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Estimating the number of cases of occupational cancer in Quebec

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Special Projects

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REPORT **R-836**

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PEER REVIEW

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

ABSTRACT

As in most industrialized societies, cancer is the leading cause of death in Quebec: it is estimated that 20,200 people will die of cancer in 2013 and that 48,700 new cases will be diagnosed.

Carcinogenesis is a complex, multifactorial process that begins many years before clinical signs of disease appear. Cancer is considered to be occupational in origin when it results from workplace exposure to a chemical, physical or biological agent, or from conditions inherent in a work activity. The disease would probably not have developed if the person had not done that job. A number of studies have estimated that from 2% to 8% of all cases of cancer are work related, depending on the country and the number of cancer sites and types considered. However, for some sites or types, the proportion of work-related cases is far higher: occupation is thought to account, for instance, for over 90% of all cases of pleural mesothelioma in men. To be able to prioritize research and prevention needs, an estimate of the extent of the problem is required. The purpose of this report is therefore to present an estimate of the number of cases of occupational cancer among Quebec workers.

The number of cases of occupational cancer was estimated by means of two complementary methods: first, using Quebec workers' compensation data for cases of occupational cancer and, second, based on published population attributable fractions for work-related cancer. While these two data sources have certain limitations, they offer the advantage of being readily available and allowing forms of cancer to be classified for the purposes of setting research priorities and guiding prevention initiatives.

According to cancer compensation data from the Commission de la santé et de la sécurité du travail (CSST, or workers' compensation board), in Quebec, fewer than 100 workers were compensated annually between 2005 and 2007 for a new diagnosis of work-related cancer. Among files opened between 1997 and 2005, compensation was paid out in 362 cases of people who died of cancer, including six women (all from mesothelioma). For men, over half of cases were mesothelioma, of the pleura or the peritoneum, with the second leading cause being lung cancer. The majority of workers compensated had been employed in manufacturing, mining or construction. Owing in part to the difficulty of establishing a cause-and-effect relationship and also to the lengthy latency period between workplace exposure and development of the disease, compensation is paid out by the CSST in only a small number of cancer cases.

The second method used to estimate the number of cases of occupational cancer consisted in applying attributable fractions for work-related cancer (published by researchers in places fairly comparable to Quebec, that is, Finland and Great Britain) to the total number of deaths from cancer and the number of new cases of cancer diagnosed each year in Quebec. This method indicates that 6% (between 5% and 8%) of all new cases of cancer could be work related (8% to 13% for Quebec men and 2% to 3% for Quebec women), for a total of 1,800 to 3,000 new cases of cancer annually between 2002 and 2006. The forms of occupational cancer that affect the greatest number of Quebec men are cancer of the trachea, bronchi and lungs, prostate, skin (excluding melanoma) and bladder, along with mesothelioma, colon cancer and non-Hodgkin's lymphomas. The most common forms of cancer for Quebec women are breast cancer and cancer

of the trachea, bronchi and lungs. It has also been estimated that 8% (between 7% and 11%) of all cancer deaths (11% to 17% among men and 2% to 4% among women) are work related, which would correspond to 1,070 to 1,700 deaths a year from cancer between 2002 and 2006. The most common forms of cancer that lead to death are cancer of the trachea, bronchi and lungs for both sexes, followed by mesothelioma, colon and prostate cancer among men, and breast cancer among women.

The above figures highlight the underestimated extent of the burden of occupational cancer in Quebec. We did not attempt to put a dollar figure on the socioeconomic impact of these diseases. An assessment of this kind was conducted in Alberta, however, using cancer data from 2006 and cost data from 2008. The researchers estimated that for 761 new cases of work-related cancer annually and 2,700 people living with some form of occupational cancer, $15.7 million was spent in direct medical costs and $64.1 million in indirect socioeconomic costs every year. The total burden must be at least as high in Quebec, where it is estimated that there are 1,800 to 3,000 new cases of work-related cancer annually.

The long latency period between exposure to a carcinogen and the appearance of clinical signs of disease means that cases being seen now are the result of exposure from 10 to 50 years ago. Yet Quebec workers are still being exposed to carcinogens, and now is the time to act if we want to have an impact on their health in the coming decades.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAEQ	Classification des activités économiques du Québec [Quebec economic activity classification]
CCDO	Canadian Classification and Dictionary of Occupations
CSST	Commission de la santé et de la sécurité du travail du Québec [Quebec occupational health and safety board]
DDCR	Dépôt de données central et régional de la CSST [CSST's central and regional data repository]
ES	Economic sector
FiTQ	Fichier des tumeurs du Québec [Quebec tumour database]
IARC	International Agency for Research on Cancer
ICD	International Classification of Diseases
INSPQ	Institut national de santé publique du Québec [Quebec national institute of public health]
ISIC	International Standard Industrial Classification
JEM	Job-exposure matrix
LABORSTA	Labour statistics database of the International Labour Organization
LFS	Labour Force Survey (Statistics Canada)
NAICS	North American Industrial Classification System
OECD	Organization for Economic Co-operation and Development
P_{exp}	Proportion of workers exposed
PAR	Population attributable risk
RR	Relative risk
SIC	Standard Industrial Classification (Statistics Canada)
SOC	Standard Occupational Classification (Statistics Canada)
WHO	World Health Organization

1. BACKGROUND

1.1 Cancer Statistics

Cancer and cardiovascular disease are the leading causes of death in industrialized countries, with cancer ranking first in Quebec and Canada [Institut national de santé publique du Québec, 2009]. For 2013, 48,700 new cases of cancer and 20,200 deaths due to cancer are forecast for Quebec [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013]. The most common forms of cancer in men are prostate, lung, colon, rectal and bladder cancer, as well as non-Hodgkin's lymphomas, while pancreatic cancer can also be added, given the number of deaths it causes. In women, the most common types are cancer of the breast, lung, colon and rectum, uterus and thyroid, to which pancreatic and ovarian cancer and non-Hodgkin's lymphomas can be added on account of the number of deaths they cause. In Canada, in the last 30 years or so, an increase has been seen in the incidence of liver and thyroid cancer and non-Hodgkin's lymphomas in both men and women, as well as kidney cancer in men and breast and lung cancer in women [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013].

Carcinogenesis is a complex, multifactorial process. As early as 1964, the World Health Organization (WHO) noted that most cases of cancer could be avoided by regulating lifestyles and various environmental factors, including those related to work [Doll & Peto, 1981].

1.2 Occupational Cancer

A case of cancer is deemed to be occupational if it has been caused by workplace exposure to a chemical, physical or biological agent or specific working conditions. It would probably not have developed if the person had not performed the work in question [Vandentorren et al., 2005].

Some cancer sites and types have been associated with occupational exposure for over a century. Take, for example, cancer of the scrotum in chimney sweeps, first reported in 1775, skin cancer in coal miners, lung cancer in metal miners, and bladder cancer in dye industry workers, all reported in the 19th century [Schüttmann 1993; Landrigan, 1996; Gawkrodger, 2004]. Since then, many other substances or occupational exposure circumstances have been associated with 10 or so cancer sites, including the lungs, bladder, skin, larynx, sinuses and nasal pharynx [Siemiatycki et al., 2004].

In 1981, Doll and Peto estimated that on average in the United States, 4% of deaths due to cancer (with a range of 2% to 8%) were attributable to work [Doll & Peto, 1981]; these figures are now considered to be an underestimate, as the authors did not take into account deaths occurring before age 65 and excluded a number of cancer sites and types now known to be associated with occupational exposure (e.g., melanoma and cancer of the pharynx).

These figures, though they may seem low, concern cancer risks that are avoidable, as Doll and Peto pointed out:

> Occupational cancer, moreover, tends to be concentrated among relatively small groups of people among whom the risk of developing the disease may be quite large, and such risks can usually be reduced or even eliminated, once they have been identified. The detection of occupational hazards should therefore have a higher priority in any program of cancer prevention than their proportional importance might suggest. [Doll & Peto, 1981: 1245]

1.3 Estimate of Occupational Cancer Burden

Since Doll and Peto's ground-breaking work [1981] (based on a qualitative review of the literature), only a few methods have been used to estimate the burden of occupational cancer. Those methods vary with the research goals, ranging from a basic description of the compensation statistics [Teschke & Barroetavena, 1992] or number of cases of cancer deemed to be exclusively associated with work [Mullan & Murthy, 1991] to detailed calculations of the cancer fractions attributable to work supported by risk estimates specific to the population in question [Rushton et al., 2008, 2010]. Alberta Health Services recently used data published on attributable fractions for occupational cancers to produce estimates of direct and indirect costs associated with them [Orenstein et al., 2010].

1.3.1 Compensation Statistics

Compensation statistics are collated for the purposes of administering an insurance program offered to companies. They therefore concern insured businesses from all the economic sectors covered and can be used to estimate the number of cases of cancer recognized as being work related. One disadvantage of these statistics, however, is that they seriously underestimate the real number of cases, for several reasons. According to data from Ontario, British Columbia and Saskatchewan, the fact that some patients or their families fail to file claims is a more significant factor in the underestimation than the rejection of claims by occupational health and safety boards [Teschke & Barroetavena, 1992]. Second, legislation governing compensation for cases of occupational cancer varies considerably from one jurisdiction to another, which makes it difficult to draw comparisons between countries. It is possible, however, to examine changes over time in compensation within a given jurisdiction [Thimpont et al., 2009].

1.3.2 Sentinel Occupational Diseases

A second indicator of the extent of occupational cancer is the number of sentinel occupational cancers. Introduced in 1976, the concept of "occupational sentinel health event" was developed for public health surveillance purposes and encompasses work-related diseases, disabilities and deaths [Mullan & Murthy, 1991]. The principle underlying the surveillance of sentinel events is that they are good indicators of changes in worker health and workplace safety. Among such sentinel events are a dozen or so forms of cancer, only three of which are almost exclusively occupational in terms of etiology: pleural mesothelioma, angiosarcoma of the liver and malignant tumours of the scrotum. Here again, although these forms of cancer are almost definitely associated with work, they provide only a partial representation of the extent of occupational cancer, as they are just 3 out of more than 30 forms potentially associated with work [Siemiatycki et al., 2004]. The three types are quite rare, however: between 111 and

136 cases of pleural mesothelioma annually in Quebec between 2001 and 2006 [Éco-Santé Québec, 2007], fewer than 40 cases of cancer of the scrotum annually [Wright et al., 2008] and fewer than 10 cases of angiosarcoma of the liver annually [Thériault et al., 2006]. Surveillance of these forms of cancer therefore does not provide much information about the overall state of occupational cancer.

1.3.3 Occupational Population Attributable Risk

The population attributable risk, or attributable fraction, is the proportion of cases of a disease (in this case, cancer) that can be attributed to exposure to a risk factor (in this case, work with exposure to carcinogens). In other words, it is the proportion of cases that could be avoided if this exposure were eliminated [Bouyer et al., 2003]. This population attributable risk (PAR) can be calculated as follows [Steenland et al., 2003]:

$$PAR = \frac{P_{exp}\,(RR - 1)}{1 + P_{exp}\,(RR - 1)}$$

where, for a given industry,

PAR = population attributable risk

P_{exp} = proportion of workers in that industry exposed to the carcinogen(s)

RR = relative risk of developing cancer among workers exposed to the carcinogen(s) compared with non-exposed workers.

The approaches most commonly used to calculate PARs are the following:

- For each "cancer site/type–workplace carcinogen" dyad, a relative risk (RR) is obtained from epidemiological studies of workers, while the P_{exp} is taken from census, specific population survey and job-exposure matrix (JEM) data.[1] In general, authors use epidemiological studies done in their own countries or in countries with comparable economic structures. The WHO took this approach to calculate the occupational cancer burden [Driscoll et al., 2005], as did several research teams [Dreyer et al., 1997; Nurminen & Karjalainen, 2001; Steenland et al., 2003].
- The results of a meta-analysis of several case-control studies are used to calculate an RR, and the proportion of workers exposed (P_{exp}) is calculated on the basis of the distribution of the occupational exposure to the carcinogen(s) in the study cases and controls. This approach has been used to estimate PARs for a single cancer site at a time, such as lung cancer [Gustavsson et al., 2000].
- Some authors have used data from a cancer registry in which occupation was recorded using a case-control approach, taking people with the type of cancer being studied as cases and those with other forms of cancer as controls [Bouchardy et al., 2002]. Then an outside source of information on labour force data is needed for the purpose of calculating PARs.

[1] A job-exposure matric is a database showing relationships between job titles and indexes of workplace exposure to one or more agents or exposure circumstances.

- The Delphi approach (consensus with iteration) has also been used with a panel of experts to estimate PARs on the basis of the experts' knowledge and experience [Morrell et al., 1998; Landrigan et al., 2002].
- British researchers have taken an approach that combines some of these methods [Hutchings & Rushton, 2012; Rushton et al., 2012a]: first a study deemed better than the others is selected by consensus, then an RR is obtained for each cancer site/type–workplace carcinogen dyad and the PAR is calculated.

The proportion of individuals exposed to carcinogens varies from one country to another, depending on each country's economic profile and its legislation governing the use of carcinogens. As the relative significance of the various cancer sites and types also varies by country, PAR is not a universal phenomenon, but rather a parameter specific to a given country and a specific point in time. Note also that PAR estimates may vary with the carcinogenic substances or exposure circumstances being considered and with the estimated risk associated with each carcinogen chosen for each type of cancer considered.

