

# Climate Change and Occupational Health and Safety in a Temperate Climate: Potential Impacts and Research Priorities in Quebec, Canada

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**Abstract:** The potential impacts of climate change (CC) on Occupational Health and Safety (OHS) have been studied a little in tropical countries, while they received no attention in northern industrialized countries with a temperate climate. This work aimed to establish an overview of the potential links between CC and OHS in those countries and to determine research priorities for Quebec, Canada. A narrative review of the scientific literature (2005–2010) was presented to a working group of international and national experts and stakeholders during a workshop held in 2010. The working group was invited to identify knowledge gaps, and a modified Delphi method helped prioritize research avenues. This process highlighted five categories of hazards that are likely to impact OHS in northern industrialized countries: heat waves/increased temperatures, air pollutants, UV radiation, extreme weather events, vector-borne/zoonotic diseases. These hazards will affect working activities related to natural resources (i.e. agriculture, fishing and forestry) and may influence the socioeconomic context (built environment and green industries), thus indirectly modifying OHS. From this consensus approach, three categories of research were identified: 1) Knowledge acquisition on hazards, target populations and methods of adaptation; 2) Surveillance of diseases/accidents/occupational hazards; and 3) Development of new occupational adaptation strategies.

**Key words:** Climate change, Occupational health and safety, Research priorities, Northern industrialized country, Delphi method

## Introduction

Over the last twenty years, most scientists have agreed regarding the rapid progression of climate change (CC). According to the conclusions of the fourth Assessment Report of the Intergovernmental Panel on Climate Change

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(IPCC), climate changes and global warming are unequivocal<sup>1,2</sup>. The IPCC predicts that the average warming of the earth's surface, associated with increased concentrations of CO<sub>2</sub> in the atmosphere, will lead to major changes in ecosystem structures and ecological interactions, with negative impacts on biodiversity and ecosystems' goods and services such as water and food supplies<sup>2</sup>. Consequently, important environmental changes are expected all over the world: 1) variability of temperature, rainfall, humidity and winds, 2) alteration of intensity and geographic distribution of extreme climatic events, 3) significant rise of water levels in coastal areas, 4) alteration of wildlife distribution, 5) increased atmospheric concentrations of pollutants and 6) deterioration of natural habitats and of the built environment<sup>2-6</sup>.

The impacts of climate conditions on human health are multiple and have been extensively studied in the general population<sup>1</sup>. But to date, the working population has received little attention and no research has analyzed climate change impacts specifically in northern countries, despite evidences of impacts on the labor market<sup>7</sup>. For instance, new climate conditions may favor hydroelectricity and forestry production and increase agricultural crops such as maize and soy in northern countries. On the other hand, climate change may also affect negatively workers' health and safety because of thermal constraints exacerbation and modification of natural resources that are the basis of the economy<sup>6</sup>.

A most useful preliminary framework for identifying how climate change could affect occupational health and safety (OHS) worldwide was published in 2009<sup>8</sup>. In addition to general research and practice considerations, this framework identified seven categories of hazards (increased ambient temperature, air pollution, UV radiation, extreme weather events, vector-borne and zoonotic diseases, changes in the built environment and emerging industries) and linked some health effects and types of work to them. Among the recommendations of the authors, two were targeting further development of the framework: the assessment of the relative magnitude and frequency of climate-related hazards on a regional basis and the development of a research and prevention agenda as well as a prioritization scheme.

In this perspective, the objectives of this work were to 1) establish an overview of the potential links between CC and OHS in northern industrialized countries with a temperate climate, and to 2) determine associated research priorities applicable to the Quebec (Canada) context.

## Methods

A narrative review of the scientific literature was done and validated by a working group of international and national experts and Quebec's stakeholders. To determine associated research priorities, a modified Delphi method was carried out with the same working group<sup>9</sup>.

### *Review of the literature*

#### Data sources, extraction and synthesis

Research articles or reviews published in peer-reviewed scientific journals between January 2005 and December 2010 were retrieved from several bibliographic databases (Embase, Pubmed, Medline, Web of Science, Toxline, Chemical Abstracts). The following keywords were used: climate, climate change or global warming, with work or occupation. Ten articles published before 2005 and obtained by snowball literature search were also consulted.

