Biyick, P.-P., Badri, A. et Gauthier, F. (2022). Towards better control of chemical risks associated with mining operations in Quebec (Canada) Part 2: Ranking of the potential effects of chemicals on the health of mining workers. International Review of Applied Sciences and Engineering. doi: https://doi.org/10.1556/1848.2022.00487

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International Review of Applied Sciences and Engineering

DOI:
10.1556/1848.2022.00487

Towards better control of chemical risks associated with mining operations in Quebec (Canada) Part 2: Ranking of the potential effects of chemicals on the health of mining workers

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Received: February 28, 2022 • Accepted: August 2, 2022

ORIGINAL RESEARCH PAPER

ABSTRACT

The mining industry, currently undergoing profound changes, is destined to play an increasingly important economic role in the province of Quebec, Canada. Activity in this sector, its real net impact on government tax revenue, the economy, society, and the creation of wealth, is the subject of much discussion. Occupational health and safety is a major preoccupation in the mining sector, in which considerable numbers of workers suffer workplace accidents or occupational diseases due to the use of industrial chemicals, compounding the problem of exposure to noxious substances that exist naturally in mines or are produced inevitably in the course of normal mining operations. Air in mines thus can become laden with a wide variety of chemical agents, in the form of suspended solids, liquid droplets, and vapors and gases. Long-term exposure to most of these agents can seriously harm the health of mineworkers. Prevention remains the key to avoiding the social and economic consequences of these hazards and will make mining a more attractive sector for investment and employment in Canada.

The principal focus of this study, presented in two articles, is to set a preliminary theoretical framework for categorizing chemicals in terms of their effects on the health of mineworkers throughout the various phases of mining projects. The objective is to decrease (over the long term) the number of occupational diseases due to the use of chemicals by raising awareness among employers and exposed workers in the mining sector.

This research was conducted in four phases. The first article presented a review of the literature [1] on the chemical aspects of health and safety in mining in the province of Quebec. In the present article, the findings on the recurrence of health problems attributable to chemicals encountered in mines and how these effects should therefore be ranked from an occupational health and safety perspective are presented. The results show that various forms of dermatitis are the most recurrent health and safety risk.

KEYWORDS

occupational health and safety, mining projects, chemical agents, globally harmonized system of classification and labeling of chemicals, safety data sheets, Quebec (Canada)

1. INTRODUCTION

In 2018, the Quebec mining industry employed 17,909 persons directly or indirectly in some aspect of mineral extraction, up to and including mine shutdown and rehabilitation of sites [2]. Numerous chemical agents come into play during the initial process of transforming ores into saleable minerals. Most of the occupational diseases caused by these agents are not diagnosed early, and symptoms often are not apparent until after several years of exposure [3, 4].

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Gases, vapors, dust, and smoke also can accumulate in mines and have harmful effects on the human body if inhaled at concentrations much higher (50 times higher may be lethal) than the safety limit, defined usually for 4 h of exposure [5]. However, the risk is seldom negligible at low concentrations and must be taken into consideration.

Chemical-associated OHS risks and potential health effects compiled previously [1] have been characterized for the chemical industry in general, using indexes such as short-term exposure and time-weighted average exposure limits, toxicological data, and the danger statement on each safety data sheet in the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) (GHS) [6]. The toxicity of a chemical depends on several factors, primarily the duration of exposure, the frequency of exposure and toxicological (concentration) data [7]. All toxic effects appear more markedly with longer exposure [8].

The Ontario occupational cancer research center estimates at 1,300 per year the number of cancers associated with exposure to asbestos, diesel motor exhaust or crystalline silica during work in mines [9]. Occupational diseases tend to have long latent periods and not to manifest themselves until long after exposure to the causal chemical agent [10]. This accounts for most of the indemnities paid out between 2008 and 2017 in the mining sector [11].

In Quebec, the number of occupational lesions related to chemicals in general is about 1,500 cases per year [12]. Of these, 326 were recorded in the mining sector during the years 2010–2012 [13]. The agents listed in our previous article [1] are the cause of afflictions of the skin and mucus membranes (irritation, eczema, etc.), the respiratory system (asthma, hypersensitivity pneumopathy, cancer, etc.), the nervous system (parkinsonian syndrome, etc.), kidneys, urinary bladder, liver (kidney failure, cancer, etc.), blood (anemia, leukemia, etc.), heart (cardiac arrhythmia, infarction, etc.) and circulatory system [14].