In the United States, for instance, Doll and Peto [1981] estimated that 4% of cancer deaths, for 21 selected cancer sites and types, were attributable to work; for lung cancer, however, the proportions of work-related deaths were higher, i.e., by 15% for men and by 5% for women [1981]. A Finnish study estimated that 8.4% of cancer deaths (13.8% for men and 2.2% for women) were attributable to work; when 27 different types of cancer were considered, on the basis of studies conducted essentially in the Nordic countries, the proportions of deaths due to lung cancer were respectively 29% for men and 5.3% for women [Nurminen & Karjalainen, 2001]. Another estimate done in the U.S. on 10 cancer sites and types came to the conclusion that 2.4% to 4.8% of cancer deaths were occupational in origin and that these percentages were 8% to 19.2% for lung cancer deaths in men and 2% in women [Steenland et al., 2003]. Finally, a more recent study of 24 cancer sites and types has yielded the following estimates for Great Britain: 8.2% of deaths (5.7% of new cases) in men and 2.3% of deaths (2.1% of new cases) in women are attributable to work; the estimates for lung cancer deaths were 21.1% for men and 5.3% for women [Rushton et al., 2010].

Two of these studies are of particular interest because they provide PAR estimates for a broader number of types of cancer, include types of cancer that develop after age 65 and come from countries that are fairly comparable to Quebec in terms of social and economic development, i.e., Finland and Great Britain [Nurminen & Karjalainen, 2001; Rushton et al., 2010, 2012a].

Rather than redo studies like those mentioned above, other authors have opted to use the attributable fractions already published for countries with comparable levels of industrialization and to apply them to their local health and labour force data, while taking into account differences in socioeconomic structure between countries as much as possible. This has been done, for instance, for Australia [Fritschi, 2006; Fritschi & Driscoll, 2006], France [Imbernon, 2003], the United States [Leigh et al., 2003] and Alberta [Orenstein et al., 2010].

In order to make data available quickly that can help guide IRSST research efforts, we propose presenting an initial estimate of cases of occupational cancer from two complementary viewpoints: first using compensation statistics compiled by the Commission de la santé et de la sécurité du travail du Québec (CSST), and then using population attributable fractions for work-related cancer published by researchers in other countries.

1.4 Objective

The objective of this research effort is to estimate, for some 20 cancer sites and types (the most frequent and the most commonly associated with an occupational origin), the number of cases in Quebec that could be attributed to work, in men and women.

2. METHODOLOGY

2.1 Compensation Statistics

For new cases of cancer, data from the CSST's central and regional data repository (Dépôt de données central et régional, or DDCR, updated to June 30, 2010) were used to highlight the number of workers who developed cancer between 2005 and 2007 (date of diagnosis) that was recognized as being occupational in origin. Nature-of-disease codes 31000 (malignant tumour) and 31001 (mesothelioma) were used. The sites (parts of the body) and types were used as coded, except for the following recodings:

- When the type "mesothelioma" was reported for the site "lung," the site was recoded "pleura" (18 cases, 15 deaths).
- When the type "mesothelioma" was reported for the site "internal abdominal site, NOS," the site was recoded as "peritoneum" (1 case, 1 death).
- When the site "pleura" was reported for the type "malignant tumour," the type was recoded as "mesothelioma" (1 case, 1 death).

Data on employment-related deaths were used to determine the number of workers whose death was recognized as being associated with occupational cancer and accepted as such by the CSST between 1997 and 2005 (date death claim accepted). The same nature-of-disease codes were used (31000 and 31001). The data sources, along with a short description of each one, are listed in Appendix 1.

2.2 Estimates Based on Attributable Fractions

Calculating the risk attributable to work in the population, known as the population attributable risk [Hutchings & Rushton, 2012], is considered to be the most robust method of estimating the burden of occupational cancer. This calculation requires four types of information specific to the population to which the PAR applies:

- A list of carcinogenic agents or exposure circumstances
- An estimate of the relative cancer risk associated with occupational exposure to each of these carcinogens
- The proportion of people exposed to each carcinogen at work, along with information on the industries and occupations involved
- The number of cancer deaths and new cases of cancer diagnosed annually in the population

With the exception of the last category, this information can be complex to obtain. While there are lists of known or probable carcinogens, like the one drawn up by the International Agency for Research on Cancer (IARC), some carcinogens may not yet be included because the carcinogen classification process is lengthy and complex. There is very little information available specific to Quebec on the quantification of the risk associated with workplace carcinogens, even for the better-known ones. Estimates of relative risks for the Quebec population are difficult to obtain because they require local studies on the carcinogens being investigated. Figures on the proportion of people exposed to each carcinogen in the workplace are also difficult to estimate accurately, unless longer, more expensive studies are conducted.

For these reasons, it was decided that for the purposes of this study, the best option was to use PARs published by other researchers, for other countries, rather than calculate PARs specific to Quebec. As mentioned earlier, only two research teams have published PARs on a wide range of cancers in countries comparable to Quebec, i.e., Finland and Great Britain [Nurminen & Karjalainen, 2001; Rushton et al., 2010, 2012b]: their publications were therefore used for this study. This method allowed us to obtain usable data faster, in the interests of establishing research priorities and providing guidance for prevention initiatives.

2.2.1 Selection of Types of Cancer Considered

The types of cancer to be investigated in this study were selected on the basis of three criteria: their frequency in terms of annual number of cases [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013; Beaupré, 2002], their known link with work [Siemiatycki et al., 2004] and whether data were available on the work-related attributable fractions [Nurminen & Karjalainen, 2001; Rushton et al., 2010, 2012a, 2012b]. The sites and types of cancer selected for the study are presented in Table 1.

Table 1 – List of cancer sites and types chosen for estimating numbers attributable to work

Cancer site or type	ICD-9 codes[1]	ICD-10 codes[1]	Evidence of occupational link[2]
Oral cavity	141-145	C01-C06	+
Pharynx	146-148, 149.0	C09-C13, C14.0	+
Esophagus	150	C15	+
Stomach	151	C16	+
Colon	153	C18	+
Rectum	154.1	C20	+
Liver	155.0, 155.1	C22.0, C22.2-C22.9	++
Pancreas	157	C25	+
Sinuses, nasal cavities	160.0	C30.0	++
Larynx	161	C32	++
Trachea, bronchi, lungs	162	C33, C34	++
Mesothelioma	(158, 163, 164.1, 187.8) + morphology M905X	C45	++
Bone	170	C40-C41	++
Skin melanoma	172	C43	++
Skin, non-melanoma	173	C44	++
Breast	174, 175	C50	+
Cervix	180	C53	+
Uterus	182	C54, C55	+
Ovaries	183.0	C56	++
Prostate	185	C61	+
Bladder	188	C67	++
Kidney	189.0-189.2	C64-C66	+
Brain	191	C71	+
Thyroid	193	C73	++
Hodgkin's disease	201	C81	+
Non-Hodgkin's lymphomas and other malignant tumours of lymphoid and histiocytic tissue	200, 202	C82-C85, C96.3	+
Multiple myeloma	203	C88, C90	+
Leukemia	204-206, 207.0, 207.2, 207.8, 208	C91-C93, C94.0, C94.2, C94.3, C94.7, C95	+

[1] ICD: International Classification of Diseases, 9th or 10th edition.
[2] Evidence of link to work, as estimated by Siemiatycki et al., 2004; Rousseau et al., 2005; and a review of monographs 1 to 102 of the International Agency for Research on Cancer (http://monographs.iarc.fr/).
+: evidence of possible/probable link; ++: evidence of proven link.

2.2.2 Number of New Cases of Cancer and Deaths from Cancer

Two health registries—available from the public health information centre of the Ministère de la Santé et des Services sociaux (with the INSPQ, Institut national de santé publique du Québec, being responsible for administering them)—were the sources of data on new cases of cancer and on the number of cancer deaths. The first is the registry of deaths (*Fichier des décès*), which collects data from hospitals, emergency services and the coroner's office in order to document the causes of Quebec deaths. The second is the Quebec registry of tumours (*Fichier des tumeurs du Québec*, or FiTQ),[2] which is a database for tracking new cancer cases that consists essentially of data provided by hospitals. One study calculated that the FiTQ ensured 97.1% exhaustivity for lung cancer, 86.0% for bladder cancer and 96.7% for all types of cancer [Brisson et al., 2003]. Neither registry contains any information on subjects' work history or possible occupational exposure.

Based on the five most recent years of data available from the public health information centre at the time of the study, i.e., from 2002 to 2006, annual means for the number of new cases of cancer and cancer deaths were obtained for the selected types of cancer, by sex.

2.2.3 Calculation of Attributable Fractions

The population attributable fractions for work-related cancer to be applied to each site and type of cancer in Table 1 were drawn from two studies: one from Finland [Nurminen & Karjalainen, 2001] and the other from Great Britain [Rushton et al., 2010, 2012b]. They present attributable fractions by sex, for all cancer deaths.

As noted earlier, the published attributable fractions were calculated chiefly on the basis of cancer mortality studies. They should therefore preferably be used to estimate the number of cancer deaths attributable to work. Nevertheless, a number of authors have applied these fractions to new cases of cancer in order to estimate the number, assuming that survival should not be affected by whether the risk factor is occupational or not [Hutchings & Rushton, 2012]. For cancer types with high mortality rates (such as cancer of the esophagus, pancreas and lung), the use of these fractions is virtually equivalent for new cases and for deaths. As for types of cancer that have very good survival rates, this use could underestimate the work-related attributable fractions; consequently, the authors of the British study tried, when data were available, to use risk estimates from cancer incidence studies for forms of cancer with longer survival times [Hutchings & Rushton, 2012].

Three values of the work-related attributable fraction were used: the lowest fraction, the highest and a plausible value calculated as explained below. The fractions were calculated for each site or type of cancer, separately for men and women, based on data published in the Finnish and British studies. The published fractions, along with the low, high and plausible values, are given in Appendix 2. The plausible values are the arithmetic mean of the low and high values. For forms of cancer associated with smoking or drinking (listed in Appendix 2, as established by the IARC [2012]), the fractions from the British study were generally preferred to those from the

[2] Since renamed the Registre québécois du cancer (Quebec cancer registry).

Finnish one because British smoking and drinking habits were deemed to be closer to those of Quebecers between 1970 and 1990 (see Section 3.2.1).

2.2.4 Comparability of Quebec, Canada, Finland and United Kingdom

Given that the factors determining the attributable fractions are the percentage of workers exposed to carcinogens and the relative risk of developing cancer among exposed subjects compared with non-exposed subjects, taking attributable fractions from elsewhere and applying them to Quebec involves certain assumptions [Hutchings & Rushton, 2012]. The biggest assumption is that the types and levels of exposure to carcinogens are similar in the populations being compared. A second major assumption is that this exposure occurred during the period of exposure relevant to the type of cancer being studied, i.e., long enough ago for the cancer to have had time to develop. The relevant exposure period considered is less than 20 years for hematopoietic cancers and 10 to 50 years for the other types of cancer [Hutchings & Rushton, 2012]. A last, albeit less significant assumption is that the distribution of major confounding factors is similar in the populations being compared.[3] The results of comparing the three countries with respect to these aspects are summarized in Section 3.3 and presented in greater detail in Appendix 3.

Economic Activity Profiles

As discussed earlier, the calculated attributable fractions for work-related cancer are specific to each country and to the time period considered. In an exploratory study, it is difficult to control completely for differences on an international level, but it is essential to determine whether significant discrepancies between economic activities in different countries could invalidate comparisons.

The economic activity profiles of Canada, Finland and the United Kingdom are based on data from the International Labour Organization’s labour statistics database, LABORSTA. The database draws on national statistical data from each country (established in accordance with the resolution concerning statistics of the economically active population, employment, unemployment and underemployment, adopted by the Thirteenth International Conference of Labour Statisticians in Geneva in 1982) [International Labour Organization, 2011]. We were unable to find comparable figures for Great Britain, so data for the United Kingdom were used.[4]

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[3] A confounding factor is a disease risk factor that is also associated with exposure, without being affected by the exposure or the disease. One of the most common potential risk factors is smoking [Rothman et al., 2008]. Smoking increases the risk of developing lung cancer and is also associated with a lower level of education, which determines occupation. It is therefore possible that a high risk of this type of cancer in some occupations may be related to the fact that the proportion of smokers is greater in these groups rather than to actual occupational exposure.

[4] The United Kingdom is made up of Great Britain (England, Scotland and Wales) and Northern Ireland. As workers in Great Britain account for 97.4% of U.K. workers, according to the Office for National Statistics, economic activity data are interchangeable between the two geographic entities [http://www.ons.gov.uk/ons/publications/index.html].

As no direct comparison between Quebec and Finland or between Quebec and the United Kingdom was available, we first established that Quebec's economic activity profile was similar to Canada's, on the basis of workforce data taken from Statistics Canada's Labour Force Surveys (LFSs).

The economic activity profiles were then compared by contrasting the number of workers in each industrial subsector, in order to determine the relative size of each sector by country. This comparison was a means of qualitatively assessing the comparability of the countries in terms of economic sectors, as exposure distribution is strongly associated with specific sectors. The oldest data available are from 1970, when only a few activity sectors were documented. However, that period corresponds realistically to the average upper boundary of the latency period of several types of cancer (35 years) and we felt it was important to go back that far to examine the correspondence between the countries.

Distribution of Potential Confounding Factors

It is difficult to assess the distribution of potential confounding factors in different countries, because even when the data do exist, they are not collected in the same way from one country to the next and are not always directly comparable. The major confounding factors, besides sex and age, are smoking and drinking, on which the WHO publishes comparative data as part of its monitoring programs [World Health Organization, 2011a, 2011b]. Available data on these potential confounding factors were compared, as were the economic activity profiles, for Canada, Finland and the United Kingdom.

