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Carcinogenic substances: Exposure profile of Quebec workers

France Labrèche

IRSST, france.labreche@irsst.qc.ca

Patrice Duguay

IRSST

Claude Ostiguy

IRSST

Nicole Goyer

IRSST

Alexandre Boucher

IRSST

See next page for additional authors

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Auteurs

France Labrèche, Patrice Duguay, Claude Ostiguy, Nicole Goyer, Alexandre Boucher, Brigitte Roberge, and Marc Baril

Chemical and Biological Hazards Prevention

Studies and Research Projects

REPORT R-830



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*France Labrèche
Patrice Duguay
Claude Ostiguy
Nicole Goyer
Alexandre Boucher
Brigitte Roberge
Marc Baril*



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IRSST – Communications and Knowledge

Transfer Division

505 De Maisonneuve Blvd. West

Montréal, Québec

H3A 3C2

Phone: 514 288-1551

Fax: 514 288-7636

publications@irsst.qc.ca

www.irsst.qc.ca

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*France Labrèche¹, Patrice Duguay², Claude Ostiguy¹,
Nicole Goyer³, Alexandre Boucher²,
Brigitte Roberge¹, Marc Baril³*

¹*Chemical and Biological Hazards Prevention, IRSST*

²*Scientific Division, IRSST*

³*IRSST*



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PEER REVIEW

In compliance with IRSST policy, the research results published in this document have been peer-reviewed.

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ABSTRACT

The list of substances and working conditions linked to a high risk of cancer continues to grow. To establish priorities in research needs and orient preventive action in the field of occupational cancer and carcinogens, it is essential to have data on worker exposure. First the scope of the problem must be determined and an overall portrait drawn up in terms of both exposure to carcinogenic substances or conditions and the number of cases of occupational cancer. This report presents the results of the first stage in work undertaken at the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) aimed at documenting the exposure of Quebec workers to carcinogenic substances or conditions. It offers an important contribution to Quebec knowledge about exposure to carcinogens; its findings should be useful to anyone interested in this topic.

Exposure estimates were compiled for 38 carcinogens listed in Schedule I of the Regulation Respecting Occupational Health and Safety (designations C1, C2 or C3) and in the list of known or probable carcinogens published by the International Agency for Research on Cancer (groups 1 and 2A). The number of workers potentially exposed to each carcinogen was obtained by applying the percentage of exposed workers in a given industry, calculated from various data sources, to the number of people working in that industry in Quebec according to the 2006 Census of Canada. The information on exposure was based on analysis data from laboratory tests performed by the IRSST for the public occupational health network, the results from a number of special projects carried out by the IRSST, data from Santé-Québec's 1998 Social and health survey (Enquête sociale et de santé 1998), Health Canada data on occupational radiation exposure and exposure data compiled as part of the CAREX Canada project conducted by the University of British Columbia. For some carcinogens, the exposure data came from two French sources: the SUMER survey of occupational health physicians by France's Ministère du travail and the Matgéne job-exposure matrices developed by the Institut de veille sanitaire.

According to these calculations, the 10 substances or conditions to which the greatest proportion of Quebec workers are exposed are solar radiation (6.6%), night work or rotating shifts including night work (6.0%), diesel exhaust (4.4%), wood dust (2.9%), polycyclic aromatic hydrocarbons (excluding diesel exhaust) (2.0%), benzene (1.7%), silica (1.5%), lead (1.3%), artificial ultraviolet radiation (1.1%) and mineral oils (1.0%).

In several industries, over 20 different carcinogens are present; these industries include *manufacturing, construction, other services except public administration, utilities, professional, scientific and technical services, and administrative, support, waste management and remediation services*. Among the manufacturing subsectors with exposure to multiple carcinogens are *non-metallic mineral products, transportation equipment, primary metals, chemicals and paper*.

Based on these percentages, it is estimated that at least 230,300 Quebecers are exposed to solar radiation and more than 150,000 to diesel exhaust on the job. Over 50,000 are exposed to carcinogens in each of the following sectors: *manufacturing, transportation and warehousing, agriculture, forestry, hunting and fishing, and health care and social assistance*.

Exposure to polycyclic aromatic hydrocarbons (PAHs), diesel exhaust, benzene and solar radiation affects most of the industries where a larger proportion of young workers is found, including *retail trade, arts, entertainment and recreation, and accommodation and food services*.

A breakdown of the data by sex shows that more women are exposed to carcinogens in *health care and social assistance* (ionizing radiation, night work, artificial UV radiation and solar radiation). Men are found in greater proportions in *agriculture, forestry, hunting and fishing, mining, quarrying and oil and gas extraction, construction, utilities, manufacturing and transportation and warehousing*. These industries are characterized by exposure to solar radiation, wood dust, night work, silica, diesel exhaust, mineral oils and lead.

Despite their limitations, the estimates are useful indicators of the extent of Quebec workers' potential exposure to carcinogens, mainly because this is the first portrait of its type based on data aggregated from a variety of sources.

Because cancers take several years to develop and it can be difficult to establish a link between a cancer and a given occupational exposure, the best strategy is prevention. The preventive approach for exposure to carcinogens is the same as for any occupational hazard: anticipation, identification, assessment and risk control (through elimination at source, substitution and reduction of exposure), as well as informing and educating employers and workers about carcinogenic substances.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH®	American Conference of Governmental Industrial Hygienists
CAEQ	Classification des activités économiques du Québec [Classification of Quebec economic sectors]
CAREX	CARcinogen EXposure: European database on occupational exposure to carcinogens (set up by T. Kauppinen of the Finnish Institute for Occupational Health)
CAREX Canada	CARcinogen Exposure Canada: Canadian database on occupational and environmental exposure to carcinogens (set up by the University of British Columbia)
CAS No.	Chemical Abstracts Service number (registry established by the American Chemical Society to index chemical substances, including compounds and mixtures, as well as biological sequences)
IARC	International Agency for Research on Cancer
ISIC	International Standard Industrial Classification
NOC	National Occupational Classification (Statistics Canada)
CMR 2005	Inventory of carcinogenic, mutagenic and reprotoxic chemicals drawn up in 2005 (France)
COLCHIC	Database on occupational exposure, with data provided by the French CRAMs and compiled by the INRS
CRAM	Caisses régionales d'assurance maladie (France) [Regional health insurance funds]
CSST	Commission de la santé et de la sécurité du travail [Quebec workers' compensation board]
SIC	Standard Industrial Classification (Statistics Canada)
SOC	Standard Occupational Classification (Statistics Canada)
DARES	Direction de l'Animation de la Recherche, des Études et des Statistiques (Ministère des Affaires sociales, du Travail et de la Solidarité, France) [Directorate for research, studies and statistics (French Ministry of labour, labour relations and solidarity)]
EQCOTESST	Enquête québécoise sur des conditions de travail, d'emploi et de santé et de sécurité du travail [Quebec survey on working, employment, and occupational health and safety conditions]
EQSP 2008	Enquête québécoise sur la santé des populations 2008 [Quebec survey on population health status, 2008] (Institut de la statistique du Québec)
ESS 1998	Enquête sociale et de santé 1998 [Social and health survey, 1998] (Institut de la statistique du Québec)

ÉVALUTIL	Program consisting of two databases on occupational exposure to asbestos and artificial mineral fibres (AMF) and a job-exposure matrix on asbestos (France)
FIOH	Finnish Institute for Occupational Health
PAH	Polycyclic aromatic hydrocarbons
InVS	Institut de veille sanitaire (France) [Institute for public health monitoring]
INRS	Institut national de recherche et de sécurité (France)
INSEE	Institut national de la statistique et des études économiques (France)
ISCO	International Standard Classification of Occupations
MAK	Maximale Arbeitsplatzkonzentration [maximum allowable workplace concentration] (Germany)
Matgéné	Program of general population job-exposure matrices set up by the InVS
JEM	Job-exposure matrix
OSHA	Occupational Safety and Health Administration (U.S.A.)
ROHS	Regulation Respecting Occupational Health and Safety, Quebec (RRQ, c. S-2.1, r. 19.01; now numbered c. S-2.1, r. 13)
ES	Economic sector
NAICS	North American Industry Classification System
CBP	Canadian Business Patterns (Statistics Canada database)
SUMER	SURveillance MÉdicale des Risques: French survey on assessments of employee occupational exposure by occupational health physicians during face-to-face interviews
UV	Ultraviolet (UV radiation)
STEV	Short-term exposure value (Quebec)
TWAEV	8-hour time-weighted average exposure value (Quebec)

1. INTRODUCTION

1.1 Background

The first instances linking specific chemical exposure to cancer in workers go back over a century and include cancer of the scrotum in chimneysweeps, associated with soot in 1775 and with tar and mineral oil in the 1800s [Waldron, 1983]. However, most other carcinogens were associated with cancer in the 20th century, especially following the Second World War [Landrigan, 1996].

The list of substances and working conditions associated with a high risk of occupational cancer continues to lengthen. The Regulation Respecting Occupational Health and Safety (RRQ, S-2.1, r. 19.01¹) classifies 24 substances, including 6 types of asbestos fibres and 4 forms of chromate, as having a detected carcinogenic effect in humans (designation C1), 55 substances as having a suspected carcinogenic effect in humans (designation C2) and 38 substances as having a detected carcinogenic effect in animals (designation C3). However, a much higher number of substances or conditions have been deemed carcinogenic by other organizations. A recent estimate of the number of carcinogens in the workplace, arrived at primarily on the basis of work by the International Agency for Research on Cancer (IARC), reported 28 definite, 27 probable and 113 possible occupational carcinogens, as well as 18 occupations or industries entailing excess risk of cancer [Siemiatycki et al., 2004].

A necessary first step in any prevention initiative is to describe the problem. For diseases with long latency periods, such as cancer, the impact of preventive action taken today may not be noticeable for 5 to 40 years, depending on the type of cancer in question. Over the last 10 years or so, a number of countries have produced estimates of the number and percentage of workers exposed to carcinogenic substances as part of their efforts to tackle occupational cancer. Estimates have been made for European countries [see, inter alia, Kauppinen et al., 2000; Mirabelli et al., 2005; Cherrie et al., 2007], as well as for other countries around the world [Partanen et al., 2003; Blanco-Romero et al., 2011]. Most of these estimates have concerned workers' current exposure, but a few studies have also added adjustment factors in order to estimate lifetime exposure prevalence, including those by the IARC for France [Autier et al., 2004] and the World Health Organization for all countries [Driscoll et al., 2004].

For Quebec, it is difficult to estimate the number of workers exposed to carcinogens because relevant data are not collected in a systematic or representative manner for all regions or all substances. Nevertheless, there is a need to learn more about carcinogen exposure in order to identify industries and occupations where corrective or preventive action may be required, the ultimate goal being to reduce the incidence and even prevent the development of occupational cancers.

1.2 Classification of Carcinogens

The carcinogenic potential of various substances or exposure circumstances is generally established on the basis of information from scientific studies. While a number of different

¹ Now numbered RRQ, S-2.1, r. 13

classifications are being used around the world (see Appendix 1 for the main ones), the evidence taken into consideration to establish them is essentially the same: human and animal studies are considered, along with information from *in vitro* studies, according to knowledge available at the time of the assessment [Gérin and Band, 2003]. It is important to note that the organizations that produce these classifications are seeking to identify substances or exposure circumstances that may pose a hazard, i.e., capable of causing cancer under certain circumstances, and not those that may pose a risk, i.e., a quantified carcinogenic effect that is to be expected following exposure to a certain hazardous “dose.”

The IARC method is described in brief below. The substances or circumstances to be studied are chosen when existing data indicate that humans are exposed to them and that a possible carcinogenic effect has been reported, either in studies or because of a chemical analogy with a known carcinogen. Relevant epidemiological and animal studies published in peer-reviewed journals are examined, along with government reports and studies aimed at establishing the mechanisms of carcinogenic action. The assessment is conducted by working groups made up of specialists combining knowledge and experience, without any conflicts of interest, and where possible, demographic diversity and a broad range of scientific viewpoints. Also included in the research teams are members of the IARC’s permanent secretariat and various outside observers (specialists with potential conflicts of interest, representatives of health authorities, scientific observers). The assessments these working groups produce classify substances and circumstances according to their carcinogenic potential in humans and animals, specifying the target organs in question as well as the health effects other than cancer [IARC, 2006a].

1.3 Estimating Exposure

There are several ways to estimate exposure to carcinogens, depending on whether data with or without measurements are available, and on the degree of accuracy of the data. While it is valuable having time-weighted averages for carcinogens for which an exposure standard exists, extrapolating the data to an entire occupation or economic sector is a tricky operation. For carcinogens for which there are no exposure standards, only data indicating their presence or absence in a form that could expose workers to the carcinogen should be considered. The existence of a threshold or minimum exposure required for the development of cancer is a controversial topic, and a number of people have espoused the no-threshold theory [Lauwerys et al., 2007].

Over the last 10 years, a number of countries have been working on estimating carcinogen exposure as part of their cancer prevention efforts. Most work has used existing exposure prevalence data, where exposure is defined as exposure to a concentration greater than the background level in the general population.

Two aspects of estimating exposure need to be clarified: the industrial and occupational classifications used, and the method of estimating the number of workers exposed.

1.3.1 Economic Sectors and Occupations

Workers’ estimated exposure is generally reported with respect to the economic sector they work in or their occupation. While there are many industrial and occupational classifications, using an

international one facilitates comparisons between countries. For research projects intended to estimate the percentage of workers exposed to carcinogens, the European Union (EU) and Australia used the second revision of the International Standard Industrial Classification (ISIC-2, 1968) published by the United Nations (UN), with different levels of precision depending on the industry, for a total of 55 industries. For occupations, the existing classifications have less in common, but still allow rough comparisons to be made. To estimate the number of workers, the EU used figures from the Organization for Economic Cooperation and Development (OECD) that included salaried workers, the self-employed, working family members and part-time workers, classified according to ISIC-2 [Kauppinen et al., 2000]. When available, labour force statistics specific to each country provide even greater precision and are therefore preferable.

1.3.2 Estimating Number of Workers Exposed

If local measurement data are not available, estimates of the percentage of workers exposed in other countries can be used and applied to the number of workers in Québec, for each economic sector. However, there are two main problems with this method. First, the percentage of workers exposed varies by industrial profile: a country with a large mining sector will report very different exposures from a country with a comparatively large agricultural sector. Second, even within the same sector, exposures can vary from one country to the next in terms of percentage of workers exposed or frequency of exposure over the workweek. For instance, a construction worker in Quebec will probably be more exposed to wood dust than a construction worker in Europe, where concrete is more commonly used for the structural framing of homes.

The most ambitious study of this kind was conducted by the EU between 1990 and 1998, based on the prevalence of worker exposure to certain carcinogens in Finland and the United States. This was the beginning of the CAREX database, and some countries have since added their own specific data to provide more precise exposure estimates, after agreeing on the substances to be selected and a common industrial classification. Experts from each member country then identified industries with low exposure levels and separated out the number of workers with exposure to more than one carcinogen so as not to count them several times. An overall report for the EU [Kauppinen et al., 1998] and a specific report for each country were published on the site of the Finnish Institute of Occupational Health (FIOH) [FIOH, 2011]. By this process, it was estimated that 23% of EU workers may have been exposed to carcinogens in the early 1990s [Kauppinen et al., 2000].

As there were no Australian exposure data, Fritschi and Driscoll [2006] applied this proportion of 23% of workers exposed to carcinogens to Australian workers, while emphasizing the importance of collecting local exposure data to corroborate the estimates [Fritschi and Driscoll, 2006; Benke and Goddard, 2006].

To estimate the total exposure burden of carcinogens, the percentage of workers who have been exposed to carcinogens, but who have since changed jobs, must be added to the current exposure prevalence figures. The reason for this is that carcinogenesis is a gradual process and cellular changes can continue after exposure ends. To take this into account, a World Health Organization (WHO) working group has recommended adjusting estimates on the basis of rates of worker turnover in certain industries and, where regional data are not available, has suggested

multiplying by four the number of currently exposed workers in order to obtain the total number of workers ever exposed [Driscoll et al., 2004].

1.4 Purpose of Study

The purpose of this study is to produce a general profile of the exposure of Quebec workers to carcinogens.

More specifically, the intention is to estimate the extent of occupational exposure to carcinogens, chiefly in terms of number of workers exposed and economic sectors affected. When the information is available, the estimates are given by sex and by age group for certain carcinogens.

2. METHODOLOGY

2.1 Selection of Carcinogens

The list of carcinogens to be taken into consideration was compiled from five sources. (See Appendix 1 for a more exhaustive list of existing classifications, along with details about their structure and designations.)

- Substances designated C1, C2 or C3 in Schedule I of the Regulation Respecting Occupational Health and Safety, (RRQ, S-2.1, r. 19.01) [Government of Quebec, 2011a]
- Substances classified A1 (confirmed human carcinogen), A2 (suspected human carcinogen) or A3 (confirmed animal carcinogen) by the American Conference of Governmental Industrial Hygienists [ACGIH®, 2010a]
- Substances classified by the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Workplace (MAK Commission) in categories 1 (human carcinogen), 2 (animal carcinogen), 4 (low carcinogenic potential with non-genotoxic mode of action) and 5 (low carcinogenic and genotoxic potential) [Greim and Reuter, 2001]
- Substances or exposure circumstances classified as confirmed (group 1) or probable (group 2A) carcinogens by the IARC [IARC, 2011]
- Substances classified as group 1 or K (known human carcinogens) and group 2 or R (reasonably anticipated human carcinogens) by the U.S. National Toxicology Program [NTP, 2011]

All the substances or exposure circumstances meeting the carcinogenicity criteria set out above and for which we were able to find exposure estimates as of October 2010 were selected for the study, i.e., a total of 38 substances or circumstances (Appendix 2).

