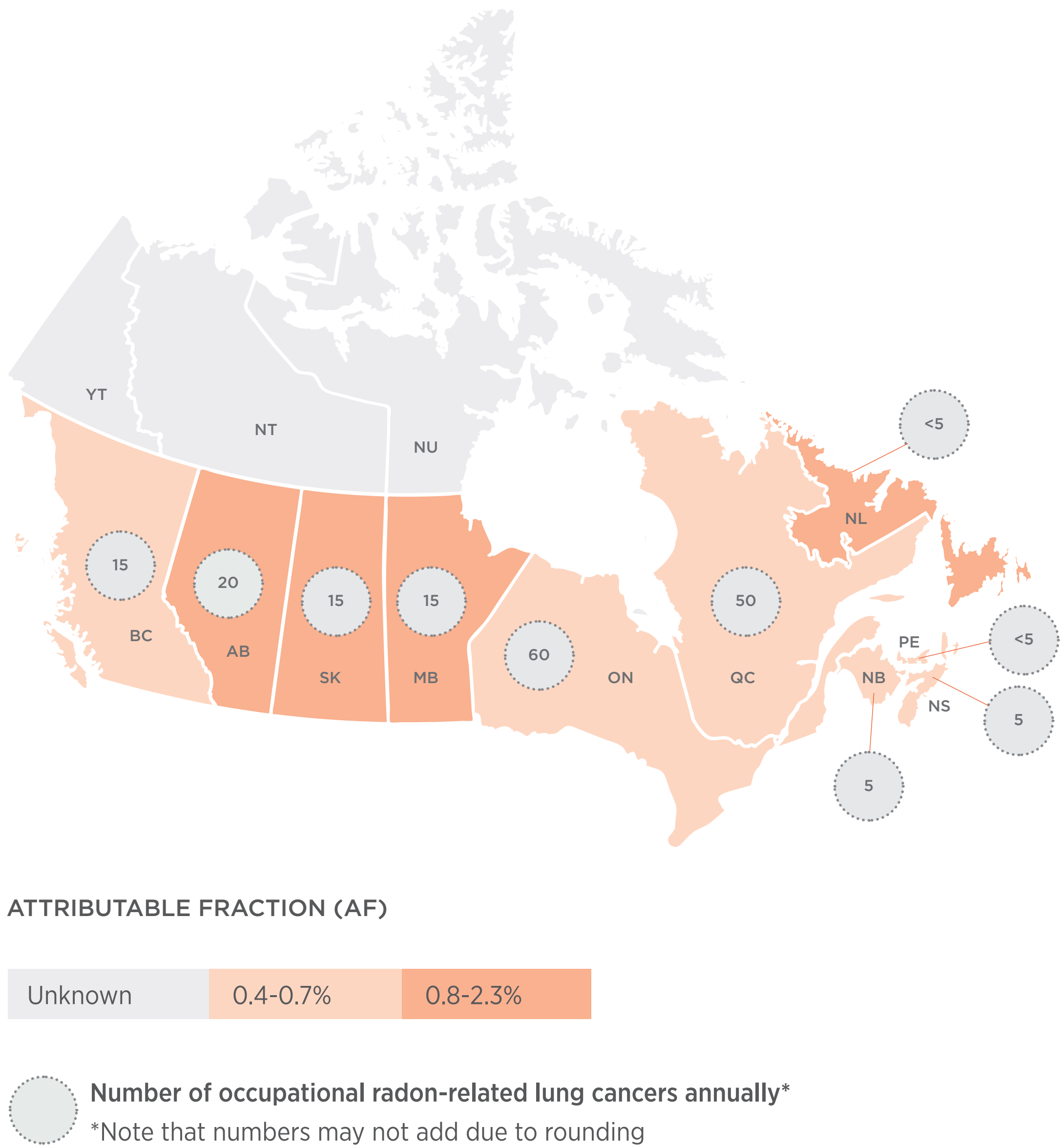

Figure 24. Provincial breakdown of total lung cancers attributed to radon exposure in 2011.

EXPOSURE REDUCTION STRATEGIES

Radon is a colourless and odourless gas, and an individual's exposure level will depend on a number of factors (e.g., geographical location, building age, foundation, ventilation). Due to these numerous factors, it is difficult to predict the levels of radon that may be present in a workplace. As a result, ongoing monitoring of radon levels in workplaces where levels are discovered to be high through testing are important for exposure reduction. Since indoor levels of radon are usually highest during winter months when buildings are sealed up, long-term measurements over the course of 3 to 12 months should be conducted to account for these seasonal variations.

Health Canada has developed Naturally Occurring Radioactive Materials (NORM) Guidelines, which may be relevant to workers engaging in NORM activities (e.g., mining, water treatment facilities, tunnelling and underground work), as well as any workplace where workers may be incidentally exposed (i.e., as a result of exposure to indoor workplace radon) (118). According to the NORM Guidelines, radon levels should be measured in all workplaces. Because Health Canada is a federal agency and workplace health and safety generally falls under provincial jurisdiction, the NORM guidelines are not legally enforceable regulations. They would need to be adopted at the provincial level by agencies with responsibility for setting and enforcing occupational health and safety regulations.

Where radon levels are lower than 800 Bq/m^3, NORM guidelines recommend changes in workplace practices and controls to limit access to high radon areas, in addition to periodic workplace monitoring (114). For incidentally exposed workers, NORM guidelines emphasize reducing radon levels to less than 200 Bq/m^3. However, the World Health Organization recommends that radon levels in indoor residential spaces should be lowered to less than an annual average concentration of 100 Bq/m^3 based on evidence of elevated lung cancer risks at very low levels of exposure (119).

Where levels exceed 800 Bq/m^3, NORM guidelines recommend that workers be educated on their status as radiation-exposed workers and the associated health risks, as well as informed of the applicable occupational exposure limits and measured workplace levels. An exposure reduction program, engineering and administrative controls, personal protective equipment and periodic worksite assessments are also recommended (114). All workers in uranium mines and mills are currently monitored for their annual radon exposure through the National Dose Registry.

Some potential radon remediation strategies for indoor workplaces include sub-floor depressurization for foundations and basements in contact with soil (to maintain a negative pressure gradient) or sub-floor ventilation for buildings where the ground floor is not in contact with soil, as well as floor sealing and membranes to reduce cracks that radon may enter through, increased ventilation and the removal of subsoil (120).

POLICY RECOMMENDATIONS FOR RADON

The general, overarching policy recommendations, presented later in this report, can be applied to radon, in addition to the following specific recommendations:

Develop, adopt and enforce regulation of radon in indoor air within provincial occupational health and safety regulations that is consistent with NORM guidelines.

NORM guidelines are considered the industry standard for radon protection in workplaces. However, because they are recommended guidelines, they do not constitute legally enforceable regulations. In addition, there are radon-exposed workers in many industries and geographical areas who are not covered by existing regulations targeting certain high-risk groups such as underground miners. Provincial radon-specific regulations could span all aspects of employer and employee responsibilities, including, but not limited to, an occupational exposure limit (see below), regular work site inspection, training on exposure measurement and mitigation, and public and worker notification.

Adopt, implement and enforce 200 Bq/m^3 of radon in air as the exposure standard for remediation in all underground and above-ground work areas.