Some risk management tools have been used to attempt to lower occupational risks in the mining industry [15]. However, this practice is often limited and does not extend systematically to the use of chemicals or the generation of noxious chemical substances by mining activities.

Having reviewed the literature available on chemical hazards in the mining industry in Quebec [1], this paper presents the second part of the framework for defining in detail the consequences of exposure of workers throughout the various phases of mining projects, by focusing on the number of recurrences of harmful effects attributable to chemicals. A ranking of risk management is then proposed accordingly. The aim is to recommend ways of raising greater awareness among exposed workers and on the long-term to decrease the numbers of occupational disease cases in the industry.

The rest of this article is organized as follows: Section 2 provides a description of the research methodology used to attain the main goal of the study overall and of this article specifically. The results of the present research are presented in Section 3 and discussed in Section 4. Conclusions are presented in Section 5.

2. METHODOLOGY

The methodological approach features a theoretical framework presented previously [1] and a practical framework, presented here. The former consisted of listing the chemical agents known to have some negative impact on workers' health during each of the four phases of a mining project and identifying these effects, based on a review of the literature [1]. The practical aspect is also two-fold: ranking of occupational diseases according to their potential recurrence, and ranking of chemical agents according to their potential of risk (Fig. 1).

2.1. Ranking of occupational diseases according to their potential recurrence

This step consists of tallying recurrences of harmful effects on mineworkers potentially due to each of the chemicals listed in Table 1 through 4 in the previous article [1]. Standardization of the potential effects and the set of chemical agents are shown in Appendix (Table A1) in the form of contingency matrix K with $q \times m$ dimensions crossing variables X_1 (potential occupational diseases) and X_2 (chemical agent) having respectively q and m modalities observed.

The harmonized system safety code indicator (H…) refers to the risk associated with using a chemical in a mining operation during any of the four phases of a mining project. It defines the likelihood of the risk associated with an agent in the sample n_j from the set of agents catalogued. Starting from this information, the risk inherent in each chemical is used also to define and rank an occupational disease based on the number n_i of recurrences. This step provides the objective elements used to determine and analyze the research results presented in the next section.

2.2. Ranking of chemical agents according to their potential of risk

Ranking the OHS effects potentially attributable to chemicals provides an evaluation of the relative risk associated with each based on the combination of the intrinsic hazard level (gravity) and the intensity (frequency) of exposure. For this model, the hazard criterion is scored on a 4-level scale based on the harmonized system (GHS) statement (or mention) of health risk on safety data sheets, namely

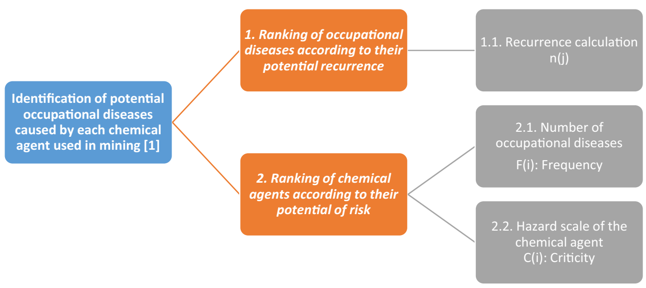

Fig. 1. Methodological approach

Table 1. Potential harmful effects of exposure to chemicals in mining

Harm caused by exposure to the chemical	Potential effects on health (occupational disease)	Organs affected
Burns or irritates on contact	Dermatitis	Skin
Genetic anomalies or other afflictions following ingestion or inhalation	Kidney disease	Internal
Not immediately apparent physiological consequences	Cancer	Skin, internal
Respiratory distress or symptoms appearing later	Asthma	Lungs, trachea
Serious lesions or irritation	Fibrosis	Eyes, skin
Respiratory or visual difficulty, rash, carcinogenesis	Mesothelioma	Skin, lungs
Respiratory tract distress after inhalation, ingestion	Pulmonary disease	Lungs
Possibly fatal reactions when inhaled or in contact with skin	Silicosis	Nose, sinuses, eyes
Possibly fatal reactions when inhaled or in contact with skin, carcinogen	Asbestosis	Lungs

Sgh05, Sgh06, Sgh07, Sgh08. The exposure criterion is defined by the "H" code and the category of hazard.

The estimated level of risk is presented in Section 4 as results in matrix form with rows corresponding to hazard category. Table A1 shows the risk code determined according to the number of recurrences as a function of the standardized potential effects on health.