2.2 Sources of Exposure Data

Data sources were chosen primarily to represent the exposure situation of Quebec workers by giving priority to sources available at the IRSST, then in Quebec. When Quebec data on a carcinogen were not available, we used the estimates produced by the CAREX Canada project at the University of British Columbia. When we were unable to obtain Quebec or Canadian data, we filled in the information for some carcinogens by using the French databases of the SUMER survey and the Matgéné program. Additional databases, such as the health care databases of the Caisses régionales d'assurance maladie (CRAM) in France, could have been queried, but obtaining the data would have taken longer and required further authorization. The database of the U.S. Occupational Safety and Health Administration (OSHA), which contains measurement data collected by compliance inspectors from as far back as 1979, was not yet available on line when the decision about which databases to include in the study was made, and so it was rejected because of time constraints. Although approximately 35% of its records were labelled as non-detects [Lavoué et al., 2011] and there are some potential sampling-related biases [Lavoué et al., 2008], it does contain a huge amount of data describing U.S. industrial environments, which may be much more similar to Quebec environments than European ones are.

The seven data sources indicated below were used to determine whether or not there was carcinogen exposure and, with the exception of the first source, the percentage of workers exposed. The sources are listed in the order of preference that was given to their data. (See Appendix 2 for the data sources used for each carcinogen.) Note that exposure is defined differently in each source, that the exposure reference period is generally the last 20 years and that each source has its own special characteristics and limitations. (See Appendix 3 for a description of each data source.)

1. The laboratory database of the IRSST, which compiles the results of analyses requested by public occupational health teams and other occupational health stakeholders. Carcinogen exposure was considered to exist when, in a given industry, more than one sample tested exceeded 20% of the standard. The data were not used to estimate the percentage, or calculate the number, of workers exposed.
2. Data collected by IRSST researchers in the course of special projects. Exposure was deemed to exist in an industry when workers were exposed to more than 30% of the standard for formaldehyde and 50% of the standard for quartz.
3. Data from the 1998 Quebec Social and Health Survey (ESS 1998) estimating the prevalence of exposure to wood dust and night work. (A specific data retrieval was performed by the Institut de la statistique du Québec.) Exposure was considered to exist when respondents reported being exposed “often” or “all the time.”
4. A Health Canada report on occupational radiation exposure in 2008 [Sont, 2009]. Everyone who wore a dosimeter was considered to have been exposed, regardless of the annual dose calculated.
5. The percentages of workers exposed to certain carcinogens, estimated in the course of the CAREX Canada project. In this case, exposure is considered to exist when a worker is exposed to a concentration greater than the background level in the general population.
6. The percentages of workers exposed, according to the French 2003 SUMER survey. Same definition of exposure as for CAREX Canada data.
7. Industries associated with a few carcinogens according to the program of general population job-exposure matrices (Matgéné). Same definition of exposure as for CAREX Canada data.

The characteristics of these data sources and the procedures followed to calculate percentages of workers exposed are set out in Appendix 3.

2.3 Sources of Labour Force Data

Following identification of the economic sectors and occupations that expose workers to carcinogens, the number of workers in question was estimated using labour force data by sector and by occupation in Quebec.

The labour force data source used was the 2006 Census of Canada. The data provided by Statistics Canada are number of paid workers² in Quebec by sex, age group, occupation (coded

² According to Statistics Canada’s definition, paid workers include wage and salary earners and self-employed persons in incorporated companies who were occupied during the week preceding census day. This category of self-employed workers is included in paid workers because they are also usually paid a salary by their own companies.

according to the National Occupational Classification, with a degree of precision of up to four digits) and industry (coded according to the North American Industry Classification System, likewise with a degree of precision of up to four digits). As the census is conducted in May and the number of workers can vary significantly from month to month in some industries (in agriculture, for instance, or construction), an adjusted number of paid workers was calculated for each “industry-occupation” dyad using data from the Survey of Employment, Payroll and Hours for 2005 to 2007 [Statistics Canada, 2008; 2010]. The adjustment factor was calculated by dividing the average annual number of workers per industry between 2005 and 2007 by the total number of workers in May 2006 (time of the census); the number of workers calculated by Statistics Canada was then multiplied by this adjustment factor for each industry.

2.4 Data Processing and Analysis

As several data sources were used, the classifications had to be standardized. To estimate the number of workers exposed to carcinogens in various industries and occupations, Statistics Canada’s reference classifications were used: the National Occupational Classification (NOC) [Statistics Canada, 2007a] and the North American Industry Classification System (NAICS) [Statistics Canada, 2007b]. These two choices required converting the classifications used in the various exposure data sources to the corresponding NOC and NAICS codes. The classifications in question are shown in Table 1. A concordance table developed at the IRSST was used, along with some Statistics Canada tables.³

Once the correspondences had been established, the labour force numbers were associated with each “carcinogen-industry-occupation” triad present in all the exposure data sources, so that the number and proportion of paid workers exposed to a carcinogen could be estimated.

Generally speaking, we had only one estimate per carcinogen-industry-occupation triad. For one of the databases, Matgéné, the estimates obtained consisted of categories having very broad ranges of percentages of workers exposed (see Appendix 3); we decided to use the lowest value of the range for each category, to avoid overestimating the proportion of workers exposed. This methodological choice concerned 3 of the 38 substances studied: chloroform, leather dust and carbon tetrachloride.

When data from the same source gave several exposure percentages for various industry or occupational subcategories, the lowest percentages were systematically selected. For example, the same NAICS four-digit code 8122 includes funeral directors along with embalmers. While a small proportion of directors are exposed to formaldehyde, at concentrations less than a third of the standard, embalmers are all exposed to levels over a third of the standard. In this profile, the exposure of funeral directors was therefore assigned to all workers in industry group 8122. Another example can be found in Matgéné data, where the percentages of workers exposed were presented in classes defined by ranges of values (1%–10%, 10%–50%, 50%–90%, > 90%): a decision was made to report the lowest value of the interval associated with each class, i.e., 1% for category 1%–10%, 10% for category 10%–50%, etc. To reflect the current exposure situation

³ Concordance tables: SOC-1991 / NOC-S 2001, SIC-1980 / NAICS 2002, ISIC Rev. 3.1 / NAICS 2002. See <http://www.statcan.gc.ca/concepts/concordances-classifications-eng.htm>.

as accurately as possible, it was decided that only the most recent exposure period would be retained when data were available for several decades, which was the case for Matgéné.

An essentially descriptive analysis was conducted, presenting exposure prevalences by industry for proven and for probable carcinogens. Then the industries in which multiple exposures to carcinogens have been reported are presented. Lastly, the number of workers exposed was estimated by applying the calculated percentages to the Quebec labour force data obtained from Statistics Canada by industry from the 2006 Census of Canada. These numbers are reported only in cases where 50 or more workers were presumed exposed and have been rounded to the nearest hundred.

Table 1 – Data sources and classifications used

Data source	Industry classification	Occupational classification
Computerized database of results of IRSST laboratory analyses	CAEQ ¹	–
Other databases available at IRSST (e.g., formaldehyde)	NAICS	–
1998 Social and Health Survey (ESS 1998)	SIC-80	SOC-80
Estimates produced by CAREX Canada project	NAICS	NOC
Health Canada data on occupational radiation exposure	Descriptive classification, National Dosimetry Services	Descriptive classification, National Dosimetry Services
SUMER	French classification of activities (NAF), Institut national de la statistique et des études économiques (INSEE), 1993 ²	French classification of occupations and socio-occupational categories (PCS), INSEE, 2003 ³
Matgéné	International Standard Industrial Classification (ISIC), United Nations, 1975	International Standard Classification of Occupations (ISCO), International Labour Organization, 1968
2006 Census of Canada data, Statistics Canada	NAICS	NOC
Canadian Business Patterns (CBP) database, Statistics Canada	NAICS	–
Business establishments database, CSST	NAICS (version adapted by Quebec's CSST for its own purposes)	–

¹ See list of abbreviations and acronyms at beginning of this report.

² INSEE. “French classification of activities (NAF)” INSEE website page, undated (French only): <http://www.insee.fr/en/methodes/default.asp?page=nomenclatures/naf1993/naf1993.htm> (July 20, 2011).

³ INSEE. “French classification of occupations and socio-occupational categories (PCS),” INSEE website page, undated (French only): <http://www.insee.fr/fr/methodes/default.asp?page=nomenclatures/pcs2003/pcs2003.htm> (July 20, 2011).

3. RESULTS

3.1 Prevalence of Exposure, by Industry

Several data sources were available for some carcinogens, and exposure percentage estimates are presented by source (appendixes 4 and 5). To produce the most accurate estimate for the Quebec context, exposure percentages were selected according to the following order of preference: Quebec data, non-Quebec Canadian data and, lastly, French data when no Quebec or other Canadian data were available.

3.1.1 *Most Prevalent Known and Probable Carcinogens*

For each of the 10 carcinogens to which more than 1.0% of Quebec workers are reportedly exposed, Table 2 indicates the percentages of workers exposed, by NAICS major industrial sector. (The results for all 38 carcinogens studied are given in Appendix 4.) Table 3 breaks down the percentages of workers exposed in the manufacturing sector for the same 10 carcinogens, by subsector. (The results for all 38 carcinogens are presented in Appendix 5.)

According to available Quebec or other Canadian data, the substances or conditions to which the greatest proportion of Quebec workers are exposed are solar radiation (6.6%), regular night work or rotating shifts including night work (6.0%), diesel exhaust (4.4%), wood dust (2.9%), polycyclic aromatic hydrocarbons (2.0%), benzene (1.7%), silica (1.5%), lead (1.3%) and artificial ultraviolet radiation (1.1%). If estimates based on French data are considered, then exposure to mineral oils (1.0%) can also be added.

3.1.2 *Industries with Highest Exposure*

Solar Radiation (IARC, Gr. 1)

According to CAREX Canada estimates, approximately 7% of Quebec workers are occupationally exposed to solar radiation. Workers in *agriculture, forestry, fishing and hunting* and *construction* are the most exposed, with 59.3% and 32.9%, respectively, of workers exposed (Table 2). Workers in *non-metallic mineral product manufacturing* would appear to be those the most exposed in the manufacturing sector (13.5%) (Table 3).

Night Work and Rotating Shifts with Night Work (IARC, Gr. 2A)

In the ESS 1998 Social and Health Survey, 10.3% of workers responded that they were exposed “often” or “all the time” to night work in their jobs, at the time the survey was conducted [Arcand et al., 2000]. The ESS 1998 data were supplemented with data from the SUMER survey, for the percentage of people working “even occasionally at night” and the percentage of people working “at night at least 200 days a year” (which corresponds to a regular night shift). Even when industries for which the coefficient of variation was too high are excluded,

Table 2 – Percentage of Quebec workers exposed to 10 most common known or probable carcinogens,¹ by NAICS major sector

NAICS code	Major sector	Solar radiation ² %	Night work ³ %	Diesel exhaust ² %	Wood dust ³ %	PAHs ² %	Benzene ² %	Silica ² %	Lead & inorganic comp. ² %	Artificial UV radiation ² %	Mineral oils ⁴ %
11	Agriculture, forestry, fishing and hunting	59.27	<u>8.10</u>	7.17	7.76	0.84	0.55	0.04	0.24	0.37	6.20
21	Mining, quarrying, and oil and gas extraction	21.40		28.24	<u>0.19</u>	3.80	0.74	21.56	2.37	2.63	
22	Utilities	7.23	<u>29.30</u>	0.79	<u>0.24</u>	0.67	0.55	0.79	0.83	1.73	6.00
23	Construction	32.94		7.81	21.63	0.59	0.61	21.97	3.74	1.14	4.40
31-33	Manufacturing	2.82	8.08	2.87	12.30	2.12	1.02	2.21	2.95	2.73	3.68
41	Wholesale trade	4.44		5.51	<u>0.32</u>	1.10	2.65	0.44	0.53	0.40	✓ ⁵
44-45	Retail trade	1.58	1.84	1.49	<u>0.11</u>	3.58	2.67	0.20	0.42	0.05	✓
48-49	Transportation and warehousing	15.74	19.15	41.01	<u>0.06</u>	2.23	8.47	1.98	0.36	0.34	
51	Information and cultural industries	2.87	3.01	0.45	<u>0.03</u>	0.11	0.23	0.005	0.50	0.001	
52	Finance and insurance	0.21		0.07	<u>0.01</u>		0.03	0.01	0.01	0.01	
53	Real estate and rental and leasing	2.57	<u>7.30</u>	2.69	<u>0.51</u>	0.72	1.24	0.62	0.36	0.18	1.50
54	Professional, scientific and technical services	2.44	6.33	0.18	<u>0.09</u>	0.06	0.15	0.13	0.06	0.86	
55	Management of companies and enterprises	1.93		0.55	<u>0.57</u>		0.21	0.16		0.57	
56	Administrative and support, waste management and remediation services	11.95	5.92	4.59	<u>0.36</u>	0.47	0.52	0.44	0.14	0.15	
61	Educational services	1.01		0.23	<u>0.16</u>	0.13	0.08	0.03	0.07	0.04	
62	Health care and social assistance	1.54	14.00	0.55	<u>0.08</u>	1.05	0.07	0.01	0.02	2.60	
71	Arts, entertainment and recreation	15.13	21.14	0.83	<u>0.39</u>	0.28	0.12	0.02	0.13	0.09	
72	Accommodation and food services	1.93	17.01	1.10	<u>0.03</u>	10.57	0.88	0.005	0.01	0.005	
81	Other services (except public administration)	2.44		8.62	<u>0.21</u>	0.99	8.56	0.10	4.41	4.72	2.01
91	Public administration	10.09		3.54	<u>0.30</u>	2.24	2.65	0.19	4.08	0.10	
All sectors		6.61	6.04	4.36	2.93	2.05	1.74	1.50	1.26	1.12	1.05

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

² Data from CAREX Canada.

³ Data from ESS 1998. For night work (even occasional night work), additional underlined figures are from the SUMER 2003 survey. For wood dust, additional underlined figures are from CAREX Canada.

⁴ Data from SUMER 2003 survey.

⁵ ✓ : Carcinogen measured at over 20% of the standard in this sector, according to IRSST laboratory data (data used to indicate presence of carcinogen only, not to estimate percentage of workers exposed).

Table 3 – Percentage of Quebec workers exposed to 10 most common known or probable carcinogens,¹ by NAICS manufacturing subsector

NAICS code	Manufacturing subsector	Solar radiation ² %	Night work ³ %	Diesel exhaust ² %	Wood dust ³ %	PAHs ² %	Benzene ² %	Silica ² %	Lead & inorganic comp. ² %	Artificial UV radiation ² %	Mineral oils ⁴ %
311	Food manufacturing	2.47	21.48	4.02	<u>0.01</u>	1.16	1.07	0.02	0.07	0.11	
312	Beverage and tobacco product manufacturing	3.82		11.04		0.38	1.44	0.13	0.11	0.35	
313	Textile mills	0.32		0.57				✓ ⁵	0.12	0.27	
314	Textile product mills	0.97		0.29					0.36	0.63	
315	Clothing manufacturing	0.27		0.40			0.10	0.03	0.02	0.04	
316	Leather and allied product manufacturing	1.56									
321	Wood product manufacturing	5.67	26.32	6.39	77.22	0.38	0.22	0.33	0.67	0.79	
322	Paper manufacturing	2.70	30.90	2.25	22.59	0.34	0.26	0.28	1.25	0.92	✓
323	Printing and related support activities	1.01	<u>11.00</u>	0.46	<u>0.05</u>	0.27	0.32	0.07	0.04	0.01	
324	Petroleum and coal product manufacturing	7.72		3.16		1.80	10.84	2.00	3.28	2.28	
325	Chemical manufacturing	1.52	<u>21.20</u>	1.55		0.46	1.16	3.13	0.43	0.33	
326	Plastics and rubber product manufacturing	0.89	<u>17.10</u>	0.99	<u>0.42</u>	1.27	3.77	4.57	0.50	0.34	
327	Non-metallic mineral product manufacturing	13.50	<u>3.96</u>	12.45	<u>0.43</u>	2.05	0.85	27.50	1.67	1.64	2.19
331	Primary metal manufacturing	6.93	27.99	13.06	<u>0.26</u>	18.43	4.54	10.59	9.51	3.72	
332	Fabricated metal product manufacturing	3.83	<u>14.10</u>	1.17	<u>0.68</u>	3.99	0.84	2.52	11.54	12.35	17.70
333	Machinery manufacturing	2.16		0.97	<u>0.12</u>	2.87	0.62	1.74	8.09	9.59	15.50
334	Computer and electronic product manufacturing	0.84				0.12	0.02	0.12	2.89	1.00	
335	Electrical equipment, appliance and component manufacturing	1.26		0.16	<u>0.29</u>	0.24	0.19	0.28	2.90	3.04	
336	Transportation equipment manufacturing	2.13	<u>10.80</u>	0.87	<u>0.84</u>	3.06	1.20	0.20	4.84	4.72	11.60
337	Furniture and related product manufacturing	1.38		0.82	60.33	0.02	0.33	0.36	1.41	1.41	
339	Miscellaneous manufacturing	1.58		0.39	<u>1.94</u>	0.07	0.33	1.54	3.13	4.42	9.50

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

² Data from CAREX Canada.

³ Data from ESS 1998. For night work (even occasional night work), additional underlined figures are from the SUMER 2003 survey. For wood dust, additional underlined figures are from CAREX Canada.

⁴ Data from SUMER 2003 survey.

⁵ ✓: Carcinogen measured at over 20% of the standard in this sector, according to IRSST laboratory data (data used to indicate presence of carcinogen only, not to estimate percentage of workers exposed).

at least 6.0% of all Quebec workers work nights either occasionally or all the time. According to data from ESS 1998 and the SUMER survey, the sectors with the highest percentages of workers doing occasional night shifts are *utilities* (29.3%), *arts, entertainment and recreation* (21.1%), *transportation and warehousing* (19.1%), *accommodation and food services* (17.0%) and *health care and social assistance* (14.0%) (Table 2). The sectors having the highest percentages of workers doing regular night shifts are *transportation and warehousing* (2.8%) and *information and cultural industries* (2.8%) (data not shown in the tables). In the manufacturing sector, the subsectors of *paper manufacturing* (30.9%), *primary metal manufacturing* (28.0%), *wood product manufacturing* (26.3%), *food manufacturing* (21.5%) and *chemical manufacturing* (21.2%) have the highest percentages of night workers (Table 3). The subsectors of *food manufacturing* (6.0%) and *transportation equipment manufacturing* (1.7%) have the highest percentages of workers who do regular night shifts (data not shown in the tables).