Workers spend significant amounts of their time at work as well as at home, making it important to apply stringent annual average limits at work and at home to reduce potentially cumulative risks of lung cancer. An annual average radon limit of 100 Bq/m^3 has been recommended by the World Health Organization for homes and residences (121). With feasibility in mind, as well as the fact that workers spend less time at work than at home, a limit of 200 Bq/m^3 is recommended. Implementing mandatory radon remediation in workplaces with an annual average radon level of 200 Bq/m^3 or higher would be stronger than current NORM guidelines, which only suggest some management of risk at the 200 Bq/m^3 level. The legislation should include requirements for conducting long-term radon tests, require remediation when levels exceed 200 Bq/m^3, and clarify when an inspection should be initiated at a workplace (121).

SECOND-HAND SMOKE

Second-hand smoke is a mixture of solid particles and gases released from burning cigarettes and exhaled cigarette smoke (122). This mixture contains numerous carcinogenic substances such as benzene, formaldehyde, and benzo(a)pyrene (122, 123). Second-hand smoke is a well-established lung carcinogen, with limited evidence that it may also cause cancers of the larynx and pharynx (122). A large study that examined the effects of second-hand smoke exposure in workplaces found that the risk of lung cancer increased by 24% among non-smoking workers who were exposed to second-hand smoke. The study also found that among workers who were classified as highly exposed to second-hand smoke, the risk of lung cancer increased by 100% (124). Other health effects associated with exposure to second-hand smoke include heart disease, exacerbation of asthmatic and allergic reactions, and premature death (123, 125, 126). The 2006 United States Surgeon General's report concluded that any exposure carries some risks to respiratory health (126).

EXPOSURE

All Canadian provinces have smoke-free regulations that restrict smoking in almost all enclosed workplaces, while some provinces allow a separated ventilated room to be built in the workplace (123). Some provinces have made exceptions for certain workplaces. For example, Ontario allows for controlled smoking areas for residents of residential care and psychiatric facilities, facilities for veterans, and hotels, motels or inns (127). In most provinces, the regulations set out permitted distances that smokers may smoke away from building entrances, windows and air intakes, although the distance varies by province, ranging from 5 metres in Alberta (128) to 6 metres in British Columbia (129), and 9 metres in both Ontario and Quebec (127, 130).

Despite a legislated smoking ban in indoor workplaces, CAREX Canada estimates that exposure still occurs and approximately 520,000 Canadian workers are exposed to second-hand smoke in their workplaces (131). The proportion of workers exposed to second-hand smoke varies by occupation (Figure 25). The sectors with the largest number of workers exposed to second-hand smoke include: trades, transport and equipment operations, where approximately 50% of exposure occurs, followed by sales and service industry (13% of all exposed workers). The largest number of exposed workers are employed in Ontario, Quebec and Alberta.

BURDEN

An estimated 130 lung, 35 pharynx and 20 larynx cancers are diagnosed each year in non-smokers in Canada. The attributable fraction of lung cancers due to occupational exposure to second-hand smoke is 0.6%. Most lung cancers due to exposure to second-hand smoke occur in the manufacturing sector and wholesale and retail trade (Figure 26).

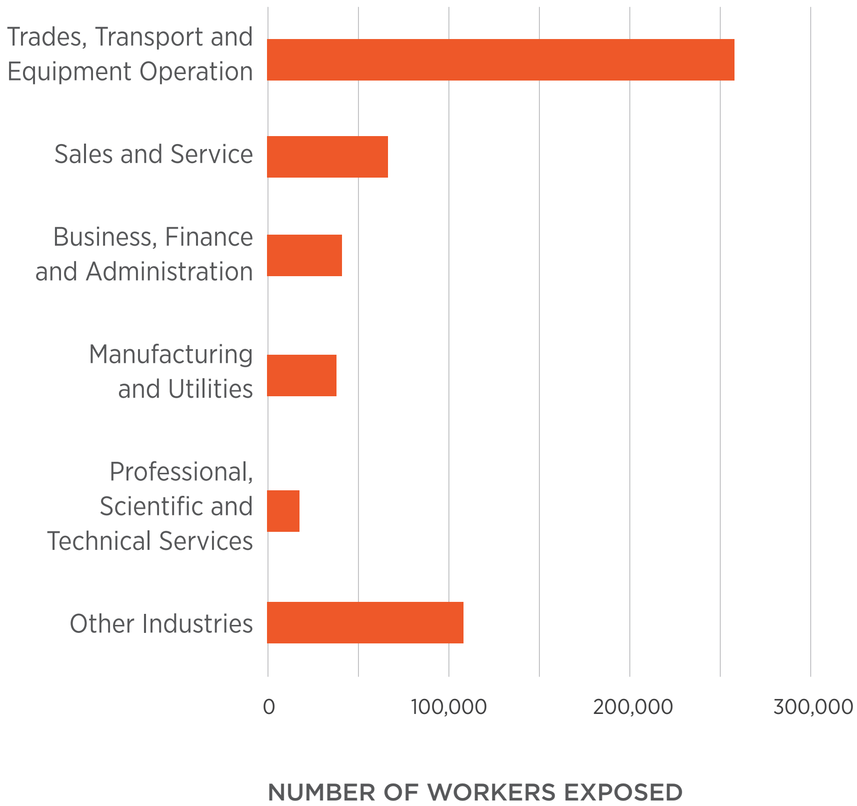

Figure 25. Number of workers occupationally exposed to second-hand smoke by level of exposure and industry in Canada in 2006.

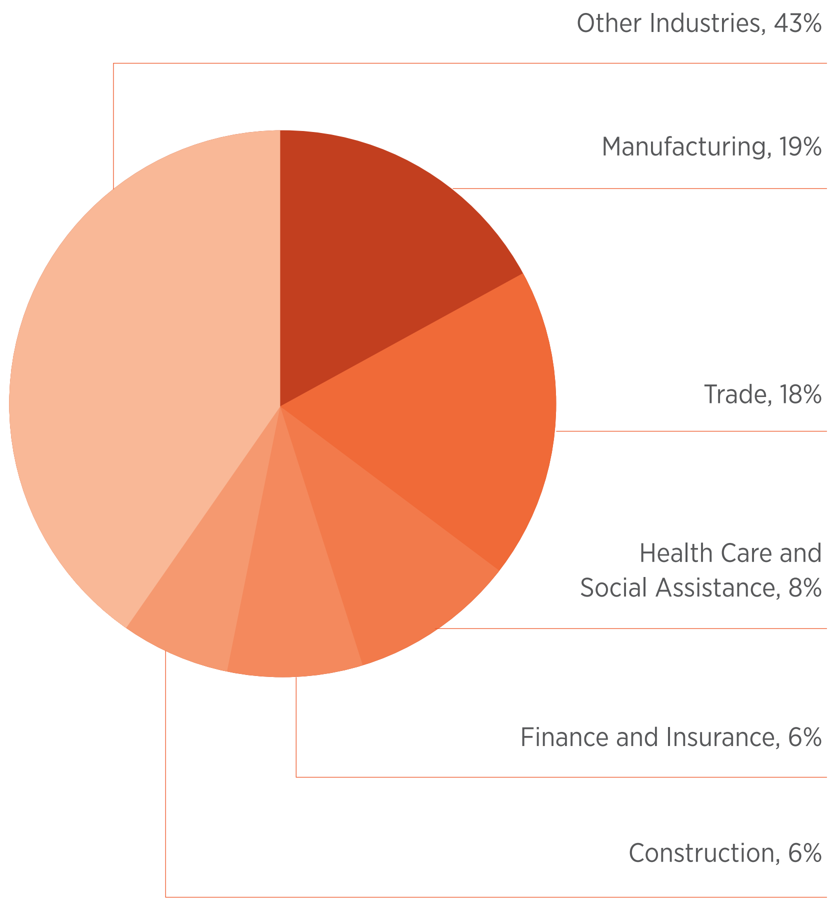

Figure 26. Industry breakdown of total lung cancers attributed to occupational exposure to second-hand smoke in Canada in 2011.