The catalogued chemicals are ranked using the 4-level qualitative health hazard scale: 4 = critical (Cat. 1, Cat. 1A/1B/1C), 3 = high (Cat. 2), 2 = moderate (Cat. 3), 1 = low (Cat. 4). The risk criterion for each chemical is chosen based on the maximal multiplication of the number of occupational diseases and the hazard level of the chemical agent.

3. RESULTS

The potential harmful effects of chemicals encountered in mines are identified in Section 3.1 below. The number of recurrences of these effects and their ranking are given in Sections 3.2–3.4.

3.1. Identifying of the potential occupational diseases of chemicals on the health of mineworkers

The chemical agents catalogued previously [1] are recognized as potential health hazards in the workplace when they bear the mention "H" for hazards in their safety data sheet, in accordance to the GHS. Only 29 mentions of hazards (47% of all physical, health and environmental risks) listed in the safety data sheets are relevant to the present research work. These concern occupational diseases well known in the Quebec mining sector: acute toxicity, serious eye lesions, eye irritation, respiratory or skin sensitivity, mutagenicity, carcinogenicity, toxicity during production, specific toxicity targeting certain organs, danger of inhalation. Table 1 shows the occupational diseases resulting potentially from exposure to each chemical as a function of the mention of hazards on the safety data sheet.

3.2. Recurrences of the occupational diseases attributable to exposure to chemicals in mines

The potential effects of exposure of mineworkers to the chemicals listed previously [1] are based on title 9 (chemical property information) and title 11 (toxicological information) of the safety data sheet. The method used to calculate n_j is also used to group chemical agents, safety data sheet information, occupational disease family, risk score and risk level in Table A1.

The numbers of recurrences of the occupational diseases defined in OHS and grouped by chemical agent are shown in Table 2.

3.3. Ranking of occupational diseases according to their potential recurrence

The relative significance of each of the 9 potential occupational diseases related to chemicals encountered in mining, based on the numbers of recurrences (Table 2 above), is represented graphically in Fig. 2 below.

3.4. Ranking of chemical agents according to their potential of risk

Based on the potential occupational diseases determined above, the chemical agents can be ranked in decreasing order as a function of the safety data sheet H (hazard) status. Figure 3 (derived from Table A1) shows their grouping into 4 hazard categories or OHS priorities (category 1/1A/1B/1C critical, category 2 high, category 3 moderate, category 4 low). Figure 4 shows the ranking relative to the maximal risk score of each chemical listed in Table A1.

Table 2. Calculated recurrences of occupational diseases in mines

Potential effects on health (occupational disease)	Total number of recurrences $n(j)$	% of recurrences
Dermatitis	105	47.3
Pulmonary disease	46	20.72
Asthma	30	13.51
Kidney disease	17	7.66
Cancer	15	6.67
Mesothelioma	4	1.8
Fibrosis	2	0.9
Silicosis	2	0.9
Asbestosis	1	0.45
Total	*222*	*100%*

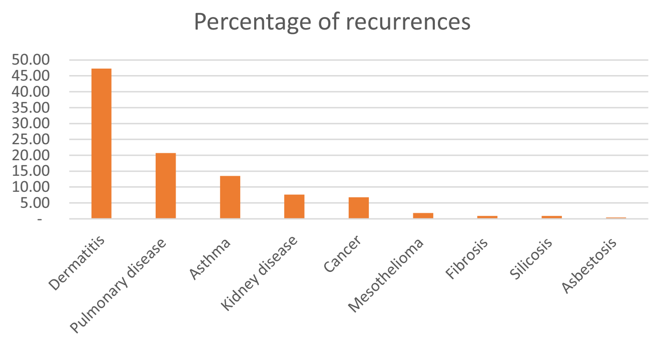

Fig. 2. Classification of occupational diseases according to their recurrence $n(j)$

4. DISCUSSION

The results in this article are in fact based entirely on the exploratory analysis of the literature available on chemicals encountered by mineworkers in Quebec, occurring naturally or used in operations associated with one or more stages of mining projects [1], and on the health hazards they appear to represent, based on safety data sheets and statistics provided by the CNESST, the provincial compensation board.