Commentaries, editorials and opinion letters were excluded, together with papers in other languages than English or French. The resulting documents were examined and only occupational studies that mentioned negative impacts of CC were retained; exceptionally, some articles pertaining to the general population were included when the information on workers was scarce and data on the general population could be inferred to workers (e.g. air pollution and workers' health). In addition, the documents had to address CC hazards, diseases, zoonoses and health effects already found or plausible in northern industrialized countries with a temperate climate. Papers on extreme cold weather were excluded because climatic predictions suggest warmer winters in Quebec. Reports and relevant information were accessed from governmental or scientific institutions, often through their web sites, such as the IPCC, the United Nations Environment Programme (UNEP), the World Health Organization (WHO), the U.S. Environmental Protection Agency (US EPA), the Center for Disease Control and Prevention (CDC), the National Institute for Occupational Safety and Health (NIOSH) and the U.S. Army, the United Kingdom National Health Service (NHS), the Quebec consortium on climate change Ouranos, Health Canada (HC), Environment Canada (EC), and Natural Resources Canada (NRC).

Finally, exposure/hazards, potential effects on OHS and the types of industries potentially affected were extracted from the retained documents, synthesised and organized following the Schulte and Chun framework<sup>8</sup>.

### Data verification

In order to verify the completeness of the review of literature, a summary of collected information was presented to a working group of national and international experts and some Quebec's stakeholders, during a two-day workshop held in November 2010 (n=19). Experts (n=7) were selected to ensure a broad expertise on CC hazards/impacts and OHS, while stakeholders (n=12) were selected in order to represent the major industrial sectors potentially affected by CC in Quebec. Therefore, the experts' group was composed of two specialists in the OHS effects of ambient temperatures and thermal constraints, two in CC health and environment impacts/adaptation, one in general health and emergency medicine, one in zoonoses and one in UV radiation impacts on human health. Moreover, stakeholders from agriculture, construction, forestry, mining, municipal services, transportation, fisheries, wind power and public health took part in the working group.

### *Identification of the local research priorities*

#### Establishment of research topics

During the workshop, experts and stakeholders were asked to identify knowledge gaps on CC impacts identified in the literature review. Based on their expertise and interests, the literature review and the workshop discussions, the working group established a list of research topics that would address those gaps.

#### Prioritization of research topics

A modified Delphi approach was used to identify research priorities. The Delphi technique is based on sequential consultations in order to seek consensus on priority issues by a procedure of voting over a choice of topics. The process usually stops when consensus is reached or agreement on priorities is sufficiently advanced<sup>9)</sup>.

This list of research topics was sent by e-mail to all members of the working group (n=19) and of the research team (n=7). Respondents were asked to complete and comment the list of research topics established during the workshop. Returned responses were examined and a revised list of research topics was produced and passed around to the same persons. In this instance, participants were asked to rank the ten most important research topics, and to add remarks at will. Votes were summed, providing a final list of research topics.

## Results

Figure 1 presents a flow chart of the studies' selection

for the literature review. The initial key words search yielded 15,097 papers. Applying the inclusion/exclusion criteria previously mentioned left 219 scientific articles for review.

The information on potential negative impacts of CC on OHS retrieved from the literature review, with the addition of the working group comments, is summarized in Fig. 2 and references are presented in Table 1. This information is essentially organized according to the framework provided by Schulte and Chun<sup>8)</sup>, with the addition of the most concerned industries, which appeared to be the most appropriate way of presenting our findings. Three levels of impacts emerge from this information consolidation: impacts on workers, impacts on natural resources and impacts on the socio-economic context. Among the impacts on workers, five categories of direct and indirect hazards were identified: heat waves and increased temperatures, air pollutants, UV radiation, extreme weather events, vector-borne and zoonotic diseases. Impacts on natural resources are associated with changes in agriculture/breeding methods, alteration in the fishing industry and disruption of the forest ecosystem. In addition, two modifications on the socio-economic working context that could pose OHS threats were identified: deterioration of the built environment and emerging green industries.