130
Lung cancer
AF = 0.6%

Figure 27 presents the occupational burden of lung cancer attributable to second-hand smoke, by province. In Manitoba and Saskatchewan the attributable fraction is slightly higher, where approximately 0.7% of lung cancers diagnosed are due to occupational exposure to second-hand smoke. Differences in the breakdown of the labour force within provinces likely contributes to variations in attributable fractions across provinces (Figure 27). Burden estimates for second-hand smoke are presented here for non-smokers due to the difficulties in separating the impact of personal smoking and second-hand smoke exposure on cancer risk.

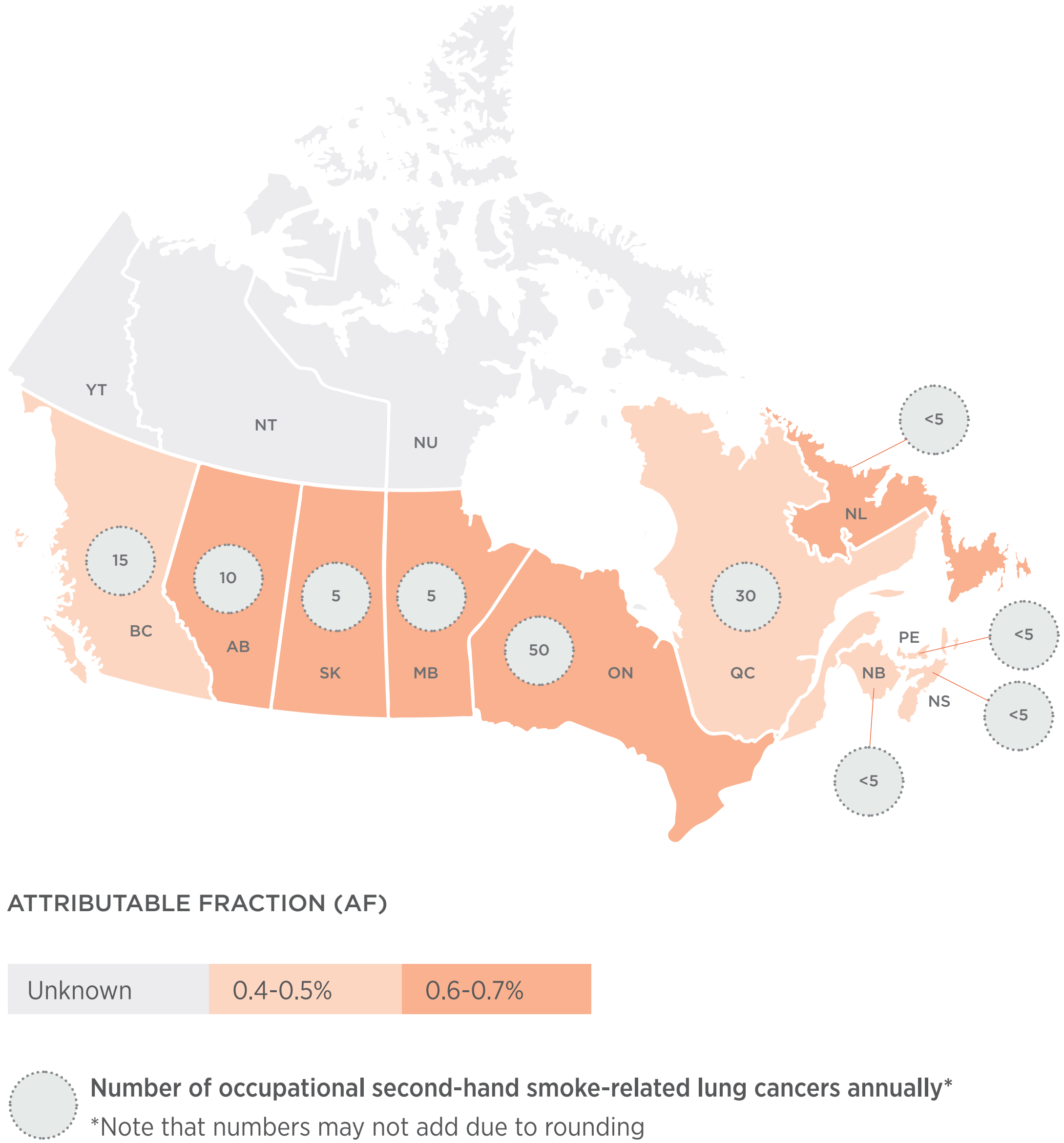

Figure 27. Provincial breakdown of total lung cancers attributed to second-hand smoke exposure in 2011.

POLICY RECOMMENDATIONS FOR SECOND-HAND SMOKE

The general, overarching policy recommendations, presented later in this report, can be applied to second-hand smoke, in addition to the following specific recommendations:

Build on successes by strengthening current smoke-free legislation and its enforcement.

Exposure to second-hand smoke has decreased in recent decades as a result of new legislation, increased awareness of the health effects associated with second-hand smoke exposure, and population-wide changes in smoking behaviour (132). However, workers continue to be exposed, even in workplaces with smoke-free policies, indicating that enforcement of existing policies may be an issue (131). Furthermore, the strength of smoke-free legislation varies by province. For example, only Ontario's legislation specifically states that home health care workers have the right to request that a person refrain from smoking in the health care workers' presence, and the degree to which this is enforced is unknown (127). Smoking bans have been evaluated as the most effective measure for reducing second-hand smoke exposure (133). Legislation must be expanded across provinces to protect workers who are not covered by current legislation (i.e., outdoor workers, workers providing services in client's homes). Furthermore, efforts must be jointly taken by agencies responsible for public health and Ministries of Labour to enforce smoke-free legislation in workplaces across all provinces. These efforts could include aligning their regulatory and enforcement strategies to the extent that their individual mandates will allow.

WORK AT NIGHT (INCLUDING ROTATING AND NIGHT SHIFT WORK)

Night shift work can be defined as a pattern of work in which people work schedules that extend beyond traditional or standard work hours (e.g., 9 a.m. to 5 p.m.) (134). Night shift work is believed to be related to the disruption of the body's natural day–night (i.e., circadian) rhythm and a misalignment of melatonin release (135), which have been associated with harmful health effects such as increases to blood pressure as well as metabolic changes in the human body that regulate insulin sensitivity and cortisol levels (136). In 2007, IARC classified shift work involving circadian disruption as a probable (IARC Group 2A) cause of female breast cancer (137), and this classification was reaffirmed in 2019 (138). The strongest evidence came from studies in nurses that demonstrated elevated female breast cancer risk associated with long-term rotating and night shift work (i.e., 20 years or more).

While there remains uncertainty about the strength of association between breast cancer and night shift work, studies published since 2007 have generally supported earlier positive findings (139, 140). Emerging evidence suggests that night shift work may also be associated with other types of cancer, such as prostate and colorectal (141, 142), but these findings have been limited with respect to their strength of association and consistency. The burden of prostate and colorectal cancers attributed to night shift work has not been calculated as evidence linking shift work to these cancers was very limited at the time that the burden study was completed. There continues to be a need for additional research into the biological pathways that might be involved in shift work-related cancers using improved, consistent definitions of night shift work.