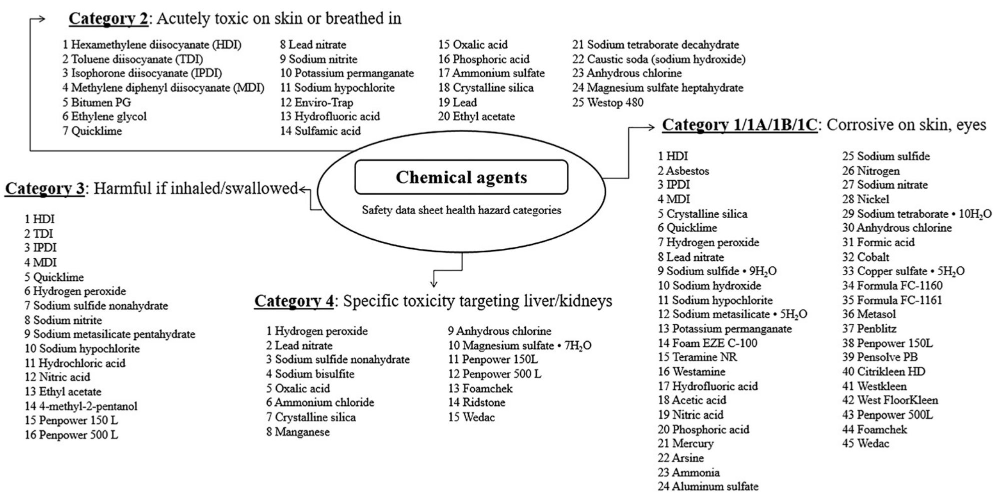

Fig. 3. Chemicals agents and cleaning products used in the mining industry, categorized by health hazard

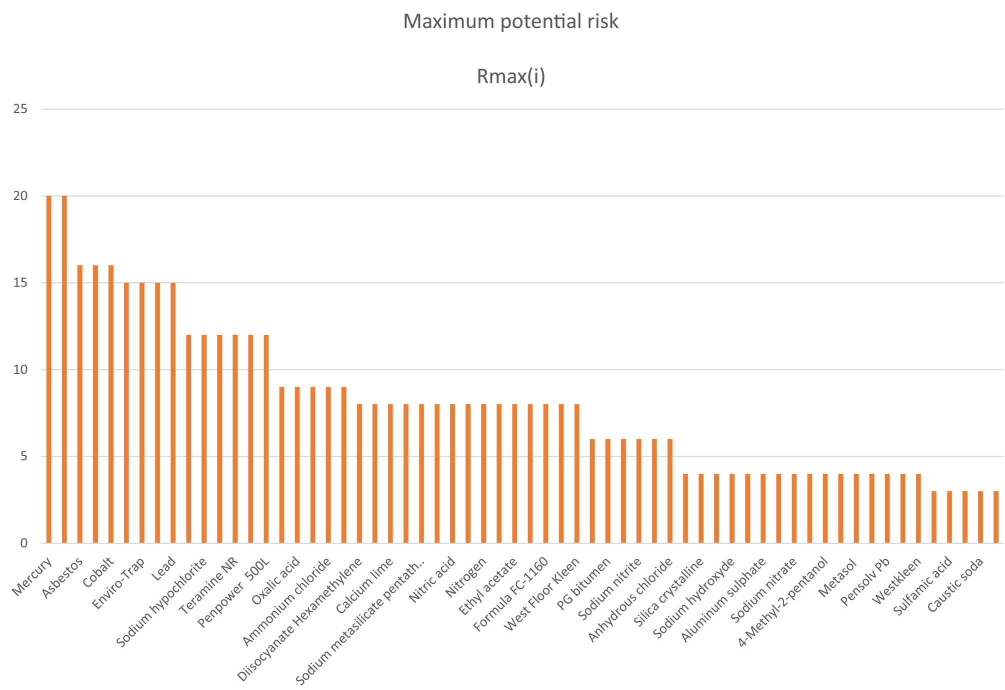

Fig. 4. Ranking of chemical agents according to their potential of risk (Rmax(i))

4.1. Representativity of the repertory of chemical agents

The list of chemicals was derived from rational evaluation of mining practices without focusing on the details of the work environment in this sector [1]. Of the 85 chemicals used during at least one of the four stages of a mine lifecycle (exploration, development, extraction, and shutdown), 64 (80%) are not rated for short-term-exposure concentration limit, 48 (60%) are not rated for time-weighted average concentration limit, 4 (5%) are not associated with any specific harm and 3 (3.75%) have no health hazard mentioned in the harmonized system. The chemicals for which short-term exposure data are available are used during extraction (16%), development (15%), shutdown (11%), and exploration (9%). In the absence of specification of these tolerable exposure limits, especially acute toxicities, the OHS-defined harm associated with exposure to these substances cannot be verified.

