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4,4'-diphenylmethane diisocyanate (MDI): Safety practices and concentration during polyurethane foam spraying

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Chemical substances and biological agents

Studies and Research Projects

REPORT **R-629**

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ABSTRACT

In recent years, some Québec construction workers have been "sensitized" to 4,4'-diphenylmethane diisocyanate (MDI). This substance is emitted during spraying of a polyisocyanate (a mixture of MDI polymers) and a polyhydroxyl compound (resin) to form a rigid polyurethane foam used for thermal insulation in buildings. The permissible exposure value (PEV) for MDI (monomer form) in Québec is 0.051 mg/m^3 (51 µg/m^3). This substance has been identified as a *sensitizer* (S) in the Regulation respecting occupational health and safety (RROHS) (*Règlement sur la santé et la sécurité du travail* RSST), which also mentions that the exposure should be kept at a minimum (ME).

Field studies (on-site spraying) reported in the scientific literature have shown significant concentrations of MDI during this process, particularly in the residential construction sector. In fact, the Lesage study (2007) confirmed the need to sample MDI aerosols and to use a collection medium that allows their optimal collection, considering the short polymerization time in this process.

The Canadian Urethane Foam Contractors Association (CUFCA) and the Alliance for the Polyurethane Industry (API) offer a training program for installers (or appliers) of this foam. The program covers the spraying methods available to obtain a quality product, which will therefore depend on the workers' skill. The safety aspect during spraying operations is hardly or not addressed at all.

Initially, this study documented occupational health and safety practices under a wide range of conditions where insulation work is carried out, including commercial or residential construction, the location of the work (indoors or outdoors), and the season (summer or winter).

The study then evaluated MDI by means of stationary sampling in the work areas. These concentrations (average concentration over the duration of the work and weighted over an 8-hour period, TWAEV) were analyzed according to the determining factors influencing the workers' exposure to MDI. The details of the work were examined in order to estimate, with a fair degree of confidence, the highest risk scenarios during foam spraying operations. The risk of exposure to MDI in monomer form (aerosols) for workers performing spraying operations is high, particularly when such operations are performed indoors where the average of the concentrations in the spraying zone reach 288 µg/m^3. In addition to these characteristics, individual and team (team consisting of an installer (or applier) and his assistant) work practices explain certain variations in the data collected.

Despite the training program for installers (or appliers) offered by an accreditation authority, nothing indicates that occupational health and safety practices are being completely followed on Québec construction sites. In the context of competency training, occupational health and safety practices as well as respiratory and skin protection need to be rigorously addressed and should be part of the workers' continuing training process.

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1. INTRODUCTION

In industrialized countries, among all exposed workers, the percentage of workers sensitized to MDI is around 5 to 10% (Nadeau 2000). MDI is emitted in the form of small aerosols (monomer and oligomer droplets) (Lesage and Ostiguy 2000) during the rigid polyurethane foam (insulating foam) spraying process on construction sites. It is identified as a sensitizer (S) in Schedule I of the Regulation respecting occupational health and safety (RROHS). Moreover, a regulation[1] modifying the Safety Code for the Construction Industry (SCCI) and the RROHS (article 42), in effect since March 2008, mention, in particular, protection and the reduction of exposure to a minimum for diisocyanates or isocyanate oligomers.

The scope of this study was to document hazardous practices and to evaluate the work environment in terms of MDI concentrations (monomer and oligomers), in stationary sampling, during spraying work (aerosols and vapours) and post-spraying (vapours) on Québec construction sites based on the work being carried out.

The distinctive feature of this field study was the variety of situations investigated where a spraying process involving a polyisocyanate (a mixture of MDI polymers) and a polyhydroxylated compound (resin) is used (thermal insulation process), and the occupational safety aspect during this work. In fact, studies reported in the scientific literature had not dealt with occupational health and safety practices, and had mainly targeted residential construction.

The first sections of this report cover the current state of knowledge, the objectives, and the evaluation strategy (sampling and analysis) used within the framework of this field study. The observations and analytical results are reported in section 5 and discussed in section 6.

[1] 1 C.S2-1, r19.01, section 1 article 2. {On line}.
http://www.csst.qc.ca/NR/rdonlyres/A689E06B-EBA7-40FE-A55A-EBAF1239FC21/4177/DC_200_1027.pdf
http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FS_2_1%2FS2_1R19_01.htm (April 2008)

2. ISSUES AND STATE OF KNOWLEDGE

2.1 Effects on health and prevalence

According to *Commission de la santé et de la sécurité du travail* (CSST, workers' compensation board) statistics, compensation is paid out for 40 to 60 new cases of occupational asthma every year. Around 250 substances are recognized as being causal agents for occupational asthma (OA).[2] As illustrated in Figure 1, 17% of all OA cases recognized in 2007 have as their causal agent a substance from the isocyanate family. Certain substances in this family are chemical irritants for the respiratory tract, eyes and skin, and are respiratory and skin sensitizers. Occupational exposure to isocyanates may induce rhinitis, which could develop into OA. These two respiratory disorders of occupational origin manifest themselves through the appearance of symptoms following repeated exposure to a sensitizing agent. These symptoms diminish or disappear a short time after the worker leaves the work environment. According to pneumologists (Bernstein et al. 1999), a worker sensitized to isocyanates may react immediately or several hours after exposure, even at very low concentrations, even lower than 1 ppb for short intervals. This allegation is also reported by other authors (Nadeau 2000, and Ostiguy et al. 2005).

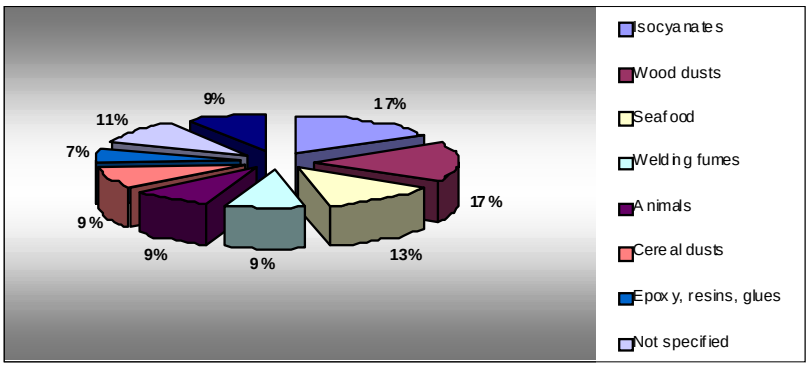

Figure 1: Causal agents for compensated occupational asthma disorders in 2007

In numerous work environments, concentrations of monomer isocyanates have been reduced or controlled by engineering or administrative means or by the wearing of respiratory protection. Nevertheless, it seems that there are still cases of sensitization. Oligomers (polyisocyanates) contain isocyanate functions that have characteristics similar to those of monomers. They may also contribute to the toxicity of isocyanates (Bernstein and al. 2006). Researchers (Karol et al. 1981) have shown that skin contact exposure to isocyanates (particularly TDI) in animals could have a sensitizing effect on subjects, leading to an asthmatic reaction during inhalation exposure. Some claim that skin exposure alone cannot be the only cause of an asthmatic reaction (Dhimiler 2007, Vanoirbeek and al. 2004, Herrick and al. 2002, and Karol and al. 1981). Although there is no consensus on the subject, it would seem that the skin is a route of exposure that could lead to respiratory sensitization among workers.

[2] {Online}. {http://www.reptox.csst.qc.ca/Documents/PlusEncore/Asthme/Htm/Asthme.htm#Chap3} (April 2008).

2.2 Principal uses

Substances in the isocyanate family enter into the synthesis of a wide range of polymers with different properties. According to Streicher et al. (2000), these polymers are involved in the manufacture of commercial mixtures such as paints, flexible and rigid foams, adhesives, resins and elastomers. In addition to the workers employed in the manufacture of these mixtures, other people may also come into contact with isocyanates during their use in the work environment, in particular during on-site spraying to form the rigid polyurethane foam used for insulation purposes on construction sites.

Diisocyanates, called monomers, and polyisocyanates, called oligomers, can form polymers by combining with other molecules. Diisocyanates can contain a proportion of monomer varying from 25 to 76%[3] (Ostiguy et al. 2005). During insulation work, a mixture comprised of a polyisocyanate (mixture of MDI polymers) and a polyhydroxylated compound called polyol (resin) is sprayed on surfaces by means of a spray gun. Several companies manufacture these products, including polymeric MDI (PMDI), which is marketed under different names such as Lupranate®, Rubinate®, Desmodur®, Voranate®, Caradate®, etc. (INERIS 2002). The PMDI used in this process consists of 45-55% polymethylenepolyphenylene diisocyanate and 45-55% 4,4'-diphenylmethane diisocyanate. Due to its low vapour pressure at ambient temperature (<0.00001 mm Hg), it can be found in the air mainly in the form of aerosols (monomer and oligomers). The resin contains, in addition to polyol, a blowing agent causing the foam to expand, and additives such as stabilizers that prevent its deterioration. Resin manufacturers offer two versions, regular and winter, to allow spraying of the foam in winter by modifying the concentration of some of its components.