EXPOSURE

CAREX Canada estimates that approximately 1.9 million workers (or approximately 12% of working Canadians) work regular night and rotating shifts (143). Since less than 1% of breast cancer diagnoses occur in men (72), the burden study focused on female night shift workers. The industries in Canada with the greatest numbers of women working night shifts are health care and social assistance, trade and accommodation and food services. Shift work is also common in the manufacturing sector as well as government services (Figure 28).

BURDEN

Night shift work may be responsible for 470 to 1,200 new cases of breast cancer each year, accounting for approximately 2.0 to 5.2% of breast cancers diagnosed annually in Canada. Nearly half (43%) of breast cancers that may be caused by night shift work are diagnosed among workers who were employed in health care and social assistance (Figure 29). Approximately 18% of these cancers occur in the accommodation and food services sector. These sectors tend to employ a large number of night shift workers to provide 24-hour care and services to Canadians.

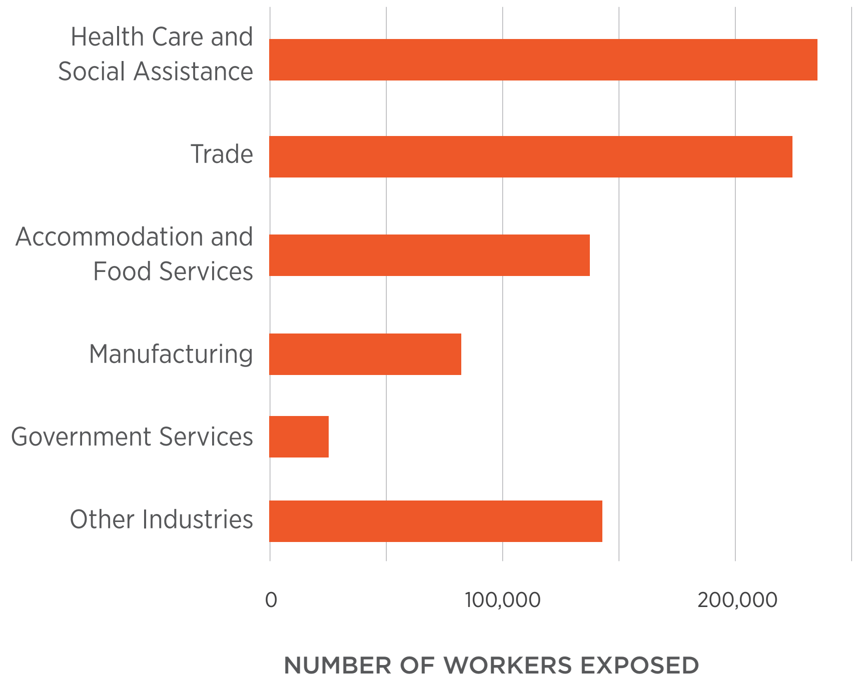

Figure 28. Number of female workers exposed to night shift work by industry in Canada in 2006.

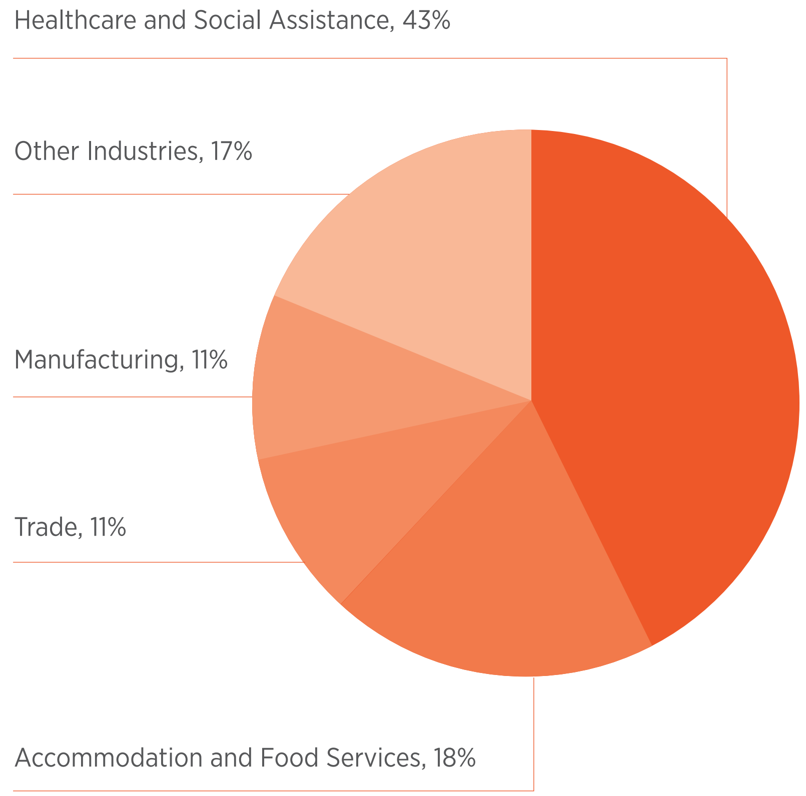

Figure 29. Industry breakdown of total breast cancers attributed to night shift work in 2011.

470 - 1,200
Breast cancers
AF = 2.0 - 5.2%

Figure 30 presents the occupational burden of breast cancer attributable to night shiftwork, by province. The provinces with the highest attributable fractions of breast cancer are Newfoundland and Labrador, Saskatchewan, and Manitoba, where 2.4-6.1%, 2.4-6.2% and 2.6-6.7% of the estimated total breast cancers diagnosed each year may be caused by shift work, respectively.