Even in a temperate climate, the increased temperatures and the raised frequency and severity of heat waves over the coming decades is likely to increase the risk of cramps, fatigue and heatstroke, the absorption of chemicals, skin problems and possibly the risk of injuries and accidents related to a decrease in vigilance, manual dexterity and altered emotional state. Smog events are also likely to become more frequent and impact workers' health and safety by increasing the risk of cardiovascular and respiratory symptoms and diseases. Human exposure to UV radiation will also be more important, resulting in increased risks of eye and skin diseases from UV radiation, while extreme weather events are expected to be on the rise, increasing health problems and injuries. Moreover, vector-borne and zoonotic diseases may also increase and 'new' disorders, scarce or never seen in Quebec before, might also appear because of changes in geographic distribution of vectors and parasites. Impacts of CC on natural resources might affect OHS by influencing economic activities and work environments, resulting in an increase of health problems related to work insecurity in economic sectors where reduced productivity may happen. CC may also affect the effectiveness, service life and safety of infrastructures and buildings, increasing health and safety risks such as acci-

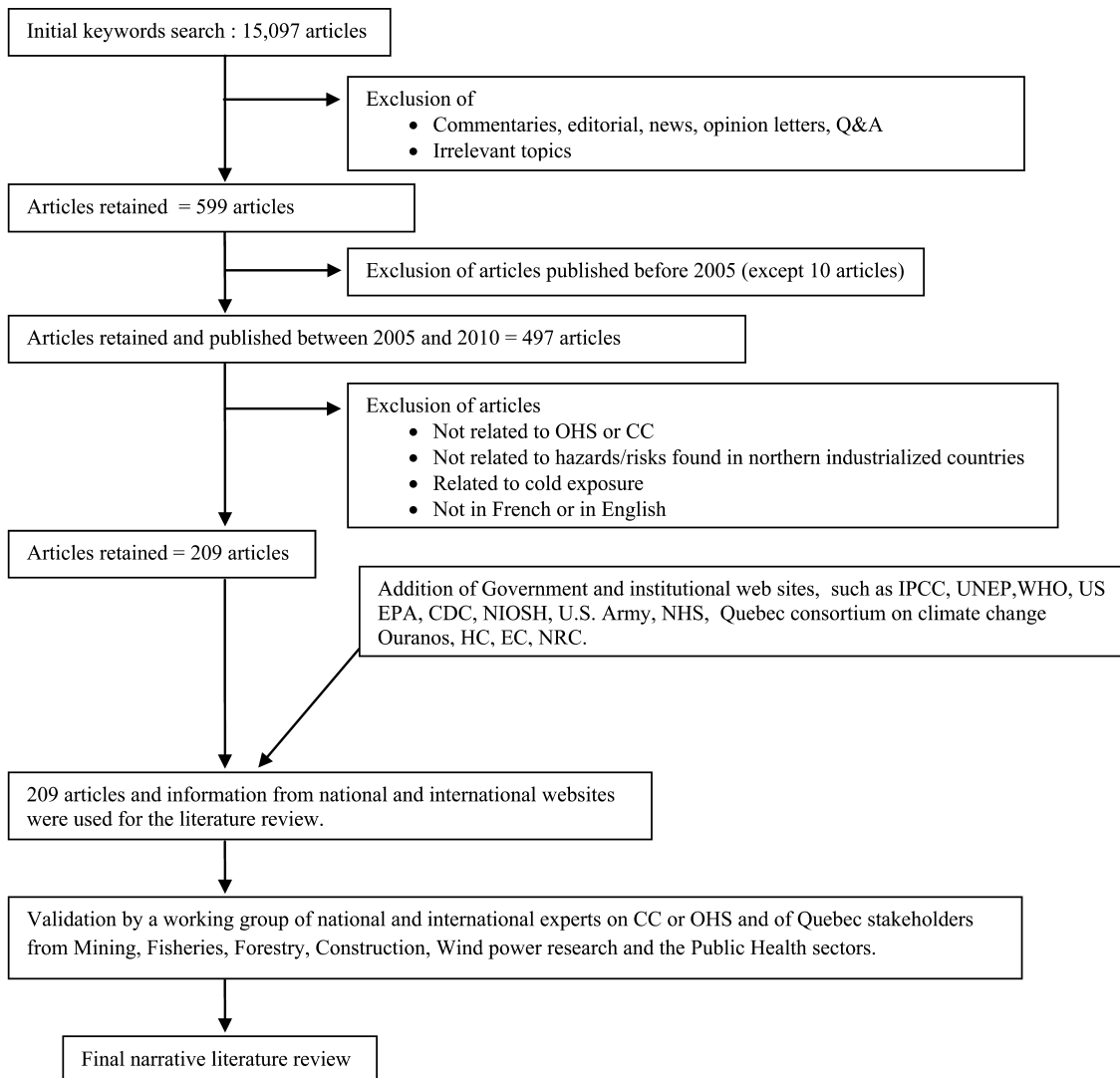


Fig. 1. Flow chart representing the studies selection for the literature review and data validation.