According to Abecassis (2000), the products cited above react in three phases to form polyurethane foam:

1. Mixing and creaming time: approximately 5 seconds;
2. Expansion or inflation time (exothermic reaction and expansion of the foam): 15 to 20 seconds;
3. Polymerization or hardening (alveolar structure): 2 to 3 minutes. This phase is totally completed 48 hours after spraying.

It is therefore important to make sure that the sampling methods and the collection medium take the rapid polymerization of this process into account and that the analytical methods can quantify the monomer and oligomer aerosols (Lesage et al. 2007, Lesage and Ostiguy 2000).

2.3 Documented levels of exposure

Although several recent articles discuss the exposure to isocyanates in the factory production of flexible foam where toluene diisocyanate (TDI) is used, few discuss the MDI exposure of workers in the construction sector (Research and Development Department, Construction Safety Association of Ontario 1987, Hosein and Farkas 1981, Bilan and al. 1989, Crespo and Galan 1999, Creely and al. 2006, and Lesage and al. 2007). These articles report significant

[3] {On line} http://www.irsst.qc.ca/fr/isocya_7.htm (April 2008).

concentrations during this polyurethane foam spraying operation: for installers (or appliers), from 0.017 to 0.4 mg/m^3, and for their assistants, from 0.01 to 0.31 mg/m^3. Although these concentrations do not correspond to a time-weighted average exposure value (TWAEV) over 8 hours, several exceed the regulations prevailing in Québec where the TWAEV for MDI (Schedule I, RROHS) is 0.051 mg/m^3 (51 µg/m^3) or 0.005 ppm for the monomer form with mention of reduction of exposure to a minimum (EM).

2.4 Training

In Canada, the practice of this skilled activity involving polyurethane foam spraying is governed by a training program of the Canadian Urethane Foam Contractors Association (CUFCA)[4] and by the Alliance for the Polyurethane Industry (API) in conformity with the standard CAN/ULC-S705.2[5] of the Underwriters' Laboratory of Canada (ULC).[6] The challenge is to communicate knowledge and to ensure that installers (or appliers) reach the necessary level of expertise for this task. Moreover, companies distributing commercially available mixes must certify installers (or appliers) in the use of their products, and in the particular requirements of the products, etc. This program only involves the work itself. The occupational health and safety (OHS) aspect is very limited.

The Québec market is mainly served by two companies that distribute commercial mixes. These companies have quality standards for the foam, and safety warnings for spraying. The occupational safety aspect in the context of this training is hardly or not covered at all. There are 85 Québec contractors that are members of CUFCA.[7] However, the number of qualified workers is not documented on this site.

[4] {On line}. {http://www.cufca.ca/training/levels_e.php} (April 2008).

[5] The Canadian standard CAN/ULC S705.1 lists the requirements for liquid components, contractors and installers. The CAN/ULC S705.2 standard sets the requirements for environmental conditions and other relevant documentation on spraying.

[6] {On line}. {http://www.ulc.ca/ABOUT_ULC/Work_program.asp} (April 2008).

[7] {On line}. {http://www.cufca.ca/lookup/search_e.php} (November 2008).

3. RESEARCH OBJECTIVES

The objectives of this study are to:

- Document the practices, based on the working methods prescribed by the training program, for the spraying of polyurethane foam;
- Document good practices in terms of occupational health and safety and hazardous practices during spraying work on Québec construction sites based on the different tasks carried out;
- Evaluate the working environment in terms of MDI concentrations (monomer and oligomers) by means of stationary sampling during foam spraying operations (aerosols and vapours) and post-spraying (vapours).

4. METHODS

In order to fulfill the study's first objective, points relating to the work methods (see Appendix I) were listed from the documentation for the training program for polyurethane foam installers (or appliers). In order to fulfill the second objective, these points were validated in the workplace in relation to the reality in which the workers (installers and assistants) carry out the spraying operation on different Québec construction sites.

The study targeted new construction sites and/or sites undergoing renovation, both residential and commercial, where the indoor (basement walls, belts) or outdoor structural elements were insulated with polyurethane foam in winter and in summer. The list of contractors using this foam was developed from the list of Québec thermal insulation contractors[8] (under categories 4231 and 4232) and that of CUFCA.[9]

4.1 Analytical methods

The sampling train recommended in method 25/3 *Organic Isocyanates in Air* of the Health and Safety Executive (HSE)[10] was used for quantifying MDI aerosols and vapours in the form of monomers and oligomers. This method allows the aerosols emitted to be collected by an impinger in a solution before polymerization (which occurs very rapidly in this process) is complete (Lesage and al. 2007, Abecassis 2000). This method was therefore preferred over the one in which the aerosol collection medium is a pre-treated glass fiber filter that is placed in a reagent solution after the 15-minute sampling.[11] This collection medium, used according to the IRSST's laboratory specifications, is not suitable for a process in which polymerization takes place rapidly.

Sampling for aerosols and for quantifying MDI vapours in monomer form according to the *Institut de recherche Robert Sauvé en santé et en sécurité du travail* (IRSST) high sensitivity (HS) method was performed at a rate of 1 L/min. over a period of 30 to 60 minutes, depending on the duration of the work or the area to be sprayed. These samples were therefore collected consecutively over the **total spraying period** on one construction site for one survey. The analytical methods are summarized in Table 1. The coefficient of variation for the samples was 5%.

[8] {On line}. {http://w3.rbq.gouv.qc.ca/rbq/owa/RBAC2.aff_liste?p_session=3179754&p_alpha=TOUS&P_type_rech=E&P_nbre=630} (April 2008). {http://w3.rbq.gouv.qc.ca/rbq/owa/RBAC2.aff_liste?p_session=3179754&p_alpha=TOUS&P_type_rech=E&P_nbre=308} (April 2008). {http://w3.rbq.gouv.qc.ca/rbq/owa/RBAC2.aff_liste?p_session=3179754&p_alpha=TOUS&P_type_rech=E&P_nbre=799} (April 2008).

[9] {On line}. {http://www.cufca.ca/lookup/search_e.php} (November 2008).

[10] Methods for Determination of Hazardous Substances HSE {On line}. {http://www.hse.gov.uk/pubns/mdhs/pdfs/mdhs25-3.pdf} (April 2008).

[11] {On line}. http://www.irsst.qc.ca/files/documents/fr/Labos/Isocyanates1.pdf (February 2009).

Table 1: Description of the MDI analysis methods

	25/3 Organic Isocyanates in Air	IRSST High Sensitivity
Analysis/detection	HPLC-UVF	HPLC and MS/MS
Collection medium	Impinger system containing a MOPIP solution	37 mm membrane impregnated with MAMA
LOQ: monomers **oligomers**	0.036 µg 0.041 µg	0.00075 µg - - - -
ACV	2.8%	< 5%

HPLC-UVF: High pressure liquid chromatography with ultraviolet and fluorescence detection
HPLC: High pressure liquid chromatography MS/MS: Double mass spectrometry
MOPIP: methoxy-2-phenyl-1-piperazine MAMA: 9-(N-methylaminomethyl) anthracene
LOQ: Analytical limit of quantification ACV: Analytical coefficient of variation

4.2 Sampling strategy

Stationary sampling of MDI (monomer and oligomers) was carried out in the spraying zone (installer or applier) and in the areas outside the spraying area (assistant and workers from other specialties). In the spraying zone, two sampling trains (aerosols and HS vapours) framed the installer (approximately 2 metres on each side and at a height of 1.5 metres - see Figures 2 and 3). An average of their analytical results was used to estimate the average concentration in this zone. For the zones outside the spraying area, sampling trains were positioned approximately 3 metres behind the installer (HS vapours and aerosols) (assistant's work area) or at the centre of the floor where the spraying work was being carried out (working area of workers from other trades). For outdoor work, a sampling train was positioned approximately 2 m downstream from the spraying zone in terms of wind direction (see Figure 3). During outdoor work, if there had been workers inside the building, HS vapours would also have been sampled.

