

# Identification of Workers Exposed Concomitantly to Heat Stress and Chemicals

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**Abstract.** In the context of climate change, concomitant exposure to heat stress and chemicals takes on great importance. However, little information is available in this regard. The purpose of this research, therefore, was to develop an approach aimed at identifying worker groups that would be potentially most at risk. The approach comprises 5 consecutive steps: – Establishment of a list of occupations for all industry sectors – Determination of heat stress parameters – Identification of occupations at risk of heat stress – Determination of exposure to chemicals – Identification of occupations potentially most at risk. Overall, 1,010 occupations were selected due to their representativeness of employment sectors in Québec. Using a rating matrix, the risk stemming from exposure to heat stress was judged “critical” or “significant” for 257 occupations. Among these, 136 occupations were identified as showing a high potential of simultaneous exposure to heat stress and chemicals. Lastly, a consultation with thirteen experts made it possible to establish a list of 22 priority occupations, that is, 20 occupations in the metal manufacturing sector, as well as roofers and firefighters. These occupations would merit special attention for an investigation and evaluation of the potential effects on workers’ health.

**Key words:** Chemical, Heat stress, Risk matrix, Occupational exposure

## Introduction

Exposure to cold or heat triggers a series of compensatory physiological responses that help the human body maintain its internal temperature despite thermal stress. In Québec, between 1983 and 2003, heat exposure caused the deaths of nine workers associated with activities such as reforestation, construction and farming. Cold work can also lead to health problems, but this issue is much less alarming, at least in Québec, where workers usually use effective protection methods<sup>1)</sup>.

Studies in the pharmacology sector show an increase in the absorption and effects of certain drugs when they are administered simultaneously to heat exposure<sup>2, 3)</sup>. In addition, epidemiological studies on the impact of simultaneous exposure to heat stress and air pollution revealed a significant effect on mortality rate<sup>4, 5)</sup>. Extrapolating these population data to workplace gives cause to believe that concomitant exposure to heat stress and chemicals is likely to increase the potential risk for workers’ health. Exposure to chemicals can affect the thermoregulatory mechanisms in humans<sup>6)</sup>, thereby reducing workers’ capacity to adapt to heat stress. For example, metal fumes can be the cause of toxic manifestations characterized by fever<sup>7, 8)</sup>. In addition, exposure to heat stress triggers a series of physiological responses that are likely to modify the absorption,

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metabolism and toxicity of chemicals<sup>9, 10</sup>). The amounts of xenobiotics absorbed through the lungs and the skin during work in a hot environment can be increased significantly due to higher pulmonary ventilation and cutaneous blood flow<sup>8, 11</sup>). Therefore, the overall impact of heat exposure translates, in most cases, into an increased concentration of xenobiotics in the biological fluids. Since the “internal dose” of contaminant is increased, more health effects may be reported by workers<sup>3, 12</sup>). The interaction of chemicals and workplace heat would therefore have a significant impact on the toxicity of contaminants when exposure levels approach admissible concentrations<sup>13</sup>). Since climate change and global warming are unequivocal, more workers will be exposed to heat stress<sup>14, 15</sup>). However, little information is available in this regard.

Therefore, the purpose of this research paper is to develop an approach aimed at identifying worker groups that would be potentially most at risk due to their concomitant exposure to heat stress and chemicals.

## Method

The general evaluation method is based on a matrix analysis and the judgement of experts. Five consecutive steps were required: – Establishment of a list of occupations for all industry sectors – Determination of heat stress parameters – Identification of occupations at risk of heat stress – Determination of exposure to chemicals – Identification of occupations potentially most at risk.

### *Establishment of a list of occupations for all industry sectors*

A list of occupations was drawn up using employment data from different sources<sup>16–20</sup>), primarily that of “*Comités sectoriels de main-d’œuvre d’Emploi Québec*”<sup>21</sup>). Occupations were broken down according to economic sectors or subsectors based on the North American Industry Classification System (NAICS)<sup>22</sup>). In order to standardize data and job titles, this study made use of the National Occupational Classification, the authoritative resource on occupational information in Canada<sup>23</sup>).

