Occupational Cancer Research Centre

OCCUPATIONAL EXPOSURE LIMITS FOR CARCINOGENS IN ONTARIO WORKPLACES: OPPORTUNITIES TO PREVENT AND CONTROL EXPOSURE

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Towards a cancer-free workplace

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Acronyms, abbreviations, and notations used

IARC	International Agency for Research on Cancer
CAREX	Carcinogen Exposure
HRSDC	Human Resources and Skills Development Canada
ACGIH	American Conference of Governmental Industrial Hygienists
NIOSH	National Institute of Occupational Safety and Health
SCOEL	Scientific Committee on Occupational Exposure Limits
GESTIS	Information system on hazardous substances of the German Social Accident Insurance
MAK	Maximum Workplace Concentrations
AGW	Arbeitsplatzgrenzwert (Occupational Exposure Limit) [German]
SER	Social and Economic Council of the Netherlands
OEL	Occupational Exposure Limit
BOELV	Binding Occupational Exposure Limit Value
RLV	Reference Limit Value
REL	Recommended Exposure Limit
ceil	Ceiling limit
ppm	parts per million
mg/m^3	milligrams per cubic metre
f/cc	fibres per cubic centimetre
c	Carcinogen
f	Respirable fibres: length > 5µm; aspect ratio ≥3:1, as determined by the membrane filter method at 400-450 times magnification (4-mm objective), using phase-contrast illumination
i	Inhalable fraction
m	Health surveillance required for handling
r	Respirable fraction
rt	Reproductive toxin
sen	Sensitization (ACGIH)
sk	Skin (ACGIH)
sk sen	Skin sensitizer (SCOEL)
td	Total dust

Introduction

Nearly 160 workplace factors are known to or likely to cause cancer in humans according to the International Agency for Research on Cancer (IARC) (1). Many of these are encountered in workplaces and the list encompasses carcinogens as wide ranging as industrial chemicals, pesticides, viruses, and certain work practices, among others. Estimates of the proportion of cancers attributed to workplace exposures very widely (2), but all of these are preventable.

Preventing occupational cancer at the source begins with reducing exposure to cancer-causing agents in the workplace. Occupational Exposure Limits (OELs) place maximum allowable limits on the concentration of a hazardous substance in workplace air (3). In Canada, they are set by provincial and national authorities and are legally enforceable. A variety of factors are considered in the development of OELs, including toxicological and epidemiological evidence as well as feasibility. The overall intent of OELs is to ensure that there are no harmful effects as a result of exposure to a particular hazard over a working lifetime. Thus, OELs are an important tool to prevent cancer and other occupational diseases.

Thousands of Ontario workers are routinely exposed to substances which are “definite”, “probable”, and “possible” human carcinogens as defined by IARC (IARC Groups 1, 2A, and 2B, respectively) (1, 4). This can be prevented and controlled by developing and enforcing OELs that protect workers from exposure to carcinogens. For these reasons, it is important to ensure that OELs in Ontario are rigorous, up-to-date, and reflect the best possible standards for workers.

Objective

The objective of this report was to compare OELs for known and suspected carcinogens in Ontario with OELs established in other Canadian provinces and selected jurisdictions worldwide. By highlighting various methodologies and considerations used to develop OELs in different provinces and countries, this multi-jurisdictional analysis aimed to identify opportunities where Ontario may strengthen its OELs in order to better prevent and control workers’ exposure to occupational carcinogens in the province.

Methods

In order to report on occupational carcinogens which are relevant to Ontario workers, we began with the research priorities identified by OCRC’s stakeholder community in 2009 (5). This diverse group of 177 representatives from academia, health care, policy, industry, and labour completed an online survey to help OCRC establish its research agenda. They stated a range of priority issues in Ontario and Canada including nearly 100 workplace exposures such as chemicals, respirable dusts and fibres, radiation, pesticides, and shiftwork (Appendix 1).

Next, we consulted the Carcinogen Exposure (CAREX) Canada website (www.carexcanada.ca) (4) to focus on specific substances within the broad categories of workplace exposures that were identified by OCRC stakeholders. CAREX Canada is a highly developed database on priority carcinogen exposures in the country. It contains comprehensive information on carcinogenic evidence, main uses, regulatory information, and the potential for occupational exposure among the Canadian population for approximately 79 carcinogens recorded thus far (Table 1). Nearly all of these fall within the research priorities established by OCRC stakeholders.

For each of the 79 carcinogens listed in CAREX, we identified OELs for Ontario, all Canadian provinces and territories, and for six additional jurisdictions: 1) the American Conference of Governmental and Industrial Hygienists (ACGIH); 2) the National Institute of Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL); 3) Germany; 4) the Scientific Committee on Occupational Exposure Limits (SCOEL); 5) Sweden; and, 6) the Netherlands. These six jurisdictions were selected because of their longstanding, active work in evaluating evidence to assign OELs. ACGIH values are often adopted by Canada at both federal and provincial levels and the OELs developed by the remaining jurisdictions provided a comprehensive framework for comparing Ontario limits.