dents and injuries. Finally, the development of new green industries in order to mitigate the impacts of CC by reducing greenhouse gas emissions might also bring new OHS issues. In addition to hazards and negative OHS effects of CC, the literature review also targeted types of industries that will potentially be affected by each category of hazard/exposure, as identified in Fig. 2 (all specific references are presented in Table 1).

Most of these industries imply outdoor activities, such as construction, agriculture, forestry, mining, fishing, municipal services and transportation. However, some indoor activities were also identified, essentially in relation to heat waves (e.g. foundries or health care) and green jobs hazards (e.g. recycling or energy industries). Moreover, numerous factors may influence the intensity

of OHS effects following an exposure to CC related hazards, such as the type and location of work and the length of exposure<sup>8, 35, 38, 43, 60, 61</sup> individual characteristics and physical conditions such as age, pregnancy, body weight or medication intake<sup>11, 12, 62–64</sup>, the wearing of protective equipments<sup>65, 66</sup>, exposure characteristics of the hazards such as pollutant concentrations<sup>3</sup> and co-exposure to multiple environmental hazards<sup>67</sup>.

A list of 30 research topics was first derived from exchanges during the workshop. Twelve research topics (Table 2) were prioritized using a modified Delphi method with 17 participants replying to two rounds of consultation. Six research topics were related to knowledge acquisition on hazards, target populations and methods of adaptation in the workplace, one research topic to surveil-



**Table 1. Main references reporting evidence on climate change hazards and their effects on occupational health and safety in northern industrialized countries with a temperate climate**