Diesel Exhaust (IARC, Gr. 2A)

According to CAREX Canada data, 4.4% of Quebec workers are exposed to diesel exhaust. The sectors with the highest percentages of exposed workers are *mining, quarrying, and oil and gas extraction* (28.2%) and *transportation and warehousing* (41.0%) (Table 2), while the manufacturing subsectors with the highest percentages are *primary metal manufacturing* (13.1%), *non-metallic mineral product manufacturing* (12.4%) and *beverage and tobacco product manufacturing* (11.0%) (Table 3). In some industry groups (4-digit code), over half of all workers are exposed, including those in *school and employee bus transportation* (81.2%), *taxi and limousine service* (75.8%), *waste collection* (71.3%), *charter bus industry* (66.3%) and *truck transportation* (64.1%) (data not shown in the tables).

Wood Dust (IARC, Gr. 1)

In the 1998 Social and Health Survey, 5.6% of workers reported that they were exposed “quite often” or “all the time” to wood dust in the jobs they occupied at the time of the survey [Arcand et al., 2000]. However, a more recent study of a larger number of workers has determined that 5% of Quebec workers are exposed often or all the time.⁴ More than a fifth (21.6%) of workers in *construction* and 12.3% of those in *manufacturing* are exposed to wood dust (Table 2), according to the study. In the manufacturing sector, 77.2% of workers in *wood product manufacturing* and 60.3% of those in *furniture and related product manufacturing* are exposed (Table 3). In the industry group of *sawmills and wood preservation* and that of *veneer, plywood and engineered wood product manufacturing*, 61.0% and 53.0% respectively of workers are exposed (data not shown in tables).

⁴ Personal communication from Robert Arcand, scientific unit chief, occupational health, Institut national de santé publique du Québec (INSPQ).

Polycyclic Aromatic Hydrocarbons, or PAHs (IARC, Gr. 1, 2A and 2B⁵)

If natural sources such as volcanic eruptions and forest fires are excluded, then the majority of PAHs are produced by the incomplete combustion of organic matter at high temperature (burning of gasoline and wood, primary metal manufacturing and incineration). We were not able to estimate exposure to each individual PAH. We do know, however, that benzo[*a*]pyrene, benz[*a*]anthracene and chrysene have been measured in Quebec workplaces, according to analyses conducted by IRSST labs. CAREX Canada has estimated that 2.0% of workers are exposed to PAHs. The sectors with the highest proportions of exposed workers are *accommodation and food services* (10.6% of sector workers exposed), *mining, quarrying, and oil and gas extraction* (3.8%) and *retail trade* (3.6%) (Table 2). In the manufacturing sector, the *primary metal manufacturing* subsector has by far the highest percentage of workers exposed, with 18.4% (Table 3). In two industries, over a third of workers are reportedly exposed: *alumina and aluminum production and processing* (33.7%) and *gasoline stations* (58.3%) (data not shown in tables).

Benzene (IARC, Gr. 1)

The use of benzene as a solvent has fallen considerably since the IARC's 1974 assessment of it as a possible carcinogen for leukemia [IARC, 1974]. Current exposure is associated primarily with its presence in petroleum products, including gasoline, and its use in the synthesis of various chemicals [ATSDR, 2007]. According to an Environment Canada study, the gasoline used in Quebec has contained an average of 0.8% benzene by volume since the early 2000s [Thompson *et al.*, 2004]. CAREX Canada has estimated that 1.7% of workers are exposed to benzene, with the highest percentages of exposed workers being in gasoline-related industries: *other services except public administration* (8.6% of sector workers exposed), which includes *automotive repair and maintenance*, along with *transportation and warehousing* (8.5%) (Table 2). In the manufacturing sector, the highest percentages of exposed workers are found in *petroleum and coal product manufacturing* (10.8%), *primary metal manufacturing* (4.5%) and *plastics and rubber product manufacturing* (3.8%) (Table 3).

Crystalline Silica or Quartz (IARC, Gr. 1)

While exposure to crystalline silica occurs in a number of industries, only a few of them have a high percentage of exposed workers. CAREX Canada has estimated that 1.5% of Quebec workers are exposed to silica, chiefly in *construction* (22.0% of sector workers exposed) and *mining, quarrying, and oil and gas extraction* (21.6%) (Table 2). The manufacturing subsectors with the highest percentages of exposed workers are *non-metallic mineral product manufacturing* (27.5%) and *primary metal manufacturing* (10.6%). In some industry groups, over 30% of workers are exposed to crystalline silica: *clay product and refractory manufacturing* (36.6%), *glass and glass product manufacturing* (31.5%) and *metal ore mining* (32.3%) (data not shown in tables).

⁵ Benzo[*a*]pyrene: Gr. 1; cyclopenta[*c,d*]pyrene, dibenz[*a,h*]anthracene and dibenzo[*a,l*]pyrene: Gr. 2A; benz[*j*]aceanthrylene, benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*c*]phenanthrene, chrysene, dibenzo[*a,h*]pyrene, dibenzo[*a,i*]pyrene, indeno[1,2,3-*cd*]pyrene and 5-methylchrysene: Gr. 2B.

Lead, Inorganic Compounds (IARC, Gr. 2A)

While inorganic compounds of lead have been classified as probably carcinogenic, a lack of data has made it impossible to determine the carcinogenic potential of organic compounds of the metal [IARC, 2006b]. The available exposure databases do not make any distinctions regarding the chemical characteristics of lead, but this lack of detailed information should not result in overestimating exposure, as most exposure is to inorganic compounds [IARC, 2006b]. Using CAREX Canada exposure estimates, we calculated that approximately 1.2% of Quebec workers are exposed to lead, notably in the following sectors: *other services except public administration* (4.4%), *public administration* (4.1%), *construction* (3.7%) and *manufacturing* (2.9%). In the manufacturing sector, the subsectors with the highest proportions of exposed workers are *fabricated metal product manufacturing* (11.5%), *primary metal manufacturing* (9.5%), *machinery manufacturing* (8.1%) and *transportation equipment manufacturing* (4.8%). Available estimates indicate that over a quarter of the workers in two industry groups are exposed: *commercial and industrial machinery and equipment (except automotive and electronic) repair and maintenance* (25.1%) and *non-ferrous metal (except aluminum) production and processing* (43.4%) (data not shown in tables).

Artificial UV Radiation (IARC, Gr. 1)

Welders, tanning appliance operators, workers in photograph development, sterilization and disinfection, printing, those that use UV lasers, and food quality control workers are, in particular, exposed to artificial UV radiation [IARC, 2006c]. Slightly over 1% of Quebec workers are thought to be exposed to this kind of radiation, according to CAREX Canada estimates. The economic sectors with the highest proportions of exposed workers are *other services except public administration* (4.7%), *manufacturing* (2.7%), *health care and social assistance* (2.6%) and *mining, quarrying, and oil and gas extraction* (2.6%). Manufacturing subsectors where the most welding is done have higher proportions of exposed workers: *fabricated metal product manufacturing* (12.3%), *machinery manufacturing* (9.6%), *transportation equipment manufacturing* (4.7%) and *primary metal manufacturing* (3.7%).

Mineral Oils (IARC, Gr. 1, mineral oils, untreated or mildly treated; Gr. 2A and 2B, some additives)

Mechanics, machinists, masons, form setters and construction labourers use mineral oils, especially mechanical oils, cutting oils and formwork oils [IARC, 1984]. The mineral oils now being used are refined to various degrees [Lafontaine and Delsaut, 2002]. However, refined oils can emit polycyclic aromatic hydrocarbons when they are heated, and some of their additives, such as formaldehyde (group 1) or n-nitrosodiethanolamine (group 2A), pose a carcinogenic risk [CCHST, 2005]. French SUMER survey estimates of the proportions of exposed workers by industry would suggest that 1.0% of Quebec workers are exposed to mineral oils, chiefly in the following sectors: *agriculture, forestry, hunting and fishing* (6.2%), *utilities* (6.0 %) and *other services except public administration* (2.0%) (Table 2). In the manufacturing subsectors of *fabricated metal product manufacturing* and *machinery manufacturing*, over 15% of workers are exposed to mineral oils, as are close to 12% of workers in *transportation equipment manufacturing* (Table 3). In the industry group *other non-metallic mineral product manufacturing*, 12.4% of workers are exposed (data not shown in tables).

Other Carcinogenic Substances or Circumstances

The other carcinogens to which over 0.1% of workers are reportedly exposed fall into a small number of major groups: ionizing radiation (1.0% of workers exposed), various metals (hexavalent chromium: 0.6%; nickel: 0.3%; cadmium: 0.2%; cobalt: 0.2%; arsenic: 0.1%), aromatic or chlorinated hydrocarbons (styrene: 0.3%; tetrachloroethylene: 0.1; dichloromethane: 0.1%; trichloroethylene: 0.1%; aromatic amines: 0.1%), formaldehyde (0.4%) and asbestos (0.6%) (see appendixes 4 and 5).

The sectors with the highest proportions of workers exposed to ionizing radiation are *utilities* (6.4%), *health care and social assistance* (5.0%) and *professional, scientific and technical services* (1.6%). The sectors with high exposure to metals are *mining, quarrying, and oil and gas extraction, manufacturing* and *construction* for all metals, as well as *utilities* for chromium (VI) and cobalt. Hydrocarbon exposure is found in a number of sectors, including *manufacturing* (chemicals, machinery, plastics and rubber products, and textile products), *health care and social assistance, other services except public administration* and *construction*. Finally, the largest number of workers currently exposed to asbestos in Quebec are in the *construction* and *utilities* sectors.

3.2 Multiple Exposures, by Industry

3.2.1 By Major Sector

The above findings underscore the problem of simultaneous exposure to multiple carcinogens. Figure 1 shows the number of carcinogens (out of the 38 studied) by major sector (two-digit NAICS code), according to two types of information sources: the results of chemical analyses conducted by IRSST labs (at the request of CSST inspectors, public occupational health teams or joint sector-based associations) and data from databases discussed earlier. Note that the two types of sources do not cover all the same carcinogens. For instance, IRSST analyses do not include physical carcinogens (ionizing, solar or artificial UV radiation), whereas some

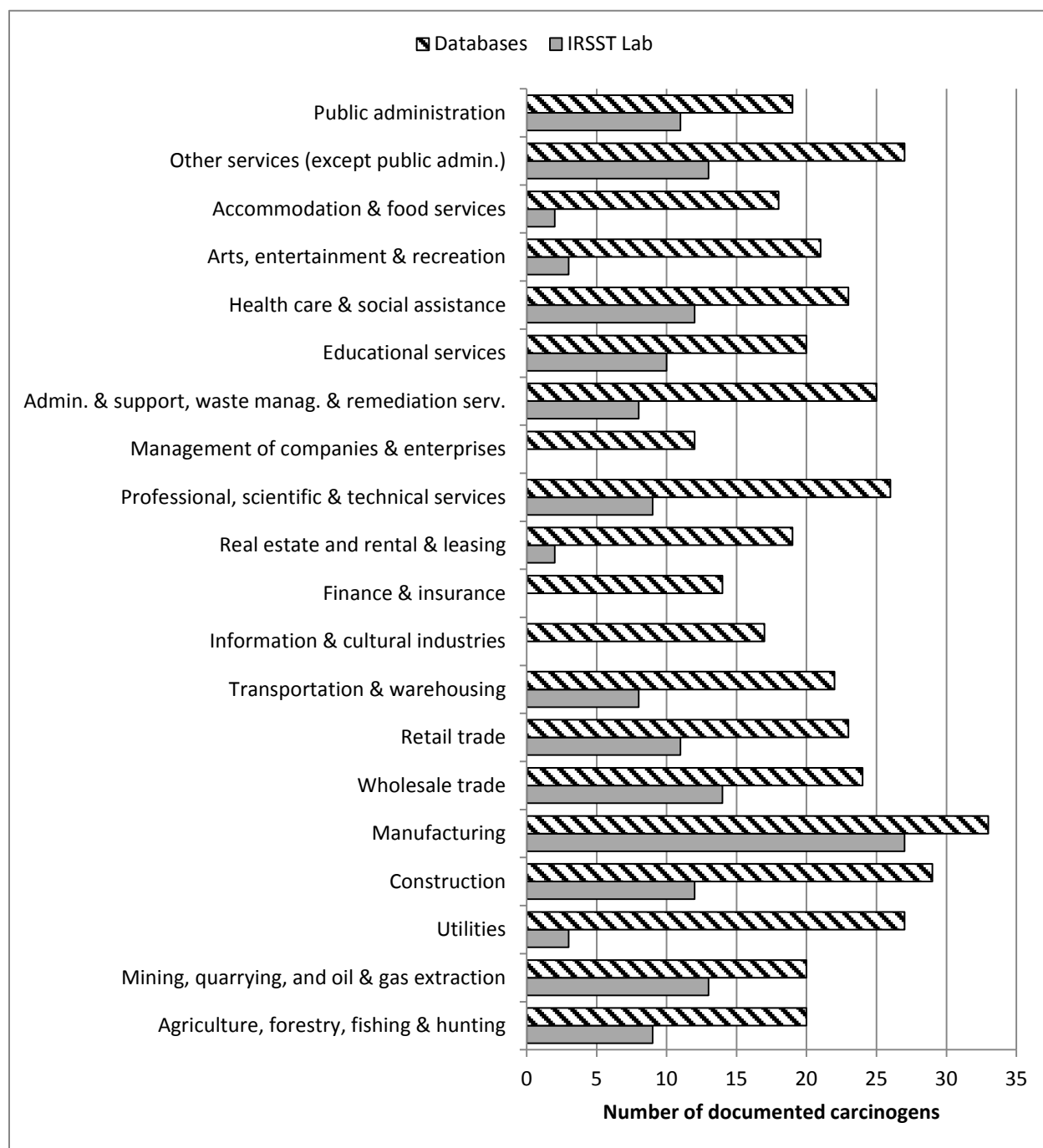


Figure 1 – Number of different carcinogens documented in major sectors of Quebec economy, by source of information

chemicals, such as individual PAHs like benzo[*a*]pyrene, are included in exposure databases only under their generic name (in this case, PAHs). Generally, however, the exposure databases cover more carcinogens than the IRSST analysis data do, which explains why the number of carcinogens listed is systematically lower for the latter source.

In addition to *manufacturing* (NAICS codes 31–33), five other major sectors are identified in the databases as involving exposure to 25 or more different carcinogens. By decreasing order of number of carcinogens, these sectors are

- *Construction* (NAICS code 23)
- *Other services (except public administration)* (81)
- *Utilities* (22)
- *Professional, scientific and technical services* (54)
- *Administrative and support, waste management and remediation services* (56)

3.2.2 By Subsector

Figure 2 provides the same type of information as Figure 1, but for more detailed subsectors of the Quebec economy (three-digit NAICS codes) in which at least 10 carcinogens are documented in one of the databases mentioned earlier. Most of these subsectors are in *manufacturing*. The manufacturing subsectors (with their three-digit NAICS codes) in which more than 25 different carcinogens have been identified according to the exposure databases are, by decreasing order of number of carcinogens,

- *Non-metallic mineral product manufacturing* (NAICS code 327)
- *Transportation equipment manufacturing* (336)
- *Primary metal manufacturing* (331)
- *Chemical manufacturing* (325)
- *Paper manufacturing* (322)

The *construction* subsectors of *specialty trade contractors* (238), *construction of buildings* (236) and *civil engineering construction* (237) are associated with over 15 different carcinogens.

In the *other services* sector, more than 15 carcinogens have been documented in the *repair and maintenance* (811) subsector, which includes the repair and maintenance of motor vehicles, electronic and precision equipment, and commercial and industrial machinery and equipment.

In the *utilities* (221) subsector, over 10 carcinogens have been identified, notably in *electrical power generation, transmission and distribution* (2211), *natural gas distribution* (2212) and *water sewage and other systems* (2213).

In the *professional, scientific and technical services* (54) sector, exposure to more than 15 carcinogens has been documented in the subsector of *scientific research and development services* (5417).