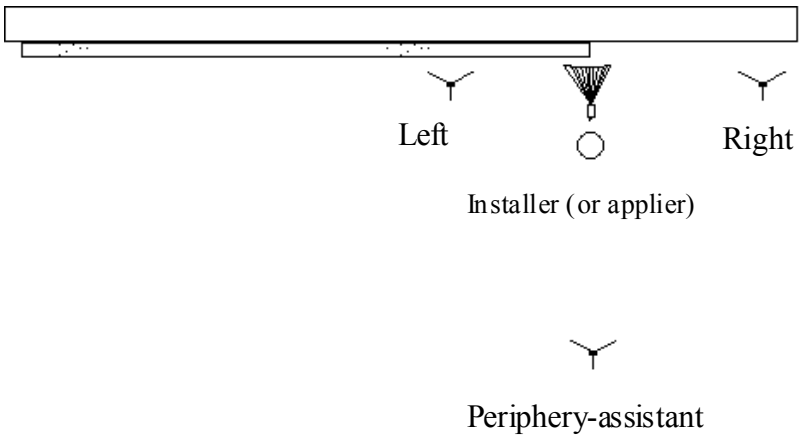

Figure 2: Sampling stations during spraying of indoor surfaces

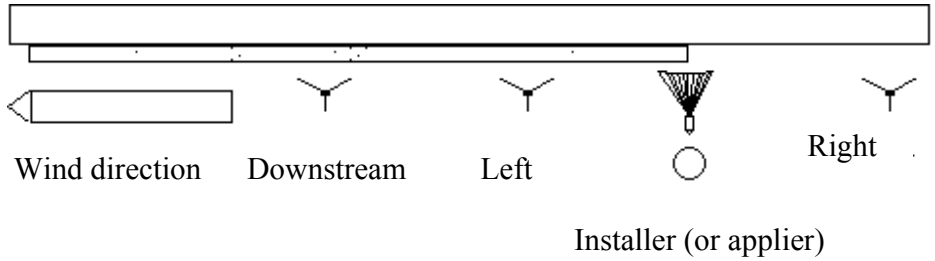

Figure 3: Sampling stations during spraying of outdoor surfaces

Finally, post-spraying samples (HS vapours) were collected for two hours (from 0 to 30 minutes, from 30 to 60 minutes, and from 60 to 120 minutes) following completion of the work. They were located at the centre of the floor where the work was carried out and on the floor above. They targeted the detection of residual MDI vapours over time.

The analytical results and information collected on the construction sites were entered in a database (DB) created in Microsoft Excel software. The collected information was, among other things, the resin used, the thickness sprayed, the season during which the work was carried out, the location (indoors or outdoors), the time of the sampling (during spraying or post-spraying), the protective equipment, the scaffolding equipment (stepladder, stationary or mobile platform, with articulated arm, etc.) and the analytical results.

The data relating to the monomer form were analyzed statistically with IHSTAT software[12] from the American Industrial Hygiene Association (AIHA) in order to validate the similar exposure group (SEG) and to document MDI exposure. Here, SEG is defined as a set of exposure determining factors for which the exposure to monomer MDI would be similar. Therefore the analysis aims to estimate, with a certain degree of confidence, the most hazardous determining factor(s) for the tasks targeted during foam spraying operations. The parameters retained were the daily average exposure value (DAEV) and the average concentration of the samples by survey and by task. They were considered in relation to three situations: 1) location of the work (indoors or outdoors), 2) season (summer or winter), and 3) the type of foam used (regular or winter resins). This treatment was also applied to the data on oligomers.

[12] Free software https://www.aiha.org/1documents/committees/EASC-IHSTAT.xls (January 2009).

5. RESULTS

The study results that are documented in this report relate to 1) a description of the construction sites visited, 2) work organization, 3) special features of the construction sites, 4) occupational health and safety practices involving hoisting equipment and protective equipment, 5) ergonomic hazards, and 6) chemical hazards (for health) and the MDI exposure risk factors for the installers and their assistants and for other workers present on site.

The list in Appendix I contains the information on points 1 to 4 above.

5.1 Description of sites

The sites visited were construction sites or renovation sites for residential buildings (condominiums, single family residences, cottages) and commercial buildings. Four foams were used by the contractors visited. Technically, the CAN/ULC-S705.2-05 standard describes the conditions during spraying: less than 17°C difference between the ambient temperature and that of the substrate, and a relative humidity of the ambient air below 80%. However, manufacturers of commercial products recommend the use of a specific mixture for cold temperatures and the installation of a temporary shelter to protect the spraying zone from rain, snow and wind.

Our 20 surveys[13] involved nine Québec thermal insulation contractors using polyurethane foam. These companies were members of prevention mutuals and had a prevention program. At least two surveys were carried out with each contractor and were classified as follows:

- 7 sites: insulation of exterior walls of a commercial building
- 1 site: insulation of exterior walls of a residence (condominium)
- 2 sites: insulation of interior walls on several different floors, including a crawl space
- 4 sites: insulation of the basement walls of a residence
- 5 sites: sealing of belts.

5.2 Work organization

A work team consists of one installer and his assistant who can take turns spraying throughout the day. Generally there is one team per site. However, on one site, there were two teams of workers doing the spraying, and on two other sites, the installer worked alone without an assistant. Moreover, some installers we met had not yet followed their training program because they had to perform a certain number of hours of on-the-job work beforehand.

For all the contractors we visited, the workers shared the work between them as follows:

a) As soon as they arrived on site, the assistant started preparing the area (masking openings, the ground with plastic sheeting held in place with a product made of volatile organic compounds (VOCs) under pressure, staples or adhesive tape), preparing

[13] The term "survey" corresponds to one more or less complete day of sampling.

equipment (compressor, hose, etc.). After the spraying work, he removed the sheeting and cleaned up the site.

b) Cleaning of the gun, quality control of the foam and the thickness sprayed, the spraying angle and the operating conditions[14] (temperature, humidity and wind speed) were the installer's responsibility.

The working day, including transport time, began between 5:30 and 6:30 a.m. and could last until completion of the work. When atmospheric or winter conditions (rain, snow, cold temperatures, wind) made it necessary, the workers suspended the work or set up a protective structure with plastic sheeting (tent-style) on the ground or on the hoisting equipment used.

The workers often ate in the box of the truck where barrels of resin and MDI were stored, without access to washrooms to wash their hands beforehand. A microwave oven was often available.

Our discussions with the workers enabled us to draw a portrait of a typical working day (approximately 8 hours per day):

1. Transport between the contractor's warehouse and the site
2. Preliminary work: heating of spraying equipment, verification of hoisting equipment where necessary, masking, gun cleaning, etc.
3. Spraying of the foam according to the customer's specifications, with breaks when needed, and a meal
4. Masking removal and cleaning of the work site (often carried out while spraying was in progress)
5. Transport to the contractor's warehouse if the working day was finished, or
6. To another site where the operations described in points 2 to 5 were repeated.

The duration of spraying in an 8-hour working day (480 minutes) varied between 180 to 230 minutes or more, if more than one site was visited. Finally, the logistics of the work on certain sites were particularly chaotic, causing frequent interruptions for the spraying team.

Although installers must be certified, they do not all have this certification. Two workers were scheduled to follow training courses in the months after our survey. Before obtaining their certification, they must perform a certain number of hours of practical experience in spraying. Eight contractors out of the nine we met were certified.

5.3 Health and safety practices

Several sites visited were cluttered with tools, materials, waste, etc. This clutter hindered the installer when moving the resin and MDI feed hose from place to place, among other things. The surfaces to be sprayed were not always easy to reach. Certain jobs, even though of short duration, were carried out in problem areas with difficult access (such as attics, attic spaces, etc.). Moreover, the workers sometimes had to enter an enclosed or confined space as described in

[14] The temperature of the primary heaters must be between 43° and 49°C (100° and 120°F) and that of the feed hose 35° to 40°C (95° to 105°F), i.e., 5 to 15°F less than the heaters.

RROHS division 1 and SCCI subsection 1.1.17.1. One of the monitored teams proceeded to insulate the walls of a crawl space with restricted access, entering it by means of a stepladder borrowed from some other workers. These workers had not received the training prescribed in the RROHS and in SCCI article 3.21. Finally, workers often did not wear safety helmets.

Frequently, workers from other construction specialties moved around or carried out work close to the spraying area. For example, a "hot" job (welding) was being done next to the spraying zone of one of the sites visited, without an isolation barrier on the foam. This practice is forbidden unless the foam is isolated from the heat and sparks by a thermal barrier.

One of the contractors visited asked that his workers be alone on the site. Another installed, at the entrance to the site, a sign announcing spraying work and recommending the wearing of protective equipment (respirator and goggles).

The occupational health and safety practices documented in this section were observed on the sites visited and mainly involved hoisting equipment, fall protection, and the use of protective equipment (respiratory, skin and eye protection).

5.3.1 Work zone approach equipment

Here, the term "work zone approach equipment" refers to all equipment used to reach the higher surfaces to be sprayed, including motorized elevating platforms, tower scaffolding, platform scaffolding, stepladders and ladders. Spraying on interior structures was done from the ground and from a stepladder or mobile scaffolding, while that on exterior structures was done from the ground and a stepladder, mobile or stationary scaffolding, motorized platforms of the scissor type or with an articulated arm. The work zone approach equipment used during this study is listed in Table 2. One installer did not use any approach equipment.

Table 2: Work zone approach equipment used on the sites visited

Equipment used	NS	Used by	Wearing of safety harness	Tarpaulin shelter
Stepladder	10	Installer only	N/A	N/A
Motorized elevating platform, scissor type	2	Installer and assistant	No	One situation
	2	Installer only	No	One situation
Motorized elevating platform, articulated arm	1	Installer only	No	No
	1	Installer and assistant	Yes	Yes
FRACO®	2	Installer only	No	Yes
Mobile scaffolding	1	Installer only	Not obligatory < 3 m	N/A
Stationary scaffolding *	1	Installer only	Not obligatory < 3 m	N/A

NS.: Number of situations or sites. N/A: Not applicable. *: Made of trestles and planks.
FRACO®: A trademark for mast-climbing work platform as defined by the SCCI, article 1.1.14.2.