3. RESULTS

3.1 Compensation Statistics

3.1.1 New Cases of Cancer Compensated by CSST (2005–2007)

Over the three years considered, there were 283 new cases of cancer for which the CSST paid out compensation, i.e., an average of 94.3 cases per year. Most of these cases occurred in people aged 65 or older (203/283, 71.7%), were chiefly mesotheliomas (180/283, 63.6%), mostly of the pleura (175/180, 97.2%), and cancers of the lung and respiratory tract (84/283, 29.7%). Compensation was paid out to women in only six cases, all pleural mesotheliomas (2 cases in the 55–64 age group, and 4 in the 65-and-over group). The distribution of these cases by age group and disease is shown in Figure 1.

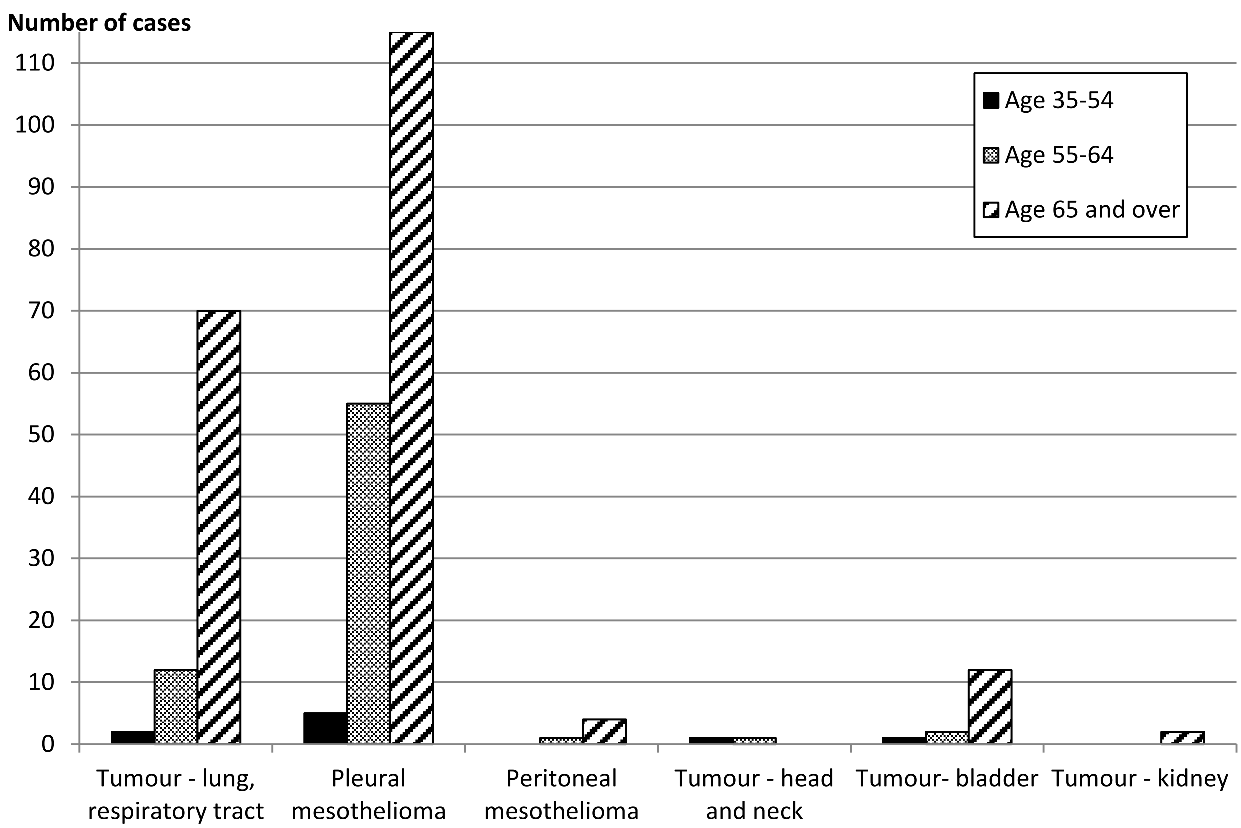

Figure 1 – Cancer sites and types for which CSST paid out compensation, by age group and site of lesion, for men and women, Quebec 2005–2007

The economic sector was not coded for a large percentage of cases, which is probably due to the fact that more than two thirds of workers were retirement age or older when they filed their claims (Table 2). For the 149 coded files, the *manufacturing* (52/149, 35.0%) and *mining* (26/149, 17.4%) sectors predominate.

Table 2 – New cases of malignant tumours for which CSST paid out compensation, by NAICS major sector and lesion site, for men and women, Quebec, 2005–2007[1]

NAICS code[2]	Economic sector	Tumour site or type						Total
		Bronchi, lungs	Pleura	Perito-neum	Bladder	Kidney	Head and neck	
11	Agriculture, forestry, fishing and hunting							
21	Mining, quarrying, and oil and gas extraction	20	6					26
22	Utilities		4					4
23	Construction	3	4				1	8
31-33	Manufacturing	13	24	1	13		1	52
41	Wholesale trade		2	1				3
44-45	Retail trade		3					3
48-49	Transportation and warehousing	1	6					7
51	Information and cultural industries	6	8	1				15
52	Finance and insurance		1					1
53	Real estate and rental and leasing							
54	Professional, scientific and technical services		2					2
55	Management of companies and enterprises							
56	Administrative and support, waste management and remediation services	3	6					9
61	Educational services		4					4
62	Health care and social assistance		5					5
71	Arts, entertainment and recreation		1					1
72	Accommodation and food services							
81	Other services (except public administration)	1	1					2
91	Public administration	2	3	1		1		7
Other sector – not coded		35	95	1	2	1		134
TOTAL 2005–2007 – ALL SECTORS		84	175	5	15	2	2	283
TOTAL – ANNUAL MEAN		**28.0**	**58.3**	**1.7**	**5.0**	**0.7**	**0.7**	**94.3**

1 There were six new cases of cancer in women, all pleural mesotheliomas.

2 North American Industrial Classification System (NAICS) code, assigned on the basis of the Classification des activités économiques du Québec (CAEQ) four-digit code associated with the employer’s insurance rate record and the CSST’s NAICS-CAEQ correspondence table.

3 Head and neck: A tumour on the cheek (including the bone) and one on the head (not otherwise specified: temple).

3.1.2 Cancer Deaths Compensated by CSST (1997–2005)

According to the CSST, compensation was paid out for 719 deaths due to occupational disease between 1997 and 2005 (see Appendix 4), including 362 deaths from cancer (4 among women), which is 50.3% of all deaths associated with an occupational disease (Figure 2). Most of the cancer-related compensated deaths were attributed to pleural mesothelioma (214/362, or 59.1%) or to cancer of the trachea, lungs or bronchi (135/362, or 37.3%).

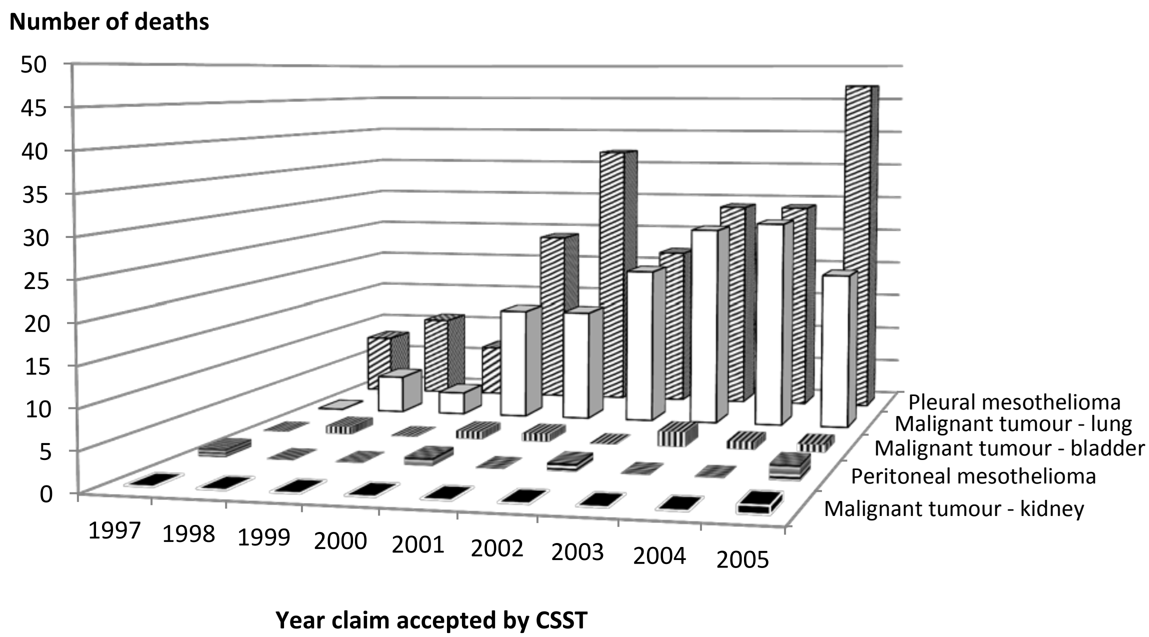

Figure 2 – Cancer deaths compensated by CSST, by year claim accepted and lesion site, for men and women, Quebec, 1997–2005

Table 3 lists the number of occupational cancer deaths for which the CSST paid out compensation, broken down by economic sector reported in the file. Deaths were recorded principally in three main sectors—*manufacturing*, *construction* and *mining*—which account for 72.9% of cancer deaths during the period, including 85.2% of cases of lung cancer and 64.5% of cases of pleural mesothelioma.

Table 3 – Cancer deaths compensated by CSST, by major NAICS sector and lesion site and type, for men and women, Quebec, 1997–2005[1]

NAICS code[2]	Economic sector	Site of tumour leading to death					Total
		Bronchi, lungs	Pleura	Perito-neum	Bladder	Kidney	
11	Agriculture, forestry, fishing and hunting		1				1
21	Mining, quarrying, and oil and gas extraction	43	22	1			66
22	Utilities		3				3
23	Construction	27	57	3			87
31-33	Manufacturing	45	59		7		111
41	Wholesale trade	2	9				11
44-45	Retail trade		4				4
48-49	Transportation and warehousing	3	11				14
51	Information and cultural industries						
52	Finance and insurance						
53	Real estate and rental and leasing		2				2
54	Professional, scientific and technical services	6	10				16
55	Management of companies and enterprises						
56	Administrative and support, waste management and remediation services	1	1				2
61	Educational services	1	9				10
62	Health care and social assistance		3				3
71	Arts, entertainment and recreation		1				1
72	Accommodation and food services						
81	Other services (except public administration)	2	2				4
91	Public administration	1	7			1	9
Other – not coded		4	11	1			14
TOTAL 1997–2005 – ALL SECTORS		135	214	5	7	1	362
TOTAL – ANNUAL MEAN		**15.0**	**23.8**	**0.6**	**0.8**	**0.1**	**40.2**

1 There were four cancer deaths among women: three cases of pleural mesothelioma and one of peritoneal mesothelioma.

2 North American Industrial Classification System (NAICS) code, assigned on the basis of the Classification des activités économiques du Québec (CAEQ) four-digit code associated with the employer's insurance rate record and the CSST's NAICS-CAEQ correspondence table.

3.2 Attributable Fractions Drawn from the Literature

3.2.1 Comparability of Quebec, Canada, Finland and United Kingdom

Analyses support the conclusion that the two biggest assumptions involved in the use of attributable fractions from other countries are probably valid (see Appendix 3 for details).

First of all, the economic activity profiles of Finland, the United Kingdom and Canada (and by extension, Quebec) have been comparable since 1970. There are therefore good grounds for believing that the exposures that have occurred over this 30-year period have been similar enough that the same types of occupational cancer can be expected to be seen between 2002 and 2006.

With respect to the similarities in the prevalence of lifestyles that could act as the most common competitive risk factors or potential confounding factors, i.e., smoking and drinking, the differences noted suggest the following limits. A greater proportion of Canadians than Finns are smokers (and Quebecers smoke more than the Canadian average[5]), and this seems to have been the case since the 1970s. As a result, for smoking-related cancers, the use of attributable fractions calculated for Finland could overestimate the work-related attributable fractions for Quebec. We therefore used the attributable fractions for Great Britain (where the prevalence of smokers and the per capita cigarette consumption are closer to Canadian rates; see appendices 2 and 3) for types of cancer associated with smoking, but not drinking, i.e., cancer of the sinuses and nasal cavities, lung, cervix, ovaries, bladder, kidney, stomach and pancreas. However, alcohol consumption was higher per person in Canada than in the other countries in 1970, but the situation had reversed by 1980, and since then Canada has had the lowest alcohol consumption of the three countries. This means that the work-related attributable fraction for Quebec could be slightly overestimated for types of cancer associated with drinking, whether or not there is a link with smoking. Nonetheless, we used the lowest attributable fractions for cancer sites for which the link with drinking is well established, i.e., cancer of the pharynx, esophagus, liver and larynx.

3.2.2 Annual Number of Incident Cancer Cases

Table 4 lists the mean annual number of incident cancer cases between 2002 and 2006, as well as the plausible, low and high estimates of the annual number of these cancer cases attributable to work. The work-related attributable fractions are taken from the studies by Nurminen and Karjalainen [2001] and by Rushton et al. [2010, 2012b]. The published fractions and the mean of the fractions of the two research teams, as well as the lowest and highest fractions, are

[5] Since at least 1985, the proportion of smokers in Quebec has always been above the Canadian average. See http://publications.gc.ca/Collection-R/LoPBdP/CIR/8622-e.htm.