For all jurisdictions, we obtained OELs for time-weighted average (TWA) concentrations corresponding to 8 hour, 15 minute, and ceiling (momentary) exposures. These parallel the ACGIH classifications of the TWA, short-term exposure limit (STEL), and ceiling limit (C), respectively (6). OELs from the included jurisdictions were identified from a variety of sources, including legislation governing OELs and scientific recommendations (Table 2) (6-34).

Thus, we cross-tabulated the 79 carcinogens listed in CAREX Canada with their OELs in Ontario and in the additional jurisdictions listed above. The OELs across jurisdictions for each of these 79 carcinogens were reviewed in detail. For the purpose of this report, we selected only those carcinogens that had both the greatest variability of OELs across multiple jurisdictions and higher OELs in Ontario because these differing values provided an indication of how to lower limits in Ontario. The remaining substances that had relatively similar OELs across jurisdictions were not discussed in this report.

Our final analysis consisted of three levels of comparisons for the selected occupational carcinogens. Ontario OELs for these agents were compared to limits established: 1) in the rest of Canada; 2) by ACGIH; and, 3) in all other jurisdictions. This comprehensive assessment helped us to identify key opportunities to reduce exposure to specific occupational carcinogens in Ontario workplaces. Estimates of the number of workers exposed in Ontario were drawn from CAREX Canada (4) and the carcinogenic classification of each agent was obtained from IARC (1).

<u>Results</u>

Of the 79 carcinogens reviewed, eight had the most different OELs across jurisdictions and had limits in Ontario that were higher than values in other jurisdictions (Table 1). These were: three industrial chemicals (chloroform, ethylbenzene, and formaldehyde); three fibres and dusts (wood dust, crystalline silica, and refractory ceramic fibres); and, two metals (nickel and its compounds and lead and inorganic compounds, as Pb). For each of these substances, we summarized the OELs by jurisdiction, described some of the criteria that were used by various jurisdictions to develop OELs, and made recommendations for the adoption or revision of OELs in Ontario. This provides context to the tabulated limits and indicates specific considerations that the province may use to improve its OELs.

Chloroform

Chloroform is one of a group of a group of compounds formed as a disinfection by-product of water chlorination. It is considered "possibly carcinogenic to humans" (Group 2B) according to IARC (35) with evidence of liver and kidney cancer in exposed mice and rats. CAREX estimates that 6000 workers in Ontario are exposed to this substance (36).

Chloroform (CAS No. 67-66-3)		
	8 hour OEL (ppm)	**15 minute OEL (ppm)**
ON	**10**	
HRSDC, AB, MB, NL, NB, PE, NS, YT	10	
BC	2 (rt)	
QC	5	
NT, NU	10	50
ACGIH	10	
NIOSH REL		2* (c)
Germany	0.5	1
SCOEL	2 (sk)	
Sweden	2 (c)	5 (c)
Netherlands	1	5

(rt) reproductive toxin
(sk) skin
(c) carcinogen
*60-minute OEL

Ontario's OEL for chloroform (7, 8) was previously adopted from the ACGIH and it was higher than the values in two Canadian provinces (9, 17) and in all European jurisdictions (23, 24, 33, 34). OELs in British Columbia and Quebec were at least twice as protective as Ontario's and Germany had the lowest limit of all included jurisdictions. Ontario's OEL exceeded the German value by 20-fold.

The ACGIH TWA for chloroform has been steadily decreasing since a limit was first established in 1946. The most notable decline occurred in 1976, when the ACGIH Committee proposed that chloroform is a suspected human carcinogen. At this point, the TWA decreased by 60%, from 25 ppm to 10 ppm, which remains the present limit value. ACGIH revised the level of carcinogenicity of chloroform in 1995 to a confirmed animal carcinogen with unknown relevance to humans (37). The lower values recommended by SCOEL (24) and legally mandated in British Columbia (9) were primarily developed to protect workers from reproductive effects that have been associated with exposure to concentrations below 10 ppm. The limit of 1 ppm in the Netherlands was similarly intended to help prevent developmental toxicity (24). Therefore, lower OEL values offer protection against both reproductive and carcinogenic effects related to occupational exposure to chloroform.

Recommendation

Ontario should lower its OEL in order to protect workers from both occupational cancer and developmental toxicity.

Ethylbenzene

Ethylbenzene (CAS No. 100-41-4)		
	8 hour OEL (ppm)	15 minute OEL (ppm)
ON	**100**	**125**
HRSDC, AB, SK, MB, QC, NL, NB, PE, NS, YT, NT, NU	100	125
BC	20	
ACGIH	20	
NIOSH REL	100	125
Germany*	20	40
SCOEL	100 (sk)	200 (sk)
Sweden	50	100

(sk) skin
*MAK value

Ethylbenzene is an industrial chemical with a variety of uses in Canada, including styrene production, paints, adhesives, and other purposes. It is also found in crude oil and automotive and aviation gasoline. Of the estimated 208,000 workers exposed to ethylbenzene across Canada, approximately one third (77,000) are in Ontario (38). IARC has classified ethylbenzene as "possibly carcinogenic to humans" (group 2B) with most evidence derived from cancer observed in mice and rats (39).