The ladders used by the workers we met complied with the regulation for portable ladders: *Portable ladders CAN3-Z11-M81*, class I. However, the height selected was not always appropriate for the height of the structures to be insulated. The stepladder used was often too

short. We also noticed that some of the workers climbed to the second last rung of the stepladder. Finally, the installer can extend his body beyond the reach of the stepladder, with a consequent risk of losing his balance and suffering a potential fall.

Since the foam spraying operation is done on vertical surfaces at various heights from the ground, there is a risk of workers and tools falling. The installer and his assistant often used a motorized elevating platform of the scissor type or with an articulated arm for outdoor work that was done more than 3 metres from ground level. Very few workers we met had taken specific training in the use of such equipment. Finally, the wearing of a safety harness with an energy absorber is recommended by good practices for workers using any hoisting equipment for work above 3 metres from ground level. We noticed that safety harnesses were not always worn when such equipment was being used.

In winter or in strong winds, the workers covered the motorized elevating platform and its articulated arm completely in plastic, making it dangerous in windy weather (see Figure 4). Any modification of such equipment should be duly approved as stipulated in regulation *B354.2-01 article 4.24* of the Canadian Standards Association. For further information on motorized elevating platforms, consult the "*Guide de bonne pratiques : La pulvérisation de mousse de polyurethane*" (Good practices guide: Polyurethane foam spraying) published jointly by the IRSST and ASP-construction.[15]

Figure 4: Non-compliant shelter on a motorized elevating platform

5.3.2 Respiratory protection

The installers wore respirators. Some wore an air-purifying respirator (APR) with chemical cartridges, powered or not, or with supplied air. However, several anomalies were observed.

[15] {On line} http://www.irsst.qc.ca/files/documents/PubIRSST/RG-623.pdf (August 2009).

First, the air intake for the pump for the supplied air respirator was outside the truck, without taking into account the direction of the truck's exhaust gases, thus contaminating the air fed into the pump. Second, the air drawn in did not comply with the definition of respirable air (Grade D air); no analyses were done. Third, two workers used the same chemical cartridge respirator with half face mask without cleaning it or testing its fit. Generally, the respirators and their chemical cartridges were stored without protection in the truck box, where the barrels of resin and MDI were also stored. Finally, according to information from the workers, cartridges are changed when there is a perceptible odour. However, diisocyanates are odourless. But the VOCs (volatile organic compounds) from the resin smell of ether. The respirators noted during the study are listed in Table 3.

Table 3: Respirators used

Type of respirator	Installer	Assistant
N95 filter air purifying for aerosols, half face mask	2	
Chemical cartridge air purifying with half face mask	7	8
Powered chemical cartridge filter air purifying with half face mask	1	0
Powered chemical cartridge filter air purifying with full face mask	1	
Supplied air (unpurified) with half face mask	7	0
Supplied air (unpurified) with full face mask	1	
No respirator	0	10

During one survey, the occupational health and safety manager on site lent a cartridge respirator to a worker who had to work close to the spraying zone. This worker had never been trained in the wearing of a respirator and did not know how to put it on properly.

5.3.3 Protective clothing

The installers (or appliers) that did not wear a respirator with full face mask wore protective goggles. They also wore cotton gloves, with only one wearing nitrile gloves underneath the cotton ones.

Whatever the season, the workers often wore their ordinary street clothes (jeans with a cotton sweatshirt with hood) without any protective coveralls. Their clothes were covered in foam and were not removed for meals or for transportation. Only one contractor insisted on the daily washing of clothing on his premises, even if the workers were wearing Tyvex® coveralls over their clothes. The protective clothing worn by the installers and assistants is listed in Table 4.

Table 4: Protecting clothing

Clothing	Installers	Assistants
Ordinary street clothes without protective clothing	7	13
Cotton coveralls without incorporated hood	10	4
Tyvex® coveralls with incorporated hood	2	1

Two contractors required that Tyvex® coveralls with hoods be worn, with one contractor requiring them for the work team, and the other only for the installer. At the end of the work and for meals, the coveralls were removed.

5.4 Ergonomic hazards

In order to cover each of the surface strips to be insulated, repeated horizontal and vertical passes need to be done with the hand and wrist. The installer holds the gun (weighing about 1.4 kg. [about 3 lb]) and applies pressure with his index finger to produce a jet of foam. With his other hand, he pulls the feed hose (see Figure 5) and measures the thickness of the foam with the gauge.

Figure 5: Spray gun and jet (Pierre Charbonneau, photographer)

The installer stood upright on the ground or on a stepladder, on the platform of the hoisting equipment, or knelt or crouched with his back bent. During these movements, his arms were not supported and were often held above his shoulders. His body was often not centred on the stepladder rungs and he stood on the two last rungs.[16] In winter, the hose became more rigid, further restricting the installer's movements when he tried to move the hose. Finally, the workers suffered from climatic constraints: heat in summer, particularly if they were wearing Tyvex® coveralls, and cold in winter.

[16] {On line} http://www.csst.qc.ca/portail/fr/publications/DC_400_1364_6.htm (March 2009).

Finally, the main awkward positions observed were:

- Repetitive movements of hand and wrist;
- Raising the hand above the head, or the elbow above the shoulder;
- Crouching position with or without back bent, or kneeling (see Figure 6).

Figure 6: Crouching position (Pierre Charbonneau, photographer)

5.5 Chemical hazards

The chemical hazard described in this report refers exclusively to MDI exposure, although other solvents are used (see Appendix 2). The surface and thickness of the foam were factors influencing the duration of the spraying work, which varied between 37 and 48% of a full working day (8 hours).

Ten teams of workers were followed for complete spraying jobs carried out for a full working day, representing 50% of the surveys. As mentioned above, the teams that were not followed for a complete spraying period had to go to another site where we were not allowed access. A brief description of the surveys carried out for each team of workers is summarized in Table 5.

Table 5: Brief description of surveys for each team of workers

Survey	Installer	Assistant	Comments
A	1	25	Full day of spraying work (outdoors) with frequent unplanned breaks, many workers on site, including welders near the spraying zone
B	2	26	Half day of spraying work (outdoors).
C	3	27	Full day of spraying work (outdoors).
D	4	*	Half day of spraying work (indoors with several uncovered openings so conditions comparable to outdoor work)
E	5	*	Half day of spraying work (indoors)
F	6	**	Full day of spraying work (indoors) on 3 floors of a residence, including crawl space
G	7	**	Half day of spraying work (outdoors). The workers went to another site (indoors) where the spraying zone was difficult to access for our sampling trains.
H	8	**	Half day of sampling
I	8	**	Day cut short due to climatic conditions for both teams
I	9	37	Day cut short due to climatic conditions for both teams
J	12	30	Full day (indoors) belt sealing
K	12	30	Full day (indoors) belt sealing
L	13	**	Full day (outdoors).
M	13	**	Half day (outdoors).
N	14	32	Half day of sampling (indoors). The workers went to another site.
O	15	**	Half day (outdoors) cut short due to climatic conditions.
P	16	33	Half day of sampling (outdoors). The workers went to another site.
Q	17	39	Two sites (belt sealing). The workers carried out spraying operations, one in morning, one in afternoon.
	18	38	
R	19	34	Half day (indoors).
S	19	34	Half day (indoors). The two workers took turns spraying.
	20	35	
T	21		Full day, two sites (indoors), one spent sealing belts.

*: No assistant. **: The assistant worked more than 10 m from the spraying zone.

5.5.1 Analytical results and average MDI concentrations

The analytical results for the stationary sampling are presented in Appendix 3. The flow rate of the pumps, measured with an electronic flow meter, did not vary more than 5% throughout the sampling. The number of samples, measurement ranges, and median per zone were as follows:

A. Spraying zone:

- 47 average MDI concentrations (94 samples), for a range of monomer MDI concentrations from 11 to 591 µg/m³ (arithmetic mean: 114.8 µg/m³, and median: 54.8 µg/m³) and for the oligomers, from 3 to 330 µg/m³ (arithmetic mean: 59.3 µg/m³, and median: 20.1 µg/m³);

B. Areas outside the spraying zone:

- **Assistants**: 24 samples for a range of monomer MDI concentrations from < 1 to 170 µg/m³ (arithmetic mean: 67.9 µg/m³, and median: 45.5 µg/m³) and for oligomers from < 1 to 99 µg/m³ (arithmetic mean: 33.0 µg/m³, and median: 24.5 µg/m³);

- **Other workers in the periphery:** 29 samples for a range of HS monomer MDI vapour and aerosol concentrations from < 1 to 11 µg/m³ (median: 0.14 µg/m³);

C. Post-spraying:

- 30 samples (22 on the floor where spraying had been done, and 8 on another floor) for a range of HS monomer MDI vapour and aerosol concentrations from < 0.01 to 2.4 µg/m³.