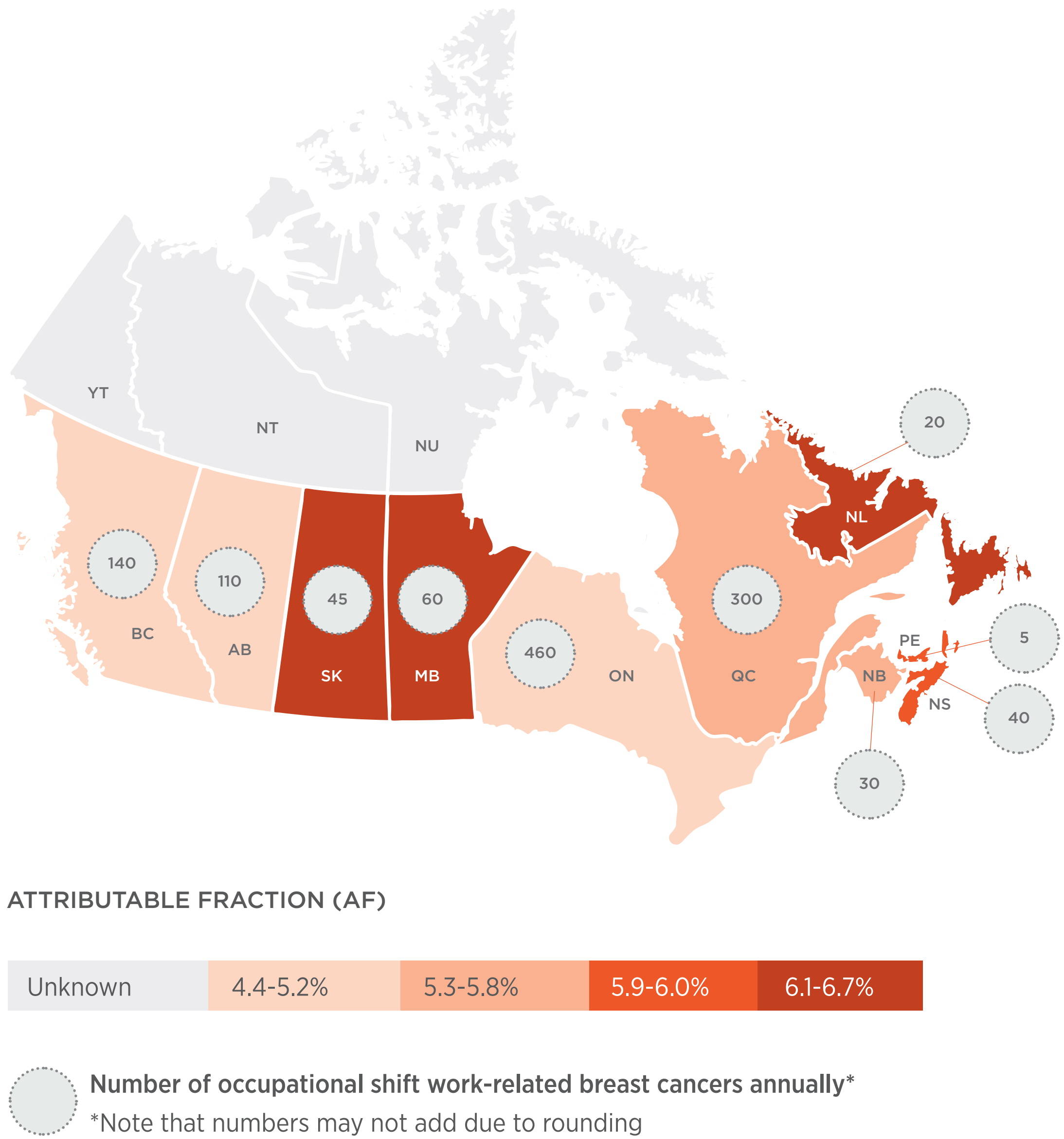

Figure 30. Provincial breakdown of total breast cancers attributed to night shift work in 2011.

Note: The numbers in this figure represent the upper estimates of the cancer burden attributed to shift work exposure.

EXPOSURE REDUCTION STRATEGIES

Reducing occupational exposures to shift work requires a different approach compared to the chemical hazards that dominate this report since shift work cannot be completely banned or easily substituted in all industries and occupations (e.g., healthcare, public safety, hotels). In addition, it is not clear what preventative measures will be effective in reducing the carcinogenic effects of shift work, other than eliminating work at night whenever possible. However, the adverse health effects of shift work may be prevented with several workplace-based measures. Implementing rotating schedules that move in a forward direction (i.e., morning-afternoon-evening shifts) has been shown to be an effective way to improve sleep quality and quantity and to reduce the impacts on health due to circadian rhythm disruption (144-146). Another way to improve shift scheduling is self-rostering, which involves the development of IT-supported systems that facilitate workers' ability to choose what days they want to work or do not want to work, and that may also include choices for shift length, start- and end- times and the option to transfer hours from one period to another, with final adjustments made by managers (147). Self-rostering allows employees to select and optimize their shift work schedule based on personal preference and fit, as well as individual tolerance to shift work, with some studies showing improved post-shift recovery and health in employees after the implementation of self-rostering (148). However, the impact of self-rostering on reducing cancer risk attributable to shift work is unclear.

There is less evidence for other types of interventions, such as the use of controlled light exposure and behavioural strategies. Medications (other than melatonin) to improve sleep or wakefulness have been associated with adverse health effects in several studies (144). Currently, standards of work for requirements of daily rest and rest between shifts vary by province. For example, Alberta, British Columbia and Ontario require 8 hours of rest between shifts (149) vs. Saskatchewan which requires 8 hours of rest in any period of 24 hours (150) and Manitoba which requires 24 consecutive hours of rest per week (151).

POLICY RECOMMENDATIONS FOR SHIFT WORK

Proposing specific policy recommendations related to shift work is challenging since current research efforts on potential strategies and interventions to reduce the health impacts of circadian rhythm disruption from shift work are still ongoing and require further investigation. The development of training programs that educate employers and employees on the risks involved in shift work should be implemented as part of a broader safety management program at workplaces where shift work occurs (152). Implementation of a fatigue risk management system that educates and trains employers and employees on fatigue risk and provides tools for employers to design and administer safe work schedules would allow employees to manage their sleep patterns more effectively based on individual needs and tolerance to shift work. Moving forward, more research on specific strategies that could reduce the potential cancer burden from shift work is needed to guide the future implementation of evidence-based preventive measures.

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

PAHs consist of a group of over 100 organic compounds that occur naturally in coal and tar deposits, can be manufactured, or can form during the incomplete combustion of organic materials such as coal, oil, gas, wood, garbage, or during cooking charbroiled meat (25, 153). PAHs are often present as a complex mixture and are therefore generally considered as a single group of substances for the purposes of risk control (25). Benzo(a)pyrene is a commonly found PAH that is often used as a general marker for PAHs.

Since 2010, the International Agency for Research on Cancer (IARC) has evaluated the carcinogenicity of more than 60 individual PAHs and 8 occupational exposures associated with specific industries that have increased PAH concentrations (153). There was strong animal and mechanistic evidence that benzo(a)pyrene causes lung cancer in humans, but limited or insufficient evidence for the carcinogenicity of the other compounds (154). Occupational exposures to some PAHs during certain work processes are associated with lung and non-melanoma skin cancer (153). There was weaker evidence for the association between PAHs and bladder cancer (153, 155). Other health effects associated with exposure to PAHs include decreased immune function, kidney and liver damage, asthma-like symptoms, cataracts and degradation of red blood cells (156).

EXPOSURE

Approximately 350,000 Canadian workers are exposed to PAHs in Canada (43). Nearly a third of all Canadian workers exposed to PAHs are employed in the accommodation and food services industry (Figure 31), where the prevalence of exposure is highest among cooks, chefs and food and beverage servers. Another third of workers exposed to PAHs are employed as mechanics in various industries. Other occupations with relatively large numbers of exposed workers include firefighters, machinists and machine operators in the manufacturing sector, as well as service station attendants and cashiers in the retail trade sector.

BURDEN

An estimated 130 lung, 80 bladder and 50 skin cancer cases are suspected to be due to occupational exposure to PAHs each year in Canada (Figure 32). These cancers account for 0.6% of lung, 1.1% of bladder and 0.07% of skin cancer cases diagnosed annually. The occupations with the highest number of PAH-associated lung and bladder cancers are machine operators and assemblers in the manufacturing sector as well as workers in the construction trades. Trades helpers, construction and transportation labourers account for the greatest number of PAH-associated skin cancers.