Ontario listed both 8-hour and 15-minute limits for ethylbenzene (7) and these are equal to the OELs in most provinces and territories (9-21). However, they were higher than the limits established by other jurisdictions which acknowledge a broad range of adverse health effects from occupational exposure to ethylbenzene. For example, the ACGIH OEL is based upon evidence of upper respiratory tract and eye irritation, acute depressant effects on the central nervous system, kidney damage (nephropathy), and cochlear impairment, among other impacts. ACGIH limits have substantially decreased over time as harmful health effects have been observed at low concentrations. In 1946, the ACGIH recommended an 8-hour limit of 200 ppm and in 1967, this value was lowered to 100 ppm. In 2011, ACGIH further decreased the limit by 80 per cent to 20 ppm (6, 37), which is equal to the limit previously set by the MAK Commission in Germany (23). British Columbia is the only Canadian jurisdiction that has similarly lowered its OEL (10) as all other provinces and territories, including Ontario, continue to use an 8-hour OEL of 100 ppm developed by ACGIH over 40 years ago. This is a recent change and area for action.

Recommendation

We support the Ministry of Labour's recommendation that the 8-hour OEL be lowered to 20 ppm and the 15-minute OEL be withdrawn.

Formaldehyde

Formaldehyde (CAS No. 50-00-0)			
	8 hour OEL (ppm)	15 minute OEL (ppm)	Ceiling OEL (ppm)
ON		**1**	**1.5**
HRSDC, MB, NL, PE, NS			0.3
SK			0.3 (sen)
BC	0.3 (sen)		1 (sen)
AB	0.75		1
QC, YT, NT, NU			2
NB	0.5	1.5	
ACGIH			0.3 (sen)
NIOSH REL	0.016 (c)		0.1 (c)
Germany*	0.3	0.6	1
SCOEL	0.2 (sk sen)	0.4 (sk sen)	
Sweden	0.5 (c) (sen) (m)		1 (c) (sen) (m)
Netherlands	0.1	0.4	

(sk sen) skin sensitizer
(c) carcinogen
(sen) sensitization
(m) health surveillance required for handling
*MAK value

Formaldehyde is carcinogenic to humans according to IARC (Group 1) as it causes nasopharyngeal cancer and potentially, leukemia and sino-nasal cancer (40). Approximately 64,000 Ontario workers are exposed to this chemical in wood and other industries (41).

Ontario listed both 15 minute and ceiling OELs for formaldehyde (7, 8) and these values were markedly elevated compared to the limits in most other jurisdictions. Ontario's ceiling limit was five times higher than the ACGIH recommended limit (6) that has been adopted at the federal level (21) and in five other Canadian provinces (12, 13, 15, 16, 19). The NIOSH REL ceiling limit (22) was the most protective value of all jurisdictions and Ontario's ceiling limit exceeded it by 15 times. Further, Ontario's 15-minute OEL was 2.5 times higher than the short-term OELs established by SCOEL (25) and legally mandated in the Netherlands (34).

ACGIH recommended a ceiling limit of 0.3 ppm in 1992 because of the potential of formaldehyde to cause eye and upper respiratory tract irritation, even at very brief exposure to low levels (37). SCOEL established health-based 8-hour and 15-minute OELs for similar reasons, recognizing that lower limits help reduce irritation-induced local cell proliferation that can lead to cancer (25). Evidence of formaldehyde carcinogenicity comes from studies of both animals and humans. Exposed mice and rats show various tumorigenic outcomes such as squamous cell carcinomas of the nasal cavity. Epidemiological studies also demonstrate positive associations between formaldehyde and nasopharyngeal cancer, with less consistent findings for leukemia (40). Ontario's ceiling limit represents a value that was developed by ACGIH during the 1970s and early 1980s and it is well above the limit that puts workers at risk of sensory irritation that can potentially lead to cancer. These values are an essential area for improvement in the province.

Recommendation

Ontario should lower its ceiling limit to 0.3 ppm. The 15 minute OEL should also be substantially lowered or simply replaced by the ceiling limit for even greater protection of workers, particularly against the irritant effects of formaldehyde that have been linked to the development of cancer.

Wood dust

Wood dust is a human carcinogen according to IARC (Group 1) (42) and approximately 93,000 workers in Ontario are exposed (43). Different jurisdictions evaluated different types of wood dust, including softwood, hardwood, and Western red cedar, as well as particle size fractions (i.e. total and inhalable). In Ontario (7), the 8-hour OEL for softwood was five times higher than the OEL set by ACGIH (6) and adopted at the federal level (21) and by five other provinces (12-16). Furthermore, Ontario's softwood limit is twice that established in BC (9). Of all jurisdictions, SCOEL appears to have the most rigorous exposure limits for both total and inhalable fractions (27). These values are much lower than Ontario's OEL for softwood dust.