Although this does not involve the workers' exposure, the equivalent of the daily average exposure value (DAEV) was calculated on the basis that there had not been exposure to MDI for the periods during which sampling did not take place. This calculation was done using equation 1, cited in the RROHS. The average concentration was calculated using the same equation, but the denominator corresponded to the total duration of sampling for a spraying period that was the subject of the survey. This duration appears in the column "Duration" in Tables 6 and 7.

$$DAEV = \frac{C_1t_1 + C_2t_2 + \ldots + C_nt_n}{t_1 + t_2 + \ldots + t_n} \qquad \text{Equation 1}$$

Where: C = measured concentration of MDI for a given period;

t = MDI exposure time corresponding to the concentration measured;

$1, 2, \ldots, n$ = Samples collected during the survey;

$t_1 + t_2 + \ldots + t_n$ = 8 hours or 480 minutes or the total duration of sampling.

The average concentrations corresponding to a DAEV and the average concentrations of the samples in a spraying zone are listed by installer in Table 6. Those in the area outside of the spraying zone, corresponding to the zone where the assistants were working, are in Table 7. The lines in bold type correspond to the teams followed for a full day. It should be remembered that this was a complete spraying period for this team.

Table 6: Inside the spraying zone : Average MDI concentrations per installer

Installer *	Location	Duration (min)	DAEV for MDI (µg/m³)		Average concentration of MDI samples (µg/m³)	
			Monomer	Oligomers	Monomer	Oligomers
1	**Outdoors**	**211**	**17.3**	**12.6**	**39.3**	**28.7**
2	Outdoors	68	4.3	2.1	30.0	15.0
3	**Outdoors**	**252**	**31.9**	**11.9**	**60.7**	**22.6**
4	Indoors	176	14.0	6.4	38.0	17.6
5	Indoors	158	31.8	11.7	96.5	35.6
6	**Indoors**	**216**	**48.1**	**22.8**	**106.8**	**50.6**
7	Outdoors	95	14.0	7.8	70.8	39.2
8a	Outdoors	161	3.7	1.4	11.0	4.1
8b	**Outdoors**	**175**	**7.8**	**5.6**	**21.3**	**15.3**
9	**Outdoors**	**211**	**36.8**	**18.7**	**83.6**	**42.5**
12a	**Indoors**	**216**	**10.9**	**5.1**	**24.1**	**11.3**
12b	**Indoors**	**226**	**13.3**	**6.3**	**28.2**	**13.4**
13a	**Outdoors**	**257**	**20.3**	**5.4**	**38.0**	**10.1**
13b	Outdoors	125	19.6	10.4	75.1	40.1
14	Indoors	117	76.4	46.0	313.5	188.6
15	Outdoors	42	0.3	0.3	3.8	3.3
16	Outdoors	147	6.6	3.7	21.7	12.1
17	**Indoors**	**115.5**	**11.5**	**5.2**	**47.9**	**21.7**
18	**Indoors**	**119**	**34.7**	**16.3**	**140.1**	**65.6**
19a	Indoors	243	243.2	134.9	480.5	266.5
19b **	**Indoors**	**288**	**209.0**	**113.1**	**347.1**	**187.9**
20 **	**Indoors**	**54**	**13.1**	**7. 8**	**116.2**	**69.1**
21	**Indoors**	**141**	**38.9**	**14.6**	**132.3**	**49.6**

Table 7: Outside the spraying zone : Average MDI concentrations per assistant

Assistant *	Location	Duration (min)	DAEV MDI (µg/m³)		Average concentration of MDI samples (µg/m³)	
			Monomer	Oligomers	Monomer	Oligomers
2	**Outdoors**	**236**	**17.9**	**11.6**	**36.5**	**23.6**
2	Outdoors	68	4.3	2.1	30.0	15.0
2	**Outdoors**	**190**	**13.0**	**5.2**	**50.0**	**20.0**
3	**Indoors**	**225**	**1.5**	**0.3**	**3.1**	**0.7**
3	**Indoors**	**151**	**4.0**	**1.8**	**12.7**	**5.6**
3	Outdoors	147	6.6	3.7	21.7	12.1
3	Indoors	246	51.6	29.5	100.7	57.5
34b **	**Indoors**	**289**	**93.7**	**52.9**	**155.6**	**87.9**
35 **	**Indoors**	**51**	**9.4**	**6.3**	**88.0**	**60.0**
3	**Indoors**	**143**	**30.2**	**9.9**	**101.5**	**33.1**
3	**Outdoors**	**211**	**36.8**	**18.7**	**83.6**	**42.5**

* The number for an installer or an assistant may be repeated if he was present during the two surveys.

** The installer and the assistant took turns spraying on the two sites visited on that particular day.

Installers 4 and 5 worked alone. Assistants 28, 29, 31 and 32 worked at a distance from the spraying zone. The workers in one team shared the spraying period: Installer 19b became assistant 35, and installer 20 became assistant 34b.

The average concentrations by zone corresponding to that of the installer and his assistant are summarized in Table 8. The averages of the concentrations for indoor work by zone are listed in Table 9.

Table 8: Average MDI concentrations by zone by location/season

Location of work:		Indoors		Outdoors	
Season:		Winter	Summer	Winter	Summer
Zone	Aerosols + vapours	Average MDI concentration (µg/m³)			
Spraying (installer)	monomer	93.0	206.7	43.0	48.2
	oligomers	50.7	106.1	20.0	26.3
Work zone assistant	monomer	12.5	90.8	53.6	41.8
	oligomers	5.5	45.7	28.6	25.1

Table 9: Average MDI concentrations by zone for indoor work

Zone	MDI	Average MDI concentration (µg/m³)	
	Aerosols + vapours	Insulation	Sealing
Spraying (installer)	monomer	288.7	83.3
	oligomers	151.1	43.1
Work zone assistant	monomer	135.6	27.3
	oligomers	71.8	10.5

The average MDI concentrations in the area outside the spraying zone (work zone for workers in other specialties) by floor with regard to the work are indicated in Table 10.

Table 10: Average MDI concentrations in the area outside the spraying zone

MDI	Average MDI concentration (µg/m³)	
	Same floor	Another floor
Aerosols + vapours: monomer	20.0	- -
Aerosols + vapours: oligomers	10.7	- -
High Sensitivity monomer vapours	1.9	2.0

The average HS monomer MDI vapour concentrations for the post-spraying samples are listed in Table 11 and illustrated in Figure 7.

Table 11: Average monomer MDI concentrations: post-spraying by floor

Post-spraying sampling	Average MDI concentration HS vapours (µg/m³)	
	Floor where spraying took place	Another floor
30 minutes	0.35 µg/m³	0.30 µg/m³
60 minutes	0.08 µg/m³	0.95 µg/m³
120 minutes	0.03 µg/m³	0.02 µg/m³

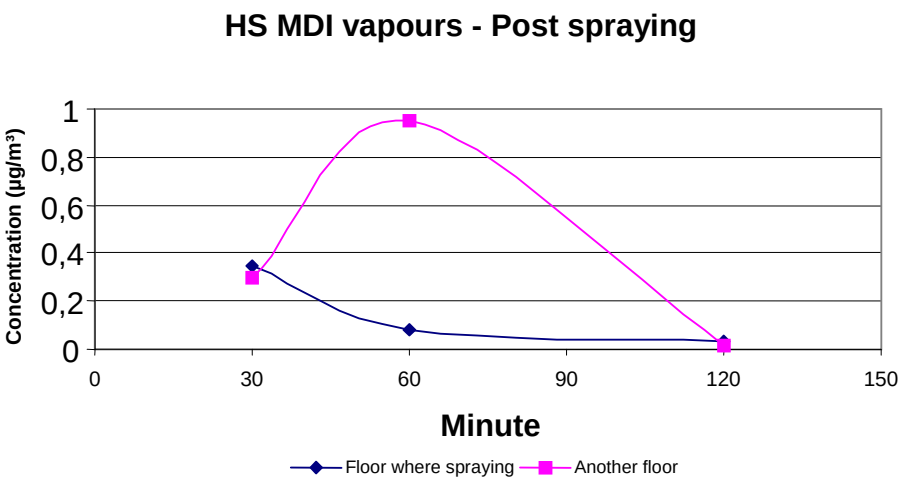

Figure 7: Average of the monomer MDI concentrations in post-spraying samples

The target parameters (DAEV and average concentrations of monomer and oligomers MDI) were analyzed statistically according to determining factors that could modify MDI exposure in the spraying zone and in the area where the assistant works. In order to do this, we checked whether the groups were similar (SEG):

I. If a distribution of more than five data is lognormal and has a geometric standard deviation (GSD) less than 3,[17] the group would be relatively similar for this determining factor.

II. If the 95th percentile of the distribution is greater than the PEV of MDI, there would be a risk of exposure, with a certain fraction exceeding the PEV, for a probability of around 5%.

Certain determining factor distributions with fewer than five data are not mentioned in the tables in Appendix 4.

5.5.2 Other exposure risks

According to the safety data sheets, there were other chemical substances present (see Appendix 2) that were not sampled. The workers were not wearing gloves when they used these products, some of which are classified as having dermal effects.

It is possible that liquid containing MDI or other solvents could splash into the eyes or onto the skin, particularly during transfer of the aspiration system from an empty barrel to a full one (a task observed once), when the residual solution is being emptied from the barrel, etc. One team had a portable eye-wash device.

[17] IHSTAT uses a GSD below 2.5.