Table 4 – Plausible, low and high estimates of annual new work-related cases of cancer, by cancer site or type and sex, Quebec, 2002–2006

	Men				*Women*			
Cancer site or type	**New cases[1]**	**Estimated work-related cases[2]**			**New cases[1]**	**Estimated work-related cases[2]**		
		Plausible	**Low**	**High**		**Plausible**	**Low**	**High**
Oral cavity[3]	277.4	3.3	3.3	3.3	157.0	0.5	0.5	0.5
Pharynx	205.2	4.1	4.1	22.2	70.6	0.4	0.4	1.7
Esophagus	234.2	7.7	7.7	15.0	75.0	0.2	0.2	0.8
Stomach	493.4	14.8	14.8	50.8	298.0	0.9	0.9	16.1
Colon[3]	1,624.4	91.0	91.0	91.0	1,613.0	0.0	0.0	0.0
Rectum[3]	656.2	20.3	20.3	20.3	410.4	0.4	0.4	0.4
Liver	301.8	0.6	0.6	10.6	145.4	0.1	0.1	7.7
Pancreas	487.4	0.1	0.1	65.3	507.6	0.1	0.1	17.8
Sinuses, nasal cavities	32.0	13.9	7.7	13.9	23.0	4.6	1.5	4.6
Larynx	308.8	9.0	9.0	28.7	71.4	0.4	0.4	1.1
Trachea, bronchi, lungs	3,841.0	810.5	810.5	1,113.9	2,710.8	143.7	143.7	143.7
Mesothelioma	104.8	98.0	94.3	101.7	28.0	15.1	7.0	23.1
Bone	35.6	0.1	0.0	0.2	31.4	0.1	0.0	0.2
Skin melanoma[3]	263.6	11.3	11.3	11.3	235.6	0.9	0.9	0.9
Skin, non-melanoma	1,166.4	116.6	80.5	152.8	1,002.4	24.6	11.0	38.1
Breast	–	n/a	n/a	n/a	5,177.0	238.1	88.0	238.1
Cervix	–	–	–	–	294.2	2.1	2.1	17.4
Uterus[3]	–	–	–	–	872.6	9.6	9.6	9.6
Ovaries	–	–	–	–	693.2	3.5	3.5	14.6
Prostate[3]	3,982.4	238.9	238.9	238.9	–	–	–	–
Bladder	1,449.0	102.9	102.9	205.8	501.4	9.5	3.5	9.5
Kidney	724.0	0.3	0.3	34.0	465.2	0.2	0.2	3.7
Brain	311.0	17.3	1.6	33.0	239.8	1.7	0.2	3.1
Thyroid[3]	166.6	0.2	0.2	0.2	538.2	0.1	0.1	0.1
Hodgkin's disease[3]	111.6	4.4	4.4	4.4	84.4	0.0	0.0	0.0
Non-Hodgkin's lymphomas	796.8	62.2	16.7	107.6	695.4	14.6	7.6	21.6
Multiple myeloma[3]	298.8	1.2	1.2	1.2	247.2	0.2	0.2	0.2
Leukemia	539.6	52.3	4.9	99.8	424.2	6.4	2.1	10.6
ANNUAL TOTAL	18,412.0	1,680.9	1,526.2	2,425.8	17,612.4	477.7	284.2	585.2
ALL CANCERS	**100.0%**	**9.1%**	**8.3%**	**13.2%**	**100.0%**	**2.7%**	**1.6%**	**3.3%**

–: not applicable; n/a: not available.

1 Arithmetic mean of annual number of new cases of cancer between 2002 and 2006, by sex (Fichier des tumeurs du Québec: Quebec tumour registry).

2 Plausible, low and high estimates of annual number of new work-related cases. See Appendix 2.

3 Where identical, the plausible, low and high values come from the same study. See comments in Appendix 2.

presented in Appendix 2. According to these estimates, between 1,800 and 3,000 of the 36,000 new cases of cancer diagnosed each year between 2002 and 2006 in Quebec are attributable to work, i.e., 6.0% (between 5.0% and 8.4%) of all new cases of cancer (between 8.3% and 13.2% in men, and between 1.6% and 3.3% in women).

The types of cancer for which there were over 100 work-related cases annually are, among men, cancer of the trachea, bronchi and lungs (*n* = 811 to 1,114 cases), prostate (*n* = 239) and bladder (*n* = 103 to 206); non-melanoma skin cancer (*n* = 81 to 153); and mesothelioma (*n* = 94 to 102) and non-Hodgkin's lymphomas (*n* = 17 to 108). Among women, in addition to cancer of the trachea, bronchi and lungs (*n* = 144), the other type of cancer of which there are over 100 work-related cases annually is breast cancer (*n* = 88 to 238) (Table 4). Of these, the three with the highest fractions attributable to work are the same for men and women, but in different proportions. Pleural mesothelioma leads the way, with 90.0% to 97.0% of cases among men and 25.0% to 82.5% of cases among women being attributable to work, followed by cancer of the sinuses and nasal cavities (24.0% to 43.3% among men and 6.7% to 19.8% among women) and cancer of the trachea, bronchi and lungs (21.1% to 29.0% among men and 5.3% among women) (see Appendix 2).

3.2.3 Annual Number of Cancer Deaths

Table 5 indicates the mean annual number of cancer deaths between 2002 and 2006, as well as plausible, low and high estimates of the annual number of these cancer deaths that can be attributed to work. As noted in the outline of the study methodology (Section 2.2.3), the same attributable fractions were used for cancer deaths and for newly diagnosed cases. According to these estimates, between 1,070 and 1,700 of the 15,600 cancer deaths in Quebec each year are work related, i.e., 7.6% (between 6.9% and 10.9%) of all deaths due to cancer (between 11.0% and 17.3% among men, and between 2.1% and 3.6% among women).

The cancer sites and types that are apparently accountable for the greatest number of work-related deaths annually among men are cancer of the trachea, bronchi and lungs (*n* = 691 to 950), cancer of the pancreas (*n* = 0 to 59), mesothelioma (*n* = 67 to 72) and leukemia (*n* = 3 to 54). Among women, cancer of the trachea, bronchi and lungs (*n* = 113) and breast cancer (*n* = 22 to 60) appear to be responsible for the greatest number of work-related cancer deaths (see Table 5).

Table 5 – Plausible, low and high estimates of annual work-related cancer deaths, by cancer site or type and sex, Quebec, 2002–2006

	Men				*Women*			
Cancer site or type	**Deaths[1]**	**Estimated work-related deaths[2]**			**Deaths[1]**	**Estimated work-related deaths[2]**		
		Plausible	**Low**	**High**		**Plausible**	**Low**	**High**
Oral cavity[3]	72.6	0.9	0.9	0.9	41.0	0.1	0.1	0.1
Pharynx	90.2	1.8	1.8	9.7	29.0	0.1	0.1	0.7
Esophagus	226.4	7.5	7.5	14.5	66.8	0.1	0.1	0.7
Stomach	339.2	10.2	10.2	34.9	221.8	0.7	0.7	12.0
Colon[3]	816.6	45.7	45.7	45.7	814.8	0.0	0.0	0.0
Rectum[3]	247.0	7.7	7.7	7.7	155.8	0.2	0.2	0.2
Liver	194.2	0.4	0.4	6.8	96.6	0.1	0.1	5.1
Pancreas	439.2	0.1	0.1	58.9	473.4	0.0	0.0	16.6
Sinuses, nasal cavities	7.8	3.4	1.9	3.4	6.6	1.3	0.4	1.3
Larynx	122.0	3.5	3.5	11.3	31.4	0.2	0.2	0.5
Trachea, bronchi, lungs	3,275.0	691.0	691.0	949.8	2,125.4	112.6	112.6	112.6
Mesothelioma	74.6	69.8	67.1	72.4	22.2	11.9	5.6	18.3
Bone	20.2	0.1	0.0	0.1	15.8	0.0	0.0	0.1
Skin melanoma[3]	86.6	3.7	3.7	3.7	50.2	0.2	0.2	0.2
Skin, non-melanoma	39.6	4.0	2.7	5.2	26.4	0.6	0.3	1.0
Breast	–	n/a	n/a	n/a	1,293.4	59.5	22.0	59.5
Cervix	–	–	–	–	67.4	0.5	0.5	4.0
Uterus[3]	–	–	–	–	182.8	2.0	2.0	2.0
Ovaries	–	–	–	–	353.4	1.8	1.8	7.4
Prostate[3]	750.4	45.0	45.0	45.0	–	–	–	–
Bladder	267.6	19.0	19.0	38.0	127.4	2.4	0.9	2.4
Kidney	247.4	0.1	0.1	11.6	153.8	0.1	0.1	1.2
Brain	239.2	13.3	1.2	25.4	186.0	1.3	0.2	2.4
Thyroid[3]	12.8	0.0	0.0	0.0	24.0	0.0	0.0	0.0
Hodgkin's disease[3]	16.6	0.6	0.6	0.6	14.4	0.0	0.0	0.0
Non-Hodgkin's lymphomas	325.4	25.4	6.8	43.9	300.0	6.3	3.3	9.3
Multiple myeloma[3]	159.0	0.6	0.6	0.6	142.8	0.1	0.1	0.1
Leukemia	289.4	28.1	2.6	53.5	225.4	3.4	1.1	5.6
ANNUAL TOTAL	8,359.0	981.8	920.3	1,443.7	7,248.0	205.7	152.6	263.5
ALL CANCERS	**100.0%**	**11.7%**	**11.0%**	**17.3%**	**100.0%**	**2.8%**	**2.1%**	**3.6%**

–: not applicable; n/a: not available.

1 Arithmetic mean of annual number of cancer deaths between 2002 and 2006, by sex (Fichier des décès du Québec: Quebec death registry).

2 Plausible, low and high estimates of annual number of work-related cancer deaths. See Appendix 2.

3 Where identical, the plausible, low and high values come from the same study. See comments in Appendix 2.

4. DISCUSSION

4.1 Limitations and Uncertainties

Owing to the lack of relevant accurate data, we used several data sources to obtain a range of plausible values for estimating the burden of occupational cancer.

The limitations of **compensation claim data** are well known: the data vary with the regulatory list of compensable diseases and the extent of the coverage provided by the insurance plan in effect in each country, the difficulty of estimating past occupational exposure (on account of cancer's long latency period, the varying number of jobs held over a person's working life, and changes to industrial processes in some sectors), the magnitude of the personal risk factors for certain types of cancer (e.g., smoking for lung cancer), physicians' knowledge of occupational risk factors for cancer, as well as the fact that some workers decide not to file claims [Teschke & Barroetavena, 1992; Aubrun et al., 1999]. All these characteristics mean that the statistics derived from these data sources represent a lower limit for the number of cases of occupational cancer.

A decision was made to use **attributable fractions developed in other countries** rather than develop attributable fractions specific to Quebec. As noted earlier, developing attributable fractions requires estimates of the relative cancer risks associated with exposure to each carcinogen studied and the proportion of people exposed to each carcinogen in the workplace. These two types of data are hard to obtain quickly, or are simply unavailable: very few studies linking cancer and occupational exposure have been conducted in Quebec, and the estimates of the proportion of workers exposed are not very accurate. To obtain figures quickly that we could use to prioritize research and treatment needs, we therefore chose a cruder estimating method, which was to use attributable fractions published for other countries, as other research teams have done, such as in Australia [Fritschi & Driscoll, 2006], the United States [Leigh et al., 2003] and Alberta [Orenstein et al., 2010]. The key condition for "importing" these attributable fractions is the comparability of the country to which they are being applied with the countries that originally developed them. This comparability should be in terms of occupational exposure to carcinogens and prevalence of other major risk factors for the types of cancer studied. Occupational exposures vary from one country to another, depending in particular on economic activity profiles and the technology used in various industries, but also on the legislation governing the use of carcinogens and oversight of that legislation; the practical indicator used in this case was the economic activity profile. Major cancer risk factors include lifestyle factors, such as smoking and drinking, environmental exposure and genetic polymorphism affecting metabolism or susceptibility to certain carcinogens [Hutchings & Rushton, 2012; Clapper, 2000]. In contrast with the above authors, who imported attributable fractions and assumed that their countries were comparable, we sought to confirm the similarity between Quebec and the other countries with respect to economic activity and two rough indicators of lifestyles associated with several types of cancer, i.e., smoking and alcohol consumption. A comparison using data from international organizations, though not perfect, suggests that using the fractions developed for Finland and Great Britain seems to be acceptable for Quebec for the purposes of prioritizing research and prevention initiatives. We did not find any data that would allow us to assess the similarity in genetic polymorphisms between countries for a set of types of cancer. This is an emerging area of research in occupational health, and while it is clear that some polymorphisms influence rates of genetic damage, the impact of such genetic damage on cancer risks is influenced by other mechanisms whose outcomes are difficult to predict [Ziech et al., 2011]. For instance, one study has reported finding an interaction between occupational exposure to polycyclic aromatic hydrocarbons and polymorphisms of cytochrome P450 on the risk of developing breast cancer [Rihs et al., 2005], whereas another study did not report any effect of deletion polymorphisms of glutathione transferases on the risk of renal cancer in workers exposed to high concentrations of trichloroethylene [Wiesenhütter et al., 2007].

The three main sources of uncertainty in the calculation of attributable fractions are the choice of carcinogens, types of cancer studied and number of cases, choice of risk estimates used and estimates of exposure to carcinogens by economic sector.

The carcinogens chosen by researchers in Finland and Great Britain are generally known or probable carcinogens according to the IARC classification and the cancer sites associated with them. A number of types of cancer and a number of potential carcinogens were not included in the analysis because not enough is known about the significance of workplace exposure in the etiology of these forms of cancer. This may lead to underestimating the real burden of occupational cancer [Straif, 2008; Clapp et al., 2008; Rushton et al., 2008]. In addition, passive smoking in the workplace, which was very prevalent in Quebec until recently, may have been responsible for some of the work-related cases of cancer now being diagnosed, but that exposure was not considered in this study, which may have contributed to further underestimating the number of current cases of lung cancer attributable to work (caused by second-hand smoke exposure 20 to 40 years ago).