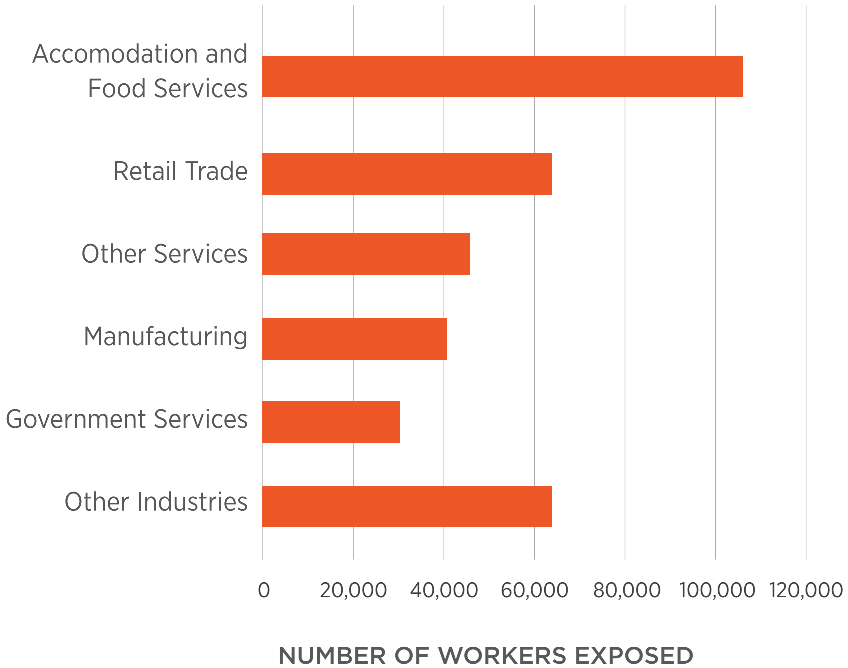

Figure 31. Number of workers occupationally exposed to PAHs by industry in Canada in 2006.

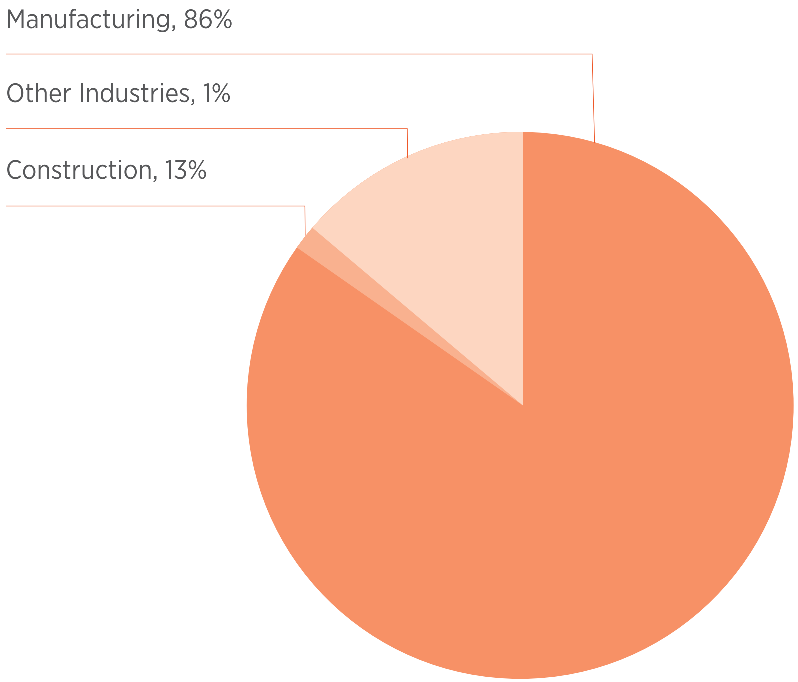

Figure 32. Industry breakdown of total lung cancers attributed to occupational exposure to PAHs in 2011.

130
Lung cancer
AF = 0.6%

Figure 33 presents the occupational burden of lung cancers attributable to PAH exposure, by province. Ontario and Nova Scotia have the highest attributable fraction of lung cancer caused by exposure to PAHs, where approximately 0.7% of the estimated total lung cancers diagnosed each year are caused by occupational exposure to PAHs (Figure 33). In Alberta, approximately 0.5% of the estimated total lung cancers diagnosed each year are caused by occupational exposure to PAHs.

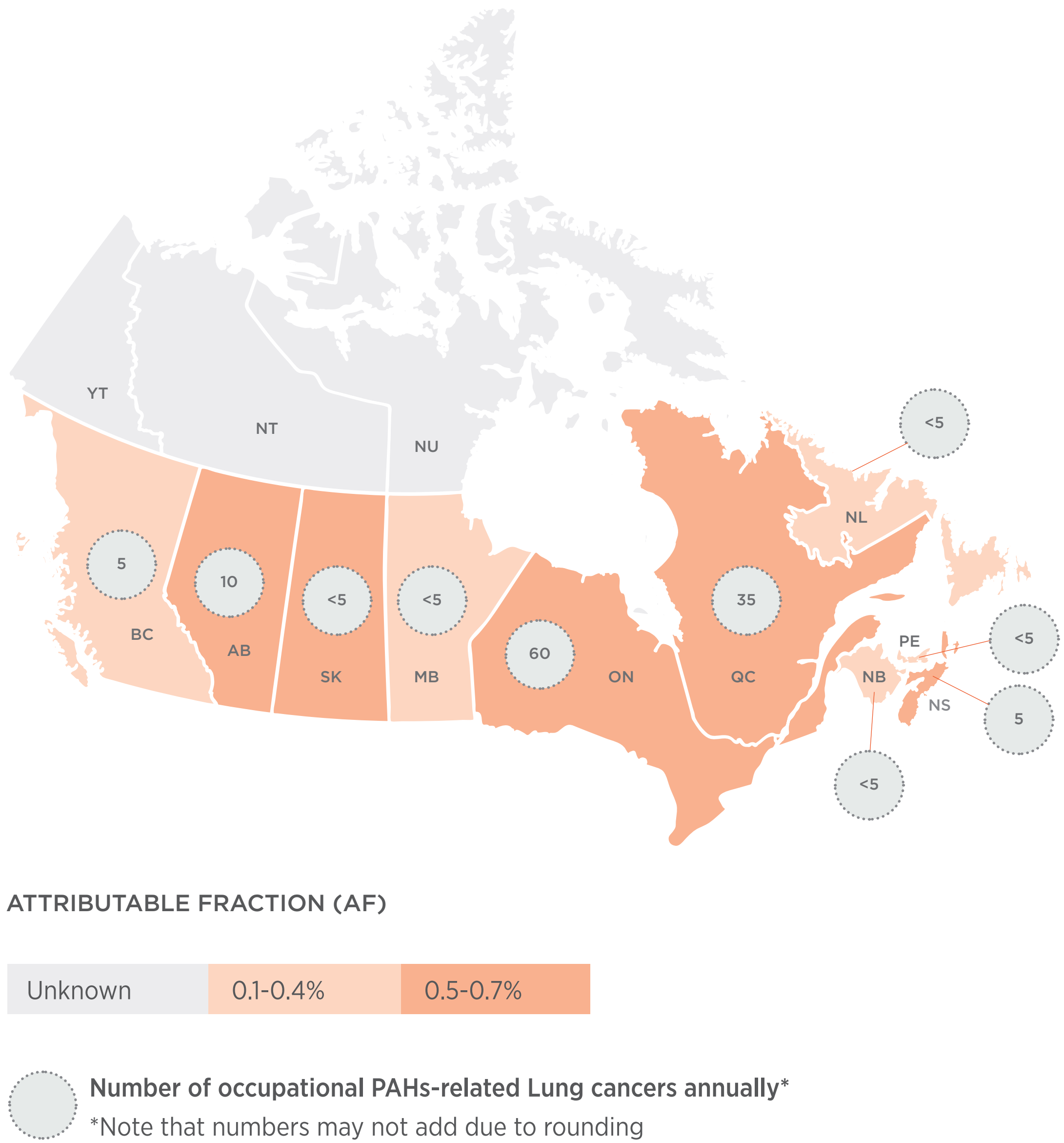

Figure 33. Provincial breakdown of total lung cancers attributed to exposure to PAHs in 2011.