Wood dust		
	8 hour OEL (mg/m^3)	15 minute OEL (mg/m^3)
ON	**5 (softwood)** **1 (certain hardwoods such as beech and oak)**	**10 (softwood)**
HRSDC	0.5 (Western red cedar) (i) (sen) 1 (all other species)	
MB, NL, PE, NS, NB	0.5 (Western red cedar) (i) (sen) 1 (all other species) (i)	
BC	2.5 (softwood, non-allergenic) 1 (hardwood, non-allergenic) 1 (allergenic)	
AB	0.5 (Western red cedar) 5 (softwood & hardwood)	
SK	5 (softwood) (sen) 1 (certain hardwoods such as beech and oak) (sen)	10 (softwood) (sen) 3 (certain hardwoods such as beech and oak) (sen)
QC	2.5 (Western red cedar) (td) 5 (softwood & hardwood) (td)	
ACGIH	0.5 (Western red cedar) (i) (sen) 1 (all other species) (i)	
NIOSH REL	1 (softwood, hardwood, Western red cedar) (c)	
Germany	5 (hardwood BOELV) 2 (hardwood RLV)	
SCOEL	0.5 (td) 1 (i)	
Sweden	2 (i (c)	
Netherlands	2 (hardwood) (i)	

(i) inhalable fraction
(sen) sensitization
(td) total dust
(c) carcinogen

The increased risk of sino-nasal cancer among workers exposed to wood dusts is well documented (42). ACGIH considers oak and beech as confirmed human carcinogens; however, the carcinogenic mechanism is not clear and it is possible that other tree species also cause cancer. ACGIH established the first OEL for wood dust in 1972, listing a TWA of 5 mg/m^3 for non-allergenic wood dusts. Changes in the OELs since then are mostly related to the tree species evaluated and the growing body of evidence on health effects such as respiratory symptoms and decreased lung function, occupational asthma (Western red cedar), and sino-nasal cancer. As a result, the ACGIH Committee's recommendation of 1 mg/m^3 for all other species is mainly based on preventing decreases in pulmonary function (37). The current wood dust OELs in Ontario are equal to those developed by ACGIH in 1981 despite the observation of adverse health effects among workers exposed at levels that are much lower than the present Ontario limits. As the SCOEL recommendation for wood dust states, workers exposed to concentrations between 0.5 mg/m^3 (total dust) and 1 mg/m^3 (inhalable dust) from various species of wood exhibited significant health impairments (27). This evidence of occupational cancer and pulmonary effects clearly demonstrates the need for Ontario to update its values as ACGIH (6) and SCOEL (27) have recently done.

Recommendation

Due to the risk of sino-nasal cancer, respiratory disease, and occupational asthma, Ontario should reduce its limits for both softwood and hardwood dusts to 1 mg/m^3 (inhalable dust) with a lower limit of 0.5 mg/m^3 (inhalable dust) for Western red cedar and other highly allergenic species.

Crystalline silica

Crystalline silica (Cristobalite CAS No. 14464-46-1; Quartz CAS No. 14808-60-7)	
	8 hour OEL (mg/m^3)
ON	**0.05 (cristobalite) (r) 0.1 (quartz) (r)**
HRSDC, MB, NL, PE, NB, NS	0.025 (crystalline silica) (r)
BC, AB	0.025 (cristobalite & quartz) (r)
SK	0.05 (cristobalite & quartz) (r)
QC, NT, NU	0.05 (cristobalite) (r) 0.1 (quartz) (r)
YT	150 particles/mL (cristobalite) 300 particles/mL (quartz)
ACGIH	0.025 (cristobalite & quartz) (r)
NIOSH REL	0.05 (quartz) (r) (c)
SCOEL	0.05 (silica dust) (r)
Sweden	0.05 (cristobalite) (r) 0.1 (quartz) (r) (m)
Netherlands	0.075 (crystalline silica) (r)

(r) respirable fraction
(c) carcinogen
(m) health surveillance required for handling

Crystalline silica is one of the most common minerals on earth. It is naturally found in soil, sand, and rocks. Quartz is the most prevalent form and along with cristobalite, it has important industrial uses in Canada including smelting and refining, glass and glass container manufacturing, foundries, and others. Approximately 143,000 workers are estimated to be exposed to this substance in Ontario (44), mainly from work in the construction industry. Ontario is also one of the main silica producing provinces in Canada, which requires rigorous OELs that protect workers from exposure.

Crystalline silica is carcinogenic to humans according to IARC (Group 1) (42). In addition to lung cancer, crystalline silica causes pulmonary fibrosis (silicosis) and chronic obstructive pulmonary disease. In this analysis we found that the OELs in Ontario (7, 8) for cristobalite and quartz were two to four times the limits listed by the ACGIH (6) for these two forms of crystalline silica, respectively. Most provinces (9, 11-16, 19) have adopted the ACGIH value for crystalline silica, which was the lowest of all jurisdictions analyzed.