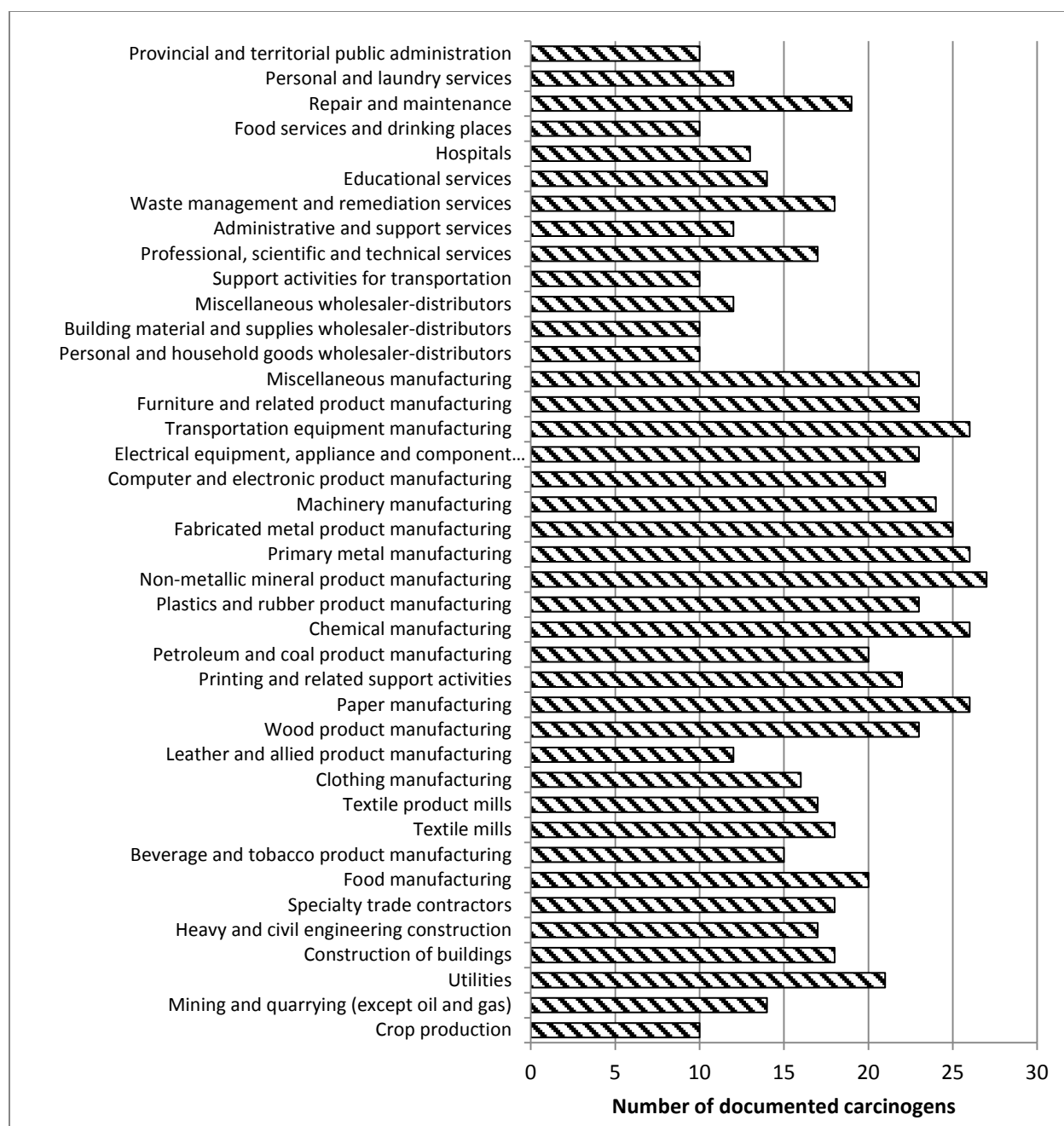


Figure 2 – Subsectors of Quebec economy in which at least 10 carcinogens have been documented in various databases

Lastly, in the *administrative and support, waste management and remediation services* (56) sector, the *waste management and remediation services* (562) subsector is similarly associated with over 15 carcinogens, especially in waste treatment and disposal.

3.3 Estimated Number of Exposed Workers

For the 10 carcinogens to which the most Quebec workers are exposed, Table 4 indicates the approximate number of workers exposed, rounded to the nearest hundred, by NAICS major economic sector (the results for the 38 carcinogens examined are in Appendix 6). For the 38 carcinogens studied, five major sectors have at least 40,000 workers exposed to a carcinogenic substance or circumstance (Appendix 6):

- *Agriculture, forestry, hunting and fishing* (NAICS code 11)
- *Construction* (23)
- *Manufacturing* (31–33)
- *Transportation and warehousing* (48–49)
- *Health care and social assistance* (62)

Table 5 shows the number of workers exposed in the manufacturing sector for the same 10 carcinogens (the results for all carcinogens are given in Appendix 7). For the 38 carcinogens studied, at least 8,000 workers are exposed to a carcinogenic substance or situation in each of five manufacturing subsectors (Appendix 7):

- *Food manufacturing* (NAICS code 311)
- *Wood product manufacturing* (321)
- *Paper manufacturing* (322)
- *Primary metal manufacturing* (331)
- *Furniture and related product manufacturing* (337)

Table 4 – Number¹ of Quebec workers exposed to 10 most common known or probable² carcinogens, by NAICS major sector

NAICS code	Major sector	Solar radiation ³	Night work ⁴	Diesel exhaust ³	Wood dust ⁴	PAHs ³	Benzene ³	Silica ³	Lead & inorganic comp. ³	Artificial UV radiation ³	Mineral oils ⁵
		<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>	<i>n</i>
11	Agriculture, forestry, fishing and hunting	49,500	<u>6,800</u>	6,000	6,500	700	500		200	300	5,200
21	Mining, quarrying, and oil and gas extraction	2,900		3,800		500	100	2,900	300	400	
22	Utilities	2,300	<u>9,400</u>	300		200	200	300	300	600	1,900
23	Construction	46,200		11,000	30,300	800	900	30,800	5,200	1,600	6,200
31-33	Manufacturing	15,000	42,900	15,200	<u>35,800</u>	11,300	5,400	11,800	15,700	14,500	19,500
41	Wholesale trade	7,200		8,900	<u>500</u>	1,800	4,300	700	900	600	
44-45	Retail trade	6,800	7,900	6,400	<u>500</u>	15,300	11,400	900	1,800	200	
48-49	Transportation and warehousing	24,800	30,200	64,700	<u>100</u>	3,500	13,400	3,100	600	500	
51	Information and cultural industries	2,600	2,800	400		100	200		500		
52	Finance and insurance	300		100			100				
53	Real estate and rental and leasing	1,300	<u>3,600</u>	1,300	<u>300</u>	400	600	300	200		700
54	Professional, scientific and technical services	4,700	12,200	300	<u>200</u>	100	300	200	100	1,700	
55	Management of companies and enterprises	100									
56	Administrative and support, waste management and remediation services	13,700	6,800	5,200	<u>400</u>	500	600	500	200	200	
61	Educational services	2,600		600	<u>400</u>	300	200	100	200	100	
62	Health care and social assistance	6,400	58,000	2,300	<u>300</u>	4,400	300	100	100	10,800	
71	Arts, entertainment and recreation	8,200	11,500	500	<u>200</u>	200	100		100		
72	Accommodation and food services	4,400	38,300	2,500	<u>100</u>	23,800	2,000				
81	Other services (except public administration)	3,600		12,900	<u>300</u>	1,500	12,800	100	6,600	7,000	3,000
91	Public administration	27,700		9,700	<u>800</u>	6,200	7,300	500	11,200	300	
ALL SECTORS		230,300	210,600	152,000	102,200	71,600	60,500	52,400	44,000	38,900	36,600

¹ Numbers reported when over 50 workers were presumed to be exposed. Rounded to the nearest hundred. These numbers have been estimated on the basis of 2006 Census of Canada data and percentages of workers exposed taken from sources identified in notes 2 to 5.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

³ Data from CAREX Canada.

⁴ Data from ESS 1998. For night work, additional underlined figures are from the SUMER 2003 survey. For wood dust, additional underlined figures are from CAREX Canada.

⁵ Data from SUMER 2003 survey.

Table 5 – Number¹ of workers exposed to 10 most common known or probable² carcinogens, by NAICS manufacturing subsector

NAICS code	Manufacturing subsector	Solar radiation ³ <i>n</i>	Night work ⁴ <i>n</i>	Diesel exhaust ³ <i>n</i>	Wood dust ⁴ <i>n</i>	PAHs ³ <i>n</i>	Benzene ³ <i>n</i>	Silica ³ <i>n</i>	Lead & inorganic comp. ³ <i>n</i>	Artificial UV radiation ³ <i>n</i>	Mineral oils ⁵ <i>n</i>
311	Food manufacturing	1,400	12,400	2,300		700	600			100	
312	Beverage and tobacco product manufacturing	300		800			100				
313	Textile mills			100				✓ ⁶			
314	Textile product mills	100									
315	Clothing manufacturing	100		100							
316	Leather and allied product manufacturing	100									
321	Wood product manufacturing	2,700	12,500	3,000	36,700	200	100	200	300	400	
322	Paper manufacturing	900	9,900	700	7,200	100	100	100	400	300	✓
323	Printing and related support activities	300	<u>2,900</u>	100		100	100				
324	Petroleum and coal product manufacturing	200		100			300		100	100	
325	Chemical manufacturing	400	<u>5,500</u>	400		100	300	800	100	100	
326	Plastics and rubber product manufacturing	300	<u>4,900</u>	300	<u>100</u>	400	1,100	1,300	100	100	
327	Non-metallic mineral product manufacturing	2,000	<u>600</u>	1,800	<u>100</u>	300	100	4,000	200	200	300
331	Primary metal manufacturing	2,000	8,200	3,800	<u>100</u>	5,400	1,300	3,100	2,800	1,100	
332	Fabricated metal product manufacturing	1,600	<u>5,700</u>	500	<u>300</u>	1,600	300	1,000	4,700	5,000	7,200
333	Machinery manufacturing	600		300		800	200	500	2,300	2,700	4,300
334	Computer and electronic product manufacturing	200							600	200	
335	Electrical equipment, appliance and component manufacturing	200							400	400	
336	Transportation manufacturing	1,000	<u>5,200</u>	400	<u>400</u>	1,500	600	100	2,300	2,300	5,600
337	Furniture and related product manufacturing	500		300	21,400		100	100	500	500	
339	Miscellaneous manufacturing	400		100	<u>400</u>		100	300	700	1,000	2,100

¹ Numbers reported when over 50 workers were presumed to be exposed. Rounded to the nearest hundred. These numbers have been estimated on the basis of 2006 Census of Canada data and percentages of workers exposed taken from sources identified in notes 2 to 5.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

³ Data from CAREX Canada.

⁴ Data from ESS 1998. For night work, additional underlined figures are from the SUMER 2003 survey. For wood dust, additional underlined figures are from CAREX Canada.

⁵ Data from SUMER 2003 survey.

⁶ ✓: Carcinogen measured at over 20% of the standard in this sector, according to IRSST laboratory data (data used to indicate presence of carcinogen only, not to estimate percentage of workers exposed).

3.4 Characteristics of Workers and Exposure to Carcinogens

3.4.1 Analysis by Sex

Women make up approximately 47% of the labour force [Statistics Canada, 2009] and are employed predominantly (i.e., they represent 60% or more of the workers) in the major sectors of *finance and insurance* (accounting for 67.1% of workers in the sector; 5.6% of all employed women work in this sector), *educational services* (66.4% of workers in the sector; 9.9% of all jobs held by women) and *health care and social assistance* (80.4% of workers in the sector; 19.4% of all jobs held by women). In manufacturing, women account for 73.0% of the labour force in the *clothing manufacturing* subsector. In the *health care and social assistance* sector, over 58,000 men and women work night shifts, over 19,000 are exposed to ionizing radiation, over 10,000 to artificial UV radiation (primarily in medical labs and in dentists', denturists' and dermatologists' offices) and over 6,000 to solar radiation (chiefly in the *child daycare services* industry) (tables 4 and 6 and appendixes 6 and 7).

Men account for at least 60% of the labour force in the major sectors of *agriculture, forestry, fishing and hunting* (70.4% of workers in the sector; 3.1% of all jobs held by men), *mining, quarrying, and oil and gas extraction* (87.3% of sector workers; 0.7% of all jobs held by men), *construction* (87.4% of sector workers; 8.4% of all jobs held by men), *utilities* (72.5% of sector workers; 1.2% of all jobs held by men), *manufacturing* (71.1% of sector workers; 19.5% of male employment) and *transportation and warehousing* (75.0% of sector workers; 6.7% of jobs held by men). Carcinogen exposure is heaviest by far in the *manufacturing* sector, in terms of both the number of different carcinogens and the total number of workers, both men and women, who are exposed (tables 4 and 6 and appendixes 6 and 7).

Manufacturing subsectors in which men and women make up similar proportions of the labour force (i.e., proportions ranging from 41% to 59% of total sector employment) are *textile product mills* (2,645 workers; 45% W, 55% M) and *leather and allied product manufacturing* (1,525 workers; 50% W, 50% M) [Statistics Canada, 2010]. The carcinogens found in these sectors are, for *textile product mills*, tetrachloroethylene and trichloroethylene (with, respectively, 1,200 and 700 workers exposed) and for *leather and allied product manufacturing*, leather dust, of course (900 workers exposed) (Appendix 7).

Table 6 – Major sectors of Quebec economy with predominantly male or female¹ labour forces potentially exposed to carcinogens (according to CAREX Canada)

NAICS Major sector	Total number of workers ²	Percentage of sector workers, by sex		Carcinogens potentially present in sector, with more than 5,000 workers exposed						
		M (%)	W (%)	Solar radiation	Night work	Diesel	Wood	PAHs	Silica	Other carcinogens
11 – Agriculture, forestry, fishing and hunting	83,530	70.4	29.6	✓	✓	✓	✓			Mineral oils
21 – Mining, quarrying, and oil and gas extraction	13,588	87.3	12.7			✓				
22 – Utilities	32,138	72.6	27.4		✓					
23 – Construction	140,216	87.4	12.6	✓		✓	✓		✓	Asbestos, mineral oils, lead
31–33 – Manufacturing	531,156	71.8	28.2	✓	✓	✓	✓	✓	✓	Benzene, cadmium, hexavalent chromium, formaldehyde, mineral oils, nickel, lead, artificial UV radiation, styrene
48–49 – Transportation and warehousing	157,765	75.1	24.9	✓	✓	✓				Benzene
52 – Finance and insurance ³	154,566	32.9	67.1							
61 – Educational services	258,128	33.6	66.4							Formaldehyde
62 – Health care and social assistance	414,340	19.6	80.4	✓	✓					Ionizing radiation, artificial UV radiation

NAICS: North American Industry Classification System; M: men; W: women; ✓: carcinogen present in sector.

¹ Predominantly female: Women make up 60% or more of sector labour force. Predominantly male: Men make up 60% or more of sector labour force.

² Numbers estimated on basis of Statistics Canada 2006 Census data (special tabulations).

³ Fewer than 5,000 workers exposed in this sector.

3.4.2 Young Workers (Aged 15–24)

Workers aged 15 to 24 make up approximately 15% of the Quebec labour force [Statistics Canada, 2009]. The major sectors having over 30% young workers are *retail trade* (33.5%) and *accommodation and food services* (39%). In two subsectors (four-digit NAICS codes), over 50% of the labour force consists of young workers: *gasoline stations* (50.7% of the labour force) and *limited service eating places* (59.6%). Some of these sectors are known to be potentially associated with known or probable carcinogens (Table 7). Exposure to PAHs, diesel exhaust, benzene and solar radiation has been documented in most of the sectors where young people account for a significant part of the labour force, according to the available data.

As discussed in section 3.2, exposure to multiple carcinogens has been found in a number of sectors (Figure 2). In 2006, close to 100,000 young people were employed in 26 sectors where over 15 carcinogens have been identified (Table 8).

Table 7 – Quebec industry groups in which young people (aged 15–24) make up over 30% of labour force and carcinogens are potentially present (according to CAREX Canada)

NAICS Industry group	Total number of workers ¹	Percentage and number of workers aged 15–24				Carcinogens potentially present				
		M (% ²)	W (% ²)	Total M & W (% ³)	Estimated number ⁴	Diesel	PAHs	Solar radiation	Benzene	Other carcinogens
4441 – Building material and supplies dealers	27,818	30.9	32.6	31.5	8,800					Wood dust
4471 – Gasoline stations	16,223	51.6	49.5	50.7	8,200	✓		✓	✓	Lead
5121 – Motion picture and video industries	13,031	20.2	30.0	24.5	3,200	✓	✓		✓	Hexavalent chromium, silica
7131 – Amusement parks and arcades	1,530	44.3	59.1	49.4	800			✓		
7212 – Recreational vehicle (RV) parks and recreational camps	3,588	23.8	41.7	32.1	1,200			✓		
7221 – Full-service restaurants	108,272	38.7	38.0	38.3	41,500	✓	✓		✓	
7222 – Limited-service eating places	52,797	59.7	59.5	59.6	31,500	✓	✓		✓	
7224 – Drinking places (alcoholic beverages)	15,100	26.5	38.1	33.8	5,100	✓	✓		✓	

NAICS: North American Industry Classification System; M: men; W: women; ✓: carcinogen present in sector.

¹ Numbers estimated on basis of figures from Statistics Canada 2006 Census (special tabulations).

² Percentages calculated in relation to total number of workers of this sex in sector.

³ Percentages calculated in relation to total number of workers (both sexes taken together) in sector.

⁴ Numbers rounded to nearest hundred.

Table 8 – Estimated percentage and number of young workers (aged 15–24) in subsectors of Quebec economy in which exposure to more than 15 carcinogens has been documented

NAICS – Subsector	Total number of workers ¹	Estimated percentage and number of workers aged 15–24			
		M (% ²)	W (% ²)	Total (% ³)	Estimated number ⁴
221 – Utilities	32,138	3.5	3.5	3.5	1,100
236 – Construction of buildings	46,052	13.9	9.7	13.3	6,100
237 – Civil engineering construction	12,865	10.0	5.6	9.5	1,200
238 – Specialty trade contractors	81,159	13.8	9.7	13.3	10,800
311 – Food manufacturing	57,518	15.4	14.4	15.0	8,600
313 – Textile mills	9,360	5.7	6.5	6.0	600
314 – Textile product mills	6,177	6.2	3.8	5.1	300
315 – Clothing manufacturing	32,812	5.8	5.5	5.6	1,800
321 – Wood product manufacturing	47,587	15.6	10.1	14.7	7,000
322 – Paper manufacturing	31,882	4.7	7.7	5.2	1,700
323 – Printing and related support activities	26,067	8.8	11.4	9.8	2,600
324 – Petroleum and coal product manufacturing	2,501	4.7	13.7	5.9	100
325 – Chemical manufacturing	26,070	7.8	6.1	7.1	1,900
326 – Plastics and rubber product manufacturing	28,523	11.6	10.2	11.2	3,200
327 – Non-metallic mineral product manufacturing	14,709	10.8	10.0	10.7	1,600
331 – Primary metal manufacturing	29,305	5.2	10.0	5.7	1,700
332 – Fabricated metal product manufacturing	40,669	12.9	9.3	12.3	5,000
333 – Machinery manufacturing	28,024	9.5	6.9	9.0	2,500
334 – Computer and electronic product manufacturing	20,271	8.5	7.2	8.1	1,600
335 – Electrical equipment, appliance and component manufacturing	13,941	8.9	6.3	8.2	1,100
336 – Transportation equipment manufacturing	47,933	7.6	5.7	7.2	3,500
337 – Furniture and related product manufacturing	35,486	14.0	9.0	12.6	4,500
339 – Miscellaneous manufacturing	22,273	11.6	8.2	10.1	2,200
541 – Professional, scientific and technical services	193,138	8.4	10.1	9.1	17,600
562 – Waste management and remediation services	7,069	12.5	8.7	11.8	800
811 – Repair and maintenance	49,115	17.5	9.3	16.2	8,000

NAICS: North American Industry Classification System; M: men; W: women.