6. DISCUSSION

The study covers a range of sites (see section 5.1), each different from the others, mainly with respect to the work carried out (insulation of walls or sealing of belts), its location (indoors or outdoors), the season in which it was done (summer or winter), the surface area of the spraying floor, and work organization (installer working alone or installer plus assistant).

Furthermore, the spraying technique used by the installers depended on their professional experience. Some had attended the training program prescribed by CUFCA, while others will attend it as soon as they have worked the required number of hours. These variables, specific to the site and work teams, affect the results of the study, limiting their scope.

The results in this report are representative of the conditions existing on the survey days on the sites visited according to the work performed.

6.1 Work organization

In the course of a single day, one team of workers could work on more than one site. There is then a longer transport time (from one site to another). The work to be carried out may differ from one site to another: insulation of exterior walls, interior walls (basements or on the upper floor), or sealing of belts.

6.2 Health and safety practices

If workers need to access enclosed or confined spaces, they must have the recommended training on the hazards and risks and must also have the appropriate equipment with them at all times to ensure that they can exit in case of an emergency. It should be remembered that, in the case encountered, the workers had not received this training.

6.2.1 Hoisting equipment

By using a stepladder not sufficiently high and standing on the top rung, the worker is in an unstable position and risks losing his balance. Figure 8 shows the position of the body on a rung of a stepladder.

Figure 8: Position of worker on a rung of a stepladder (Pierre Charbonneau, photographer)

Even though there is no strict legal obligation, **good occupational health and safety practices** recommend the wearing of a safety harness to protect against falls from heights of over 3 metres with any motorized elevating platform (scissor-type, articulated arm) since its guard-rail does not protect the worker from such things as whiplash resulting from mechanical failure, collision, etc. The fact that the workers had not been trained to work on this hoisting equipment may explain why this rule of good practice was not observed.

The wind can render a plastic shelter unstable (see Figure 4) when installed on hoisting equipment. The plastic sheeting should be wound around the horizontal and vertical members and railings of the equipment (Figure 9) since it is there to protect the equipment and not to allow work to continue despite unfavourable weather conditions.

Figure 9: Protection of vertical members and cross members of hoisting equipment

6.2.2 Protective equipment

Theoretically, no worker should be present in the spraying zone unless he is wearing appropriate personal protective equipment, including a properly fitting respirator supplying fresh air. According to Table 3, none of the assistants we met had worn a respirator when they were in the spraying zone, in particular assistants 26 and 33 who were in the hoisting equipment.

Specific respirator training (use, maintenance, tight fit, etc.) should be given so that workers know how to wear a respirator correctly.

Anyone close to the spraying zone should wear the appropriate protective equipment. The work should be posted on a sign at the entrance to the site. It should also be mentioned that no worker may enter the spraying zone without personal protective equipment as specified by the regulations.[18]

[18] The CAN/ULC S705.2 standard establishes the requirements for environmental conditions and other documentation relevant to spraying operations.

Considering the state of knowledge on dermal exposure to diisocyanates, it would be advisable that protective clothing made of appropriate materials be worn in order to protect workers in this sector. The Service du repertoire toxicologique (REPTOX) of the CSST[19] recommends the wearing of polyethylene/vinyl alcohol and ethylene/polyethylene gloves (PE/EVAL/PE) and impervious protective clothing made of Barricade® covering the whole body.

In addition to the CSST, other organizations suggest occupational health and safety practices for the spraying of isocyanate-based products. For example, Work Safe Alberta[20] recommends the wearing of a respirator with a full face mask or airtight goggles/mask to protect the eyes, coveralls to protect the arms and legs, and resistant gloves, without specifying the material.

6.3 Ergonomic hazards

The adoption of a rigid posture in order to remain stable on a stepladder can cause significant muscle strain in the back, particularly if the worker is on the next to last step. Access to this level is not recommended. Moreover, the narrow support surface does not allow the installer to pivot his feet. This means that he can only turn his body, with the risk of losing his balance.

6.4 Chemical hazards

Since the installers wore respirators and the sampling trains used included an impinger containing a collecting solution, stationary sampling was done. It should be remembered that the results obtained represent contamination of the work areas and not worker exposure.

6.4.1 MDI concentration in the spraying zone

The average of the MDI concentrations in the spraying zone, taking all categories of sites together, exceeds the permissible exposure value in Québec by about 2.3 times, and in the area outside the spraying zone (where the assistants work), by about 1.3 times. As an example, installer 14 was in the spraying zone on the first site we visited. There was an average MDI concentration of 313.5 µg/m³ in this zone, more than six times the PEV, and a DAEV of 76.4 µg/m³. Whatever the duration of spraying on the second site, the PEV was exceeded on the first site by estimating a zero concentration on the second site.

Next, let us examine the results for the installer-assistant teams that took turns in the spraying operation (Table 12). The DAEV corresponding to the work zone of installer 19b and assistant 35 was 217.6 µg/m³, while for the work zone of installer 20 and assistant 34b, it was 106.7 µg/m³.

Table 12: Average concentrations of monomer MDI by task

Team	Duration (min)	MDI concentration during spraying	Duration (min)	MDI concentration during assistant's tasks	DAEV (µg/m³)
19b-35	288	347.1 µg/m³	51	88.0 µg/m³	217.6
20-34b	54	116.2 µg/m³	289	155.6 µg/m³	106.7

[19] {On line} {http://www.reptox.csst.qc.ca/Produit.asp?no_produit=12393&nom=Diisocyanate%2D4%2C4%27+de+diph%E9nylm%E9thane+%28MDI%29} (April 2008).

[20] {On line} http://employment.alberta.ca/documents/WHS/WHS-PUB_ch005.pdf (December 2008).

The period during which installer 19b carried out the tasks of an assistant was shorter (51 minutes) than that in which he was spraying (288 minutes). During execution of the assistant's tasks, the workers did not wear respiratory protective equipment and the monomer MDI concentrations were 1.7 and 3.1 times above the PEV. The assistant must wear a respirator.

As mentioned above, the assistants were sometimes in the spraying zone. For example, assistant 37 was present with installer 9 on the platform where a shelter had been installed (Figure 4). The average MDI concentration under this shelter was 83.64 µg/m³ (1.6 times the PEV). Frequently, the assistant present on hoisting equipment did not wear any respirator, while our results show high concentrations of MDI.

In the case of installer 16 (who was wearing a respirator) and his assistant 33 (who was not wearing a respirator), their calculated DAEV took into account only the work carried out on the first site that they visited on the day of our survey.

The MDI concentrations for the work performed in summer were higher than those observed in winter (Table 8), and those for insulation work performed indoors would correspond, for the spraying zone, to 5.7 times the PEV, and for the assistant's area, to 2.7 times the PEV (Table 9). Hypotheses can be made regarding the surface of the work floor, the thickness and quantity of foam sprayed, or the installer's experience.

The previously mentioned studies obtained results varying from 17 to 400 µg/m³ for the installer (0.3 to 7.8 times the PEV in Québec). Our stationary sampling results in the spraying zone varied from 11 to 591 µg/m³ (0.2 to 11.6 times this PEV). They are comparable to those reported in the literature.

In conclusion, the concentrations in the spraying zone for indoor work were the highest, particularly in summer, while those for outdoor work were equivalent in both summer and winter.

6.4.2 MDI concentration outside the spraying zone

The average of the concentrations in the assistant's work area is about 1.7 times lower than that in the spraying zone (see Appendix 3). The previously mentioned studies had obtained results of 10 to 310 µg/m³ in the assistant's work area (0.2 to 6.1 times this PEV). Our results for the assistant's area were from 2 to 170 µg/m³ (0.04 to 3.3 times the same PEV), and therefore lower than those reported in those studies.

In the zones occupied by workers of other trades, the averages of the analytical results for HS MDI monomer vapours were low: about 3.8% of the PEV (Table 10). In these areas, which were rather distant from the spraying, the probable presence of aerosols was low, unless it was accidental spraying off target. The absence of workers from other trades reduced their risk of MDI exposure as prescribed in the RROHS, which mentions reducing such exposure to a minimum. It is therefore advisable that the employment contract mention that no worker can be present in the spraying zone unless he is wearing personal protective equipment.

In conclusion, the assistants outside the spraying zone came into contact with MDI aerosols to a lesser degree. Workers from other trades located outside the spraying zone (> 10 m) came into contact with low concentrations of monomer MDI vapour (about 4% of the PEV).

6.4.3 Post-spraying MDI concentration

The HS MDI vapour results from the post-spraying samples (Table 11) varied from the analytical limit of quantification to 2.4 µg/m³. This last result was obtained in the first hour following the end of spraying, while the result for the next hour was 0.013 µg/m³. There would have been an average concentration of 0.029 µg/m³ two hours after the end of spraying (≤ 0.01% of the PEV).

The highest result reported in the Lesage et al. (2007) study was 19 µg/m³ in the first 15 minutes following the end of spraying. However, the very great majority of the post-spraying results (except for four) in that study were below the 0.036 µg analytical limit of quantification. In fact, all of the results after one hour were below this limit. The difference between the results in that study and ours lies mainly in the limit of quantification of the analytical methods (see Table 2). In fact, the analytical limit of quantification for the monomer MDI vapour analyzed according to the high sensitivity IRSST method was 0.00075 µg, while that in the Lesage et al. (2007) study was 0.036 µg for the monomer.