The choice of risk estimates made by the Finnish and British researchers depended on the availability of valid studies conducted in Nordic, European, North American or other countries "industrialized to a degree comparable to theirs," without further details as to what this might mean [Nurminen & Karjalainen, 2001; Rushton et al., 2010, 2012a, 2012b]. These authors point out that the attributable fractions in question were, for the most part, based on cancer mortality studies; this was not a problem for the Finns, who restricted their estimates to mortality data [Nurminen & Karjalainen, 2001]. The British researchers noted this and specified that the same attributable fractions were used for mortality data and for cancer incidence data [Rushton et al., 2010, 2012a]. They therefore assumed that the attributable fractions were the same for deaths and incident cases. This could result in underestimating the numbers of incident cases when, for example, occupational exposure sharply increases the incidence of a specific histological type of rarely lethal tumour, whereas most of the deaths are the result of another histological type, for which the work-related attributable fraction is very low. An overestimation would also be possible if the real fraction of cancer cases attributable to work were very high for a histological type of very lethal cancer, but not for a histological type with very long survival. As very few studies produce specific risk estimates by histological type of cancer, it is hard to predict the overall effect of using attributable fractions based on estimates from mortality studies rather than incidence studies.

As for the last source of uncertainty, regarding estimating exposure to carcinogens, the Finnish and British researchers used job-exposure matrices developed with data from Finland and the

United States and later tailored to fit to several European countries. They were therefore limited to the carcinogens in the job-exposure matrices and also assumed that these matrices applied to occupational exposure in their respective countries. We cannot examine in detail here all the factors that influence occupational exposure to carcinogens in a given country.

4.2 Number of Cases of Occupational Cancer

As noted in the literature, the number of cancer cases for which compensation is paid out represents only a small fraction of all occupational cancer cases and the use of these statistics alone cannot provide an accurate picture of the occupational cancer burden. Fewer than 100 new cases of cancer between 2005 and 2007 (of which just two cases per year among women) and around 40 cancer deaths between 1997 and 2005 have been compensated annually in Quebec. If the plausible attributable fractions for cancer from Finland and Great Britain are applied to Quebec, then from 1,800 to 3,000 of the 36,000 new cases of cancer per year in Quebec between 2002 and 2006, and from 1,070 to 1,700 of the 15,600 cancer deaths per year are occupational in origin.

Our study estimated that 6.0% (between 5.0% and 8.4%) of all new cases of cancer could be work related. The percentages are higher among men, i.e., 9.1% (between 8.3% and 13.2%), than among women, 2.7% (between 1.6% and 3.3%). For cancer deaths, the proportions are slightly higher, i.e., 7.6% (between 6.9% and 10.9%) of all cancer deaths, again with a substantial difference in the rates between men and women: 11.7% (between 11.0% and 17.3%) among men, and 2.8% (between 2.1% and 3.6%) among women. These figures are of the same order of magnitude as percentages reported elsewhere in the industrialized world, ranging from 4.1% of cancer deaths [Doll & Peto, 1981] to 8.4% (13.8% among men and 2.2% among women) [Nurminen & Karjalainen, 2001], depending on the authors. The most recent study estimating the proportion of cancer cases attributable to work indicates 5.3% of cancer deaths (8.2% among men and 2.3% among women) [Rushton et al., 2012b].

4.2.1 Tracheal, Bronchial and Lung Cancer

Lung cancer is the second most common form of cancer in men (after prostate cancer) and women (after breast cancer), but it is the leading cause of cancer deaths for both sexes [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013]. It has been known for over a century that some cases of lung cancer are related to workplace exposure [Schüttmann, 1993] and since then, the IARC has classified over 30 agents or occupational exposure circumstances as known, probable or possible pulmonary carcinogens, with at least some evidence in humans [Cogliano et al., 2011]. Workplace agents deemed to be responsible for the greatest number of cases in Europe include asbestos, silica, diesel exhaust and metalworking agents [Nurminen & Karjalainen, 2001; Rushton et al., 2010]. These same authors have estimated that between 21% and 29% of cases of lung cancer in men, and 5% of those in women, are attributable to work.

Regardless of the method used to estimate the burden, cases of lung cancer still account for around half of all cases of occupational cancer [Straif, 2008]; this is true for our study, in which we have estimated that they represent 48% of all new cases of work-related cancer in men and

30% in women, while 70% of occupational cancer deaths in men and 54% in women are cases of lung cancer.

4.2.2 Breast and Prostate Cancer

Breast and prostate cancer are the most common forms of cancer in the general population, each accounting for over 4,000 new cases annually in Quebec [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013]. Breast cancer in women has been associated with exposure to ethylene oxide (used to sterilize medical instruments and some food products, such as spices) and with rotating shift work involving night shifts and associated with circadian rhythm disruptions [IARC, 2008, 2010]. Occupational exposure to cadmium, arsenic and their compounds, as well as work in the rubber industry, has been associated with prostate cancer, with limited evidence in humans [Cogliano et al., 2011].

Although these forms of cancer are very common and only a small percentage of cases are attributable to work—5% for breast cancer and 6% for prostate cancer—they still account for a significant proportion of new cases of cancer of occupational origin: respectively, 50% of all cases of cancer attributable to work among women and 14% among men.

4.2.3 Skin Cancer

Non-melanoma skin cancer (the most common forms of which are squamous cell carcinoma and basal cell carcinoma) generally respond fairly well to treatment. They are estimated to be the most common forms of cancer in the general population, but are known to be underestimated in the statistics, as most cancer registries do not systematically compile information about these cases [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013]. One recent study has estimated that 36% to 42% of cancer cases not reported to the Quebec tumour registry by hospital pathology laboratories were cases of skin cancer [Vézina & St-Onge, 2007]. The main occupational causes associated with this type of cancer, with sufficient evidence in humans, are exposure to the sun, arsenic and its inorganic compounds, coal tar pitch, untreated or mildly treated mineral oils, and soot [Cogliano et al., 2011].

4.2.4 Pleural Mesothelioma

Malignant mesothelioma is a rare form of cancer of the mesothelium, the membrane that surrounds a number of organs, including the lungs, the heart and the organs in the abdominal cavity. It is a very lethal form of cancer, with a mean survival rate in the United States of 39% after one year and 8% after five years [Young et al., 2007]. In Quebec between 2002 and 2006, an average of 105 new cases were diagnosed annually in men, and 28 in women.

The only known risk factor for this type of cancer, with sufficient evidence in humans, is exposure to asbestos, in all its forms [Cogliano et al., 2011]. While people can be exposed to this mineral outside of work, most estimates by various authors indicate that 52% to 98% of cases are attributable to occupational and para-occupational exposure [Boffetta et al., 2010; Lacourt et al., 2010; Rushton et al., 2010]. It is for this reason that most claims filed by workers who have mesothelioma are accepted [Goldberg et al., 2006; Payne & Pichora, 2008] and that, generally speaking, mesothelioma is the type of cancer for which the greatest number of patients receive compensation in Quebec and several other countries [Goldberg et al., 2006; Hyland et al., 2007; Payne & Pichora, 2008; Kirkham et al., 2010]. There are reportedly over 110 new work-related cases annually in Quebec and around 80 deaths.

4.2.5 Bladder Cancer

In Quebec, bladder cancer is the fourth most common form of cancer in men and the eighth most common in women [Canadian Cancer Society's Advisory Committee on Cancer Statistics, 2013]. Like lung cancer, bladder cancer has been associated with occupational exposure for over a century [Landrigan, 1996]; the first workplace exposure associated with it was dye manufacturing. A recent IARC review of carcinogenic substance classifications noted more than 10 agents or exposure circumstances for which evidence exists in humans, including arsenic and its inorganic compounds, benzidine, 2-naphthylamine, ortho-toluidine, painting, aluminum production and rubber production [Cogliano et al., 2011].

Smoking is a known personal risk factor for bladder cancer, which complicates the measurement of the work-related risk, estimated at 7% in men and around 2% in women by Rushton and colleagues [2010, 2012b].

4.2.6 Sinus and Nasal Cavity Cancer

Cancer of the sinuses and nasal cavities is rare (32 new cases in men and 23 in women in Quebec annually), but these forms of cancer account for the second highest proportion of work-related cases after mesothelioma: between 24% and 43% in men, and between 7% and 20% in women [Nurminen & Karjalainen, 2001; Rushton et al., 2012b]. The forms of occupational exposure associated with these cancers, with evidence in humans, are wood and leather dust, formaldehyde, nickel compounds and chromium (VI) compounds [Cogliano et al., 2011].

4.3 Carcinogenesis and Exposure to Carcinogens

Two main types of mechanisms appear to be involved and probably together play a role in carcinogenesis: genetic mechanisms, based on a direct toxic effect on a cell's genetic material, and epigenetic (non-genetic) mechanisms, based on a toxic effect on the mechanisms of cell division [Lauwerys et al., 2007]. The main stages in the development of cancer are initiation (first genetic alteration of the cell), promotion (multiplication of the affected cell into a benign tumour) and progression or propagation (out-of-control cell proliferation or a malignant tumour), which corresponds to the clinical phase of the disease, during which cancer is diagnosed [Gérin & Band, 2003].

Several years may go by between these different stages, and more than one carcinogen may be involved. This is why latency—the period from the initial exposure to a carcinogen to the actual cancer diagnosis—is a key concept; the exposures responsible for most cases of cancer probably occurred 20 to 40 or even 50 years before the first clear signs of the disease. In the case of hematopoietic cancers (leukemia, lymphoma, etc.), the latency period seems to be shorter, from 5 to 10 years [Armenian, 1987; Richardson, 2008]. However, the relevant exposure period may range from 10 to 50 years for most types of cancer, and from 1 to 20 years for hematopoietic cancers [Hutchings & Rushton, 2012].

As for the intensity of the exposure dose required to cause cancer, there are two opposing theories: the first posits that there is a threshold (corresponding to the capacity of the body's mechanisms to rid itself of toxic substances), below which cancer cannot develop, whereas the second claims that no threshold can be determined, as in spite of the body's detoxification mechanisms, carcinogenic molecules can evade them and bind to DNA [Lauwerys et al., 2007]. This explains the fact that, when it comes to prevention, any exposure to a carcinogen, and not necessarily the intensity of that exposure, is the most useful indicator for surveillance purposes.

A recent study of the levels measured in British companies revealed that the mean levels for 12 of the 19 carcinogens for which the most measurements were available exceeded the standards [Cherrie et al., 2007]. In Quebec, between 2006 and 2008, Montreal's Direction de santé publique (public health department) filed 129 reports to the CSST about situations that exceeded the standards for exposure to chemicals. Close to half of these reports (60 situations) concerned carcinogens and, in a few cases, including for beryllium, silica and cadmium, exposure levels were five times higher than the standard. The problems in these workplaces have since been corrected, but this underscores the need to remain vigilant [Sassine et al. 2010]. One recent IRSST study estimated that over 150,000 Quebec workers were exposed to diesel exhaust, over 100,000 to wood dust and over 50,000 to polycyclic aromatic hydrocarbons, benzene or silica. The study was unable, however, to estimate the overall percentage of Quebecers currently exposed to at least one carcinogen in their workplace [Labrèche et al., 2012]. European studies have estimated that 10.1% to 23% of workers were exposed to at least one carcinogen [Arnaudo et al., 2013; Kauppinen et al., 2000]. If these European proportions are applied to Quebec data,[6] it is plausible that from 356,300 to 871,000 Quebec workers may be exposed to at least one carcinogen in the workplace. To obtain more accurate estimates for Quebec, an extensive survey of a representative sample of workers, ideally with exposure measurements for a large number of carcinogens, would have to be conducted.

4.4 Occupational Cancer Burden

Using their results on the number of new cases of cancer and cancer deaths associated with work, by sector of economic activity and carcinogen exposure, the Great Britain researchers developed scenarios for estimating the impact of preventive measures, in terms of number of cancer cases avoided, in order to help authorities decide on priorities for action [Hutchings & Rushton, 2011]. This approach offers the advantage of identifying initiatives that will have the greatest effect at least cost; the authors show, for instance, that it can be more effective in small companies to ensure compliance with existing exposure standards than to try to bring in stricter standards [Hutchings & Rushton, 2011]. A study of this kind goes beyond the framework of this research project, but could prove useful over the medium term in the Quebec context.

[6] Estimate of 3,527,838 paid workers after adjusting for monthly variations in economic activity, custom table, Canada Census 2006.

The figures presented above highlight the underestimated extent of the burden of occupational cancer in Quebec. We did not attempt to quantify the direct and indirect costs associated with these cases of cancer. However, Alberta Health Services recently carried out a similar exercise, based on the number of cases of cancer diagnosed in 2006 and the costs for 2008 [Orenstein et al., 2010]. The researchers estimated that every year, on average, 761 new cases of cancer related to occupational exposure are diagnosed, and 2,700 people are living with cancer that has a work-related origin, which would translate into estimated direct costs of $15,682,000 per year; indirect costs (loss of economic resources and reduced productivity) were estimated at another $64,100,000 per year [Orenstein et al., 2010]. Analogous costs for Quebec, between 2002 and 2006, could be two to four times higher, as our study estimated the annual number of new cases of cancer related to occupational exposure in Quebec to be between 1,800 and 3,000.

5. CONCLUSION AND RECOMMENDATIONS

In order to plan and set priorities for preventive action, it is essential to know the extent of the problem to be addressed. This report presents an initial effort at quantifying the magnitude of the phenomenon of occupational cancer in Quebec. The purpose of the study was to estimate the number of cases of cancer that could be attributable to work, with respect to some 20 cancer sites or types among the most common and most frequently associated with the workplace. Given the annual increase in the number of cases of cancer, the figures presented here, drawn from cancer data from 2002 to 2006, would be higher in 2013. Identifying these cancer sites and types helps occupational health and safety decision makers to organize preventive initiatives that target the carcinogens responsible for the most common forms of cancer.