### *Determination of heat stress parameters*

Six basic parameters are generally used to evaluate heat transfer in the workplace. First, those of an environmental nature: air temperature (dry temperature), air humidity, air speed and temperatures of surrounding surfaces (radiation temperature). There are also parameters related to clothing and energy expenditure (work metabolism)<sup>24</sup>). While all

these factors are measurable quantitatively, the last two depend mainly on requirements related to production rules and procedures, as well as the tasks carried out by an individual at his work station.

Only four of these six parameters were selected to prioritize occupations at risk of heat stress: temperature, humidity, radiating energy and work energy expenditure. Air circulation speed and clothing insulation are factors that could not be taken into consideration since their use would have required speed measures and real-time observation data for each specific work situation. The impact of heat waves was not taken into account, nor was that of exposure to cold among individuals working outside during the winter.

In addition, it should be noted that the parameter related to energy expenditure takes on great importance in evaluating occupational exposure to heat stress, due to certain circumstances characterizing the job. For example, a roofer’s work must be carried out in clear, sometimes hot weather, based on an unconventional schedule, and requires significant physical exertion due to the heavy loads and different restrictive body positions involved. To evaluate this parameter, the Ainsworth Compendium of Physical Activities of Arizona State University<sup>25</sup>), which assigns MET (metabolic equivalent) intensity units to physical activity, was used.

### *Identification of occupations at risk of heat stress*

To identify the occupations at risk of heat stress, each of the 4 heat stress parameters was evaluated by using judgement criteria and developing a risk rating matrix. There is always a part of subjectivity in an approach based on professional judgement. However, the use of risk matrices in this study gives a systematic dimension to the evaluation of heat stress parameters.

### *Judgement criteria for each heat stress factor*

The 4 heat stress parameters were evaluated using criteria from occupational health and safety standards and regulations<sup>26, 27</sup>). These criteria then made it possible to judge *a priori* the role and significance of each heat stress parameter in terms of working conditions. It may therefore be a satisfactory work situation showing thermal comfort, without risk, or, conversely, an unsatisfactory situation. Table 1 presents an overview of the judgement criteria used.

### *Heat stress risk rating matrix*

The characterization of the risk stemming from heat

**Table 1. Judgement criteria for evaluating heat stress**

Factors	Judgement	Criteria
Temperature	Low	Cool, cold or freezing temperature
	Normal	Generally between 15 and 27°C
	High	From 28 to 35°C
	Very High	Over 35°C
Humidity	Low	Dry throat, nose and/or eyes after 2–3 h (<20%RH <sup>1</sup> )
	Normal	Same as outside (between 30 and 60/70%HR)
	High	Clammy skin (60–80%RH)
	Very High	Wet skin (>80%RH)
Radiation	Cold	Cold sensation on hands/face after 2–3 min
	Normal	No perceptible heat radiation
	Hot	Hot sensation on hands/face after 2–3 min
	Very Hot	Impossible to keep hands/face exposed for 2 min or less
Work Load	Light (<1.6 MET <sup>2</sup> )	Work seated, requiring moderate exertion
	Average (1.6 and 3.0 MET)	Work seated or standing with greater exertion
	Heavy (3.1 and 6.0 MET)	Intense physical exertion
	Very Heavy (>6.0 MET)	Very intense, sustained physical exertion

<sup>1</sup>Relative humidity. <sup>2</sup>Metabolic equivalent of task.

**Table 2. Heat stress risk rating matrix**

Probability of occurrence	<i>Unlikely</i>	Negligible	Tolerable	Significant	Significant
	<i>Likely</i>	Negligible	Tolerable	Significant	Critical
	<i>Frequent</i>	Negligible	Tolerable	Significant	Critical
	<i>Very frequent</i>	Tolerable	Significant	Significant	Critical
		<i>Low</i>	<i>Average</i>	<i>High</i>	<i>Very High</i>
Severity					

stress for a given occupation was evaluated based on an exposure matrix approach<sup>28, 29</sup>). As part of this research, a model was created for allocating a risk rating using 2 basic risk evaluation components, namely, the probability of occurrence and the severity of the heat stress. The heat stress risk rating matrix is presented in Table 2.

The probability of occurrence scale presents 4 levels: unlikely, likely, frequent and very frequent. The severity scale, which reflects the extent of heat stress to which the worker is exposed, also presents 4 levels: low, average, high and very high. The severity of heat stress was evaluated by considering the criteria presented in Table 1.

It is the combination of the 2 scales that made it possible to develop a 16-box risk rating matrix (Table 2). In this matrix, 4 risk ratings were established: negligible, tolerable, significant and critical.