The limits established by the ACGIH and SCOEL (28) were developed with the intention to prevent silicosis that may be a risk factor for lung cancer. Steenland and Sanderson (45) found a significant increase in risk of death due to lung cancer at average exposure levels greater than 0.065 mg/m^3 of respirable silica, suggesting that an 8-hour limit of 0.1 mg/m^3 for quartz would likely be insufficient to protect workers' health. Ontario's current limits for quartz and cristobalite represent values proposed by ACGIH in the 1980s, before the Committee lowered them to 0.025 mg/m^3 in 2005 (37). There is an immediate need to change the province's OELs for both quartz and cristobalite.

Recommendation

Based on well-established carcinogenic and other health risks related to occupational exposure to crystalline silica and the large number of Ontario workers exposed, Ontario's OELs should be lowered to 0.025 mg/m^3 (respirable fraction) to reduce the risk of occupational cancer and silicosis.

Refractory ceramic fibres

Refractory ceramic fibres are a type of synthetic vitreous fibres (or man-made mineral fibres) that are mainly used in numerous high-temperature applications due to their insulating qualities. Over half of the 3200 Canadian workers estimated to be exposed to refractory ceramic fibres are in Ontario (46) yet Ontario's OEL (7) for this suspected carcinogen was 2.5 times higher than the OEL recommended by ACGIH (6) and enforced at the federal level in Canada (21), in most Canadian provinces (9, 11-16, 19), and in Sweden (33).

Refractory ceramic fibres	
	8 hour OEL (f/cc)
ON	**0.5 (f)**
HRSDC, BC, AB, SK, MB, NB, NL, PE, NS	0.2 (f)
QC	1
ACGIH	0.2 (f)
SCOEL	0.3
Sweden	0.2 (c) (m)
Netherlands	0.5

(f) respirable fibres: length > 5µm; aspect ratio ≥3:1, as determined by the membrane filter method at 400-450 times magnification (4-mm objective), using phase-contrast illumination
(c) carcinogen
(m) health surveillance required for handling

Chronic animal inhalation and epidemiological studies show that exposure to refractory ceramic fibres is associated with the development of pulmonary fibrosis and pleural and lung function abnormalities that closely resemble the health effects linked to asbestos exposure (47-49). IARC considers refractory ceramic fibres a possible human carcinogen (Group 2B) (47, 48) based on increased risk of lung cancer and mesothelioma in animal studies. The ACGIH OEL is set between the limit for asbestos (0.1 f/cc) and the limit for other types of synthetic vitreous fibres (1 f/cc). Ontario's OEL may be derived from this value proposed by ACGIH in 1996 (6, 37). The epidemiological data that has emerged since then shows increased cancer risk over a long latency period, emphasizing the need for Ontario to revise its limit accordingly.

Recommendation

Workplace exposure to refractory ceramic fibres is linked to health effects that closely resemble those associated with asbestos exposure, such as pulmonary fibrosis and pleural and lung function abnormalities. Ontario should establish a limit that is at least half of its present OEL.

Nickel

Nickel and its compounds (CAS No. 7440-02-0)		
	8 hour OEL (mg/m^3)	15 minute OEL (mg/m^3)
ON	**1 (elemental) (i)** **0.1 (soluble inorganic compounds) (i)** **0.2 (insoluble inorganic compounds) (i)**	
HRSDC, AB, MB, NL, NB, PE, NS	1.5 (elemental) (i) 0.1 (soluble inorganic compounds) (i) 0.2 (insoluble inorganic compounds) (i)	
BC	0.05 (elemental, soluble inorganic, and insoluble inorganic compounds)	
SK	1.5 (elemental) 0.1 (soluble inorganic compounds) 0.2 (insoluble inorganic compounds)	3 (elemental) 0.3 (soluble inorganic compounds) 0.6 (insoluble inorganic compounds)
QC	1 (elemental) 0.1 (soluble inorganic compounds) 1 (insoluble inorganic compounds)	
ACGIH	1.5 (elemental) (i) 0.1 (soluble inorganic compounds) (i) 0.2 (insoluble inorganic compounds) (i)	
NIOSH REL	0.015 (c)	
SCOEL	0.01 (excludes metallic Ni) (i) 0.005 (r)	
Sweden	0.5 (td) (sen)	

(i) inhalable fraction
(r) respirable fraction
(td) total dust
(c) carcinogen
(sen) sensitization

Canada generated 15% of the world's nickel in 2007, mainly for use in stainless steel production. Half of this amount was mined from Ontario, which has the largest number of exposed workers (18,000) compared to the rest of Canada (50).

In general, most jurisdictions listed OELs for three forms of nickel and its compounds: elemental nickel, soluble inorganic nickel compounds, and insoluble inorganic nickel compounds. While Ontario's OEL for elemental nickel (7) was slightly lower than the limit recommended by ACGIH (6), it was 20 times higher than the OEL in British Columbia (9) and 100 times higher than the OEL determined by SCOEL (30). Ontario's OELs for the other two forms of nickel were also dramatically higher than the OELs in British Columbia and by SCOEL.

Nickel compounds are classified as carcinogenic to humans (Group 1) according to IARC (42).