The suggested good practices following the situations observed during the study are summarized in Table 13.

Table 13: Good practices recommended and poor practices observed

Regulation/standard/recommendation/good practices		Poor practices observed
Good practices	• Winding the plastic sheeting around the hoisting equipment's members	✓ Producing temporary shelters on hoisting equipment
	• Protection of respirator in a hermetically sealed bag • Seal (fit) test	✓ Respirator and cartridges incorrectly stored ✓ No fit test
	• To be stipulated in employment contract: People other than those involved in spraying are prohibited	✓ Presence of workers from other specialties
	• Wearing of safety harness to protect from falls from heights and with energy absorber if falls from heights greater than 3 metres are possible, no matter what other equipment is used	✓ Hardly any or no harnesses worn
	• Height of stepladder appropriate for height of work http://www.csst.qc.ca/portail/fr/publications/DC_400_1364_6.htm	✓ Height of stepladders inappropriate for height of work ✓ Standing on second rung from top ✓ Body weight not centered on step
CSST, *Service du répertoire toxicologique* (REPTOX)	• Wearing of PE/EVAL/PE gloves and leakproof protective clothing made of Barricade® covering the whole body	✓ No nitrile gloves worn under cotton gloves ✓ Tyvex® coveralls hardly worn
CSST-IRSST, *Guide pratique de protection respiratoire*	• Supplied air respirators • If coveralls with hood are not worn, then wear full hood and supplied air respirator	✓ Supplied air respirators hardly used by installers

Regulation/standard/recommendation/good practices		Poor practices observed
Standard CAN/ULC-S705.2 of Underwriters' Laboratories of Canada (ULC)	• Wearing of gloves, coveralls with hood, goggles or protective mask, safety shoes, safety helmet	✓ No gloves made of nitrile or other appropriate material ✓ No Tyvex® coveralls with hood ✓ Frequently no safety helmet
	• Training program for installers	✓ Before training, a number of hours of on-the-job spraying work are required
	• Protect the foam from heat and sparks with a thermal barrier if there are ignition sources close to the spraying zone	✓ No protection
	• Sign announcing spraying work	✓ No signs ✓ Presence of workers
	• No workers must be present in the spraying zone without respirators and goggles	✓ Presence of workers in spraying zone without protective equipment
RROHS article 264 SCCI article 2.9.1 CAN/CSA Z259.10-M90	• Wearing of safety harness to protect against falls from heights, with energy absorber	✓ Not respected ✓ No training in the use of hoisting equipment
RROHS article 48 Standard CAN3Z180.1-M85	• Air tested once a year	✓ Air not compliant (not tested) ✓ Air potentially contaminated by exhaust gases
RROHS articles 1, 297 to 302, 306 SCCI article 1.1.17.1	• Enclosed or confined spaces - training	✓ No training in hazards and risks, measurement of concentrations, etc. ✓ Not included in the training program for installers
Polyurethane MDI Handbook[21]	• No eating or drinking in places where MDI is handled or stored	✓ Not respected

6.4.4 Statistical analysis

According to the statistical analysis (Appendix 4), there is a risk of MDI exposure for the installers (or appliers) during indoor work in summer. Summer outdoor work for assistants appears to present a lower risk of MDI monomer exposure if it is done outside the spraying zone.

There is considerable variation in the majority of the distributions of most determining factors for these two parameters since:

1) The DAEV did not always correspond to a complete spraying period. Some teams went to another site where no sampling was carried out.
2) The DAEV and the average concentrations for a survey varied with the installer's skill and experience, from one worker to another for the same task, the same location and the same season.

[21] {On line}. {http://www2.basf.us/urethanechemicals/Specialty_Systems/pdfs/2000mdihandbook.pdf} (November 2008).

3) The DAEV and average concentrations for a survey corresponded to different levels of productivity, depending on the site and the work, the weather conditions, and the volume of the building (interiors). The work was frequently different from one day to another, varying mainly according to the customer's particular requirements.
4) The DAEV and average concentrations for the assistant's tasks reflected the variability in their professional practices. Some entered and stayed in the spraying zone while others did not.
5) The DAEV and average concentrations for a survey varied from one installer to another, depending on their skill and professional experience.

As mentioned previously, only the monomer form of isocyanates is regulated in the RROHS, although oligomers are scientifically recognized as being toxic (section 2, Issues and State of Knowledge). The United Kingdom, through the HSE, is a country that has a reference value reflecting all of the isocyanate functions and taking into account the scientific data on the toxicity of oligomers. It would be appropriate for the Québec PEV to be reconsidered in order to take all of the isocyanate functions into account.

6.5 Other risks of exposure

Since several of the products used have effects resulting from skin contact, it is recommended that gloves be worn because skin irritation and inflammation may result from such contact, depending on the quantities and frequency of use. For the case of splashing, workers should have a kit containing a portable eye-wash device and bottled water to rinse their hands and faces.

6.6 Recommendations

Different avenues may lead to the control of MDI exposure risks, in particular by informing workers about:

- the chemical hazards in handling isocyanates (occupational asthma and contact dermatitis)
- the wearing of supplied air respirators by installers and assistants present in the spraying zone
- the safe storage of cartridges and respirators
- the wearing of appropriate personal protective equipment (nitrile or PE/EVAL/PE gloves, and coveralls with hoods made of Tyvex® or Barricade®)
- the hazards and risks related to enclosed or confined spaces (qualified workers, environmental monitoring, supervisor, etc.)
- the wearing of gloves made of materials appropriate for the solvents present in the product being used (consultation of safety data sheets)
- the wearing of safety harnesses to protect against falls from heights during the use of hoisting equipment.

This information should, among other things, be distributed in the training program and be the subject of periodic refresher training.

In summary, one of the particular characteristics of this study was the variety of work situations observed during polyurethane foam spraying. The sources of uncertainty in the reported results are mainly related to environmental fluctuations, which are greater than those related to the sampling and laboratory analyses. The latter are minor and even negligible compared to the others. The height of the spraying strips varied continually, while that of the sampling trains remained fixed at approximately 1.5 m from the ground (equivalent to the installer's breathing zone during the spraying of the middle sections). In fact, the installer sprayed the upper, middle and lower parts of each strip. Furthermore, the trains were positioned on each side of the installer so as not to hinder the work or the movement of the worker and his equipment. These movements, in relation to the positioning of the trains, affected the concentrations obtained in each of the trains surrounding the spraying zone. Also, the environmental fluctuations depended on the type of site (commercial or residential) and on its surface area, features of the work (insulation of walls, sealing), on its location, the season, the work method, and the installer's experience.

7. CONCLUSION

The results of this study relate to the workers' immediate environment and not their actual personal exposure. The work zones of workers spraying polyurethane foam, particularly in the spraying zone, were exposed to monomer MDI that could exceed the Québec PEV, and to oligomers. In view of these results, the workers must wear supplied air respirators. The air fed into the device should meet the requirement of the standards (Grade D air). The workers must also protect themselves against the possibility of skin contact by wearing gloves and coveralls with hoods, even though there is no consensus in the literature on sensitization through skin exposure to MDI.

Workers close to the spraying zone are at risk of exposure to MDI vapours. It would therefore be advisable to avoid any work close to this zone. A sign must be posted announcing the work and the requirement to wear protective equipment.

Post-spraying samples have shown that residual monomer MDI vapours are present for approximately two hours. However, their concentrations are low ($\leq$ 0.01% of PEV).

In addition to the chemical hazards, the study has pinpointed the health and safety practices to be changed and the relative weaknesses of this aspect of the work in the installers' training program. The organizations providing training to foam installers should more rigorously integrate all aspects of occupational health and safety, particularly for the construction site health and safety course, for all construction site workers. We reiterate that motorized elevating platforms must be used with safety harnesses to protect against falls from heights, that respiratory and skin protection must be used, and that other workers should not be permitted entry into the spraying zone. Based on the results of this study, a good practices guide has been produced jointly with ASP- Construction.[22]

[22] {On line} http://www.asp-construction.org/utilisateur/documents/prevenir-aussi/prevenir_printemps2009.pdf (April 2009).