#### *Determination of exposure to chemicals*

More than 37,000,000 chemicals are listed in the

Chemical Abstracts Service databases, and over 100,000 are used in the workplace. Also, a worker may be in the presence of dozens of products on his job site. Therefore, it is virtually impossible to know the average exposure values for each chemical in different workplaces. The most suitable approach in this context was therefore to use a classification by product groups.

#### *Chemical product groups*

The presence of chemicals for occupations whose heat stress risk was judged significant or critical was documented by considering 8 product groups: solvents, dust, pesticides, polycyclic aromatic hydrocarbons, toxic gases, heavy metals, asbestos/silica and reagents/other chemicals. The information was obtained from the databases of the Institut de Recherche Robert-Sauvé en Santé et en Sécurité de Travail for the 2001–2008 period<sup>30</sup>) and the National Occupational Exposure Survey for the 1981–1983 period<sup>31</sup>). In the absence of meaningful quantitative data

**Table 3. Example of occupations per industry sector and heat stress risk rating**

INDUSTRY SECTOR: AGRICULTURE, FISHING AND HUNTING (EXCEPT SUPPORT ACTIVITIES FOR FORESTRY)							
OCCUPATIONS	TEMPERATURE	HUMIDITY	RADIATION	WORK LOAD	PROBABILITY	SEVERITY	RISK RATING
Beekeeper/Apiculturist/Apiarist	Normal	Normal	Normal	Light	Average	Low	Negligible
Farm hand (unskilled worker)	High	High	Hot	Heavy	Very High	Very High	Critical
Aquaculturist	Normal	High	Normal	Average	Low	Low	Negligible
Tree surgeon (urban area)	High	High	Hot	Average	High	Average	Significant
Sugar bush worker/maple tapping worker	Low	High	Cold	Heavy	Average	Average	Tolerable
Maple syrup maker	Low	High	Cold	Heavy	Average	Average	Tolerable
Aquaculture support worker	Normal	High	Normal	Heavy	Average	Low	Negligible
Semiskilled grain farm worker	High	High	Very Hot	Very Heavy	Very High	Very High	Critical
Semiskilled cattle production worker	High	High	Hot	Heavy	High	High	Significant
Cattle production helper	High	High	Hot	Heavy	High	High	Significant
Semiskilled horticulture worker	High	Normal	Hot	Heavy	High	High	Significant
Semiskilled dairy production worker	High	High	Hot	Heavy	High	High	Significant
Dairy farm helper	High	High	Hot	Heavy	High	High	Significant
Semiskilled fish farm worker	Normal	High	Normal	Average	Average	Low	Negligible
Semiskilled pig production worker	High	High	Hot	Heavy	High	High	Significant
Pig production helper	High	High	Hot	Heavy	High	High	Significant
Poultry farm worker	High	Normal	Hot	Heavy	High	Average	Tolerable

on the exposure of workers, exposure to chemicals was evaluated based on the known and documented presence of chemicals that may be found at work stations associated with different occupations.

Evaluation of simultaneous exposure to heat stress and chemicals

A professional judgement was then made for each occupation by considering the theoretical significance of simultaneous exposure to heat stress and chemicals. A scale of 1 to 5 (1 being the highest) was allocated to each occupation.

#### *Development of list of priority occupations per sector*

A final list was compiled using the occupations rated 1 and 2 in the previous step. This list was then submitted to a group of 13 experts including 11 industrial hygienists working in the Québec occupational health and safety network, a university professor deeply involved in the field of thermal stress and an occupational health and safety inspector of the Québec workers' compensation board. These experts were chosen for their hands-on experience in work hygiene, so that they could validate and prioritize the occupations in terms of extent of simultaneous exposure to heat stress and chemicals. They were asked to use a scale of 1 to 10 for prioritization purposes (1 representing the greatest risk) for each occupation on this list. The experts'

average rating and standard deviation were calculated for each profession.

## **Results**

Since the objective of this research paper is to develop an approach aimed at identifying worker groups that would be potentially most at risk due to their concomitant exposure to heat stress and chemicals and considering the tens of pages of results, we will limit ourselves here to just a few examples.