¹ Numbers estimated on basis of figures from Statistics Canada 2006 Census (special tabulations).² Percentages calculated in relation to total number of workers of this sex in sector.³ Percentages calculated in relation to total number of workers (both sexes taken together) in sector.⁴ Numbers rounded to nearest hundred.

4. DISCUSSION

4.1 Limitations

Measurements of worker exposure to carcinogens are rare and, when available, generally concern only a few facilities or a few sectors at most. Since this information is so difficult to obtain, an industry or an occupation is often used as an indicator of exposure [Teschke, 2003; Steenland et al., 2003; Langner et al., 2010; Robinson et al., 2011]. Nevertheless, some groups have tried to refine estimates of exposure to carcinogens by also taking non-measurement exposure data into consideration, such as process hazard analysis data or job-exposure matrix data; this method has been used to draw up carcinogen exposure profiles around the world [Kauppinen et al., 2000; Nelson et al., 2005; Fritschi and Driscoll, 2006; Kim et al., 2010] and in Canada [Demers et al., 2007; Orenstein et al., 2010]. Not having quantified exposure data is not too important for the purposes of an exposure profile, as our objective was not to estimate the degree of risk to workers, but rather to identify sectors in which workers may be exposed to carcinogens.

A number of choices and assumptions were made for this study. They are summarized in Table 9, along with their possible impact on the study findings. The characteristics and limitations of each data source are set out in detail in Appendix 3. However, none of these sources provides information about sectors with only a small number of workers or with only a low number of available measurements: the acceptable thresholds vary by data source. It should be noted that the exposure percentages obtained reflect relatively recent exposure (last 20 years) and do not necessarily correspond to carcinogen exposure in 2011 or to total accumulated past exposure that might be responsible for cases of cancer diagnosed in 2011.

From the available data, it was impossible to identify the occupations in which concomitant exposure to several carcinogens occurred, which made it impossible to determine the total number of workers exposed to all carcinogens in a given sector. While it is known that 26 carcinogens have been documented in the *transportation equipment manufacturing* subsector, there is no way of knowing whether some workers are exposed to all 26 carcinogens or exactly how many workers are regularly exposed to more than one carcinogen.

When several data sources are available for the same substance or exposure circumstance, it is difficult to make any direct comparisons between the profile based on Quebec data (IRSST laboratory data, special project data, and 1998 Social and Health and Survey data) and that obtained using CAREX Canada data or a French data source. This difficulty was foreseeable in that the methods used to produce the estimates vary greatly from one data source to the next.

The classifications used to identify occupations and industries also represent an additional source of uncertainty beyond our control. The use of occupational data raised the issue of the lack of specificity of the codes in the National Occupational Classification.

Table 9 – Choices made in selecting data and potential impacts on findings

Choices made	Potential impacts on findings
<p>Selection of substances classified as known or probable carcinogens (IARC groups 1 and 2A; or ROHS designations C1, carcinogenic effect detected in humans; C2, carcinogenic effect suspected in humans; or C3, carcinogenic effect detected in animals)</p>	<ul style="list-style-type: none"> • Taking other classifications into account could have slightly increased the number of carcinogens to consider • However, taking possible carcinogens (group 2B) into consideration would have added over a hundred substances and included ones for which there is less evidence
<p>Decision made not to consider economic sectors or occupations classified by the IARC as being known or probable carcinogens (e.g., aluminum smelting, or the occupation of painter, classified as group 1)</p>	<ul style="list-style-type: none"> • Possible underestimation for some carcinogens, but these sectors are probably identified as exposing their workers to the specific carcinogenic substance responsible for the sector being classified as carcinogenic to start with (e.g., PAHs in the aluminum industry)
<p>Exposure data from multiple sources, easily accessible</p>	<ul style="list-style-type: none"> • Disparate data, with characteristics and limits that vary from one source to the next (see Appendix 3 for a description of the data sources) • Exposure data could have been obtained for a larger number of substances, but that would have taken longer: it would have increased the number of carcinogens considered, as well as the number of workers exposed • Although all the sectors selected here exist in Quebec, exposure levels may be different in different countries: this is the rationale behind setting priorities for exposure data according to their place of origin: Quebec (IRSST and ESS 1998) > Canada (CAREX Canada) > France (SUMER survey, Matg��n�� job-exposure matrices)

Choices made	Potential impacts on findings
<p>Exposure defined differently, depending on source of data:</p> <ul style="list-style-type: none"> • IRSST laboratory data: More than one sample measured at more than 20% of the standard • Special IRSST projects: Sectors and occupations in which workers are exposed to more than 30% of the standard for formaldehyde and more than 50% of the standard for quartz • ESS 1998: Exposure reported “often” or “all the time” • Data on occupational radiation exposure: Wearing dosimeter • CAREX Canada, SUMER survey and Matg��n�� job-exposure matrices (JEMs): Presence at concentration greater than background level vs. absence 	<ul style="list-style-type: none"> • IRSST data: Higher levels of exposure (more than just finding the carcinogen in a given sector), so possible underestimation of presence in some sectors, but greater certainty in identified sectors • ESS 1998 data: Percentages of workers exposed are not reported by the Institut de la statistique du Qu��bec when the coefficient of variation is too high, i.e., in general when there are fewer than 8,000 workers exposed in a given sector. As a result, a number of sectors could be excluded • CAREX Canada and SUMER survey data: Occupational exposure noted as soon as it exceeds background level, so accurate assessment of presence of carcinogen, but less certainty about precise level of exposure • Matg��n�� data: Lower value of broad exposure classes is used, so tendency to underestimate the proportion of workers exposed in a given sector
<p>When data from the same source indicated several exposure percentages depending on industry or occupational subcategory, the lowest percentages were chosen (see example of NOC code G912 below: Funeral directors are exposed to formaldehyde far less than embalmers are, even though the two are in the same occupational group)</p>	<ul style="list-style-type: none"> • Probably an underestimation of the percentage of workers exposed • This concerns Matg��n�� data in particular, which were the only data available for 3 substances: chloroform, leather dust and carbon tetrachloride
<p>Decision not to take labour force turnover into consideration when estimating number of workers exposed</p>	<ul style="list-style-type: none"> • May lead to an underestimation of the percentage of workers exposed and at risk of developing some form of occupational cancer

The NOC was developed to provide occupational information critical to “labour market and career intelligence, skill development, occupational forecasting, labour supply and demand analysis, employment equity and numerous other programs and services” [Human Resources and Skills Development Canada, 2010].

As a result, the NOC groups occupations according to skill level and type of training required, which does not always correspond to workers’ occupational exposure. For instance, funeral directors and embalmers are classified together under the same NOC code, G912, yet only a small percentage of funeral directors are exposed to formaldehyde in the workplace—and then at concentrations less than one third of the standard—whereas all embalmers are exposed to levels above one third of the standard. In this case, as in the case of Matgéné data, we opted for the lower exposure limit. Although this choice led to an underestimation of the number of workers exposed in a given economic sector, there is little likelihood it had any major effect on the order of priority of carcinogenic substances in terms of percentage of workers exposed. The three substances for which only Matgéné data were available (chloroform, leather dust and carbon tetrachloride) are not very prevalent in workplaces in general, only in some very specific sectors. Since the purpose of this study was to draw up a general profile of the exposure of Quebec workers to certain carcinogens, we felt it was more important to order relevant substances and sectors by carcinogen exposure than to produce a precise estimate of the number of workers exposed.

For the French databases, we were unable to use occupations because occupational classifications used in France are difficult to match up with the NOC.

4.2 Most Prevalent Carcinogens

Generally speaking, the exposure percentages calculated for Quebec workers are comparable with those estimated in European countries for solar radiation [Danet et al., 2010; Kauppinen et al., 2000], night work [Williams, 2005; McMenemy, 2007; IARC, 2010], diesel exhaust [Danet et al., 2010; Kauppinen et al., 2000], lead [Kauppinen et al., 2000], benzene [Kauppinen et al., 2000] and artificial ultraviolet radiation [Équipe SUMER, 2006c].

In contrast, Quebec exposure percentages are higher than those in European countries for wood dust [Danet et al., 2010; Kauppinen et al., 2000] and polycyclic aromatic hydrocarbons [Kauppinen et al., 2000]. Higher wood dust exposure may well be related to wood being more widely used in Quebec than in most European countries, especially in construction [Ministère du Développement économique, de l’Innovation et de l’Exportation, 2011]. In the case of PAHs, the difference in percentages may be due to the fact that the PAH sources considered are not exactly the same for CAREX Canada and for the CAREX European job-exposure matrix; for example, frying is included as a source of PAHs by CAREX Canada [CAREX Canada, 2011a], but not in the estimates produced by the CAREX JEM [Kauppinen et al., 2000]. This results in a substantial difference in the estimated proportion of workers exposed in the food services sector.

Lastly, Quebec workers are less exposed than European workers to silica [Équipe SUMER, 2006b; Kauppinen et al., 2000] and mineral oils [Équipe SUMER, 2006b]. In European construction, more materials containing crystalline silica (e.g., concrete slab roofs) are used than in Quebec, where other materials are common (e.g., asphalt shingles for roofing).

4.3 Multiple Exposures

The concept of multiple exposures, though touched on regularly in the literature, has seldom been systematically quantified.

As part of preparing CAREX, corrective factors for multiple exposures specific to each sector were developed by Finnish authors and then applied by all European Union countries participating in the effort [Kauppinen et al., 2000]. By using the corrective factors, they were able to estimate the number of workers exposed, counting only once workers deemed to be exposed to several carcinogens in the same sector. The method used to arrive at these corrective factors has not been published, however, and does not seem to have been validated. The authors estimated that 23% of European workers were exposed to one of the 85 carcinogens studied [Kauppinen et al., 2000]. Note that passive exposure to tobacco smoke was included in calculating the percentages of exposed workers.

The 2003 SUMER survey directly estimated multiple exposures, as it was based on individual questionnaires filled in by a random sample of French occupational health physicians and employees. The weakness of the survey was that it did not cover the national and territorial public service, part of the transportation sector (urban transit and marine transport), mining, fishing or France Telecom. On the basis of the data collected, it was estimated that 13.3% to 13.5% of French employees are exposed to at least one carcinogen in the workplace [Guignon and Sandret, 2005]. The difference in percentage in relation to CAREX is likely due in large part to the fact that the SUMER survey considered fewer carcinogens ($N = 28$) in its calculation, excluding second-hand smoke and solar radiation, for instance. We did not include second-hand smoke in this report because the Quebec Tobacco Act came into force in 2006, prohibiting smoking in enclosed spaces and certain outdoor covered spaces [Gouvernement du Québec, 2011b]. Moreover, it would be difficult to estimate exposure to second-hand smoke among outdoor workers.

Other groups that are working on estimating the exposure of the general population proceed as we have done, substance by substance, without producing an overall estimate of exposure for the entire population [CAREX Canada, 2011b; Luce and F  votte, 2006].

By applying the percentages calculated in Europe, we estimate that between 13.3% and 23% of Quebec workers, i.e., 460,000 to 800,000 workers, are exposed to at least one carcinogen.

4.4 Special Issues

A number of studies have shown that the risk of developing occupational cancer is higher for workers whose first exposure to a carcinogen occurred earlier in their careers. This has been reported for exposure to asbestos and mesothelioma [Harding and Darnton, 2010], exposure to pulmonary carcinogens and lung cancer [Kreuzer et al., 1999], exposure to vinyl chloride and liver cancer [Wong et al., 2002] and exposure to wood or formaldehyde and nasopharyngeal carcinoma [Hildesheim et al., 2001].

As men make up the majority of the labour force in sectors where carcinogen exposure is more prevalent (agriculture, forestry, fishing and hunting; mining, quarrying, and oil and gas extraction; construction; utilities; manufacturing; transportation and warehousing), there can be little doubt that a greater proportion of men than women are exposed to carcinogens. However, with the data we had, we could not produce estimates of exposure percentages by sex. CAREX data do not include specific estimates by sex [Kauppinen et al., 2000]. The 2003 SUMER survey, on the other hand, did estimate that in France, 20.4% of male workers and 4.3% of female workers were exposed to at least one carcinogen; the authors also note the predominance of men in sectors with a higher prevalence of exposure to carcinogens [Guignon and Sandret, 2005].

The sectors identified as exposing young Quebec workers to carcinogens correspond to some of the sectors mentioned by NIOSH [NIOSH, 2003], especially agriculture, construction, maintenance and gasoline stations. Information collected by the European Agency for Safety and Health at Work indicates that a higher proportion of young workers are exposed to a number of hazardous substances, including agricultural chemicals, cleaning products, petroleum and solvents [Verjans et al., 2006]. According to the 2003 SUMER survey, a higher percentage of young people are exposed to carcinogens than any other age group: 17.1% of workers under age 25, compared with less than 13.7% of workers aged 25 and older. The same survey also reveals that apprentices have the highest exposure rates (19%), followed by young temporary workers (15%) [Guignon and Sandret, 2005].

5. CONCLUSION

The data presented here most certainly underestimate the number of Quebec workers currently exposed to carcinogens, with larger underestimation in sectors where there are fewer workers. Nevertheless, it is clear that at least 6.6% of Quebec workers, or over 230,000 people, are exposed in the workplace to at least one of the 38 substances or exposure circumstances examined here. If the rate of labour force turnover or more substances or exposure circumstances were taken into consideration, this percentage would no doubt increase significantly. Note also that close to 100,000 young people aged 15 to 24 work in industrial sectors where a large number of carcinogens have been documented.

This study highlights the fact that there is a lack of information that would make it possible to reach a consensus about the exposure of Quebec workers to known or probable carcinogens. As the prevention of occupational risk depends on better knowledge of exposed populations and exposure mechanisms, and the assessment and management of health risks, prevention efforts should concentrate on these aspects, keeping in mind that preventive action taken today will only be verifiable in 5 to 40 years' time, depending on which forms of cancer are in question.

This is the first report to estimate Quebec workers' exposure to carcinogens. It is a significant contribution to knowledge in this area, and the findings should be of use to anyone interested in this problem.

6. RECOMMENDATIONS

Deciding on priorities is no easy task: there are numerous substances and circumstances to consider, many industries and occupations and thousands of workers. The criteria to be applied in setting priorities also vary by objective. Among the criteria that could be used to set research priorities, the following are worth considering:

- Number of workers exposed, by carcinogen or by industry
- Worker age – In general, the younger the age at which exposure begins, the higher the risk of developing cancer
- Multiple exposures, particularly to carcinogens having the same target organs
- Exceedances of exposure standards – Note, however, that for some carcinogens, the standards were established to guard against effects other than cancer, such as irritant effects for formaldehyde or renal toxicity for cadmium (ACGIH®, 2010b)
- Lethality of various types of cancer – For example, lung cancer is far more lethal than skin cancer, with a five-year survival rate of 16%, compared with 91% for skin melanoma (Horner et al., 2010); however, cancers with low lethality can have a non-negligible impact in terms of monetary and social costs because of the treatments required, doctor's visits, absence from work, patient suffering and worries, etc.

Prioritizing prevention efforts also means taking their feasibility and impact into account. While it may be feasible to make a substitution for an organic solvent or enclose a process, it is harder, if not impossible in some cases, to eliminate night work. On the other hand, since it seems that it is not night work per se, but night work over long periods (over 20 years) that has a carcinogenic effect [IARC, 2010], it should be possible to make scheduling changes in order to mitigate the carcinogenic effect.