EXPOSURE REDUCTION STRATEGIES

Numerous engineering and administrative measures can be used to control occupational exposure to PAHs. Engineering controls include: implementing local exhaust ventilation systems (157), implementing systems to capture and filter PAHs from the air, and ensuring that workers are separated from contaminated air with barriers (158). Examples of administrative controls include: maintaining ventilation and other control systems, employing wet cleaning methods where appropriate, limiting exposure duration by adjusting workers' schedules and limiting overtime hours (158). Maintaining good skin hygiene (e.g., showering, changing clothes after exposure) may also reduce absorption of PAHs through the skin (159).

POLICY RECOMMENDATIONS FOR PAHs

The general, overarching policy recommendations, presented later in this report, can be applied to PAHs, in addition to the following specific recommendation:

Implement effective engineering controls in workplaces where exposure occurs, particularly at high levels.

Implementing preventive measures such as effective engineering controls in key sectors can significantly reduce occupational exposure to PAHs in industries where workers may be exposed at high concentrations. For example, regular inspection and preventive maintenance of ventilation systems installed in restaurants and other food premises would reduce occupational exposures to PAHs among cooks and kitchen staff.

ARSENIC

Arsenic is used in wood preservatives and metal, mining, glass-making and semiconductor industries (40). Examples of applications that use arsenic include batteries, alloys, pigments, high-power microwaves, computer chips and antifouling agents in paints (40). Arsenic is a known human carcinogen that causes lung cancer from inhalation, skin cancer primarily from food and water sources and bladder cancer primarily from water sources (40). Long-term exposure to arsenic has also been linked to other health effects including nerve damage and skin effects, such as the formation of corns or warts (160). Short-term exposure has been associated with possible respiratory, kidney and cardiovascular damage (160).

EXPOSURE

Approximately 25,000 Canadian workers are exposed to arsenic in various industries (43). The majority of workplace exposures to arsenic occur in the manufacturing and construction industries, accounting for nearly three quarters of all workers exposed. Most exposures in these industries occur through contact with wood that has been treated with arsenic (e.g., among carpenters and construction trades labourers). Exposure occurs in a wide variety of other occupations, including farmers and machine operators. A figure displaying the industry breakdown of occupational arsenic exposure is not included in this report.

BURDEN

Approximately 60 lung cancers are caused by occupational arsenic exposure each year in Canada, which accounts for 0.3% of all lung cancers diagnosed annually in the country. The burden results for arsenic mirror the exposure patterns, with most of the lung cancers (74%) occurring in workers in the manufacturing and construction industries. Occupations with the greatest burden of lung cancers due to arsenic exposure are trades helpers, construction workers and machine operators. Since arsenic-related skin and bladder cancers are not due to occupational exposures, the burden for these cancers was not calculated. Of the 60 total lung cancers, 32% occur in workers in Ontario, followed by 27% in Quebec, 13% in British Columbia, 7% in Alberta, and less than 5% in the remaining provinces. Due to small numbers, a figure displaying the industry breakdown of total lung cancers attributed to occupational exposure to arsenic is not included in this report.

EXPOSURE REDUCTION STRATEGIES

The elimination of arsenic-treated wood in the construction sector could lead to substantial reductions in exposure. A number of substitutes exist, including acid copper chromate, alkaline copper quaternary, borates, among others (161). Standard engineering and administrative controls may be implemented to reduce occupational exposure to arsenic in other industries (162). For example, when equipment and ventilation is properly installed, operated and maintained, exposure is more likely to be well-controlled. Change rooms, showers and laundering facilities at the workplace are also recommended. Protective clothing should be laundered at workplace facilities at least weekly. Workspaces should be cleaned regularly using vacuums with HEPA filters or by wet methods. In some occupations, regular air monitoring and health assessments may be a part of the workplace occupational health and safety strategy to reduce exposures (162). Finally, workers should be educated on the health effects associated with arsenic exposure and trained on how to properly use equipment and control measures. The general, overarching policy recommendations, presented later in this report, can be applied to arsenic.

BENZENE

Benzene is a volatile organic compound primarily used in the manufacture of chemicals such as plastics, dyes, detergents, drugs and pesticides (163). It also occurs naturally in petroleum products and can be found in crude oil and gasoline (163). Benzene has been classified as a known human carcinogen based on evidence that it causes acute myeloid leukemia (AML) (163). There is also limited evidence that benzene causes acute lymphocytic leukemia (ALL), chronic lymphocytic leukemia (CLL), multiple myeloma, and myelodysplastic syndrome (163, 164). Exposure to benzene can also cause bone marrow damage, which can lead to changes in blood production and the number of circulating blood cells, as well as a supressed immune system (165, 166).

EXPOSURE

Approximately 374,000 Canadian workers are occupationally exposed to benzene (43). Of these workers, 91% are exposed to low levels and the remaining 9% are exposed to moderate or high levels. Within the manufacturing sector, the occupations most commonly exposed to moderate or high levels of benzene include mineral and metal processing workers, as well as printing machine operators since benzene can be found in inks. Within the transportation and warehousing sector, though overall exposure levels are lower, large numbers of motor vehicle and transit drivers and mechanics are exposed to benzene through motor vehicle exhaust. A figure displaying the industry breakdown of occupational benzene exposure is not included in this report.

BURDEN

Approximately 20 leukemia cases (all AML, ALL and CML cases combined) occur each year due to occupational exposures to benzene in Canada. Most leukemia cases caused by occupational exposure to benzene occur in the manufacturing sector (31%), followed by transportation/warehousing (18%), trade (13%), and other services (13%). Of the 20 total leukemia cases, 39% occur in workers in Ontario, followed by 26% in Quebec, 11% in Alberta, 10% in British Columbia, 6% in Manitoba, and 5% or less in the remaining provinces. Nationally, these cancers account for 0.5% of all cases of leukemia, however, the attributable fraction was higher in Manitoba and Nova Scotia, where approximately 0.7% and 0.6% of leukemia cases diagnosed are due to occupational exposure to benzene, respectively. Occupational exposure to benzene also causes approximately 5 multiple myeloma cases in Canada each year, accounting for 0.2% of all multiple myeloma cases diagnosed annually. Due to small numbers, a figure displaying the industry breakdown of total leukemia cases attributed to occupational exposure to benzene is not included in this report.

EXPOSURE REDUCTION STRATEGIES

A number of chemical substitution options are available for benzene in order to reduce workplace exposures. For example, certain alcohols and cyclohexane compounds can be used as solvents in its place (167). However, the toxicity of benzene substitutes should also be considered before implementation. Effective engineering controls include: using local exhaust hoods; process enclosure through, for example, fume hoods and glove boxes (167, 168); automated systems to dispense benzene to reduce the number of workers handling the substance; and, back-up controls, such as double mechanical pump seals, to control exposure in case of equipment failure (167, 168).

Administrative controls include training programs to educate workers on potential exposures and appropriate workplace practices, as well as monitoring programs to better assess workplace exposure (167). Hygiene practices, such as not eating, drinking or smoking in areas where benzene is used or stored, should be followed. Other administrative controls include establishing protocols for cleaning up spills, and storage and product labelling (167). The general, overarching policy recommendations, presented later in this report, can be applied to benzene.