Hazards	Effects on health and safety	References
<b>Impacts of CC on persons</b>		
Heat waves and increased temperatures	<ul style="list-style-type: none"> <li>• Cramps, Fatigue and Heatstroke</li> <li>• Renal &amp; cardiovascular problems</li> <li>• Increased absorption of chemicals</li> <li>• Dehydration and decrease in cognitive performance</li> <li>• Skin problems</li> <li>• Accidents related to decrease in vigilance; decrease in manual dexterity</li> <li>• Altered emotional states</li> <li>• Death</li> </ul>	10–13) 14) 15, 16) 17) Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010 18, 19) 20) 13, 21–23)
Air pollutants (Ozone, airborne particles, volatile organic compound and allergens)	<ul style="list-style-type: none"> <li>• Cardiovascular/ Respiratory symptoms and diseases</li> <li>• Atopic sensitization and increased allergic symptoms</li> </ul>	12, 24–30) 3, 31)
UV Radiation	<ul style="list-style-type: none"> <li>• Skin diseases including cancer and eye diseases</li> </ul>	32–35)
Extreme weather events	<ul style="list-style-type: none"> <li>• Cardiovascular/ respiratory diseases</li> <li>• Atopic sensitization (pollen and aeroallergens)</li> <li>• Vector borne diseases</li> <li>• Falls, injuries &amp; fatalities</li> <li>• Mental health disturbances</li> </ul>	4, 12, 36) 3, 27) 4, 12) 4,12) and Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010 37, 38)
Vector-borne and zoonotic diseases	<ul style="list-style-type: none"> <li>• Encephalitis caused by arthropods (St. Louis, La Crosse, Eastern Equine)</li> <li>• Hantavirus Pulmonary Syndrome</li> <li>• West Nile Virus</li> <li>• Lyme Disease</li> <li>• Brucellosis</li> </ul>	4) 4) 4, 39) 4, 40–42) 38)
<b>Impacts of CC on natural resources</b>		
Changes in production, harvests, work methods in agriculture/breeding	<ul style="list-style-type: none"> <li>• Insecurity and consequences on physical &amp; mental health due to a decreased employment</li> <li>• Vector-borne and zoonotic diseases</li> <li>• Variation in chemical exposure</li> </ul>	6, 43–45) 46–48) 49)
Changes in harvest, working methods in fishing	<ul style="list-style-type: none"> <li>• Insecurity and consequences on mental health</li> <li>• Diseases related to marine toxins</li> <li>• Fishing under difficult conditions</li> </ul>	6) 50) and Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010 Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010
Disruption of forest ecosystem and changes in distribution of toxic plants	<ul style="list-style-type: none"> <li>• Allergies and lung irritation</li> <li>• Difficult logging conditions</li> </ul>	8) 6) and Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010
<b>Socio-economic context</b>		
Deterioration of built environment infrastructures	<ul style="list-style-type: none"> <li>• Insecurity and consequences on mental health</li> <li>• Environment creating new hazards</li> <li>• Accidents related to road infrastructure damages</li> </ul>	Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010 51, 52) 51, 52) and Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010
Increase in emerging «green» industries	<ul style="list-style-type: none"> <li>• Exposure to chemical and biological agents, and radiation</li> <li>• Insecurity and consequences on mental health due to a decreased employment</li> <li>• Environment creating new hazards</li> </ul>	5, 8, 13, 53, 54) Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010 53, 55–59) and Exchanges during Montreal CC and OHS workshops, Nov. 24–25, 2010

**Table 2. Twelve research priorities applicable to the Quebec context and identified through the modified Delphi study**

Research priorities
<p>Knowledge acquisition on hazards, target populations and methods of adaptation in the workplace</p> <ul style="list-style-type: none"> <li>• Study past CC extreme events in order to identify type of work involved and develop mitigation strategies from this information.</li> <li>• Evaluate new OHS hazards related to CC exposures and their potential impacts on infrastructures.</li> <li>• Study the increased toxicity and health effects of different biological/chemical agents and materials during episodes of extreme heat, air pollution, drought or intense rainfall.</li> <li>• Assess current and future risks related to aeroallergens and zoonoses.</li> <li>• Study thermal and hydric stress due to wearing protective equipment during extreme heat episodes.</li> <li>• Identify categories of workers vulnerable to accidents and diseases associated with CC impacts, considering their working conditions and individual characteristics.</li> </ul>
<p>Surveillance of diseases, accidents and occupational hazards</p> <ul style="list-style-type: none"> <li>• Define accident and disease indicators and gather information in order to enable surveillance of health effects attributable to the climate.</li> </ul>
<p>Development of occupational adaptation strategies</p> <ul style="list-style-type: none"> <li>• Identify and evaluate adaptation methods established in other countries.</li> <li>• Develop training tools to prepare health care workers for the potential health effects of CC, in particular regarding heat strokes, zoonoses and vector-borne diseases.</li> <li>• Develop suitable protective clothing and other equipments that are adequate for extreme climates in order to favor their actual wearing by workers.</li> <li>• Explore CC adaptation methods using organization of work and work schedule management.</li> <li>• Develop methods to heighten workplace (workers and employers) awareness of CC potential OHS risks, both short-term (e.g. violent storms and accidents) and long-term (e.g. skin cancer and UV radiation).</li> </ul>

Moreover, OHS impacts might vary within the country due to regional micro-climates or local socio-economic characteristics which will play a role in how risks and hazards will impact on population groups<sup>68</sup>).