Occupational exposure to soluble inorganic nickel compounds is associated with lung damage and suspected nasal cancer risk. Studies of workers demonstrate that exposure to insoluble inorganic nickel compounds is linked to lung cancer (37, 42). Because of this well-established evidence, the ACGIH limits for nickel and its compounds have not changed dramatically since values were first developed in 1966. The OEL recommended by SCOEL was among the most protective of all jurisdictions. It was primarily based upon non-cancer effects on the lung and is likely low enough to also help prevent carcinogenicity (30). Reducing nickel limits in Ontario can help protect against cancer as well as other occupational diseases.

Recommendation

Occupational exposure to small concentrations of soluble and insoluble inorganic nickel compounds are associated with increased risks of nasal and lung cancer. Further efforts should be made to reduce the limits in Ontario to the levels by British Columbia.

Lead

Lead and inorganic compounds, as Pb (CAS No. 7439-92-1)		
	8 hour OEL (mg/m^3)	15 minute OEL (mg/m^3)
ON	**0.05**	
HRSDC, BC, AB, MB, QC, NL, NB, PE, NS	0.05	
SK	0.05	0.15
YT, NT, NU	0.15	0.45
ACGIH	0.05 30 µg/100mL blood	
NIOSH REL	0.05 60 µg Pb/100mL blood	
Germany	0.15 (inhalable aerosol BOELV) 0.1 (RLV)	
SCOEL	0.15 (BOELV) 100 µg Pb/m^3 30 µg Pb/100 mL blood	
Sweden	0.1 (total dust) (rep) (m) 0.5 (respirable dust) (rep) (m)	
Netherlands	70 µg Pb/100 mL blood	

(rt) reproductive toxin
(m) health surveillance required for handling

Lead is a naturally occurring metal in the earth's crust that is normally found as lead sulfide. It forms both organic and inorganic compounds with many substances. IARC considers inorganic lead compounds as a probable human carcinogen (Group 2A) and metallic lead as a possible human carcinogen (Group 2B) (51, 52). This latter classification may change soon as there is a strong, growing body of evidence that shows that lead exposure is carcinogenic to humans.

Occupational lead exposure can occur from fumes (e.g. battery production), dusts, steel welding, and soldering. Canada is the world's ninth largest lead producer and approximately 70,000 workers in Ontario are exposed to lead (53). Ontario (7) listed an air concentration limit which was the same as the OEL recommended by the ACGIH (6) and legally mandated in most of Canada (9, 11-17, 19, 21). This value was the lowest among all jurisdictions surveyed in this analysis. However, the province has not yet adopted or established its own biological exposure limit for lead as other jurisdictions have (e.g. ACGIH, SCOEL) (6, 31). Considering that a large number of Ontario workers are exposed to lead, it is ubiquitous in the environment, and blood values are more strongly associated with health effects compared to air concentrations, it is important to establish biological limits in Ontario that protect workers from exposure. This is particularly important for women of childbearing potential as high blood lead levels increase the risk of having a child with cognitive defects.

Recommendation

Ontario should develop or adapt a rigorous blood lead OEL since blood lead levels are much more indicative of adverse health effects than airborne concentrations.

Other occupational carcinogens

Ontario's OELs for the majority of the 79 carcinogens listed in Table 1 were similar to the OELs across the multiple jurisdictions included and therefore, most of these substances were not discussed in detail in this report. For example, Ontario's OELs for benzene, asbestos, cadmium and cadmium compounds, and hexavalent chromium compounds were generally aligned with limits across Canada and in other jurisdictions. Even where values were relatively homogeneous across jurisdictions, it is important to note that OELs for certain substances are continuing to decrease over time (37). Ontario should monitor these standards and take a lead in establishing rigorous values. This is particularly important for substances that are known to be carcinogenic to humans even at very low levels of occupational exposure.

A number of substances did not have an Ontario OEL yet had high estimated numbers of workers exposed in the province. For example, approximately 449,000 Ontario workers are exposed to solar radiation (54); 275,000 to diesel engine exhaust (55); 103,000 to polycyclic aromatic hydrocarbons (56); 18,000 to ionizing radiation (57), and; 1,150,000 to shift work (58). Additionally, almost 70,000 workers in Ontario are exposed to lead (53) and there is no biological limit value for lead in the province. No OELs were listed in the province for pharmacologic agents and pesticides. Most of these agents are also known and suspected carcinogens (1). Though there are many difficulties associated with evaluating exposure to these carcinogens, these are important gaps to fill with research and through strengthened provincial policies governing OELs.

Discussion

In this analysis we compared Ontario OELs with limits across Canada and in six additional jurisdictions. Eight carcinogens from the list of 79 included in CAREX Canada's database of carcinogen profiles and exposure estimates (4) were discussed in detail in this report because their OELs differed across jurisdictions and their limits in Ontario exceeded the values in other jurisdictions. These eight substances were: chloroform, ethylbenzene, formaldehyde, wood dust, crystalline silica, refractory ceramic fibres, nickel and its compounds, and lead and inorganic compounds (as Pb). By comparing OELs and providing context to specific considerations that were used by different jurisdictions to develop their limits, we have illuminated several opportunities for Ontario to strengthen its OELs and help protect workers from exposure to occupational carcinogens.