4.2. Characteristics used to rank chemicals based on potential occupational diseases

Among the numerous agents to which mineworkers are exposed by inhalation are gaseous fallout from the use of explosives, diesel motor exhaust, smoke or dust produced by drilling, rock fractures and evacuation, metal refining, welding, and vapors from cleaning products. About 47% of the most recurrent harms representing occupational disease are dermatitis, followed by pulmonary disease (21%) and asthma-like syndromes (14%). Allergic contact dermatitis is enhanced by pre-existing skin conditions. Cuts, sores, and abrasions also facilitate the development of allergen-associated dermatitis. The grouping of these principal categories of occupational disease is only approximate, based on what was suggested by the data retrieved during this study. It should be noted that occupational disease risk factors can be controlled by technical means that employers are free to implement to reduce or prevent needless exposure of mineworkers to chemical hazards, including safe work methods, properly adapted ventilation systems and adequate monitoring of air quality, spills, and worksite cleanliness.

4.3. Characteristics used to rank chemicals as hazards

Safety data sheets, an essential decision aid tool, contain limited information but nonetheless sufficient for ranking chemical agents using a simplified method based on determining the number of recurrences of symptoms or conditions suggesting a health hazard, as shown in Table A1.

Using the number of recurrences and the H status, ranking of the chemicals in decreasing order allowed to define four families (Fig. 4), based on maximal hazard scores of 20–16, 15–12, 9–6, and 4–3, and each corresponding to a specific category of OHS-defined health hazard. The fourth family contains 50% of the chemical agents, these causing burns on the skin and serious lesions on the eyes of mineworkers. This finding and its implications are straightforward. Using a simple method and minimal information, a mining company can orient a prevention program and OHS strategies insofar as chemical agents are concerned. However, this method does not yet suggest how to reduce specific chemical risks.

4.4. Prevent occupational diseases

The prevention of occupational diseases caused by chemical agents is a difficult task and mines must tackle the source of the problem. Several researches recommend these measures [16, 17]:

- Know the hazards in the workplace (e.g. learn about the products that are used, their hazards and the measures to protect yourself).
- Develop (for employers) and adopt (for employees) systems, procedures, practices and programs that are designed to protect people from chemical hazards in the workplace.
- Transmit all information concerning health hazards and exposure to employees. Provide appropriate training and information regarding the hazards that are present.
- Work with health professionals to assess occupational illnesses that have characteristics indicating that they are likely in the workplace.
- Keep a list of all jobs held and the sectors of activity in which workers may be exposed to chemical agents.
- Review the conditions of employment.
- Train workers and managers to make them aware of OHS legislation and regulations.
- Offer OHS support for workers and managers.
- Develop tools to facilitate their work (e.g. software to consult the worker's experience and the training courses followed before entrusting them with tasks).
- Stay on standby to be able to replace chemical products with others that do not present any danger.
- Provide individual and collective protective equipment and ensure their proper use and maintenance.

This list proposes the main lines and the mines must set up a fairly detailed prevention program. They can refer to the various occupational disease prevention programs in other activity sectors in Quebec, such as construction and manufacturing. It is clear that the involvement of an occupational physician is necessary in this preventive work.

4.5. Limitations of this research, and prospects

This portrait of the health risks associated with exposure to chemical agents encountered in mining, both those used in operations and those that occur naturally, remains incomplete. Among the limitations of this preliminary and exploratory study are the absence of mineralogical analysis of aerosols and discussion of specific methods of raising awareness among exposed workers and of lowering over the long term the risks of developing occupational diseases.

The evaluation of the chemical hazards was based mainly on safety data sheets, primarily the hazard symbol and associated statement, which was advantageous for our purposes. However, the incompleteness of the short-term and time-weighted average exposure concentration data was an obstacle to obtaining more detailed results. Analyses of field samples or workplaces in which multiple mining-related contaminants are present would have strengthened our study. It is nevertheless possible to compare in considerable detail product information available at supplier websites and occupational disease statistics to rank the risks thus identified. Future research could build on the present study, using the results presented here as a database in a project focused more on the management of chemical risks associated with mining activities, for example the design of risk ranking software.

5. CONCLUSION

This paper exposes the health risks associated with chemicals to which workers are exposed during mining operations in Quebec. The research began by reviewing the literature to compile a catalog of the chemical agents used or encountered naturally during at least one phase of the mining project lifecycle and to identify worker health conditions potentially due to this exposure, referring mainly to general harmonized system safety data sheets. The results of this review are published elsewhere [1]. Then sought to guide OHS priorities by ranking the potential effects of chemicals on the health of mineworkers as a function of their recurrence in claims for worker compensation. According to this objective ranking, dermatitis was the most frequent basis for claims, recurring 105 times, while the most problematic family of chemicals had a hazard score of 20.