GENERAL POLICY RECOMMENDATIONS TO PREVENT OCCUPATIONAL CANCER IN CANADA

Policy recommendations offer a higher potential for impact by targeting numerous workplaces across different sectors and various regions. Throughout this report, carcinogen-specific policies are identified that could be implemented by the federal and/or provincial governments to reduce or prevent exposures to known and suspected occupational carcinogens in Canada.

In addition, there are three broad policy recommendations that apply to all carcinogens.

1. Strengthen occupational exposure limits across all Canadian jurisdictions.

2. Reduce or eliminate the use of cancer-causing substances with toxic use reduction policies in workplaces.

3. Create registries of workplace exposures to occupational carcinogens that will facilitate the tracking of exposures over time.

STRENGTHEN OCCUPATIONAL EXPOSURE LIMITS ACROSS ALL CANADIAN JURISDICTIONS

Occupational Exposure Limits (OELs) should be strengthened, provincially and federally, to align with recent evidence on health effects and be at least as protective as limits set by the American Conference of Governmental Industrial Hygienists (ACGIH). It is possible that some workers may develop cancer at levels of exposure that are lower than the ACGIH limits, which is why it is important for every Canadian jurisdiction to keep abreast of the latest scientific evidence on cancer and other health effects. As OELs are lowered, opportunities for collaboration between regulators, exposure scientists and universities with laboratory capabilities (e.g., University of British Columbia, University of Toronto, Université de Montréal) to develop and/or adopt newer and more cost-effective sampling technologies should be explored and applied broadly across Canada. Strengthening OELs, while also ensuring they are both technically and economically feasible for employers to implement and for regulators to enforce, will lead to the effective protection of workers from overexposure.

Recommendations on the establishment of consistent OELs across Canada could be led by a national-level committee with representatives from relevant provincial, territorial and federal agencies, key stakeholders, including organized labour and employer groups, and scientific experts. Such pan-Canadian committees have previously been effective at establishing the Guidelines for Canadian Drinking Water Quality (169), for updating the Workplace Hazardous Materials Information System in 2015 (170), and for ensuring their implementation. A national-level committee could also be used to recommend both aspirational health-based limits as well as interim OELs for compliance during the transition. This was an approach adopted by the Health Council of the Netherlands, which proposed two health-based OELs for diesel engine exhaust that are roughly equal to and less than background levels (approximately 1 $\mu g/m^3$ elemental carbon), while acknowledging that it will take many years to achieve these levels (75).

One example of how current OELs could be strengthened and harmonized across jurisdictions is by addressing silica exposure. Growing scientific evidence has demonstrated the adverse health effects of silica. In 2005, seven Canadian provinces and the federal government implemented a more rigorous OEL of 0.025 mg/m^3 for all forms of silica (81). It is recommended that the remaining provinces (New Brunswick, Ontario, Northwest Territories, Nunavut, Saskatchewan, Quebec, and the Yukon) change their OELs for silica to the more rigorous level of 0.025 mg/m^3.

REDUCE OR ELIMINATE THE USE OF CANCER-CAUSING SUBSTANCES WITH TOXICS USE REDUCTION POLICIES IN WORKPLACES

Toxics use reduction policies aim to reduce the use and creation of toxic substances to prevent pollution and protect human health (171). While these policies tend to focus on the health of the general public, many of the provisions can also be applied to worker exposure and health. For example, reports of carcinogen use in specific workplaces and industries can serve as an indicator of potential workplace exposures, particularly where detailed exposure data are not available at a given facility. Ontario implemented its Toxics Reduction Act in 2010 based on Massachusetts' Toxics Use Reduction Program (which was enacted in 1989), requiring facilities to quantify the use, creation, transformation, release and disposal of toxic substances, and to prepare plans to reduce the use or creation of the substances. This type of policy could be implemented in other provinces to help track industrial carcinogen use and spur reductions in use of priority substances.

The development of chemical use registries that track and inform workers of the amount of toxic chemicals used in various industries could benefit workplace exposure surveillance activities. At the federal level, a chemical use database could be established under the Canadian Government's Chemicals Management Plan, which already advises on chemical risk assessment and risk management processes for several priority chemicals for environmental exposures (172). The Chemicals Management Plan's Priority Substances List could also be expanded with input from relevant stakeholders (e.g., worker representatives, employers and regulators) to help prioritize chemical substitution in workplaces based on the level of risk each substance may pose to human health.

The establishment of a research institute whose focus is the development of substitutes to many toxic chemicals would also likely increase the number of industries that take preventive measures. Massachusetts has a Toxics Use Reduction Institute (TURI) whose mandate is to foster research into developing alternatives to many toxic chemicals used in manufacturing processes as well as improving awareness of exposures and substitution options among industries and workers. For example, many industries in Massachusetts have substituted formaldehyde-based resins with soy- and water-based resins (173) based on TURI's work with those industries. These and other types of substitutions for carcinogens have been shown to lead to long-term declines in the use of carcinogens in manufacturing processes and releases of carcinogens in the environment (174). A research funding program that provides funding opportunities and/or small grants to develop alternatives could also help generate more research into chemical alternatives going forward.

CREATE REGISTRIES OF WORKPLACE EXPOSURES TO OCCUPATIONAL CARCINOGENS THAT WILL FACILITATE THE TRACKING OF EXPOSURES OVER TIME

There has been a significant decrease in workplace exposure measurement and monitoring in Canada since the 1990s and a shift in responsibility from regulators to employers in conducting exposure measurement surveys (175). Development of effective exposure surveillance programs is possible through increased routine exposure monitoring by ministries of labour and related agencies, as well as by employers. Exposure surveillance results should be free and easily accessible to regulators, employers, employees and the general public (e.g., on a website or in a database such as the Canadian Workplace Exposure Database (22)) to have the greatest impact on exposure prevention. Where necessary, tools should be developed to help interpret the data, in order to make it truly accessible to workers and the general population.

An alternative approach is to develop registries of exposed persons. For example, the Finnish ASA Register, established in 1979, requires employers to provide data on the use of a set list of priority carcinogens and to notify exposed workers to labour safety authorities on an annual basis. The Register has had a direct impact on reducing workplace exposures, with a substantial number of workplaces reporting reductions in exposure to carcinogens after its implementation (176). Two similar registries exist in Canada, but with a narrower focus. The National Dose Registry monitors workers' exposure to ionizing radiation, while Ontario's Asbestos Workers Register includes asbestos-exposed workers (177).

Exposure surveillance and aggregate exposure information from registries can help prevent occupational exposure by providing a regular and standardized method of informing workers, unions, employers and regulators of potential exposures. They can help identify where there is a heightened need for inspection, enforcement, training and remediation. They can also facilitate future research on prevention, monitor exposure trends over time and assess the impact of new regulations to reduce exposure. In addition to monitoring known hazardous substances, monitoring exposure to new chemicals introduced into workplaces can facilitate the early detection of potentially hazardous or carcinogenic substances.

CONCLUSION

The findings of this report demonstrate that exposure to 13 carcinogens commonly found in the workplace is responsible for over 10,000 newly diagnosed cancer cases in Canada each year. These numbers represent a substantial burden of cancer cases due to largely preventable exposures. This report highlights many primary prevention opportunities for strategic policy action that would not only reduce the burden of occupational cancer, but also protect public health. These policies could originate from various levels of government and any organization that plays a role in preventing occupational cancer (including, for example, organized labour, employer associations, workers' compensation boards, as well as provincial ministries of labour, environment, mining and health). Positive and meaningful change on occupational cancer in Canada will require a comprehensive and inter-sectoral approach.

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