Several important findings have emerged from this analysis, with implications for policy and the health of Ontario workers who are exposed to occupational carcinogens. In general, the limits set by Germany, SCOEL, Sweden, and the Netherlands were found to be lower than Ontario's OELs and NIOSH RELs were low relative to most jurisdictions for the eight carcinogens explored in detail. Many values in Canada were equal to the ACGIH OELs since several provinces adopt ACGIH limits. For all carcinogens, there was a clear trend of decreasing OELs over time as accumulating bodies of evidence demonstrated that adverse health effects occurred at lower levels of occupational exposure. Furthermore, there were several priority carcinogens that do not currently have OELs in Ontario yet thousands of workers in the province are estimated to be exposed to these agents. OELs or other limits on exposure for these carcinogens are needed.

The development of OELs is a complex process that involves multiple considerations. Some of these factors are toxicological evidence of carcinogenicity and other chronic and acute health effects in humans and animals; epidemiological studies that demonstrate associations between occupational exposure to a substance and cancer; the technical feasibility of implementing and enforcing OELs in workplaces; and the many interacting political, economic, and social forces that are specific to each jurisdiction, among others. Therefore, the same occupational carcinogen may have different OELs across jurisdictions depending on how they are determined and what the OEL is intended to protect against. The variances in OELs across jurisdictions will lead to differences in workers' level of exposure, which subsequently contribute to higher occupational cancer rates in certain areas.

Conclusions

In summary, we recommend that Ontario lower its OELs for the eight selected occupational carcinogens explored in detail in this report. The province's limits for these substances need to be changed to reflect recent evidence that demonstrates carcinogenicity and other adverse health effects at lower levels of exposure. Ontario should aim to minimize exposure to all occupational carcinogens since no data are currently available on developing OELs that reduce or eliminate risk with complete certainty. Since Ontario is currently in the process of revising its OELs (59), this report's specific recommendations to lower limits in the province can assist with these deliberations while enabling the province to be a leader in establishing rigorous values. An integrative approach that involves continued research and policy efforts are fundamental for protecting workers' health and preventing occupational cancer in Ontario.

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Table 1: Carcinogens currently listed in the CAREX Canada carcinogen profiles and estimates (n=79) (4)

1,2-Dichloroethane	Environmental Tobacco Smoke
1,3-Butadiene	Epichlorohydrin
1,4-Dioxane	***Ethylbenzene**
2,4-D	Ethylene Oxide
2-Nitropropane	***Formaldehyde**
Acetaldehyde	Gasoline
Acrylamide	Hydrazine
Acrylonitrile	Indeno[1,2,3-cd]pyrene
Adriamycin	Indium Phosphide and Other Indium Compounds
Antimony Trioxide	Ionizing radiation
Antineoplastic agents	***Lead**
Arsenic	Lindane
Artificial UV Radiation	Magnetic Fields
Asbestos	MCPA
Benzene	MCPP
Benzo[a]pyrene	Melphalan
Benzo[b]fluoranthene	MOCA
Benzo[k]fluoranthene	Naphthalene
Benz[a]anthracene	***Nickel and its compounds**
Beryllium	Nitrobenzene
Bitumens	PAHs
Bromodichloromethane	para-Dichlorobenzene
Cadmium	Particulate Air Pollution
Carbon black	Pentachlorophenol
Carbon tetrachloride	Phthalates
Chlorambucil	Polychlorinated Biphenyls
Chlorination by-products	Propylene Oxide
***Chloroform**	Radon
Chlorothalonil	***Refractory Ceramic Fibres**
Chromium (hexavalent)	Shiftwork
Cisplatin	Solar Radiation
Coal Tar and Coal-Tar Pitches	Styrene and Styrene-7,8-Oxide
Cobalt	Sulfuric Acid Mists
Creosotes	Tetrachloroethylene
***Crystalline Silica**	Titanium Dioxide
Cyclophosphamide	Toluene Diisocyanates
Dichloromethane	Trichloroethylene
Dichlorvos	Vanadium Pentoxide
Diesel Engine Exhaust	Vinyl Chloride
	***Wood Dust**

*Carcinogens with the most heterogeneous OELs across included jurisdictions and OELs that were higher in Ontario (n=8)