Despite certain limitations, this research has contributed to the identification of strengths and deficiencies in the evaluation of chemical hazards. In view of the number of chemical agents encountered throughout the lifecycle of a mining project and their potential effects on worker health, the findings of this study reiterate the urgency of OHS research and field practice and suggest how these activities might be ranked.

Author Contributions: This paper is entirely based on the results of research conducted by Paul-Patrice Biyick as part of his master's project in industrial safety and hygiene under the direction of Professors Adel Badri and François Gauthier. Adel Badri has written the paper in collaboration with Paul-Patrice Biyick and François Gauthier. All authors have read and agreed to the published version of the manuscript.

Funding: The authors thank the Université du Québec à Trois-Rivières (UQTR), Fonds de recherche du Québec - Société et culture (FRQSC) and Natural Sciences and Engineering Research Council of Canada (NSERC) for their financial support.

REFERENCES

[1] P.-P. Biyick, A. Badri, and F. Gauthier, "Towards better control of chemical risks associated with mining operations in Quebec (Canada) - Repertory of chemicals used in mining," *Int. Rev. Appl. Sci. Eng.*, 2022.

[2] L. Madore, "Mines en chiffres : la production minérale au Québec en 2018," 2020.

[3] Institut National de Recherche et de Sécurité, "Accidents du travail et maladies professionnelles (AT-MP)," 2021.

[4] International Labour Organization, "List of occupational diseases - identification and recognition of occupational diseases: Criteria for incorporating in the ILO list of occupational diseases," 2010.

[5] Ministère de l'Énergie et des Mines de la Colombie Britannique, "Manuel de sauvetage minier de l'ouest du Canada," 2015.

[6] Organisation Mondiale de la Santé, "Rapport historique sur les effets pour l'homme de l'exposition aux perturbateurs endocriniens chimiques," 2013.

[7] M. Valcke, "Caractérisation des facteurs toxicocinétique interindividuelle aux fins de l'analyse du risque toxicologique," 2014.

[8] M. Reynier, "Le règlement REACH, conséquences pour la prévention des risques cliniques en milieu professionnel," 2007.

[9] Cancer Care Ontario, "Ontario cancer statistics 2018," 2019.

[10] Centre international de recherche sur le cancer, "Les gaz d'échappement des moteurs diesel cancérogènes," 2012.

[11] Centre canadien d'hygiène et de sécurité au travail, "Le point sur les dangers pour le système respiratoire," 2019.

[12] Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST), "Statistiques annuelles 2019," 2019. 192 p.

[13] Institut de Recherche Robert-Sauvé en Santé et en sécurité du Travail, "Plan quinquennal 2018-2022: Prévention des risques chimiques et biologiques," 2017.

[14] Ministère du Travail de la Formation et du Développement des compétences de l'Ontario, "Maladies professionnelles dans le secteur minier," 2019.

[15] S. Beaupré, "Des risques, des mines et des hommes : La perception du risque chez les mineurs de fond de l'Abitibi-Témiscamingue," *Les Presses de l'Université du Québec,* vol. 2e édition, 2012.

[16] E. Ledoux, S. Beaugrand, C. Jolly, S. Ouellet and P.-S. Fournier, "Prise en charge de la SST dans les mines souterraines: témoignages de cadres et de représentants des travailleurs Étude exploratoire," IRSST R-1016, 2010. Available: Prise en charge de la SST dans les mines souterraines: témoignages de cadres et de représentants des travailleurs (irsst.qc.ca).

[17] Canadian Centre for Occupational Health and Safety (CCOHS), "Occupational hygiene - occupational disease," 2022. Available: Occupational Hygiene - Occupational Disease: OSH Answers (ccohs.ca).