Overall, 1,010 occupations spread through more than 20 NAICS sectors or subsectors were selected as being the most representative job groups of Québec's economic sectors. The characterization of their risk potential based on their associated heat stress was evaluated based on a matrix exposure approach using the probability of occurrence and the severity of heat stress. A few results are presented in Table 3 for certain occupations falling into the sectors of agriculture, fishing and hunting. This matrix, where 4 risk ratings were used (negligible, tolerable, significant and critical), revealed that the risk stemming from exposure to heat stress was judged "critical" or "significant" for 257 occupations and concerned only exposure to heat.

Exposure to chemicals regarding these 257 occupations was then evaluated and a few results are presented in Table 4. Since 136 of these occupations presented a high poten-

**Table 4. Examples of industry sectors and jobs most at risk of heat stress in the presence of chemicals**

INDUSTRY SECTOR	Jobs Most at Risk of Heat Stress	CHEMICAL GROUPS							PRIORITY RATING	
		SOLVENTS	DUST	PESTICIDES	PAH <sup>1</sup>	GAS	HEAVY METALS	ASBESTOS/SILICA		REAGENTS/OTHER SUBSTANCES
AGRICULTURE, FISHING AND HUNTING (EXCEPT SUPPORT ACTIVITIES FOR FORESTRY)	Farm hand (unskilled worker)	✓	✓	✓	✓	✓			✓	1
	Tree surgeon (urban area)			✓				✓		5
	Semiskilled grain and fodder production worker	✓	✓	✓	✓	✓			✓	1
	Semiskilled cattle production worker		✓						✓	5
	Cattle production helper		✓						✓	5
	Semiskilled horticulture worker		✓	✓			✓		✓	4
	Semiskilled dairy production worker	✓							✓	2
	Dairy farm helper	✓							✓	2
	Semiskilled pig production worker					✓				3
	Pig production helper			✓		✓				3
	Semiskilled ovine production worker		✓	✓						1
	Ovine production helper		✓	✓						1
	Greenhouse helper			✓			✓		✓	3
	Farmer	✓	✓	✓	✓	✓			✓	1
	Grower	✓	✓	✓	✓	✓			✓	1
	Vineyard worker		✓	✓						3
	Mariculture technician									4

<sup>1</sup>PAH : polycyclic aromatic hydrocarbons.

tial of exposure to both heat stress and chemicals with 1 and 2 priority ratings, a table was produced with these occupations only and submitted to experts for prioritization purposes (Table 5). The sectors of non-metallic mineral product manufacturing/primary metal manufacturing/fabricated metal product manufacturing (FMPM), agriculture, forestry, fishing and hunting, construction, plastic and rubber product manufacturing, and public service/administration are the most significant. The job groups most concerned are mainly related to production, handling and maintenance work.

Lastly, this consultation made it possible to draw up a list of 22 priority occupations (experts' average rating < 3) based on the risk potential stemming from a concomitant exposure to heat stress and chemicals (Table 6).

## Discussion

This research has enabled the development of an innovative approach to identify and prioritize workers potentially the most at risk due to a concomitant exposure to heat stress and chemicals. These occupations were identified using an approach based on a matrix analysis and the judgement of experts. The matrix analysis allowed the identification of several occupations falling into the sectors of non-metallic mineral product manufacturing/primary metal manufacturing/fabricated metal product manufacturing (FMPM), agriculture, forestry, fishing and hunting, construction, plastic and rubber product manufacturing, and public service/administration as being workplaces where concomitant exposure to heat and