Given the lack of information that would make it possible to achieve a consensus about exposure to known or probable carcinogens, about the knowledge potentially exposed people have of it, about compliance with standards in the industries affected and about prevention activities undertaken in workplaces, it is recommended that future research be planned on the basis of the above-mentioned criteria, with the following goals:

- More accurately characterize worker exposure to the most prevalent carcinogens (especially for young workers) by drawing up a worker risk profile for each industry in question
- Quantify the extent of multiple exposures to carcinogens, especially for young workers
- Complete exposure estimates for all chemicals classified as carcinogens and measured at the IRSST and for new substances or circumstances that will be assessed by CAREX Canada in the near future
- Identify, for the industries in question, the production processes and modes of work organization that influence exposure (in terms of the relative percentages of workers exposed, number of carcinogens, and length, frequency and level of exposure)
- Document existing work practices and exposure control measures in establishments

- Document the most relevant and appropriate exposure detection and control methods for workplace situations specific to Quebec in order to reduce occupational exposure to carcinogens
- Explore biological methods of monitoring exposure (DNA adducts, markers of exposure to cytotoxic drugs, PAH metabolites, etc.) and health risks
- Develop and implement communications, public awareness and information dissemination strategies for establishments in the industries in question

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APPENDIX 1 – SOME CLASSIFICATIONS OF THE CARCINOGENICITY OF SUBSTANCES OR CIRCUMSTANCES FOUND IN WORKPLACES

Classifications Used to Select Carcinogens of Interest for this Study

- *Regulation Respecting Occupational Health and Safety (ROHS, RRQ, S-2.1, r. 19.01)* – Three designations of carcinogenic potential (see Schedule I)
 - **C1:** Carcinogenic effect detected in humans
 - **C2:** Carcinogenic effect suspected in humans
 - **C3:** Carcinogenic effect detected in animals
 - http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=3&file=/S_2_1/S2_1R13_A.htm
- *American Conference of Governmental Industrial Hygienists (ACGIH)*
 - **A1:** Proven carcinogen in humans
 - **A2:** Suspected carcinogen in humans
 - **A3:** Proven carcinogen in animals, with unknown relevance to humans
 - **A4:** Not classifiable as a human carcinogen (lack of data)
 - **A5:** Not suspected as a human carcinogen
 - <http://www.acgih.org/tlv/>
- *German Commission for the Investigation of Health Hazards of Chemical Compounds in the Workplace (MAK Commission)*
 - **Cat. 1:** Proven carcinogen in humans, contributing significantly to cancer risk
 - **Cat. 2:** Suspected carcinogen in humans (limited data for humans, and sufficient or limited data for animals)
 - **Cat. 3:** Possible carcinogen for humans, but insufficient data (provisional classification)
 - **Cat. 4:** Potentially carcinogenic with non-genotoxic effect, probably contributing little to cancer risk in humans
 - **Cat. 5:** Low carcinogenic and genotoxic potential, not contributing significantly to cancer risk in humans if standards are observed
 - http://www.dfg.de/en/dfg_profile/statutory_bodies/senate/health_hazards/structure/working_groups/derivation_mak/index.html
- *International Agency for Research on Cancer (IARC)* – Classification into five groups
 - **Group 1:** Carcinogenic substances/circumstances for humans
 - **Group 2A:** Probably carcinogenic substances/circumstances for humans
 - **Group 2B:** Possibly carcinogenic substances/circumstances for humans
 - **Group 3:** Insufficient data to determine carcinogenic potential for humans
 - **Group 4:** Probably non-carcinogenic substances/circumstances for humans ($n = 1$, Caprolactam, precursor to a synthetic polymer)
 - <http://monographs.iarc.fr/>

- *U.S. National Toxicology Program (NTP) – 12th Report on Carcinogens, 2011*
 - **Group 1 or K:** Substance known to be human carcinogen
 - **Group 2 or R:** Substance reasonably anticipated to be human carcinogen
 - <http://ntp.niehs.nih.gov/roc12/INDEXC5F2.HTM>

Other Internationally Recognized Classifications

- *U.S. Environmental Protection Agency – Integrated Risk Information System (IRIS)*
Classification of descriptors based on *Guidelines for Carcinogen Risk Assessment* (2005)
 - **A:** Carcinogenic to humans
 - **B1:** Likely to be carcinogenic to humans (insufficient human evidence)
 - **B2:** Likely to be carcinogenic to humans (sufficient animal evidence)
 - **C:** Suggestive evidence of carcinogenic potential
 - **D:** Inadequate information to assess carcinogenic potential
 - **E:** Not likely to be carcinogenic to humans
 - <http://www.epa.gov/iris/>
- *European Union – CMR (carcinogenic, mutagenic, reprotoxic) classification*
 - **Category 1:** Substances known to be carcinogenic to humans ($n = 26$)
 - **Category 2:** Substances which should be regarded as if they are carcinogenic to humans ($n = 135$)
 - **Category 3:** Substances which cause concern for humans (possible carcinogenic effects) ($n = 115$)
 - Classification that will apply as of December 1, 2010 (CLP Regulation 1272/2008):
 - **Category 1A:** Substances known to have carcinogenic potential for humans
 - **Category 1B:** Substances presumed to have carcinogenic potential for humans (animal evidence)
 - **Category 2:** Suspected human carcinogens
 - <http://www.prc.cnrs-gif.fr/IMG/pdf/cmr-criteria-clp.pdf>

APPENDIX 2 – LIST OF SUBSTANCES OR CIRCUMSTANCES CONSIDERED TO BE KNOWN OR PROBABLE CARCINOGENS FOR WHICH DATA WERE OBTAINED FOR THIS STUDY

Name in ROHS	CAS No.	ROHS Sche- dule 1	MAK*	ACGIH*	IARC *	NTP*	Target organ**	Data sources***
Acetaldehyde	75-07-0	C3	5	A3	2B	R	Bronchi, lungs	IRSST lab
Acrylamide	79-06-1	C2	2	A3	2A	R	–	CAREX
Acrylonitrile	107-13-1	C2	2	A2	2B	R	Lungs	CAREX
Asbestos Actinolite Amosite Anthophyllite Chrysotile Crocidolite Tremolite	12172-67-7 12172-73-5 17068-78-9 12001-29-5 12001-28-4 14567-73-8	C1	1	A1	1	K	Lungs, mesothelioma (pleura, peritoneum), larynx, ovaries	IRSST lab, CAREX
Aromatic amines 2-Naphthylamine o-Toluidine o-Anisidine Benzidine	–	C1 C2 C3 C1	1 1 2 1	A1 A3 A3 A1	1 1 2B 1	K R R K	Bladder	SUMER
Arsenic & inorganic compounds	7440-38-2	–	1	A1	1	K	Lungs, skin, bladder	CAREX
Benzene	71-43-2	C1	1	A1	1	K	Hematopoietic system	CAREX, SUMER
Beryllium [7440- 41-7], metal and compounds	7440-41-7	C1	1	A1	1	K	Lungs	IRSST lab, CAREX
Polychlorinated biphenyls	1336-36-3	C2	3B	C2	2A†	R	? Liver	CAREX
Wood dust Oak, beech, birch, mahogany, teak, walnut, other woods	–	–	–	A1 A2 A4	1	K	Nasopharynx, nasal cavities, sinuses	ESS98, CAREX, SUMER
Coal tar pitch volatiles, as benzene solubles	65996-93-2	C1	1	A1	1	K	Lungs	IRSST lab, CAREX, SUMER
Cadmium, elemental and compounds	7440-43-9	C2	1	A2	1	K	Lungs	CAREX, SUMER
Chloroform	67-66-3	C2	4	A3	2B	R	–	Matgéné
Chromium VI and inorganic compounds	7440-47-3	C1	1	A1	1	K	Lungs	CAREX, SUMER
Cobalt and compounds	–	C3		A3	2B	R (sul- phate)	? Lungs	CAREX
Creosotes	8001-58-9	–			2A	K	? Lungs, skin	CAREX
Leather dust		–			1	-	Nasal cavities, sinuses	Matgéné

Name in ROHS	CAS No.	ROHS Sche- dule 1	MAK*	ACGIH*	IARC *	NTP*	Target organ**	Data sources***
Dichloromethane (methylene chloride)	75-09-2	C2	3A	A3	2B	R	–	IRSST lab, CAREX, SUMER
Diesel exhaust	–	–	2	–	2A†	R (partic- ulates)	? Lungs	IRSST, CAREX, SUMER
Epichlorohydrin	106-89-8	C2	2	A3	2A	R	–	SUMER
Formaldehyde	50-00-0	C2	4	A2	1	K	Nasopharynx, hematopoietic system	IRSST, CAREX, SUMER
Mineral oils (untreated or mildly treated)	–			A2	1	K	Skin (nonmelanotic)	IRSST lab, SUMER
Polycyclic aromatic hydrocarbons Benz(a)anthracene Benzo(a)pyrene Chrysene	56-55-3 50-32-8 218-01-9	C2 C2 C2	2 2 2	A2 A2 A3	2B 1 2B	R R –	Lungs, bladder, skin (nonmelanotic)	CAREX
Methyl iodide	74-88-4	C2	3	A2	3	–	–	IRSST lab
Nickel and compounds	–	–	1	A1	1	K	Lungs, nasal cavities, sinuses	CAREX, SUMER
Ethylene oxide	75-21-8	C2	2	A2	1	K	? Hematopoietic system, breast	CAREX
Pentachlorophenol	87-86-5	C2	2	A3	2B	–	–	CAREX
Lead and inorganic compounds	7439-92-1	C3	2	A3	2A	R	? Stomach	CAREX, SUMER
Ionizing radiation	–				1	K	Bladder, kidneys, hematopoietic system, brain, thyroid, etc.	Health Canada
Solar radiation	–				1	K	Skin, ? eyes, lips	CAREX
Artificial UV radiation	–				1	R	Skin, ? eyes, lips	CAREX
Silica – crystalline, quartz	14808-60-7	C2	1	A2	1	K	Lungs	IRSST, CAREX, SUMER
Styrene (monomer)	100-42-5	C3	5	A4	2B	R	? Hematopoietic system	CAREX, SUMER
Tetrachloroethylene	127-18-4	C3	3B	A3	2A	R	? Esophagus, cervix, hematopoietic system	CAREX, SUMER
Carbon tetrachloride	56-23-5	C2	4	A2	2B	R	–	Matgéné
Shift work (night)	–	–	–	–	2A	–	Breast (women)	ESS98, SUMER
Trichloroethylene	79-01-6		1	A2	2A†	R	? Liver, hematopoietic system	IRSST lab, CAREX, SUMER

Name in ROHS	CAS No.	ROHS Sche- dule 1	MAK*	ACGIH*	IARC *	NTP*	Target organ**	Data sources***
Antimony trioxide	1309-64-4	C3		A2	2B	–	Lungs	CAREX

* See Appendix 1 for meaning of abbreviations and numbers.

** Data taken from monographs published on IARC website (<http://monographs.iarc.fr/index.php>).

*** IRSST lab: Data from IRSST laboratory; IRSST: Special IRSST project; ESS98: Social and health care survey, 1998, Institut de la statistique du Québec; CAREX: CAREX Canada; SUMER: French SUMER survey; Matgéné: French job-exposure matrix, Institut de veille sanitaire, France.

† These chemicals or agents have recently been classified as group 1 carcinogens (carcinogenic for humans).

APPENDIX 3 – CHARACTERISTICS OF DATA SOURCES AND PROCEDURES FOR DETERMINING ECONOMIC SECTORS AT RISK AND PERCENTAGES OF WORKERS EXPOSED

Data from IRSST Laboratory

The findings of laboratory analyses conducted for prevention purposes between 2001 and 2008 are available as individual results for each sample analysed. Most of the analyses were requested by members of occupational health teams at the health and social services agencies (Agences de santé et des services sociaux), health and social services centres (Centres de santé et de services sociaux), CSST inspection services or joint employer-employee sector associations. As the data in this database are supplied by occupational health teams that, in their work, focus on specific contaminants in a restricted number of economic sectors, they obviously cannot be regarded as a representative profile of exposure to all occupational carcinogens or even of exposure to all carcinogens found in a specific economic sector. The IRSST laboratory database contains non-exhaustive data in terms of number of establishments or substances sampled for a given sector, and it is impossible to determine how representative it is.

For the analysis data available, economic sectors for which there were at least two results at 20% of the Quebec standard or higher were chosen: undetected or very low values could thus be excluded. In the case of a few substances for which there was no standard or time-weighted average concentration, or that were not listed as carcinogens in the Regulation Respecting Occupational Health and Safety, a value taken from a European or U.S. standard was used (see table below). Exposure to asbestos was considered when the substance was used in a process, but not when it was the result of a contaminated building.

Substance	CAS No.	TWAEV, according to ROHS (mg/m ³)	Threshold value used (mg/m ³)	Source of threshold value
Acetaldehyde	75-07-0	–	45	Denmark, Sweden (Belgium)
Arsenic	7440-38-2	0.1	0.01	Denmark, France, Sweden, Spain, United States (OSHA)
Nickel		1.0	0.5	Austria, Denmark, United Kingdom
Chrysene	218-01-9	–	0.2	United States (OSHA)
Formaldehyde	50-00-0	–	1.23	Half of the current short-term exposure value for Quebec

TWAEV: 8-hour time-weighted average exposure value

Data from IRSST Special Projects

Data from three special projects were used: (1) a study of formaldehyde levels measured by the IRSST in the early 2000s or estimated from the literature in 10 economic sectors (covered by several IRSST reports listed at the end of this appendix, see Goyer et al., 2004); (2) a 2005 project on diesel particulate matter in mining and urban transportation (Roberge et al., 2006); and (3) a small number of analyses of silica in peatlands in 2003 (Duchaîne et al., 2004) and when used for abrasive blasting in the late 1990s (Dion et al., 1998).

In the formaldehyde and peatland projects, all workers who could possibly have been exposed in the sectors concerned were assessed. To calculate the percentage of workers exposed in an industry group identified by a four-digit NAICS code, the following steps were taken:

1. Using the project data, the percentage of workers exposed at moderate or higher levels (formaldehyde: $\geq 1.23 \text{ mg/m}^3$; quartz: $\geq 0.05 \text{ mg/m}^3$) was calculated for each carcinogen-NAICS-NOC triad.
2. Using data from the 2006 Census of Canada, the number of workers and the relative proportion for each NAICS-NOC dyad (with the assumption that all possibly exposed workers had been studied) were calculated.
3. Using the data obtained in steps 1 and 2, the number of workers exposed was calculated for each carcinogen-NAICS-NOC triad.
4. Using the data obtained in step 3, the number of workers exposed for each carcinogen-NAICS dyad was tallied.

In the study on diesel exhaust, the researchers did not attempt to estimate the exposure of all mining workers, but rather focused on diesel equipment operators (the most exposed of the NAICS groups studied). The exposure percentages can therefore not be extended to all NAICS workers, and must be considered specific to equipment operators in the mining sector.

Social and Health Survey, 1998

The 1998 Social and Health Survey was conducted by means of at-home interviews in 12,000 Quebec households. A specific section of the survey concerned people aged 15 and over having a full- or part-time paid job. The question asked to estimate the percentages of workers exposed was: “At your current job or jobs, are you exposed to any of the following situations: Night shift work? Wood dust?” The percentages considered here reflect workers who answered “often” or “all the time” to the two questions.

For the respondent’s current job, the industry and occupation were documented and coded according to the Standard Industrial Classification and the Standard Occupational Classification, used by Statistics Canada. As the published survey report did not contain sufficient detail for our purposes, a specific data retrieval request was submitted to obtain the percentages of people who had reported these two exposures, with the data broken down by sex, industry and occupation. As recommended by the Institut de la statistique du Québec, only percentages with a coefficient

of variation of 25% or less were retained. Generally, this corresponded to more than 8,000 workers exposed in a given sector.

CAREX Canada

The CAREX Canada program at the University of British Columbia began as a pilot project in the late 1990s. Its aim is to estimate the number of Canadians exposed to known, probable and possible carcinogens in their workplace or usual living environment. The estimates produced are based on existing data sources, preferably Canadian ones, and on census data. The method followed to produce the estimates is very similar to that developed by the Finnish Institute for Occupational Health (FIOH) and used by the European Union and the World Health Organization to create CAREX, an international information system on occupational exposure to carcinogens [Kauppinen et al., 2000].

A major component of the project is development of an exposure database containing exposure measurement data from a variety of sources: federal and provincial government agencies, Canadian researchers and employers willing to provide CAREX Canada with their data. Measurement data are supplemented by data published in the literature, generally in the last 20 years, with preference being given to Canadian data whenever possible. A national committee of experts in assessment of occupational exposure to carcinogens oversees the project. At the time when we obtained the data from the CAREX Canada project team, estimates of Canadian worker exposure had been produced for 32 substances or exposure circumstances, by economic sector and certain occupational categories. For these estimates, exposure is defined as any exposure above background level in the general population. The data available are percentages of workers exposed, presented according to different occupation-industry combinations, depending on the degree of precision available: either for a few occupations, regardless of economic sector, by combining a three-digit NAICS code and one occupation, or by combining a four-digit NAICS code and a number of occupations. A non-exhaustive example, for exposure to cadmium, is given in the table below.

Example of cadmium exposure data available in CAREX Canada database

Proportion exposed	Industry	NAICS	Occupation	NOC
0.75	All industries – NAICS 2002	0	Foundry workers	J122
0.001	All industries – NAICS 2002	0	Painters, sculptors and other visual artists	F036
0.25	All industries – NAICS 2002	0	Plastic products assemblers, finishers and inspectors	J225
0.25	All industries – NAICS 2002	0	Plastics processing machine operators	J132
0.1	All industries – NAICS 2002	0	Welders and related machine operators	H326
0.1	Miscellaneous manufacturing	339	Chemical plant machine operators	J131
0.1	Other miscellaneous manufacturing	3399	Central control and process operators, mineral and metal processing	J111

Health Canada, Environmental and Radiation Health Sciences Directorate

Under section 144 of the Regulation Respecting Occupational Health and Safety (RRQ, c. S-2.1, r. 19.01), “Workers exposed to ionizing radiation shall be monitored by dosimetry.” Since 1951, National Dosimetry Services has been providing Canadian workers with personal, cumulative, occupational monitoring services for ionizing radiation and recording the data in the National Dose Registry (NDR). Health Canada’s Environmental and Radiation Health Sciences Directorate publishes an annual report on the number of workers wearing dosimeters and their annual radiation dose for the two years preceding the report. Exposure percentages were calculated on the basis of the number of workers wearing a dosimeter in 2006, according to the most recent report available [Sont et al., 2009].

SUMER Survey, 2003

The SUMER (SURveillance MÉdicale des Risques [medical monitoring of risks]) survey was conducted by the French Ministry of Labour’s [Ministère du travail] Direction des relations du travail and Direction de l’animation de la recherche, des études et des statistiques between June 2002 and the end of 2003. The survey covered all employees of the general social security system and the Mutualité Sociale Agricole, public hospitals, the postal service, Électricité de France and Gaz de France (ÉDF-GDF), French national railways (SNCF) and Air France. Note that the survey did not include employees in the national and territorial public service, parts of the transportation sector (urban transit and marine transport), mining, fishing or France Télécom. First, a representative sample was taken among occupational health physicians and then among employees who were their patients. Over 1,750 occupational health physicians queried 56,345 employees about their work-related activities during the week worked before the survey. Close to 89% of employees responded (with 6,330 refusing or being unable to respond).

The main questionnaire collected information about the employee and the place where he or she worked. In the second part, the physician recorded the employee’s exposure, at any intensity, during the preceding week, on the basis of a list of over 200 workplace situations, classified into four categories: organizational constraints, physical nuisances, exposure to biological agents and exposure to chemical agents.

To increase the representativeness of the set of respondents, the data obtained were weighted according to the following sociodemographic characteristics: sex, age bracket, socio-occupational category, industry group and size of establishment. As there is no compulsory census in France, reference populations were constituted from the annual social data declarations (DADS) that companies must make about their labour forces to the Ministère du travail, de l’emploi et de la santé, from the Enquête Emploi employment survey and from specific sources for large companies added in 2003 and for the Mutualité Sociale Agricole (MSA).