Table 2: Jurisdictions and supporting documentation included in analysis

Jurisdiction	Supporting documentation
Ontario (7,8)	Ontario Occupational Health and Safety Act. R.R.O. 1990, Regulation 833: Control of Exposure to Biological or Chemical Agents. Last Amendment: O. Reg. 419/10. http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900833_e.htm Ontario Occupational Health and Safety Act. Ontario Regulation 490/09: Designated Substances. Last Amendment: O. Reg. 259/10. http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_090490_e.htm
Canada (21)	Canada Occupational Health and Safety Regulations SOR/86-304. Minister of Justice.
British Columbia (9, 10)	Occupational Health and Safety Regulation Guideline G5.48-1: Table of Exposure Limits. http://www2.worksafebc.com/PDFs/regulation/exposure_limits.pdf
Alberta (11)	Alberta Occupational Health and Safety Act. Alberta Occupational Health and Safety Code 2009. http://employment.alberta.ca/documents/WHS/WHS-LEG_ohsc_2009.pdf
Saskatchewan (19)	Occupational Health and Safety Regulations, 1996, O1-1R1. http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/O1-1R1.pdf
Manitoba (12)	The Workplace Safety and Health Act (CCSM c. W210). Workplace Safety and Health Regulation 217/2006. http://safemanitoba.com/uploads/regulations/reg2006consolidated.pdf
Quebec (17)	Occupational Health and Safety Act Schedule 1: Permissible Exposure Values for Airborne Contaminants. http://www2.publicationsduquebec.gouv.qc.ca/documents/lr/txtspc/S-2.1R19.01_EN_00001727.pdf
Nova Scotia (16)	Occupational Health Regulations made under Section 74 of the Health Protection Act SNS 2004, c. 4, OIC 76-1510 (December 21, 1976), NS Reg. 112/76. http://www.gov.ns.ca/just/regulations/regs/hpaohs.htm
New Brunswick (14)	Regulation 91-191 under the Occupational Health and Safety Act (OC 91-1035). http://www.gnb.ca/0062/PDF-regs/91-191.pdf
Prince Edward Island (15)	Chapter O-1.1: Occupational Health and Safety Act, General Regulations. 31 October 2008. http://www.gov.pe.ca/law/regulations/pdf/O&01G.pdf
Newfoundland and Labrador (13)	Regulation 70/09. Occupational Health and Safety Regulations, 2009 under the Occupational Health and Safety Act (OC 2009-233). 7 August 2009. http://assembly.nl.ca/Legislation/sr/regulations/rc090070.htm#42_
Northwest Territories and Nunavut (20)	Safety Act. General Safety Regulations RRNWT 1990,c.S-1. http://www.wcb.nt.ca/YourWSCC/Resources/Documents/Safety%20Regs/General_Safety_NWT.pdf

Yukon Territories (18)	Yukon Occupational Health Regulations. http://www.wcb.yk.ca/Media/documents/Occupational_Health_Regs.pdf
American Conference of Governmental Industrial Hygienists (ACGIH) (6)	ACGIH 2011 Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices.
National Institute of Occupational Safety and Health (NIOSH) (22)	Recommended Exposure Limits from the NIOSH Pocket Guide to Chemical Hazards. http://www.cdc.gov/niosh/npg/
Scientific Committee on Occupational Exposure Limits (SCOEL) (24-32)	Recommendation from the Scientific Expert Group on Occupational Exposure Limits for chloroform. (SEG/SUM/30). SCOEL, 1995. Recommendation from the SCOEL on OELs for formaldehyde (SCOEL/SUM/125). SCOEL, March 2008. Recommendation from the Scientific Expert Group on Occupational Exposure Limits for ethylbenzene (SEG/SUM/28). SCOEL, 1995. Recommendation from the SCOEL: Risk Assessment for wood dust (SCOEL/SUM/102 final). SCOEL, December 2003. Recommendation from the SCOEL for silica, crystalline (respirable dust) (SCOEL/SUM/94). SCOEL, November 2003. Recommendation from the SCOEL for refractory ceramic fibres (SCOEL/SUM/165). SCOEL, September 2011. Recommendation from the SCOEL for nickel and inorganic nickel compounds (SCOEL/SUM/85). SCOEL, June 2011. Recommendation from the SCOEL for lead and its inorganic compounds (SCOEL/SUM/83). SCOEL, January 2002. Binding Occupational Exposure Limits. http://ec.europa.eu/social/main.jsp?catId=153&langId=en&internal_pagesId=684&moreDocuments=yes&tableName=INTERNAL_PAGES
Germany (23)	Recommended (MAK) and legally-binding (AGW) values from GESTIS: International limit values for chemical agents. http://www.dguv.de/ifa/en/gestis/limit_values/index.jsp
Sweden (33)	Provisions of the Swedish Work Environment Authority on Occupational Exposure Limit Values and Measures against Air Contaminants (AFS 2005:17).
Netherlands (34)	Social and Economic Council of the Netherlands (SER). OEL Database. http://www.ser.nl/en/oel_database.aspx

Appendix 1: Research priorities identified by OCRC survey respondents (5)

Occupational exposure category	Number, n[1]	Commonly listed exposures[2]
Chemicals	30	--
Respirable dusts and fibres	27	Asbestos, fiberglass, silica
Radiation	24	Electromagnetic fields, nuclear, cell phone, computer, sun
Shiftwork	16	--
Pesticides	15	--
Nanomaterials	14	--
Exhaust	14	Diesel, gas
Metals and metal compounds	13	--
Work environment	12	Indoor air, environmental tobacco smoke
Solvents	9	Solvents, benzene
Wood, fossil fuels and oils	7	--
Pharmaceuticals	4	Antineoplastic drugs
Plastic and rubber	4	--
Food preparation exposures	2	--

[1] Number of respondents that identified each exposure
[2] Listed by two or more respondents