Appendix

Table A1

Chemical Agent	Hazard code (H)	Hazard category	Potential harm to health									Number of occupational diseases F(i): Frequency	Hazard level of the chemical agent C(i): Gravity	Relative potential risk R(i)= F(i)*C(i)	Maximum potential risk Rmax(i)	Chemical Agent
			Cancer	Kidney	Mesothelioma	Pulmonary	Asbestosis	Fibrosis	Silicosis	Dermatitis	Asthma					
Diisocyanate Hexamethylene	H315; H319	Cat.2								1		1	3	3	8	Diisocyanate Hexamethylene
	H317	Cat.1/1A /1B								1		1	4	4		
	H331; H335	Cat.3		1		1				1		3	2	6		
	H334	Cat.1/1A/1B								1	1	2	4	8		
Toluene diisocyanate	H315; H319	Cat.2								1		1	3	3	6	Toluene diisocyanate
	H331, H335	Cat.3				1			1	1		3	2	6		
Asbestos	H350	Cat.1A/1B								1		1	4	4	16	Asbestos
	H372	Cat.1			1		1	1		1		4	4	16		
Isophorone diisocyanate	H331;H335	Cat.3		1						1		2	2	4	4	Isophorone diisocyanate
	H315; H319	Cat.2								1		1	3	3		
	H314	Cat.1/1A /1B								1		1	4	4		
Diisocyanate 4-4 diphenylmethane	H331; H335	Cat.3								1		1	2	2	8	Diisocyanate 4-4 diphenylmethane
	H315 ;H319	Cat.2								1		1	3	3		
	H350	Cat.1A /1B	1							1		2	4	8		
Silica crystalline	H350	Cat.1A/1B								1		1	4	4	4	Silica crystalline
PG bitumen	H351	Cat.2	1							1		2	3	6	6	PG bitumen
Ethylene glycol	H302	Cat.2				1				1		2	3	6	6	Ethylene glycol
Calcium lime	H315	Cat.2								1		1	3	3	8	Calcium lime
	H318	Cat.1								1		1	4	4		
	H350	Cat.1A/1B	1							1		2	4	8		
	H372	Cat.3		1						1		2	2	4		
Hydrogen peroxide	H318	Cat.1								1		1	4	4	8	Hydrogen peroxide
	H317	Cat.1A/1B	1							1		2	4	8		
	H335	Cat.3				1				1	1	3	2	6		
	H302; H332	Cat.4				1				1		2	1	2		
Lead nitrate	H318	Cat.1								1		1	4	4	12	Lead nitrate
	H360	Cat.1A/1B	1	1						1		3	4	12		
	H373	Cat.2	1							1		2	3	6		
	H302; H332	Cat.4				1				1	1	3	1	3		
Sodium sulfide nonahydrate	H318 ;H314	Cat.1 Cat.1B								1		1	4	4	4	Sodium sulfide nonahydrate
	H311	Cat.3								1		1	2	2		
	H302	Cat.4				1				1		2	1	2		
Sodium hydroxyde	H318	Cat.1								1		1	4	4	4	Sodium hydroxyde
	H314	Cat.1B								1		1	4	4		
Sodium hypochlorite	H314	Cat.1B								1		1	4	4	12	Sodium hypochlorite
	H318	Cat.1		1		1				1		3	4	12		
Sodium nitrite	H314	Cat.2								1		1	3	3	6	Sodium nitrite
	H301	Cat.3				1				1	1	3	2	6		
Sodium metasilicate pentath..	H314	Cat.1B								1		1	4	4	8	Sodium metasilicate pentath..
	H318	Cat.1								1		1	4	4		
	H335	Cat.3		1		1				1	1	4	2	8		
Sodium bisulphite	H302	Cat.4				1				1	1	3	1	3	3	Sodium bisulphite
Potassium permanganate	H314 ; H318	Cat.1/1C								1		1	4	4	15	Potassium permanganate
	H362 ; H373	Cat.2	1	1	1	1				1		5	3	15		
Chlorine	H315 ; H319	Cat.2				1				1	1	3	3	9	9	Chlorine
	H331	Cat.3				1				1	1	3	2	6		
Enviro-Trap	H351	Cat.2	1	1		1				1	1	5	3	15	15	Enviro-Trap
Foam-EZE C-100	H310	Cat.1				1				1	1	3	4	12	12	Foam-EZE C-100
Teramine NR	H310	Cat.1				1				1	1	3	4	12	12	Teramine NR
Westamine	H310	Cat.1	1			1				1	1	4	4	16	16	Westamine
Hydrofluoric acid	H310	Cat.2		1		1				1	1	4	3	12	12	Hydrofluoric acid
	H330 ; H318	Cat.1				1				1	1	3	4	12		