Exposure data are available in the form of records describing the main exposures stated by employees in reports accessible on the website of the Ministère du travail, de l’emploi et de la santé

(<http://www.travail-emploi-sante.gouv.fr/etudes-recherche-statistiques-de,76/statistiques,78/conditions-de-travail-et-sante,80/sumer-enquete-surveillance,1999/>). For chemical exposure, the data are presented as percentages of workers exposed by sector of the level 36 listing of French economic activities (i.e., 36 economic sectors, which correspond

roughly to the Quebec CSST's priority activity sectors). The results were included where the number of people surveyed was not too low: a percentage was given when there were more than 40 employees exposed in a given sector, and when there were between 10 and 40 workers exposed, the sector was mentioned without specifying the percentage exposed. As regards night work, the responses to the question asked of employees ("Do you work nights, even occasionally?") were presented according to whether the respondents worked occasionally or at least 200 nights per year (which corresponds almost to a permanent night shift).

Matgéné Program

The occupational health department of the Institut de veille sanitaire (InVS) in France coordinates a generic job-exposure matrix (JEM) production program, tailored to the general population in France, called Matgéné.

The JEMs produced under the program are specific to a substance or group of substances. Each matrix is prepared by a group of experts from several different organizations, including InVS, the Institut national de la santé et de la recherche médicale (Inserm), university institutes in occupational medicine and the Institut national de recherche scientifique (INRS). Occasionally, joint projects are undertaken with the Caisses régionales d'assurance maladie (CRAM) in France or with foreign research teams, notably the Finnish Institute of Occupational Health.

The exposure indexes produced vary by JEM, but they usually include an indicator of the percentage of workers exposed in a given sector or occupation (four exposure probability classes: 1%–10%, 10%–50%, 50%–90%, > 90%) and an indicator of the mean level of exposure in a workday (low, medium, high, very high). For some JEMs, the presence of exposure peaks (yes/no) and changes in exposure by period are also noted.

For the exposure classes, the lowest value in the associated range was chosen: 1% for the 1%–10% class, 10% for the 10%–50% class, etc. All levels of exposure were considered. For the vast majority of carcinogen-SIC-NOC combinations, there was more than one exposure period. To reflect the current situation as accurately as possible, a decision was made to keep only the most recent period, even if the exposure percentage might be slightly higher than in a previous period. In general, the exposure period covered the years 1985 to 2007.

So far, JEMs have been produced for these proven (IARC group 1 or ROHS designation C1) or probable (IARC group 2A) carcinogens:

- Leather dust
- Five chlorinated solvents: trichloroethylene, tetrachloroethylene (perchloroethylene), dichloromethane (methylene chloride), carbon tetrachloride and chloroform
- Petroleum fuels and solvents (benzene; special-boiling-point spirits and other non-aromatic fractions; gasoline; white spirits, naphthas and other light aromatic fractions; diesel, fuels and kerosenes)
- Free crystalline silica
- Phytosanitary products (arsenic-based pesticides: crop-exposure matrix, but no job-exposure matrix)

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Appendix 4 – Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹ by NAICS Major Economic Sector

NAICS code	Economic sector	Acetaldehyde	Acrylamide	Acrylonitrile	Asbestos	Aromatic amines	Arsenic	Benzene	Beryllium	Polychlorinated biphenyls
11	Agriculture, forestry, fishing and hunting						0.30	0.55	✓	0.01
21	Mining, quarrying, and oil and gas extraction		0.45		0.26		1.14	0.74	0.01	0.26
22	Utilities		0.21	0.003	<u>5.30</u>		0.41	0.55	0.003	1.61
23	Construction		0.30	0.001	11.84 <u>2.70</u>		0.85	0.61	0.14	0.19
31-33	Fabrication	✓	0.31	0.19	0.27		0.56	1.02 <u>0.18</u>	0.07	0.11
41	Wholesale trade			0.01			0.02	2.65	0.001	0.03
44-45	Retail trade			0.003	0.001		0.01	2.67		0.003
48-49	Transportation and warehousing				0.07		0.02	8.47	0.002	0.05
51	Information and cultural industries				0.005		0.01	0.23		0.04
52	Finance and insurance						0.001	0.03		
53	Real estate and rental and leasing						0.004	1.24		0.02
54	Professional, scientific and technical services		0.01	0.004	0.12		0.01	0.15	0.001	0.02
55	Management of companies and enterprises						0.03	0.21		
56	Administrative and support, waste management and remediation services			0.004	0.25		0.03	0.52		0.02
61	Educational services		0.001				0.003	0.08	✓	0.004
62	Health care and social assistance			0.0002		<u>0.91</u>	0.001	0.07	✓	0.003
71	Arts, entertainment and recreation			0.004			0.04	0.12		0.02
72	Accommodation and food services							0.88		0.001
81	Other services (except public administration)			0.001	0.53 <u>0.33</u>		0.09	8.56	0.05	0.05
91	Public administration				0.02		0.001	2.65		0.03
ALL SECTORS			0.06	0.03	0.56 <u>0.17</u>	<u>0.11</u>	0.15	1.74 <u>0.03</u>	0.02	0.05

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed);

[]: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹ by NAICS Major Economic Sector (cont'd)

Wood dust	Coal tar pitch volatiles	Cadmium	Chloroform	Chromium VI	Cobalt	Creosotes	Leather dust	Dichloro-methane	Diesel exhaust	Economic sector	NAICS code
7.76 2.01 6.30	✓	0.04		0.06	0.02				7.17 14.20	Agriculture, forestry, fishing and hunting	11
0.19	✓	0.86		5.11	2.86				[32.88] 28.24	Mining, quarrying, and oil and gas extraction	21
0.24	✓	0.06		0.30	0.25	0.07			0.79	Utilities	22
21.63 15.35 11.10	0.27 5.50	0.13		0.50	0.14	0.03		0.29	7.81 8.20	Construction	23
12.30 6.73 4.70	0.36	1.36	<i>0.20</i>	3.00 0.61	0.85	0.01	<i>0.17</i>	0.49 0.25	2.87	Fabrication	31-33
0.32	0.001	0.08		0.16	0.05			0.01	5.51	Wholesale trade	41
0.11	0.0002	0.01		0.01	0.01				1.49	Retail trade	44-45
0.06	0.001	0.04		0.19	0.03	0.05		0.02	[2.49] 41.01 7.20	Transportation and warehousing	48-49
0.03				0.37	0.01				0.45 7.20	Information and cultural industries	51
0.01		0.001		0.02	0.002				0.07	Finance and insurance	52
0.51 1.10		0.02		0.04	0.03				2.69 2.50	Real estate and rental and leasing	53
0.09		0.01	<i>0.13</i>	0.07	0.01			0.003	0.18	Professional, scientific and technical services	54
0.57		0.05			0.10				0.55	Management of companies and enterprises	55
0.36		0.02		0.19	0.04	0.004		0.01	4.59	Administrative and support, waste management and remediation services	56
0.16		0.002		0.06	0.003			0.07	0.23	Educational services	61
0.08	0.01	0.002		0.01	0.01			✓	0.55	Health care and social assistance	62
0.39		0.02		0.06	0.01				0.83	Arts, entertainment and recreation	71
0.03	0.0004	0.0004		0.001	0.001				1.10	Accommodation and food services	72
0.21	0.001	0.30		0.75	0.18		<i>0.19</i>	0.62	8.62 3.03	Other services (except public administration)	81
0.30		0.01		0.05	0.01				3.54	Public administration	91
2.93 1.81 1.33	0.07 0.22	0.24 0.20	<i>0.04</i>	0.58 0.09	0.17	0.01	<i>0.03</i>	0.12 0.04	4.36 1.35	ALL SECTORS	

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed);

[]: IRSSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

**Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹
by NAICS Major Economic Sector (cont'd)**

NAICS code	Economic sector	Epichlorohydrin	Formaldehyde	Mineral oils	Polycyclic aromatic hydrocarbons	Methyl iodide	Nickel & compounds	Ethylene oxide	Pentachlorophenol	Lead & inorganic compounds	Ionizing radiation
11	Agriculture, forestry, fishing and hunting		0.04	<u>6.20</u>	0.84		0.14		0.32	0.24	
21	Mining, quarrying, and oil and gas extraction		0.07		3.80		3.30			2.37	
22	Utilities		0.07	<u>6.00</u>	0.67		0.34		0.74	0.83	<u>7.64</u>
23	Construction		0.16	<u>4.40</u>	0.59		0.57		0.04	3.74 <u>2.10</u>	
31-33	Fabrication		[0.17] 1.64 <u>0.15</u>	<u>3.68</u>	2.12	✓	1.42 <u>0.40</u>	0.04	0.03	2.95 <u>0.09</u>	
41	Wholesale trade		0.07	✓	1.10		0.18	0.01		0.53	
44-45	Retail trade		0.03	✓	3.58		0.02			0.42	
48-49	Transportation and warehousing				2.23		0.16			0.36	
51	Information and cultural industries				0.11		0.02			0.50	
52	Finance and insurance						0.002			0.01	
53	Real estate and rental and leasing		0.01 <u>0.70</u>	<u>1.50</u>	0.72		0.09			0.36	
54	Professional, scientific and technical services		0.19		0.06		0.02			0.06	<u>1.62</u>
55	Management of companies and enterprises						0.16				
56	Administrative and support, waste management and remediation services		0.02		0.47		0.08		0.004	0.14	
61	Educational services		[4.99] 0.07		0.13		0.01			0.07	
62	Health care and social assistance		[0.03] 0.20 <u>1.80</u>		1.05		0.01	0.12		0.02	<u>5.04</u>
71	Arts, entertainment and recreation		0.03		0.28		0.09			0.13	
72	Accommodation and food services		0.001		10.57		0.003			0.01	
81	Other services (except public administration)		[0.23] 0.06	<u>2.01</u>	0.99		0.78			4.41	
91	Public administration		0.06		2.24		0.03			4.08	
ALL SECTORS		<u>0.10</u>	[0.41] 0.31 <u>0.25</u>	<u>1.05</u>	2.05		0.32 <u>0.06</u>	0.02	0.02	1.26 <u>0.10</u>	<u>1.00</u>

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed);
[]: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné; **Underlined regular**: Health Canada.

**Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹
by NAICS Major Economic Sector (cont'd)**

Solar radiation	Artificial UV radiation	Silica (quartz)	Styrene (monomer)	Tetrachloroethylene	Carbon tetrachloride	Shift work (night)	Trichloroethylene	Antimony trioxide	Economic sector	NAICS code
59.27	0.37	0.04	0.004			8.10		0.01	Agriculture, forestry, fishing and hunting	11
21.40	2.63	[0.51] 21.56	0.01				✓	0.07	Mining, quarrying, and oil and gas extraction	21
7.23	1.73	0.79	0.01			29.30	0.03	0.03	Utilities	22
32.94	1.14	21.97 5.40	0.16	0.001			0.001 1.90	0.03	Construction	23
2.82	2.73	[0.01] 2.21 0.54	1.68	0.77	<i>0.24</i>	8.08 6.91	0.71 0.24	0.24	Fabrication	31-33
4.44	0.40	0.44	0.02	0.02			0.04	0.01	Wholesale trade	41
1.58	0.05	0.20	0.01	0.0002		1.84	0.002	0.002	Retail trade	44-45
15.74	0.34	1.98				19.15 20.40	0.001	0.01	Transportation and warehousing	48-49
2.87	0.001	0.005		0.07		3.01 20.40	0.08		Information and cultural industries	51
0.21	0.01	0.01		0.004				0.001	Finance and insurance	52
2.57	0.18	0.62 1.00	0.004			7.30		0.004	Real estate and rental and leasing	53
2.44	0.86	0.13	0.03	0.05	<i>0.003</i>	6.33	0.04	0.001	Professional, scientific and technical services	54
1.93	0.57	0.16	0.05					0.03	Management of companies and enterprises	55
11.95	0.15	0.44	0.01	0.01		5.92	0.07	0.003	Administrative and support, waste management and remediation services	56
1.01	0.04	0.03	0.003	0.002				0.002	Educational services	61
1.54	2.60	0.01	0.001			14.00 4.81		0.0002	Health care and social assistance	62
15.13	0.09	0.02	0.01	0.004		21.14	0.002	0.004	Arts, entertainment and recreation	71
1.93	0.005	0.005	0.001			17.01 10.10		0.001	Accommodation and food services	72
2.44	4.72	0.10 0.16	0.004	0.29	<i>0.27</i>		0.03 0.33	0.07	Other services (except public administration)	81
10.09	0.10	0.19		0.003			0.001	0.35	Public administration	91
6.61	1.12	1.50 0.32	0.27 0.30	0.14 0.30	<i>0.05</i>	6.04 4.31	0.12 0.13	0.07	ALL SECTORS	

¹ IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed);

[]: IRSSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Appendix 5 – Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹ by NAICS Manufacturing Subsector

NAICS code	Manufacturing subsector	Acetaldehyde	Acrylamide	Acrylonitrile	Asbestos	Aromatic amines	Arsenic	Benzene	Beryllium	Polychlorinated biphenyls	Wood dust
311	Food manufacturing		0.002				0.01	1.07		0.08	0.01
312	Beverage and tobacco product manufacturing						0.01	1.44		0.13	
313	Textile mills	✓	3.63	0.18	✓		0.03			0.12	
314	Textile product mills			0.10			0.02			0.06	
315	Clothing manufacturing						0.01	0.10		0.01	
316	Leather and allied product manufacturing	✓		0.11			0.03				
321	Wood product manufacturing			0.004	✓		1.92	0.22	0.02	0.09	77.22 53.40
322	Paper manufacturing	✓	1.78	0.02	0.72		0.16	0.26	0.05	0.27	22.59 1.70
323	Printing and related support activities	✓		0.02			0.01	0.32		0.03	0.05
324	Petroleum and coal product manufacturing				6.04		1.56	10.84		0.32	
325	Chemical manufacturing	✓	0.43	0.09	✓		0.63	1.16 3.60	0.09	0.07	
326	Plastics and rubber product manufacturing	✓		2.91	✓		0.09	3.77	✓	0.11	0.42
327	Non-metallic mineral product manufacturing		0.93	0.07	0.88		1.16	0.85	0.06	0.04	0.43
331	Primary metal manufacturing	✓	1.63	0.02	0.46		2.13	4.54	0.17	0.26	0.26
332	Fabricated metal product manufacturing			0.005	✓		0.87	0.84	0.14	0.08	0.68
333	Machinery manufacturing			0.02	✓		0.51	0.62	0.12	0.19	0.12
334	Computer and electronic product manufacturing			0.02	0.02		1.03	0.02	0.15	0.11	
335	Electrical equipment, appliance and component manufacturing	✓		0.04	✓		0.55	0.19	0.01	0.34	0.29
336	Transportation equipment manufacturing			0.07	1.41		0.32	1.20	0.08	0.10	0.84
337	Furniture and related product manufacturing	✓		0.01			0.07	0.33	0.02	0.03	60.33 23.52 56.10
339	Miscellaneous manufacturing			0.09	✓		0.16	0.33	0.52	0.04	1.94 22.70

¹ IARC groups 1 and 2A or ROHS designations C1, C2 et C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

**Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹
by NAICS Manufacturing Subsector (cont'd)**

Coal tar pitch volatiles	Cadmium	Chloroform	Chromium VI	Cobalt	Creosotes	Leather dust	Dichloro- methane	Diesel exhaust	Manufacturing subsector	NAICS code
	0.01	<i>0.03</i>	0.09	0.04				4.02	Food manufacturing	311
	0.04		0.14	0.03				11.04	Beverage and tobacco product manufacturing	312
	0.10		0.44	0.04			0.51	0.57	Textile mills	313
	0.18		0.18	0.05			1.64	0.29	Textile product mills	314
	0.003		0.05	0.03			0.03	0.40	Clothing manufacturing	315
	0.14		0.97	0.03		26.20	0.23		Leather and allied product manufacturing	316
✓	0.31		0.47	0.27	0.12		0.05	6.39	Wood product manufacturing	321
0.003	0.11		2.36	0.13			0.08	2.25	Paper manufacturing	322
	0.06		18.00	0.05			0.49	0.46	Printing and related support activities	323
0.60	0.24		1.28	0.96	0.64		0.76	3.16	Petroleum and coal product manufacturing	324
0.65	0.28	<i>4.09</i>	0.47	0.78			<u>3.84</u> 5.10	1.55	Chemical manufacturing	325
	8.77		0.96	0.65			1.65	0.99	Plastics and rubber product manufacturing	326
0.33	0.85		0.65	1.34			0.06	12.45	Non-metallic mineral product manufacturing	327
5.63	8.58		9.94	3.73			0.16	13.06	Primary metal manufacturing	331
0.005	1.66		<u>8.21</u> 5.10	2.36			0.18	1.17	Fabricated metal product manufacturing	332
	1.23		6.70	1.33			1.83	0.97	Machinery manufacturing	333
	0.14		0.37	0.20					Computer and electronic product manufacturing	334
0.13	1.31		0.47	1.15			0.09	0.16	Electrical equipment, appliance and component manufacturing	335
0.002	0.72		<u>1.86</u> 2.40	1.50			0.05	0.87	Transportation equipment manufacturing	336
0.003	0.25		0.47	0.33			0.19	0.82	Furniture and related product manufacturing	337
	0.46		1.02	0.88			0.13	0.39	Miscellaneous manufacturing	339

¹ IARC groups 1 and 2A or ROHS designations C1, C2 et C3.