**Table 5. Examples of prioritization of occupations**

#	Industry sector	NOC-4 Description <sup>1</sup>	Priority Occupations	Average rating	SD <sup>2</sup>	Min	Max	N <sup>3</sup>
1	Agriculture, fishing and hunting (except support activities for forestry)	Agricultural labourer (n=12 780)	Farm hand (unskilled worker)	5.00	2.65	1	10	13
2			Semiskilled ovine production worker	4.62	1.85	1	8	13
3			Ovine production helper	4.38	1.94	1	8	13
4			Semiskilled grain and fodder production worker	4.92	2.22	1	10	13
5			Semiskilled dairy production worker	5.15	1.95	1	8	13
6			Dairy farm helper	5.08	1.98	1	8	13
7		Farmer and farmer manager (n=15 861)	Farmer	5.92	2.29	1	10	13
8		Grower	5.92	2.29	1	10	13	
9	Food, beverage and tobacco product manufacturing	Hand worker (n=1 927)	Day labourer (reception of goods)	7.00	2.24	1	10	13
10		Food, beverage and tobacco product processing worker (n=14 300)	Food processing labourer	7.31	1.89	3	10	13
11	Construction	Construction trades helper and labourer (n=15 135)	Day labourer	4.92	1.55	2	8	13
12			Civil engineering site labourer	4.69	1.65	2	8	13
13		Roofer and shingler (n=3 007)	Roofer	2.15	1.14	1	4	13
14		Heavy equipment operator (except crane) (n=5 687)	Heavy equipment operator (excavator, grader, backhoe, etc.)	5.92	2.22	2	9	13
15		Bricklayer-mason (n=2 900)	Bricklayer-mason	4.62	2.29	1	10	13
16		Concrete finisher (n=1 250)	Ciment-finisher	4.38	1.66	1	7	13
17		Ironworker (n=805)	Reinforcing rod worker	5.08	2.18	2	8	13
18		Boilermaker (n=180)	Boilermaker (tower crane, tanks, boilers assembling)	3.69	2.18	2	8	13

<sup>1</sup>National occupational classification<sup>21)</sup>, <sup>2</sup>SD: standard deviation, <sup>3</sup>Number of experts rating this occupation.

chemicals is significant. While few studies are available on this subject, some occupations falling into these sectors had already been mentioned in the literature. In this regard, authors report that farmers<sup>10)</sup>, pesticide spreaders<sup>10)</sup>, firefighters<sup>8)</sup> and workers assigned to plastic production, dry heat vulcanization and the production of formaldehyde resins<sup>12)</sup> may be particularly exposed simultaneously to heat and chemicals. Other workers with more marginal occupations, such as race car drivers<sup>10)</sup> and ceramics artists<sup>32)</sup>, were also mentioned.

As already mentioned in the method, the list of 136 occupations prioritized by our research team was then submitted to experts so they could validate and prioritize the occupations in terms of extent of simultaneous exposure to heat stress and chemicals. This exercise made it possible to identify 22 occupations most at risk (Table 6). They include 20 occupations falling into the FMPM sector, as well as roofers and firefighters.

This approach is similar to the Delphi method<sup>33)</sup>. The

principle of this method is that prediction made by an expert group or panel of experts are reliable. However, while the Delphi method in the standard version requires from the experts to answer questionnaires in two or more rounds, this study used only one round because of the similarity of the results. In fact, standard deviations were quite small.

Many workers in the FMPM sector, particularly casters, smelter operators and forge helpers, work in a hot environment due to the high temperatures of the smelters. They load and prepare the ovens, add alloy ingredients if necessary, carry out skimming and mold cleaning operations. They sometimes wear restrictive clothing and use heavy equipment. These workers are exposed to fumes (iron, manganese, zinc, cadmium, arsenic, metallic oxides, chrome, nickel), dust (silica, copper, aluminium), as well as carbon monoxide, formaldehyde, nitrogen oxides and sulphur<sup>20, 34)</sup>.

Roofers are exposed to hot summer temperatures. They

**Table 6. Occupations prioritized by experts**

Occupations	Average Rating	SD <sup>1</sup>	Min	Max	N <sup>2</sup>
Gold caster <sup>3</sup>	2.09	1.5	1	6	11
Roofer <sup>4</sup>	2.15	1.1	1	4	13
Caster <sup>3</sup>	2.31	1.5	1	6	13
Smelter operator <sup>3</sup>	2.31	1.5	1	5	13
Forge helper <sup>3</sup>	2.38	1.0	1	5	13
Firefighter <sup>5</sup>	2.42	1.8	1	7	12
Metal processing labourer <sup>3</sup>	2.46	1.1	1	5	13
Firing kilns labourer <sup>3</sup>	2.46	1.3	1	5	13
Smelting furnace helper <sup>3</sup>	2.46	1.3	1	5	13
Foundry labourer <sup>3</sup>	2.46	1.3	1	5	13
Casting helper <sup>3</sup>	2.54	0.9	2	5	13
Moulder <sup>3</sup>	2.54	1.3	1	6	13
Oven operator <sup>3</sup>	2.54	1.6	1	6	13
Ceramic oven operator <sup>3</sup>	2.58	1.4	1	5	12
Brick kiln operator <sup>3</sup>	2.67	1.4	1	5	12
Metal fabricating machine operator <sup>3</sup>	2.69	1.5	1	6	13
Furnace operator <sup>3</sup>	2.69	1.7	1	6	13
Steel hardener <sup>3</sup>	2.77	1.5	1	6	13
Extruder operator <sup>3</sup>	2.83	1.6	1	6	12
Smelting furnace operator <sup>3</sup>	2.85	1.6	1	6	13
Die-casting machine operator <sup>3</sup>	2.92	1.6	1	6	12
Boilermaker <sup>3</sup>	2.92	1.5	1	5	12