The second objective of this project was to determine local research priorities in order to address potential negative impacts of CC on OHS in Quebec. The consensual research agenda obtained through the Delphi approach, which suited both stakeholders' and scientists' perceptions, showed that the most important perceived area for future work was the acquisition of knowledge; this is coherent with the fact that the topic of CC impacts on OHS has never been studied in Quebec, or in a northern industrialized country with a temperate climate. Most stakeholders of the working group reported that they had never thought about this topic in the past, but became concerned during the workshop and actively participated in the identification of the hazards, OHS effects, potentially affected industries and research priorities. Interestingly, our regional assessment brought up research topics largely similar to what Schulte and Chun<sup>8</sup>) recommended in their conclusion. These are the improvement of epidemiologic surveillance with the development of health indicators, and also the general acquisition of knowledge on CC and OHS. A third topic recommended by Schulte and Chun<sup>8</sup>), namely

the identification of occupational hazards related to new «green jobs», was listed among the initial research topics (increased health risks related to greener materials), but was not ranked among the top priorities after the second round of consultation.

This study presents limitations that need to be pointed out. First of all, this work has intentionally not gone very deep on CC impacts on the labor market and employment. Also, adaptation strategies were excluded from this analysis as we were not yet exploring solutions to the identified hazards<sup>7</sup>). Secondly, this work has only targeted negative effects of CC, although some CC effects on OHS will likely be positive; for example, with adequate insect pest control, some specific agricultural production and forestry activities might even be favored, increasing revenues and job numbers in these industries. Longer mild seasons may also favor some tourist activities, such as golf, hunting and fishing<sup>4</sup>). Thirdly, the working group selection, based on presently known CC impacts, has perhaps restricted identification of new hazards or industries during the workshop.

A delicate part of the Delphi procedure is the selection of a panel of participants that is representative of all bodies involved in the topic of interest<sup>69</sup>); it is very likely that a different set of stakeholders and scientists would have resulted in a different research agenda. Moreover,

the retained sets of priorities were obtained after only two consultations and it is possible that additional consultations would have resulted in a slightly different consensus. Nevertheless, the degree of unanimity among the various responses was quite satisfactory, and the excluded items essentially targeted only one or two industries, likely having a low impact in the general issue of CC impacts on OHS.

The research priorities were established according to scientific knowledge available at a given time and in a given economic and political context. Changes in the economic and political environments will likely bring modifications that will affect climate change mitigation<sup>68</sup>. For instance, international pressures on greener industries will lead to labor market changes, as already experienced in the Canadian energy, postal and automotive services sectors<sup>7</sup>. Thus research priorities have to be revised and updated over time, following important changes in the economy, but also if there are important modifications in climate predictions or CC impacts in Quebec.

Finally, the potential health threats to workers in areas of the world with hotter climates, where people from Quebec may work or where Quebec corporations have production activities with local staff, were not reviewed, but this issue would need to be considered in future research. The potential occupational health threats from climate conditions in hotter parts of the world have been analyzed in two series of papers, published in 2009 and 2010 in the journal *Global Health Action*<sup>70, 71</sup>.

In conclusion, the global context of CC in the upcoming decades is likely to impose major changes in some industries and occupations worldwide. This work highlighted five categories of hazards that are likely to impact OHS in northern industrialized countries: heat waves /increased temperatures, air pollutants, UV radiation, extreme weather events and vector-borne/ zoonotic diseases. These hazards will affect working activities related to natural resources (i.e. bring changes in production and harvesting methods in agriculture, fishing and forestry) and may influence the socioeconomic context (deterioration of the built environment and emergence of green industries), thus indirectly modifying OHS. Our study showed that the global framework developed by Schulte and Chun<sup>8</sup> was relevant to address CC impacts on OHS in a temperate climate region. Bringing together regional and international experts and stakeholders proved useful to produce a consensual list of research topics. Regardless of the country considering the issue of CC impacts on OHS, it is likely that worldwide research priorities will fit into the large

categories identified in our study. A concerted research effort is needed to increase our knowledge on hazards, target populations and methods of adaptation in the workplace; to ensure a proper surveillance of diseases, accidents and occupational hazards; and to develop new occupational adaptation strategies.

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