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**Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹
by NAICS Manufacturing Subsector (cont'd)**

NAICS code	Manufacturing subsector	Epichlorohydrin	Formaldehyde	Mineral oils	Polycyclic aromatic hydrocarbons	Methyl iodide	Nickel & compounds	Ethylene oxide	Pentachlorophenol	Lead & inorganic compounds	Ionizing radiation
311	Food manufacturing		0.16		1.16		0.22	0.15		0.07	
312	Beverage and tobacco product manufacturing		0.77		0.38		0.45			0.11	
313	Textile mills		[0.02] 2.22				0.20			0.12	
314	Textile product mills		0.55				0.26			0.36	
315	Clothing manufacturing		0.18				0.09			0.02	
316	Leather and allied product manufacturing						0.06				
321	Wood product manufacturing		[0.34] 7.22		0.38		0.65		0.39	0.67	
322	Paper manufacturing		0.41	✓	0.34		0.99			1.25	
323	Printing and related support activities		0.01		0.27		0.23			0.04	
324	Petroleum and coal product manufacturing		0.52		1.80		3.24			3.28	
325	Chemical manufacturing		[0.06] 0.74 3.10		0.46	✓	0.33	0.50		0.43	
326	Plastics and rubber product manufacturing		[0.55] 0.42		1.27		0.40			0.50	
327	Non-metallic mineral product manufacturing		0.73	2.19	2.05		0.88			1.67	
331	Primary metal manufacturing		[0.13] 3.39		18.43		6.90			9.51	
332	Fabricated metal product manufacturing		0.66	17.70	3.99		5.08 4.30			11.54	
333	Machinery manufacturing		0.34	15.50	2.87		2.71			8.09	
334	Computer and electronic product manufacturing		0.04		0.12		0.38			2.89	
335	Electrical equipment, appliance and component manufacturing		0.01		0.24		2.02 2.80			2.90 3.50	
336	Transportation equipment manufacturing		0.07	11.60	3.06		1.49			4.84	
337	Furniture and related product manufacturing		[1.95] 7.74		0.02		0.46			1.41	
339	Miscellaneous manufacturing		0.37	9.50	0.07		0.53			3.13	

¹ IARC groups 1 and 2A or ROHS designations C1, C2 et C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Percentage of Quebec Workers Exposed to Known or Probable Carcinogens,¹ by NAICS Manufacturing Subsector (cont'd)

Solar radiation	Artificial UV radiation	Silica (quartz, cristobalite)	Styrene (monomer)	Tetrachloroethylene	Carbon tetrachloride	Shift work (night)	Trichloroethylene	Antimony trioxide	Manufacturing subsector	NAICS code
2.47	0.11	0.02	✓			21.48 20.80		0.002	Food manufacturing	311
3.82	0.35	0.13						0.03	Beverage and tobacco product manufacturing	312
0.32	0.27	✓	0.05	12.39			7.72	3.12	Textile mills	313
0.97	0.63		0.27	19.60			12.00	3.76	Textile product mills	314
0.27	0.04	0.03		0.57			0.03		Clothing manufacturing	315
1.56			0.20	1.90			12.99		Leather and allied product manufacturing	316
5.67	0.79	0.33	3.70			26.32	0.01	0.02	Wood product manufacturing	321
2.70	0.92	0.28	0.03	0.003		30.90	0.09	0.02	Paper manufacturing	322
1.01	0.01	0.07	0.04	3.54		11.00	1.85	0.004	Printing and related support activities	323
7.72	2.28	2.00					0.88	0.04	Petroleum and coal product manufacturing	324
1.52	0.33	3.13	2.62		4.09	21.20	2.01	0.04	Chemical manufacturing	325
0.89	0.34	4.57	8.70	0.02	0.73	17.10	0.81	0.37	Plastics and rubber product manufacturing	326
13.50	1.64	27.50 2.74	5.11	0.03		3.96	0.03	1.22	Non-metallic mineral product manufacturing	327
6.93	3.72	10.59	0.04	0.34		27.99	0.39	0.45	Primary metal manufacturing	331
3.83	12.35	[0.20] 2.52 5.10	0.03	0.75		14.10	0.75 3.10	0.29	Fabricated metal product manufacturing	332
2.16	9.59	1.74	0.05	0.15			0.09	0.21	Machinery manufacturing	333
0.84	1.00	0.12	0.08	0.005			0.02	0.05	Computer and electronic product manufacturing	334
1.26	3.04	0.28 2.70	0.96	0.08			0.08	0.31	Electrical equipment, appliance and component manufacturing	335
2.13	4.72	0.20	1.78	0.06		10.80	0.07	0.10	Transportation equipment manufacturing	336
1.38	1.41	0.36	5.77	0.04			0.04	0.04	Furniture and related product manufacturing	337
1.58	4.42	1.54	0.39	0.07			0.09	0.08	Miscellaneous manufacturing	339

¹ IARC groups 1 and 2A or ROHS designations C1, C2 et C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate percentage of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Appendix 6 – Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Major Economic Sector

NAICS code	Economic sector	Acetaldehyde	Acrylamide	Acrylonitrile	Asbestos	Aromatic amines	Arsenic	Benzene	Beryllium	Polychlorinated biphenyls
11	Agriculture, forestry, fishing and hunting						200	500		
21	Mining, quarrying, and oil and gas extraction		100				200	100		
22	Utilities		100		1,700		100	200		500
23	Construction		400		16,600 3,800		1,200	900	200	300
31-33	Fabrication	✓	1,600	1,000	1,400		3,000	5,400 900	400	600
41	Wholesale trade							4,300		
44-45	Retail trade							11,400		
48-49	Transportation and warehousing				100			13,400		100
51	Information and cultural industries							200		
52	Finance and insurance							100		
53	Real estate and rental and leasing							600		
54	Professional, scientific and technical services				200			300		
55	Management of companies and enterprises									
56	Administrative and support, waste management and remediation services				300			600		
61	Educational services							200	✓	
62	Health care and social assistance					3,800		300	✓	
71	Arts, entertainment and recreation							100		
72	Accommodation and food services							2,000		
81	Other services (except public administration)				800 500		100	12,800	100	100
91	Public administration				100			7,300		100
ALL SECTORS		✓	2,200	1,000	19,500 6,000	3,800	5,000	60,500 900	700	1,800

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Major Economic Sector (cont'd)

Wood dust	Coal tar pitch volatiles	Cadmium	Chloroform	Chrome VI	Cobalt	Creosotes	Leather dust	Dichloro-methane	Diesel exhaust	Economic sector	NAICS code
6,500 1,700 5,300									6,000 11,900	Agriculture, forestry, fishing and hunting	11
		100		700	400				[4,500] 3,800	Mining, quarrying, and oil and gas extraction	21
100				100	100				300	Utilities	22
30,300 21,500 15,600	400 7,700	200		700	200			400	11,000 11,500	Construction	23
35,800	1,900	7,200	<i>1,100</i>	16,000 3,200	4,500	100	<i>1,000</i>	2,600 1,300	15,200	Fabrication	31-33
500		100		300	100				8,900	Wholesale trade	41
500									6,400	Retail trade	44-45
100		100		300	100	100			[3,900] 64,700 11,400	Transportation and warehousing	48-49
				300					400 6,600	Information and cultural industries	51
									100	Finance and insurance	52
300 500									1,300 1,200	Real estate and rental and leasing	53
200			200	100					300	Professional, scientific and technical services	54
										Management of companies and enterprises	55
400				200					5,200	Administrative and support, waste management and remediation services	56
400				200				200	600	Educational services	61
300									2,300	Health care and social assistance	62
200									500	Arts, entertainment and recreation	71
100									2,500	Accommodation and food services	72
300		400		1,100	300		300	1,000	12,900 4,500	Other services (except public administration)	81
800				100					9,700	Public administration	91
102,200 63,200 46,300	2,300 7,700	8,300 7,000	<i>1,300</i>	20,300 3,200	5,800	200	<i>1,200</i>	4,200 1,300	152,000 47,100	ALL SECTORS	

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Major Economic Sector (cont'd)

NAICS code	Economic sector	Epichlorohydrin	Formaldehyde	Mineral oils	Polycyclic aromatic hydrocarbons	Methyl iodide	Nickel & compounds	Ethylene oxide	Pentachlorophenol	Lead & inorganic compounds	Ionizing radiation
11	Agriculture, forestry, fishing and hunting			<u>5,200</u>	700		100		300	200	
21	Mining, quarrying, and oil and gas extraction				500		400		-	300	
22	Utilities			<u>1,900</u>	200		100		200	300	<u>2,500</u>
23	Construction		200	<u>6,200</u>	800		800		100	5,200 <u>2,900</u>	
31-33	Fabrication		[900] 8,700 <u>800</u>	<u>19,500</u>	11,300	✓	7,500 <u>2,100</u>	200	200	15,700 <u>500</u>	
41	Wholesale trade		100	✓	1,800		300			900	
44-45	Retail trade		100	✓	15,300		100			1,800	
48-49	Transportation and warehousing				3,500		200			600	
51	Information and cultural industries				100					500	
52	Finance and insurance										
53	Real estate and rental and leasing		<u>300</u>	<u>700</u>	400					200	
54	Professional, scientific and technical services		400		100					100	<u>3,100</u>
55	Management of companies and enterprises										
56	Administrative and support, waste management and remediation services				500		100			200	
61	Educational services		[12,900] 200		300					200	
62	Health care and social assistance		[100] 800 <u>7,500</u>		4,400			500		100	<u>20,900</u>
71	Arts, entertainment and recreation				200					100	
72	Accommodation and food services				23,800						
81	Other services (except public administration)		[300] 100	<u>3,000</u>	1,500		1,200			6,600	
91	Public administration		200		6,200		100			11,200	
ALL SECTORS		<u>3,500</u>	[14,200] 10,900 <u>8,600</u>	<u>36,600</u>	71,600	✓	11,200 <u>2,100</u>	700	800	44,000 <u>3,400</u>	<u>34,800</u>

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed);
[]: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgén ; Underlined regular: Health Canada.

**Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,²
by NAICS Major Economic Sector (cont'd)**

Solar radiation	Artificial UV radiation	Silica (quartz)	Styrene (monomer)	Tetrachloroethylene	Carbon tetrachloride	Shift work (night)	Trichloroethylene	Antimony trioxide	Economic sector	NAICS code
49,500	300					<u>6,800</u>			Agriculture, forestry, fishing and hunting	11
2,900	400	[100] 2,900					✓ ³		Mining, quarrying, and oil and gas extraction	21
2,300	600	300				<u>9,400</u>			Utilities	22
46,200	1,600	30,800 <u>7,600</u>	200				<u>2,700</u>		Construction	23
15,000	14,500	11,800 <u>2,900</u>	8,900	4,100	<i>1,300</i>	<u>42,900</u> <u>36,700</u>	3,800 <u>1,300</u>	1,300	Fabrication	31-33
7,200	600	700					100		Wholesale trade	41
6,800	200	900	100			<u>7,900</u>			Retail trade	44-45
24,800	500	3,100				<u>30,200</u> <u>32,200</u>			Transportation and warehousing	48-49
2,600				100		<u>2,800</u> <u>18,700</u>	100		Information and cultural industries	51
300									Finance and insurance	52
1,300	100	300 <u>500</u>				<u>3,600</u>			Real estate and rental and leasing	53
4,700	1,700	200	100	100		<u>12,200</u>	100		Professional, scientific and technical services	54
100									Management of companies and enterprises	55
13,700	200	500				<u>6,800</u>	100		Administrative and support, waste management and remediation services	56
2,600	100	100							Educational services	61
6,400	10,800	100				<u>58,000</u> <u>20,000</u>			Health care and social assistance	62
8,200	100					<u>11,500</u>			Arts, entertainment and recreation	71
4,400						<u>38,300</u> <u>22,800</u>			Accommodation and food services	72
3,600	7,000	100 <u>200</u>		400	<i>400</i>		<u>500</u>	100	Other services (except public administration)	81
27,700	300	500						1,000	Public administration	91
230,300	88,900	52,400 <u>11,200</u>	9,300 <u>10,500</u>	4,700 <u>10,500</u>	<i>1,700</i>	<u>210,600</u> <u>150,100</u>	4,100 <u>4,400</u>	2,500	ALL SECTORS	

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

³ ✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Appendix 7 – Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Manufacturing Subsector

NAICS code	Manufacturing subsector	Acetaldehyde	Acrylamide	Acrylonitrile	Asbestos	Aromatic amines	Arsenic	Benzene	Beryllium	Polychlorinated biphenyls	Wood dust
311	Food manufacturing							600			
312	Beverage and tobacco product manufacturing							100			
313	Textile mills	✓	300		✓						
314	Textile product mills										
315	Clothing manufacturing										
316	Leather and allied product manufacturing	✓									
321	Wood product manufacturing				✓		900	100			36,700 25,400
322	Paper manufacturing	✓	600		200		100	100		100	7,200 500
323	Printing and related support activities	✓						100			
324	Petroleum and coal product manufacturing				200			300			
325	Chemical manufacturing	✓	100		✓		200	300 900			
326	Plastics and rubber product manufacturing	✓		800	✓			1,100	✓		100
327	Non-metallic mineral product manufacturing		100		100		200	100			100
331	Primary metal manufacturing	✓	500		100		600	1,300		100	100
332	Fabricated metal product manufacturing				✓		400	300	100		300
333	Machinery manufacturing				✓		100	200		100	
334	Computer and electronic product manufacturing						200				
335	Electrical equipment, appliance and component manufacturing	✓			✓		100				
336	Transportation equipment manufacturing				700		200	600			400
337	Furniture and related product manufacturing	✓						100			21,400 8,300 19,900
339	Miscellaneous manufacturing				✓			100	100		400 5,100

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

**Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,²
by NAICS Manufacturing Subsector (cont'd)**

Coal tar pitch volatiles	Cadmium	Chloroform	Chromium VI	Cobalt	Creosotes	Leather dust	Dichloromethane	Diesel exhaust	Manufacturing subsector	NAICS code
			100					2,300	Food manufacturing	311
								800	Beverage and tobacco product manufacturing	312
								100	Textile mills	313
							100		Textile product mills	314
								100	Clothing manufacturing	315
						1,000			Leather and allied product manufacturing	316
✓	147		200	100	100			3,000	Wood product manufacturing	321
			800					700	Paper manufacturing	322
			4,700				100	100	Printing and related support activities	323
								100	Petroleum and coal product manufacturing	324
200	100	1,100	100	200			1,000 1,300	400	Chemical manufacturing	325
	2,500		300	200			500	300	Plastics and rubber product manufacturing	326
	100		100	200				1,800	Non-metallic mineral product manufacturing	327
1,600	2,500		2,900	1,100				3,800	Primary metal manufacturing	331
	700		3,300 2,100	1,000			100	500	Fabricated metal product manufacturing	332
	300		1,900	400			500	300	Machinery manufacturing	333
			100						Computer and electronic product manufacturing	334
	200		100	200					Electrical equipment, appliance and component manufacturing	335
	300		900 1,200	700				400	Transportation equipment manufacturing	336
	100		200	100			100	300	Furniture and related product manufacturing	337
	100		200	200				100	Miscellaneous manufacturing	339

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.

Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Manufacturing Subsector (cont'd)

NAICS code	Manufacturing subsector	Epichlorohydrin	Formaldehyde	Mineral oils	Polycyclic aromatic hydrocarbons	Methyl iodide	Nickel & compounds	Ethylene oxide	Pentachlorophenol	Lead & inorganic compounds	Ionizing radiation
311	Food manufacturing		100		700		100	100			
312	Beverage and tobacco product manufacturing		100								
313	Textile mills		200								
314	Textile product mills										
315	Clothing manufacturing		100								
316	Leather and allied product manufacturing										
321	Wood product manufacturing		[200] 3,400		200		300		200	300	
322	Paper manufacturing		100	✓	100		300			400	
323	Printing and related support activities				100		100				
324	Petroleum and coal product manufacturing						100			100	
325	Chemical manufacturing		200 800		100	✓	100	100		100	
326	Plastics and rubber product manufacturing		[200] 100		400		100			100	
327	Non-metallic mineral product manufacturing		100	300	300		100			200	
331	Primary metal manufacturing		1,000		5,400		2,000			2,800	
332	Fabricated metal product manufacturing		300	7,200	1,600		2,100 1,700			4,700	
333	Machinery manufacturing		100	4,300	800		800			2,300	
334	Computer and electronic product manufacturing						100			600	
335	Electrical equipment, appliance and component manufacturing						300 400			400 500	
336	Transportation equipment manufacturing			5,600	1,500		700			2,300	
337	Furniture and related product manufacturing		[700] 2,700				200			500	
339	Miscellaneous manufacturing		100	2,100			100			700	

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Number¹ of Quebec Workers Exposed to Known or Probable Carcinogens,² by NAICS Manufacturing Subsector (cont'd)

Solar radiation	Artificial UV radiation	Silica (quartz, cristobalite)	Styrene (monomer)	Tetrachloroethylene	Carbon tetrachloride	Shift work (night)	Trichloroethylene	Antimony trioxide	Manufacturing subsector	NAICS code
1,400	100		✓	-		12,352 11,964			Food manufacturing	311
300			-	-					Beverage and tobacco product manufacturing	312
		✓		1,160			723	292	Textile mills	313
100				1,200			700	200	Textile product mills	314
100				200					Clothing manufacturing	315
100				100			500	-	Leather and allied product manufacturing	316
2,700	400	200	1,800	-		12,500			Wood product manufacturing	321
900	300	100				9,900			Paper manufacturing	322
300				900		2,900	500		Printing and related support activities	323
200	100		-						Petroleum and coal product manufacturing	324
400	100	800	700		<i>1,100</i>	5,500	500		Chemical manufacturing	325
300	100	1,300	2,500		<i>200</i>	4,900	200	100	Plastics and rubber product manufacturing	326
2,000	200	4,000 400	800			600		200	Non-metallic mineral product manufacturing	327
2,000	1,100	3,100		100		8,200	100	100	Primary metal manufacturing	331
1,600	5,000	1,000 2,100		300		5,700	300 1,300	100	Fabricated metal product manufacturing	332
600	2,700	500						100	Machinery manufacturing	333
200	200								Computer and electronic product manufacturing	334
200	400	400	100						Electrical equipment, appliance and component manufacturing	335
1,000	2,300	100	900			5,200			Transportation equipment manufacturing	336
500	500	100	2,000						Furniture and related product manufacturing	337
400	1,000	300	100						Miscellaneous manufacturing	339

¹ Numbers reported when over 50 workers presumed exposed. Rounded to the nearest hundred. Numbers estimated on basis of 2006 Census of Canada data and percentages of workers exposed according to sources identified below.

² IARC groups 1 and 2A or ROHS designations C1, C2 and C3.

✓: IRSST laboratory data (used to indicate presence of carcinogen only, not to estimate number of workers exposed); []: IRSST project; **Bold**: ESS98; Regular: CAREX Canada; **Underlined bold**: SUMER; *Italics*: Matgéné.