<sup>1</sup>SD: standard deviation, <sup>2</sup>Number of experts rating this occupation, <sup>3</sup>Non-metallic Mineral Product Manufacturing/Primary Metal Manufacturing/Fabricated Metal Product Manufacturing Sector, <sup>4</sup>Construction Sector, <sup>5</sup>Public Service / Public Administration Sector.

spread bitumen or hot tar on the roof and cover the entire surface with gravel. They may also install asphalt shingles, nailing and stapling them to the roof. They are simultaneously exposed to crystalline silica, asphalt, bitumen and tar fumes, organic solvents, inorganic insulation dust (asbestos, mineral wool) and sulfur dioxide<sup>34, 35</sup>.

Firefighters are exposed to heat stress due to the fact that they occasionally work in confined space and wear clothing or equipment that is often very restrictive. They are simultaneously exposed to different chemicals found on the premises where they must intervene: carbon monoxide, benzene, particles, asbestos, cyanide, hydrogen chloride, polycyclic aromatic hydrocarbons, fumes, stored products, products used to control fires, etc<sup>8, 36</sup>.

Since exposure to heat can lead to increased pulmonary or cutaneous absorption of chemicals<sup>8, 11</sup>, workers operating in the aforementioned occupations may report more health effects compared with workers exposed to neutral heat environments<sup>12</sup>. Heat stress can have a significant impact on the absorption and toxicokinetics of chemicals only if both heat and chemical exposures are simultaneous and only if the thermal stress is sufficiently intense to trig-

ger physiological compensatory responses associated with heat exposure<sup>9, 10</sup>. The impact of heat stress on chemical toxicokinetics is more likely to be significant when the WBGT (Wet-Bulb Globe Temperature) index is not respected<sup>27</sup>.

As meteorological conditions such as high ambient temperature and humidity can promote the absorption of chemicals, more workers may experience chemical intolerance or toxicity in the context of global warming<sup>9, 10, 15</sup>. Because of varying individual susceptibility (such as age, physical fitness, acclimatization) and environmental factors (such as air movement, radiant heat, etc), it is currently difficult to accurately predict the impact of climate change on workers' health. However, individuals working in hot environment and exposed to a significant level of chemical or workers with pre-existing illness may be more at risk<sup>15</sup>. Many workers who labour in thermally stressful occupations give up wearing their protective equipment because of their discomfort, which can promote the absorption of chemicals<sup>10</sup>. In addition, these equipments can impede heat loss and lead to marked hyperthermia when worn in the summer months, situation that is likely

to be encountered more often in the context of climate change<sup>10</sup>).

Many chemicals may affect thermoregulatory mechanisms and thereby reduce workers' ability to adapt to heat<sup>6</sup>). These chemicals include vasoconstrictor agents, such as lead and its inorganic components<sup>10</sup>), organophosphorus compounds and carbamates<sup>8, 10</sup>), as well as the metallic oxides present in welding fumes, smelters or emitted during galvanizing activities<sup>7</sup>). Among the occupations prioritized in this study, it is interesting to note that many FMPM sector workers may be exposed to metallic oxide fumes, which is likely to affect their ability to adapt to heat stress.

## Conclusion

An approach based on a matrix analysis and the judgement of experts made it possible to identify 22 occupations where workers were significantly exposed to both heat and chemicals, that is, 20 occupations in the FMPM sector, roofers and firefighters. The literature data suggests that these workers may report more health effects than workers experiencing the same level of exposure in a neutral thermal atmosphere. The former may also adapt less easily to heat due to the presence of chemicals affecting thermoregulatory mechanisms. Therefore the workplaces targeted in this study should be prioritized in the context of subsequent research aimed at estimating the potential risk stemming from simultaneous exposure to heat and chemicals in the context of climate change and global warming.

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