Despite their limitations, the data obtained not only confirm that occupational cancer is a significant burden in terms of number of cases and deaths, but also underscore how this burden is substantially underestimated if only compensation statistics are considered. In light of these initial estimates, the following steps are recommended:

- Disseminate these results to the various partner organizations working in occupational health and safety (Commission de la santé et de la sécurité du travail, public health branches and agencies, joint sector-based associations, employer-employee associations, etc.).
- Document the carcinogens responsible for occupational cancer where incidence and mortality are high in terms of number of cases (cancer of the trachea, bronchi and lungs, prostate cancer, breast cancer, non-melanoma skin cancer, bladder cancer, mesothelioma, colon cancer, non-Hodgkin’s lymphomas and leukemia).
- Complement this work by conducting a study more specific to Quebec (with calculation of attributable fractions using Quebec exposure data and risk estimates associated with carcinogens found in Quebec industries), including estimates of the economic burden of occupational cancer.

Beyond the results set out here, prudent occupational health and safety management suggests the following general recommendations:

- Promote stricter compliance with rules governing labelling of carcinogens and related exposure standards, where they exist, in the workplace, by aiming to reduce exposure to the lowest possible level, as stipulated in Quebec regulations.
- Develop systems to identify and classify carcinogens as they are introduced into the workplace, as well as ways to disseminate information to those who have a duty to be well-informed in the workplace.

For the benefit of workers, it may also be a good idea to develop an individual file detailing each worker’s carcinogen exposure circumstances that would be filled in throughout his or her working life. Keeping this kind of record has been a regulatory requirement in France for a few years now.[7]

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[7] See Article R4412-40 of the French Labour Code (*Code du Travail*): http://www.legifrance.gouv.fr/affichCodeArticle.do;jsessionid=FBEAC500F22CC5194AEF78BFEE4FD32E.tpdjo06v_2?idArticle=LEGIARTI000018530855&cidTexte=LEGITEXT000006072050&dateTexte=20080520

Unlike lifestyle-related cancers, past risk factors for occupational cancer are not the responsibility of the individuals involved. Occupational cancer represents a substantial proportion of cancer cases, but it is avoidable, which is why special importance should be given to preventive action. Besides demonstrating a concern for worker health, investing in occupational cancer prevention helps to reduce compensation that must be paid out, as well as the human costs of work-related morbidity and mortality. In addition, reducing carcinogen exposure in the workplace can also have an impact on the quality of the environment and the health of people living nearby. Over the medium and long term, it should prove to be a worthwhile investment for workers, companies and society at large.

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APPENDIX 1 – DATA SOURCES AND BRIEF DESCRIPTION

Data source	Brief description	Variables
Cancer		
CSST's central and regional data repository (DDCR)	Data on employment injuries for which the CSST paid out compensation	Age, sex, year of event; site, etiologic agent and nature of injury ES: CAEQ, CSST priority sectors, NAICS Occupation: CCDO
Database of deaths for which compensation paid: CSST special compilation	Data on deaths for which the CSST paid out compensation	Age, sex, year death compensation claim accepted; site, etiologic agent and nature of injury ES: CAEQ, CSST priority sectors Occupation: CCDO
Quebec registry of deaths (1981–2007, updated 2010, available at INSPQ)	Data on primary and secondary causes of deaths, as recorded	Age, sex, year of death, primary and secondary causes of death (CIM-10 codes)
Quebec registry of tumours (1984–2006, updated 2009, available at INSPQ)	Diagnostic data on tumours reported when patients hospitalized	Age, sex, year of diagnosis, diagnosis (CIM-9 codes and tumour morphology)
Economic activity profiles		
Surveys of employment, payrolls and hours (SEPH) and census of population, Statistics Canada, custom table	Canadian labour force data	Labour force in numbers and percentages Industry, sex ES: SIC or NAICS (depending on year)
Economic statistical data for Canada, Finland and the United Kingdom	Data on the economically active population of each country, according to a definition adopted by the Thirteenth International Conference of Labour Statisticians (Geneva, 1982)	Economically active population, in numbers Industry, sex ES: ISIC (International Standard Industrial Classification, revisions 2 and 3)

CAEQ: Classification des activités économiques du Québec [Quebec classification of economic activities]; CCDO: Canadian Classification and Dictionary of Occupations; CSST: Commission de la santé et de la sécurité du travail du Québec [Quebec occupational health and safety board]; ES: Economic sector; ICD: International Classification of Diseases; INSPQ: Institut national de santé publique du Québec [Quebec national institute of public health]; ISIC: International Standard Industrial Classification; NAICS: North American Industrial Classification System; SIC: Standard Industrial Classification (Statistics Canada); SOC: Standard Occupational Classification (Statistics Canada)

APPENDIX 2 – WORK-RELATED FRACTIONS OF CANCER CASES USED FOR CALCULATIONS

Cancer site or type	Published attributable fractions (%)				Estimated attributable fractions (%)						Comments
	Nurminen & Karjalainen, 2001		Rushton et al., 2012b		Plausible[1]		Low		High		
	M	W	M	W	M	W	M	W	M	W	
Oral cavity	1.2	0.3	n/a	n/a	1.2	0.3	1.2	0.3	1.2	0.3	Data from a single study
Pharynx[2]	2.0	0.5	10.8	2.4	2	0.5	2	0.5	10.8	2.4	Lowest fractions used as plausible values
Esophagus[2]	6.4	0.2	3.3	1.1	3.3	0.2	3.3	0.2	6.4	1.1	Lowest fractions used as plausible values
Stomach[3]	10.3	5.4	3.0	0.3	3.0	0.3	3	0.3	10.3	5.4	Rushton's fractions used as plausible values
Colon	5.6	0.0	n/a	n/a	5.6	0.0	5.6	0.0	5.6	0.0	Data from a single study
Rectum	3.1	0.1	n/a	n/a	3.1	0.1	3.1	0.1	3.1	0.1	Data from a single study
Liver[2]	3.5	5.3	0.2	0.1	0.2	0.1	0.2	0.1	3.5	5.3	Lowest fractions used as plausible values
Pancreas[3]	13.4	3.5	0.02	0.01	0.02	0.01	0.02	0.01	13.4	3.5	Rushton's fractions used as plausible values
Sinuses and nasal cavities[3]	24.0	6.7	43.3	19.8	43.3	19.8	24.0	6.7	43.3	19.8	Rushton's fractions used as plausible values
Larynx[2]	9.3	0.5	2.9	1.6	2.9	0.5	2.9	0.5	9.3	1.6	Lowest fractions used as plausible values
Trachea, bronchi, lungs[3]	29.0	5.3	21.1	5.3	21.1	5.3	21.1	5.3	29.0	5.3	Rushton's fractions used as plausible values
Mesothelioma	90.0	25.0	97.0	82.5	93.5	53.8	90.0	25.0	97.0	82.5	
Bone	0.6	0.6	0.04	0.01	0.3	0.3	0.04	0.01	0.6	0.6	
Melanoma	4.3	0.4	n/a	n/a	4.3	0.4	4.3	0.4	4.3	0.4	Data from a single study
Skin, non-melanoma	13.1	3.8	6.9	1.1	10.0	2.5	6.9	1.1	13.1	3.8	
Breast[4]	n/a	1.7	n/a	4.6	n/a	4.6	n/a	1.7	n/a	4.6	Rushton's fractions used as plausible values

Cancer site or type	Published attributable fractions (%)				Estimated attributable fractions (%)						Comments
	Nurminen & Karjalainen, 2001		Rushton et al., 2012b		Plausible[1]		Low		High		
	M	W	M	W	M	W	M	W	M	W	
Cervix[3]	–	5.9	–	0.7	–	0.7	–	0.7	–	5.9	Rushton's fractions used as plausible values
Uterus	–	1.1	–	n/a	–	1.1	–	1.1	–	1.1	Data from a single study
Ovaries[3]	–	2.1	–	0.5	–	0.5	–	0.5	–	2.1	Rushton's fractions used as plausible values
Prostate	6.0	–	n/a	–	6.0	–	6.0	–	6.0	–	Data from a single study
Bladder[3]	14.2	0.7	7.1	1.9	7.1	1.9	7.1	0.7	14.2	1.9	Rushton's fractions used as plausible values
Kidney[3]	4.7	0.8	0.04	0.04	0.04	0.04	0.04	0.04	4.7	0.8	Rushton's fractions used as plausible values
Brain	10.6	1.3	0.5	0.1	5.6	0.7	0.5	0.1	10.6	1.3	
Thyroid	n/a	n/a	0.1	0.02	0.1	0.02	0.1	0.02	0.1	0.02	Data from a single study
Hodgkin's disease	3.9	0.0	n/a	n/a	3.9	0.0	3.9	0.0	3.9	0.0	Data from a single study
Non-Hodgkin's lymphomas	13.5	3.1	2.1	1.1	7.8	2.1	2.1	1.1	13.5	3.1	
Multiple myeloma	n/a	n/a	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1	Data from a single study
Leukemia	18.5	2.5	0.9	0.5	9.7	1.5	0.9	0.5	18.5	2.5	

n/a: not available.

[1] Arithmetic means selected as plausible values: the two studies consider different carcinogens.

[2] Alcohol consumption higher in Quebec than in Finland and United Kingdom between 1970 and 1990, leading to an overestimate of the work-related fraction for these cancer sites associated with drinking: lowest work-related fractions used as plausible values. Exposures between 1970 and 1990 are included in the relevant exposure period for cancer cases diagnosed between 2002 and 2006 in Quebec.

[3] Low rate of smoking in Finland between 1970 and 1990, compared with Quebec, leading to an overestimate of the work-related fraction for these cancer sites associated with smoking: United Kingdom work-related fractions used as plausible values. Exposures between 1970 and 1990 are included in the relevant exposure period for cancer cases diagnosed between 2002 and 2006 in Quebec.

[4] Work-related fractions from the United Kingdom used as plausible values, as they take into account night work, which was associated with breast cancer in the late 2000s.

APPENDIX 3 – DETAILED COMPARABILITY OF QUEBEC, CANADA, FINLAND AND UNITED KINGDOM

In examining the comparability of different countries, we considered two aspects: the similarity of their economic activity profiles, and prevalence indicators for two major potential confounding factors for several types of cancer: smoking and drinking.

1. ECONOMIC ACTIVITY PROFILES

We used work-related cancer percentages that appeared in publications from two countries: Finland and Great Britain. As the percentages vary with the economic activity profile, among other things, we had to determine whether significant economic differences between the countries might invalidate a comparison.

Since there are no statistical data directly comparable between Quebec and these two countries, but the data do exist for Canada, we first had to review the comparability of Quebec and Canada, and then compare the economic activity profiles of Canada, Finland and the United Kingdom (as we were unable to obtain data solely for Great Britain, which accounts for 97.4% of the workers in the United Kingdom).

Quebec-Canada Comparability

Figures 3 and 4 give the proportions of Quebec and Canadian workers in different economic sectors between 1991 and 2006. They show that Quebec's economic activity profile was very similar to Canada's over that period, with a few slight differences. In Quebec the number of workers in *manufacturing* was, on average, 3 to 4 percentage points higher than in Canada as a whole between 1991 and 2006. In the other sectors, the difference was around 1 percentage point or lower.

The labour force figures from the 1961, 1971 and 1981 censuses also indicate differences generally of 1 percentage point or less in the workforce proportions by sector of activity between Quebec and Canada. Two small differences can be seen for these years: as in later years, the proportion of Quebec's workforce in *manufacturing* was around 3 to 4 percentage points higher than Canada's as a whole in 1961, 1971 and 1981, while the proportion of its workers in *agriculture* was approximately 2 percentage points lower [Dominion Bureau of Statistics, 1963a, 1963b; Statistics Canada, 1975a, 1975b, 1984].

To conclude, using Canadian data appears to be an acceptable equivalent for the purposes of determining the comparability of Quebec's economic activity profile with those of Finland and the United Kingdom.