	H314	Cat.1A/1B				1				1		2	4	8		
Acetic acid	H314	Cat.1A/1B/1C		1						1		2	4	8	8	Acetic acid
Hydrochloric acid	H314 ; H335	Cat.3				1				1	1	3	2	6	6	Hydrochloric acid
Sulfamic acid	H315 ; H319	Cat.2								1		1	3	3	3	Sulfamic acid
Nitric acid	H318	Cat.1				1				1		2	4	8	8	Nitric acid
	H314	Cat.1B		1						1		2	4	8		
	H331	Cat.3				1				1	1	3	2	6		
Oxalic acid	H318	Cat.1								1		1	4	4	9	Oxalic acid
	H373	Cat.2		1		1				1		3	3	9		
	H302 ;H312	Cat.4				1				1		2	1	2		
Phosphoric acid	H314	CAT.1B								1		1	4	4	9	Phosphoric acid
	H318	Cat.2				1				1	1	3	3	9		
Mercury	H372	Cat.1		1	1	1				1	1	5	4	20	20	Mercury
Arsine	H314 ; H318	Cat.1				1				1		2	4	8	8	Arsine
Ammonia	H314; H318	Cat.1								1		1	4	4	4	Ammonia
Aluminum sulphate	H318	Cat.1								1		1	4	4	4	Aluminum sulphate
Sodium sulphide	H314; H318	Cat.1								1		1	4	4	4	Sodium sulphide
Ammonium chloride	H302	Cat.2				1				1	1	3	3	9	9	Ammonium chloride
	H319	Cat.4		1		1				1	1	4	1	4		
Ammonium chloride	H315; H319	Cat.2				1				1	1	3	3	9	9	Ammonium chloride
Nitrogen	H318	Cat.1				1				1		2	4	8	8	Nitrogen
Sodium nitrate	H314 ; H318	Cat.1								1		1	4	4	4	Sodium nitrate
Crystalline silica	H302 ; H351	Cat.2	1			1		1	1	1		5	3	15	15	Crystalline silica
	H332	Cat.4								1		1	1	1		
Nickel	H350	Cat.1A/1B	1							1		2	4	8	8	Nickel
Lead	H373	Cat.2		1	1	1				1	1	5	3	15	15	Lead
Manganese	H302 ; H332	Cat.4				1				1	1	3	1	3	3	Manganese
Ethyl acetate	H336	Cat.3	1			1				1	1	4	2	8	8	Ethyl acetate
	H319	Cat.2								1		1	3	3		
Sodium tetraborate decahydrate	H319	Cat.2								1		1	3	3	20	Sodium tetraborate decahydrate
	H360	Cat.1A/1B	1	1		1				1	1	5	4	20		
Caustic soda	H336	Cat.2								1		1	3	3	3	Caustic soda
Anhydrous chloride	H317 ; H318	Cat.1								1		1	4	4	6	Anhydrous chloride
	H315	Cat.2	1							1		2	3	6		
	H302	Cat.4				1				1	1	3	1	3		
Sulfate heptahydrate	H315 ; H319	Cat.2								1		1	3	3	3	Sulfate heptahydrate
	H302	Cat.4				1				1		2	1	2		
Formic acid	H314	Cat.1A/1B		1						1		2	4	8	8	Formic acid
Cobalt	H317 ; H334	Cat.1/1A/1B	1			1				1	1	4	4	16	16	Cobalt
Copper sulfate pentahydrate	H318	Cat.1								1		1	4	4	4	Copper sulfate pentahydrate
4-Methyl-2-pentanol	H335	Cat.3				1					1	2	2	4	4	4-Methyl-2-pentanol
Formula FC-1160	H318	Cat.1				1				1		2	4	8	8	Formula FC-1160
Formula FC-1161	H318	Cat.1								1		1	4	4	4	Formula FC-1161
Metasol	H318	Cat.1								1		1	4	4	4	Metasol
Penblitz	H318	Cat.1								1		1	4	4	4	Penblitz
Penpower 150L	H302 ; H312	Cat.4								1		1	1	1	8	Penpower 150L
	H335	Cat.3								1		1	2	2		
	H318	Cat.1				1				1		2	4	8		
Pensolv Pb	H314	Cat.1								1		1	4	4	4	Pensolv Pb
Citrikleen HD	H314	Cat.1								1		1	4	4	4	Citrikleen HD
Westkleen	H314	Cat.1								1		1	4	4	4	Westkleen
West Floor Kleen	H315 ; H319	Cat.1								1	1	2	4	8	8	West Floor Kleen
Penpower 500L	H302 ; H312	Cat.4				1				1		2	1	2	12	Penpower 500L
	H336	Cat.3										0	2	0		
	H318	Cat.1				1				1	1	3	4	12		
Recurrence of occupational diseases n(j)			15	17	4	46	1	2	2	105	30					