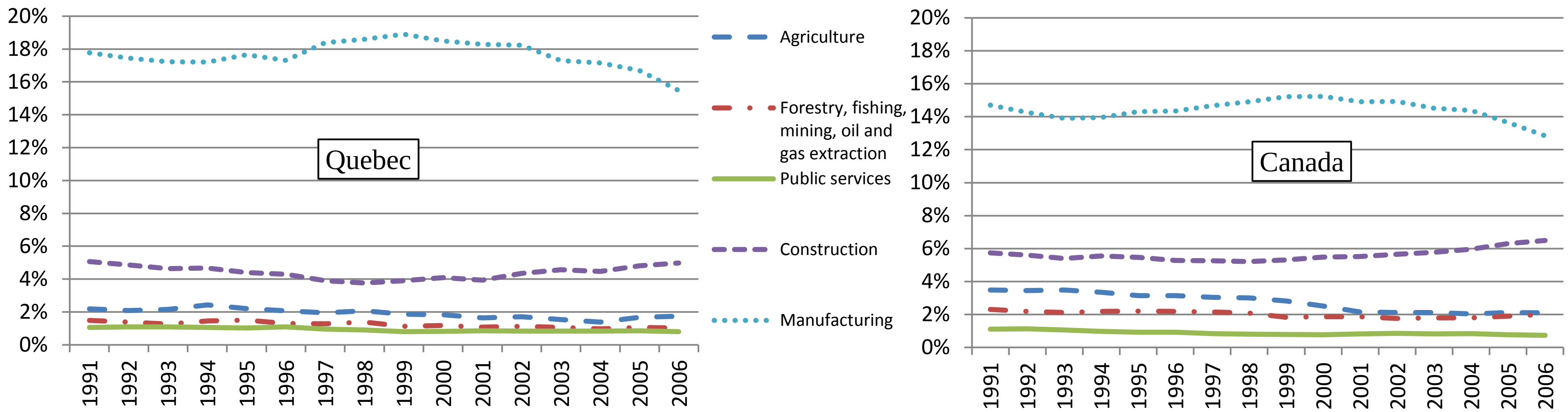

Figure 3 – Proportional distribution of workers in Quebec and Canada by major goods-producing sector, 1991–2006

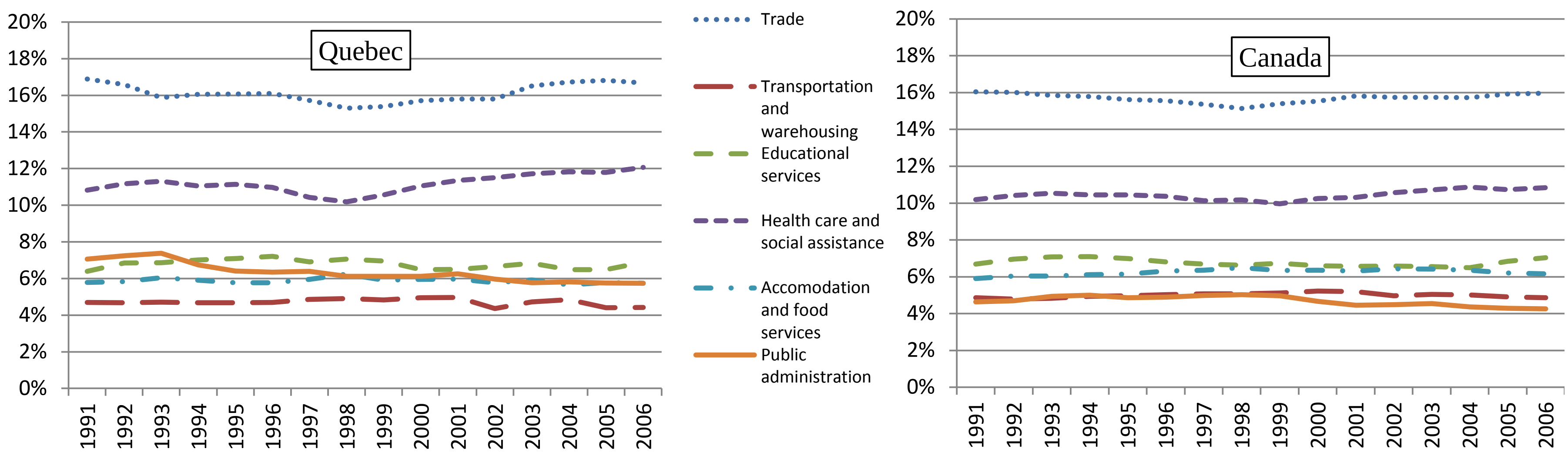

Figure 4 – Proportional distribution of workers in Quebec and Canada by major service sector, 1991–2006

Canada-Finland-United Kingdom Comparability

Figures 5 to 10 show the proportional breakdown of workers by sex in the main economic sectors accounting for the bulk of workers in Canada, Finland and the United Kingdom between 1970 and 2000. Given the long latency period between carcinogen exposure and the occurrence of most cancers, activity profiles from 1970 are the ones most relevant to our study, as that leaves an average of 35 years for the development of cancer cases seen between 2002 and 2006. For cancers of the hematopoietic system, however, which have a shorter latency, the relevant exposure period may be as recent as 2000.

It can be seen that the major sectors of *agriculture, forestry, fishing and hunting* employed a larger proportion of the labour force in Finland than in the other two countries, especially in the 1970s, and that this difference diminished thereafter (Figure 5). The proportion of workers in *manufacturing*, a sector with many carcinogens, was higher in the United Kingdom in the 1970s, and then the differences gradually became less significant; beginning in 1980, the proportion of workers in *manufacturing* in Canada dropped below the levels in the other two countries (Figure 6). The *construction and public works* sectors, as well as *transportation, warehousing and communications*, employed similar proportions of workers between 1970 and 2000, with the three countries being very comparable (figures 7 and 8). In the *wholesale trade, retail trade, food services and accommodation* sectors, Canada generally employed a greater proportion of its labour force (between 2% and 10%) than the other two countries (Figure 9). Lastly, in the *community, social and personal services* sectors, which have a predominantly female workforce, the differences in the proportion of workers varied from 5% to 10% between countries after 1980; in 1970, Canada had a higher proportion of workers in this group of sectors (Figure 10).

To summarize, Canada's employment profile was closer to that of the United Kingdom, for men, in the *transportation and warehousing*, *wholesale trade and services* sectors, whereas it was closer to that of Finland in the *agriculture, forestry, fishing and hunting* sectors and in *manufacturing*. For women, Canada's employment profile was closer to that of the United Kingdom in the *agriculture, forestry, fishing* and *hunting* sectors and in *services*, whereas it was closer to that of Finland in the *wholesale trade* and *manufacturing*.

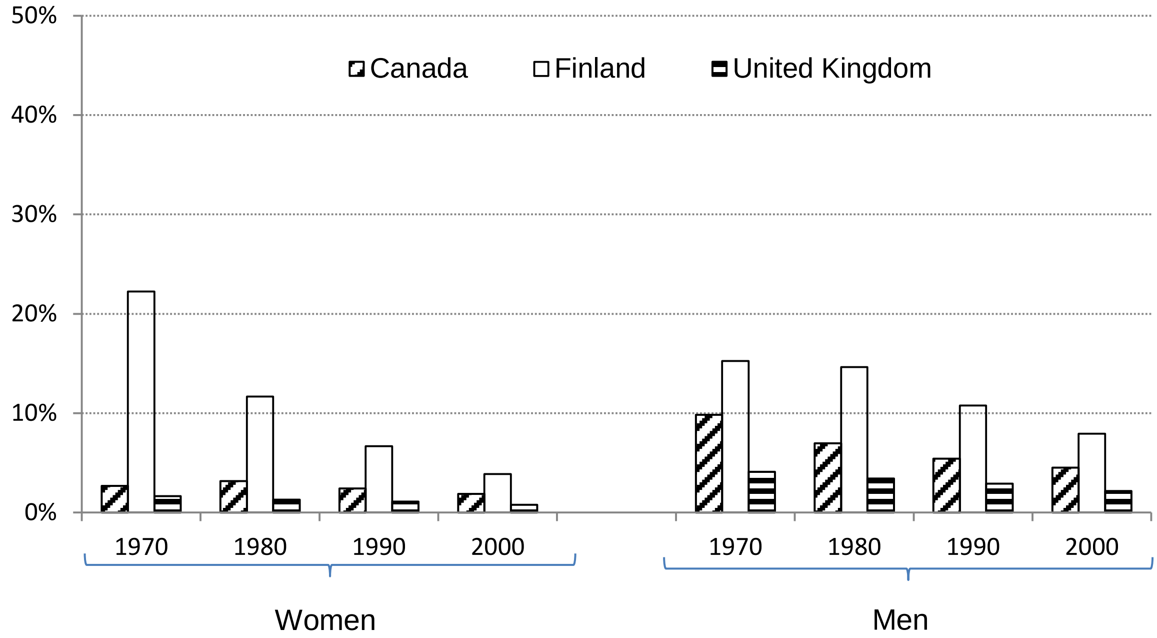

Figure 5 – Proportional distribution of workers by sex in agriculture, forestry, fishing and hunting, in Canada, Finland and the United Kingdom, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

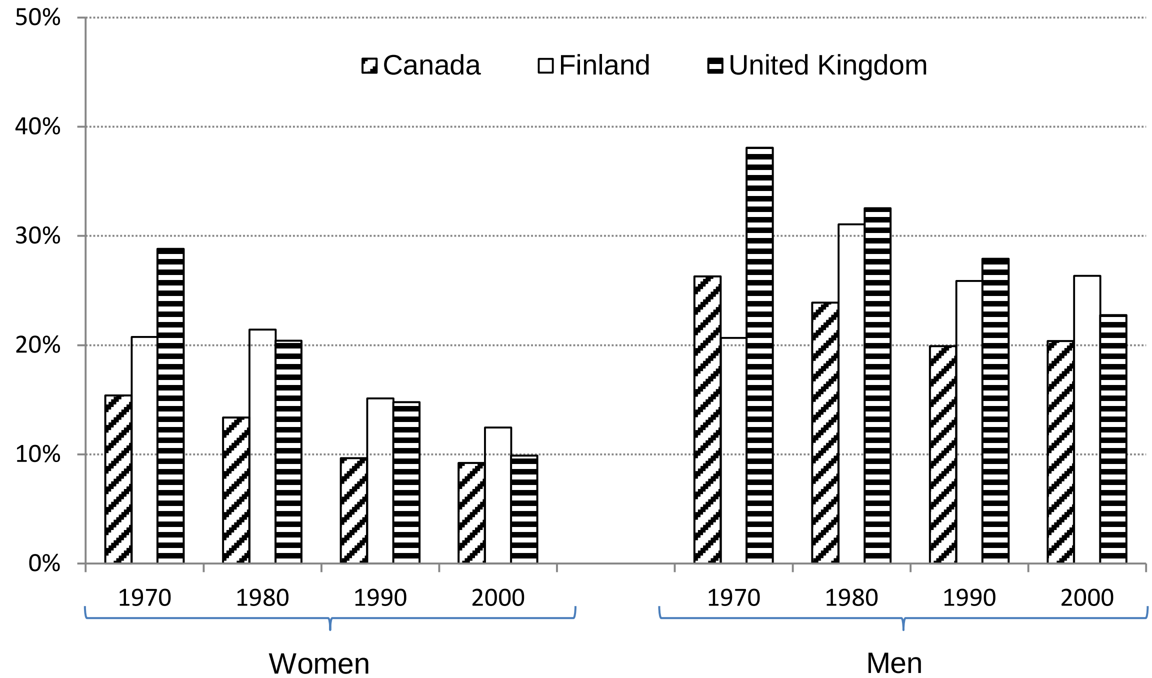

Figure 6 – Proportional distribution of workers in manufacturing, in Canada, Finland and the United Kingdom, by sex, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

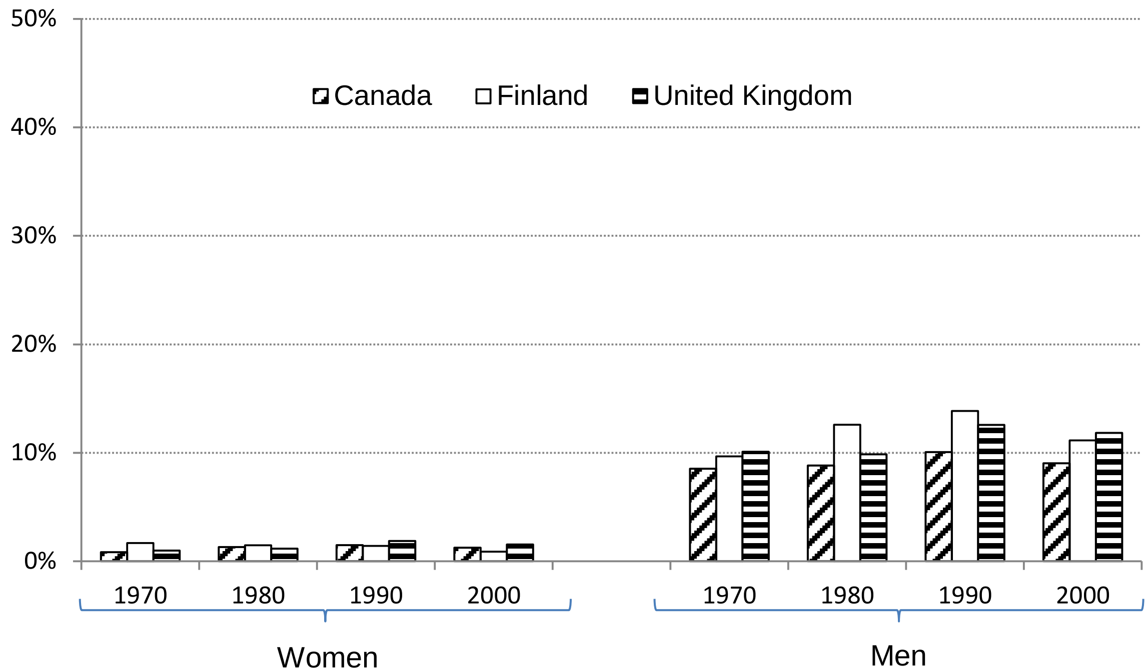

Figure 7 – Proportional distribution of workers in construction and public works, in Canada, Finland and the United Kingdom, by sex, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

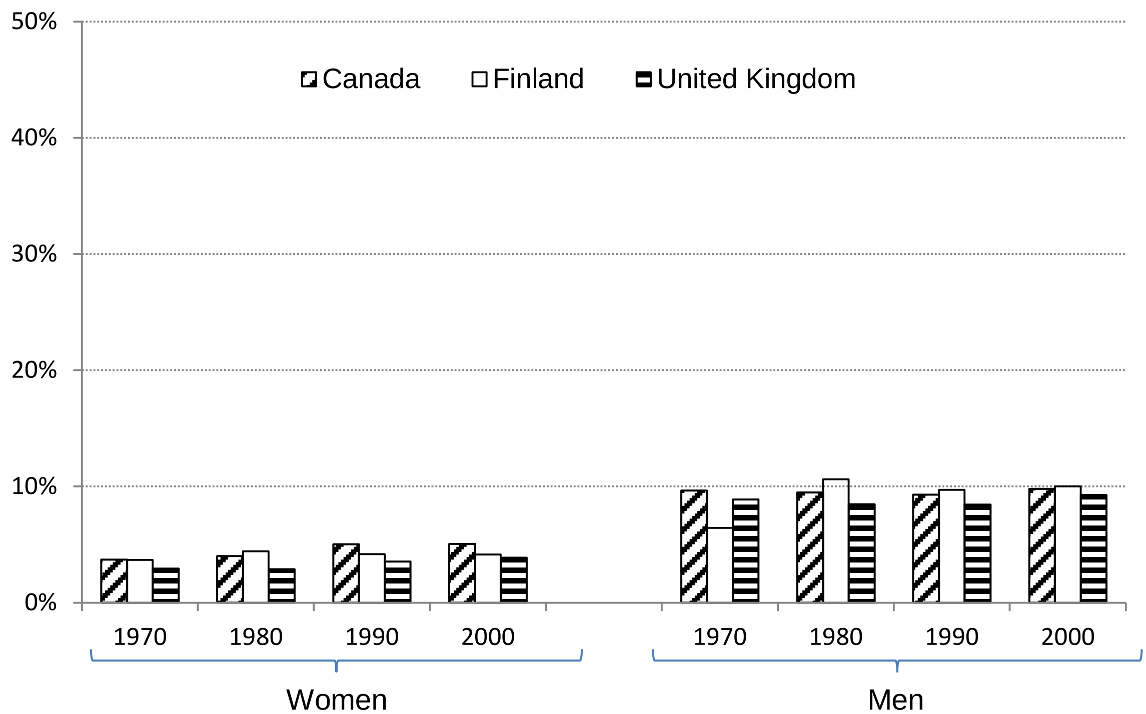

Figure 8 – Proportional distribution of workers in transportation, warehousing and communications, in Canada, Finland and the United Kingdom, by sex, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

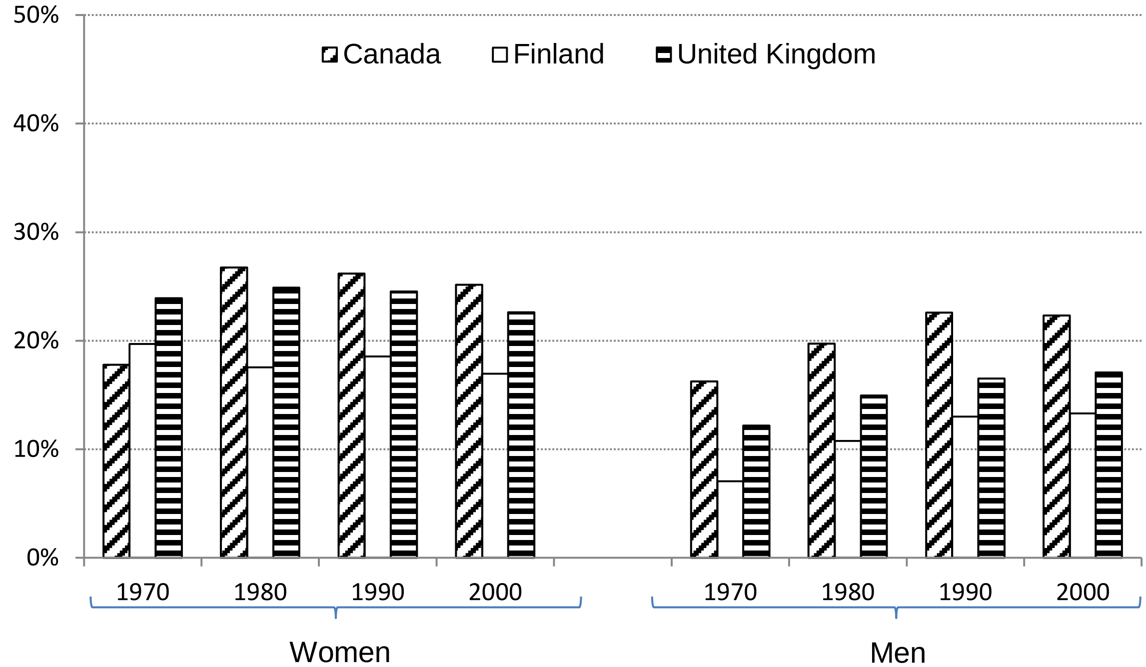

Figure 9 – Proportional distribution of workers in wholesale trade, retail trade, and accommodation and food services, in Canada, Finland and the United Kingdom, by sex, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

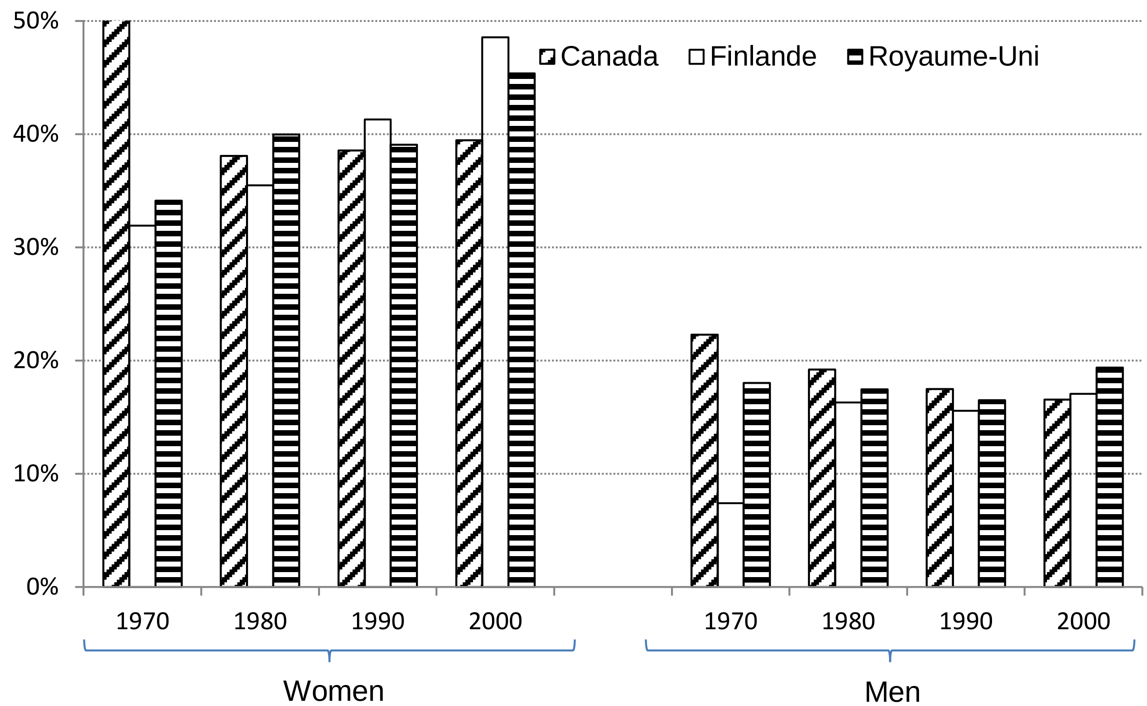

Figure 10 – Proportional distribution of workers in community, social and personal services, in Canada, Finland and the United Kingdom, by sex, 1970–2000 (1970 and 1980: International Standard Industrial Classification [ISIC], Rev. 2; 1990 and 2000: ISIC, Rev. 3)

2. DISTRIBUTION OF POTENTIAL CONFOUNDING FACTORS

We were able to obtain some information on two lifestyle choices that can act as competitive risk factors or potential confounding factors: smoking and alcohol consumption. Table 6 indicates per capita cigarette consumption between 1970 and 2000 and the prevalence of smokers aged 15–16 and over between 1974 and 2009 in Canada, Finland and the United Kingdom. It can be seen that smoker prevalence has been fairly similar in Canada and the United Kingdom since the 1970s, but that more recently a larger proportion of Finns seem to be smoking. Since 1970, however, per capita consumption has always been higher in Canada and the U.K. than in Finland.

Table 7 gives the per capita consumption of pure alcohol for the three countries between 1970 and 2000, as well as the rates of death from cirrhosis of the liver, an indicator of alcohol-related diseases. It can be seen that alcohol consumption per capita was higher in Canada than in the other two countries in 1970 and 1980, but that subsequently the reverse became true. The death rates from cirrhosis of the liver in 2000 are consistent with lower per capita alcohol consumption among Canadians in more recent decades.

3. CONCLUSIONS REGARDING CANADA-FINLAND-UNITED KINGDOM COMPARABILITY

The above analyses enable us to conclude that one of the main assumptions underlying the use of attributable fractions from other countries is probably valid: the economic activity profiles of Finland, the United Kingdom and Canada (and, by extension, Quebec) are sufficiently similar, and have been so since 1970, which allows for a maximum latency period of 36 years for cases of cancer occurring between 2002 and 2006.

As regards the prevalence of smoking and alcohol consumption, the differences noted suggest the following limitations. Since per capita cigarette consumption is higher in Canada (and Quebecers smoke more than the Canadian average[8]), and has been since at least the 1970s, the proportion of cancer cases attributable to work could be a slight overestimate for cancers associated with smoking using the attributable fractions calculated for Finland; it is therefore better to use the attributable fractions for Great Britain, which are closer to the Canadian situation, for types of cancer associated with smoking, but not with alcohol, i.e., cancer of the sinuses and nasal cavities, lungs, cervix, ovaries, bladder, kidney, stomach and pancreas. However, Canadian per capita alcohol consumption in 1970 was higher than in the other countries, but the situation subsequently changed and since 1980, Canada has had the lowest alcohol consumption of the three countries. This implies that the work-related attributable fraction could be slightly overestimated for types of cancer associated with alcohol consumption; it would therefore be better to use the lowest attributable fractions for cancers for which the link with alcohol consumption is firmly established, i.e., cancer of the pharynx, esophagus, liver and larynx.

[8] Since at least 1985, the proportion of smokers in Quebec has always been higher than the Canadian average. See http://publications.gc.ca/Collection-R/LoPBdP/CIR/8622-e.htm.

Table 6 – Per capita cigarette consumption and proportion of current smokers at various times, Canada, Finland and the United Kingdom

Country	Annual per capita cigarette consumption[1]				Prevalence of current smokers[2] (%)							
					1974–77[3]		**1985[4]**		**1999–2001[5]**		**2008–2009[6]**	
	1970	**1980**	**1990**	**2000**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Canada	3,313	3,544	2,045	1,820	51	38	31	28	24	20	23	16
Finland	1,929	1,351	1,842	1,171	35	20	39	21	27	20	30	21
United Kingdom	2,920	2,586	2,094	1,553	51	41	36	32	29	25	22	21

1 Guindon & Boisclair, 2003 (pp. 41–43).
2 Canada: smokers aged 15 and up; Finland: aged 15–64; United Kingdom: aged 16–100.
3 Canada: Physicians for a Smoke-Free Canada, 2011; Finland: Heloma et al., 2004; United Kingdom: Robinson & Harris, 2011.
4 Smoking prevalence in the year shown and adult per capita cigarette consumption in 1985 in 65 countries and areas, 1988.
5 Canada: Health Canada, 2007; Finland, United Kingdom: World Health Organization Regional Office for Europe, 2012.
6 World Health Organization, 2011a.

Table 7 – Per capita consumption of alcohol at various times, and rates of death from cirrhosis of the liver, Canada, Finland and the United Kingdom

Country	**Annual per capita consumption of alcohol[1]** (litres)				**Rates of death from cirrhosis of liver in 2000, ages 15 and up** (rate/100,000)[2]	
	1970	**1980**	**1990**	**2000**	**Men**	**Women**
Canada	8.8	10.7	7.4	7.7	10.6	4.2
Finland	5.8	7.9	9.5	8.6	18.1	6.7
United Kingdom	7.1	9.4	9.8	10.4	13.2	7.2

1 OECD, 2005.
2 World Health Organization, 2011b.

APPENDIX 4 – DEATHS DUE TO OCCUPATIONAL DISEASE, BY YEAR CLAIM ACCEPTED BY CSST, AND LESION SITE AND TYPE, QUEBEC, 1997–2005

Lesion site and nature	**Year 1997**		**1998**		**1999**		**2000**		**2001**		**2002**		**2003**		**2004**		**2005**		**1997–2005**		**Total**
	M	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	**M**	**W**	
Deaths from cancer	9	0	17	0	10	0	41	0	52	1	43	1	58	0	57	1	71	1	358	4	362
• *Malignant tumour of bronchi, lung or respiratory tract*	*–*	*–*	*5*	*–*	*3*	*–*	*15*	*–*	*15*	*–*	*21*	*–*	*27*	*–*	*28*	*–*	*21*	*–*	*135*	*0*	*135*
• *Pleural mesothelioma*	*8*	*–*	*11*	*–*	*7*	*–*	*24*	*–*	*36*	*1*	*21*	*1*	*29*	*–*	*28*	*1*	*47*	*–*	*211*	*3*	*214*
• *Peritoneal mesothelioma*	*1*	*–*	*–*	*–*	*–*	*–*	*1*	*–*	*–*	*–*	*1*	*–*	*–*	*–*	*–*	*–*	*1*	*1*	*4*	*1*	*5*
• *Malignant tumour of bladder*	*–*	*–*	*1*	*–*	*–*	*–*	*1*	*–*	*1*	*–*	*–*	*–*	*2*	*–*	*1*	*–*	*1*	*–*	*7*		*7*
• *Malignant tumour of kidney*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*–*	*1*	*–*	*1*		*1*
Deaths from other causes	74	2	46	2	55	0	25	0	28	1	26	0	29	0	29	0	38	2	350	7	357
Total	83	2	63	2	65	0	66	0	80	2	69	1	87	0	86	1	111	3	715	11	719