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APPENDIX 1: LIST OF POINTS RELATING TO WORK METHODS

Polyurethane foam spraying: Work methods

Site: New construction ☐ Renovation: ☐ Year of construction _____

Type of building: Single floor residence: ☐ Dimension: _____

Cottage: ☐ Dimension: _____

Commercial: ☐ Dimension: _____

How many workers carry out spraying? _____ **Installer** _____ **Assistant** _____

Tasks performed by assistant: Preparation (masking) ☐ **Cleaning** ☐ **Spraying** ☐

_____

_____

_____

_____

Presence of other workers on the site:_____

Presence of other people in the residence: _____

Truck: Condition of site: Cluttered Yes ☐ No ☐ _____

_____

Condition of equipment: Clean Yes ☐ No ☐ Gun: _____

Work Indoors ☐ Outdoors ☐

Basement: ☐ **Floor:** _____

Height of ceiling *: _____

Access by a door: ☐ Opening *: ☐

By a ladder* ☐ Stepladder ☐

Condition of site_____

_____

_____

Number of outside doors:_____

Number of windows or wall openings and condition:

North ☐ _____ : Masked ☐ Closed ☐

South ☐ _____ : Masked ☐ Closed ☐

West ☐ _____ : Masked ☐ Closed ☐

East ☐ _____ : Masked ☐ Closed ☐

*** NB: This might be an enclosed or confined space. See below.**

Ground level: ☐ **Height**_____

Height of structure:_____

Condition of ground: _____

Condition of walls: _____

Condition of site: _____

_____

_____

Number of outside doors:_____

Number of windows or wall openings and condition:

North ☐ _____ : Masked ☐ Closed ☐

South ☐ _____ : Masked ☐ Closed ☐

West ☐ _____ : Masked ☐ Closed ☐

East ☐ _____ : Masked ☐ Closed ☐

Polyurethane foam spraying: Work methods

Spraying performed from: Ground ☐ Stepladder ☐ Ladder ☐

Hydraulic hoisting equipment used:

Scissor-type: ☐ Height _____ Articulated arm: ☐ Height _____

Platform: ☐ Height _____ Other: _____

_____

Thickness sprayed: _____

Number of coats: _____

(2 in. < coats > ½ in.)

Safety to be promoted when using hydraulic equipment: _____

_____

Gun cleaning: Product used: _____ Duration of cleaning: _____

Delimitation of exclusion zone: Yes ☐ No ☐

Sign announcing spraying work: Yes ☐ No ☐

Message: _____

_____

If an enclosed or confined space:

Explain the configuration of this space and its features:

_____

Partially closed ☐ Completely closed ☐

Access by ladder ☐ Stepladder ☐ Other _____

Design or construction _____

_____

_____

Ventilation: natural ☐ mechanical ☐ _____

Contaminants emitted or contained: _____

_____

Are the workers informed that it is a confined space? Yes ☐ No ☐

If so, what are their instructions or procedures? _____

_____

_____

_____

_____

Polyurethane foam spraying: Work methods

Ergonomics: Weight of gun: _____

Awkward postures: Working …

1. with hands above head _____
2. with hands repeatedly raised above head _____
3. with bent elbows _____
4. with back bent more than 45° _____
5. with bent neck _____
6. with bent wrists _____twisted wrists _____
7. crouching _____

Tasks performed by other workers present:

Welding: Yes ☐ No ☐ Type of welding _____

Distance from the spraying zone: _____

Excavation and formwork: Yes ☐ No ☐ Roofing: Yes ☐ No ☐

Electrician: Yes ☐ No ☐ Carpenter: Yes ☐ No ☐

Plumber: Yes ☐ No ☐ Installation of ventilation: Yes ☐ No ☐

Use of propane-powered equipment:

_____

Describe the work performed by these workers and at what distance from the spraying zone:

_____

_____

_____

Installer's protective equipment:

Respirator: Yes ☐ No ☐

Full face mask ☐ Half mask ☐

Supplied air: filtered (pump at belt):

Pump ☐ Compressor ☐

Filter unit (respirable air) Yes ☐ No ☐

Near gas emission (truck): _____

Cartridges_____

Type _____

How often changed: _____

Assistant's protective equipment:

Respirator: Yes ☐ No ☐

Full face mask ☐ Half mask ☐

Supplied air: filtered (pump at belt):

Pump ☐ Compressor ☐

Filter unit (respirable air) Yes ☐ No ☐

Near gas emission (truck): _____

Cartridges_____

Type _____

How often changed: _____

Polyurethane foam spraying: Work methods

Storage of respirator when not used _____

Respirator training: Yes ☐ No ☐

Received by: Respirator representative ☐
Firm ☐

Someone from company ☐ Other ☐

Falls from heights: Harness: Yes ☐ No ☐

Explain _____

_____

Clothing: Coveralls ☐ Street clothes ☐

Material: Tyvex® ☐ Other _____

Gloves: Yes ☐ No ☐

Material _____

Appearance of clothing: _____

Maintenance: in company ☐ at home ☐

Safety helmet: Yes ☐ No ☐_____

Goggles: Yes ☐ No ☐ _____

Safety shoes: Yes ☐ No ☐

Storage of respirator when not used

_____

Respirator training: Yes ☐ No ☐

Received by: Respirator representative ☐
Firm ☐

Someone from company ☐ Other ☐

Falls from heights: Harness: Yes ☐ No ☐

Explain _____

_____

Clothing: Coveralls ☐ Street clothes ☐

Material: Tyvex® ☐ Other _____

Gloves: Yes ☐ No ☐

Material _____

Appearance of clothing: _____

Maintenance: in company ☐ at home ☐

Safety helmet: Yes ☐ No ☐_____

Goggles: Yes ☐ No ☐ _____

Safety shoes: Yes ☐ No ☐

Spraying season:

Summer ☐ Winter ☐

Ambient temp: _____°C Humidity: _____ Direction of air currents: _____

Velocity (<24 Km/h): _____

Doors and windows opened during work: _____

Type of shelter: _____ Propane heating: _____

Ventilation:_____

Sanitary installations: Portable toilet: Yes ☐ No ☐ Eye wash: Yes ☐ No ☐

Comments: _____

_____

_____

APPENDIX 2: LIST OF PRODUCTS USED

Product	Substance[23]	CAS#[24]
	4,4'-Diphenylmethane diisocyanate (MDI)	101-68-8
	Polymeric MDI (PMDI)	9016-87-9
Polyol (proportions vary according to version, regular or winter)		25723-16-4
	Dichloroethylene (two isomers)	156-60-5
	1,4-Dioxane	123-91-1
	1,1-Dichloro-1-fluoroethane	1717-00-6
	1,1,2-Trichloro-1,2,2-trifloroethane	76-13-1
	N,*N*-Dimethyl-2-aminoethanol	108-01-0
	1,1-Chloro-1,1-difluoroethane	75-68-3
	Diethylamine	109-89-7
	1,3-Dioxane	505-22-60
	Traces of xylenes	1330-20-7
Foaming agent	1,1,1,2,2-Pentafluoropropane (HFC 245FA).	460-73-1
Gun cleaning solvent	Dipropylene glycol monomethyl ether	34590-94-8
Adhesive (contact glue)	Hexane	110-54-3
	Acetone	67-64-1
	Toluene	108-88-3

[23] These substances are mentioned in the product safety data sheets. This list does not contain all the substances because some may only be in trace amounts in the mixture.

[24] CAS#: This is the registration number for a chemical substance in the database of the Chemical Abstracts Service, a division of the American Chemical Society.

APPENDIX 3: ANALYTICAL RESULTS

Table A-3a: Average concentrations of samples collected in the spraying zone (installers or appliers)

Table A-3b: Analytical results from outside the spraying zone (assistants)

Table A-3c: Analytical results from outside the spraying zone (other workers)

Table A-3d: Analytical results post-spraying by floor

Table A-3a: Average concentrations of samples in the spraying zone (installers or appliers)

	Site	Work	Process	Duration (min)	MDI concentration (µg/m³)[25]		
					Monomer	Oligomers	Vapours
1	commercial	outdoor	Insulation	58	20.50	13.00	0.02
1	commercial	outdoor	Insulation	101	56.87	37.48	0.02
2	commercial	outdoor	Insulation	68	30.00	15.00	0.16
3	commercial	outdoor	Insulation	126	41.50	10.20	0.04
3	commercial	outdoor	Insulation	126	79.96	34.98	0.03
3	commercial	outdoor	Insulation	52	26.00	29.00	0.16
4	residential	indoors	Insulation	26	22.01	3.07	
4	residential	indoors	Insulation	78	36.97	20.17	
4	residential	indoors	Insulation	72	45.00	20.00	
5	residential	indoors	Insulation	84	84.61	27.37	
5	residential	indoors	Insulation	74	110.00	45.00	
6	residential	indoors	Insulation	85	16.51	5.50	
6	residential	indoors	Insulation	82	55.00	20.00	
6	residential	indoors	Insulation	49	350.10	180.00	
7	commercial	outdoor	Insulation	55	100.00	60.00	
7	commercial	outdoor	Insulation	40	30.69	10.48	
8b	commercial	outdoor	Insulation	95	18.50	12.50	
8b	commercial	outdoor	Insulation	80	24.53	18.65	
8a	commercial	outdoor	Insulation	161	11.00	4.09	
9	commercial	outdoor	Insulation	121	75.19	29.50	
9	commercial	outdoor	Insulation	90	95.00	60.00	
12b	residential	indoors	Sealing	77	15.00	6.00	0.36
12b	residential	indoors	Sealing	74	40.00	20.00	0.36
12b	residential	indoors	Sealing	75	30.20	14.61	0.27
12a	residential	indoors	Sealing	39	1.80	0.67	0.16
12a	residential	indoors	Sealing	80	40.06	15.03	0.29
12a	residential	indoors	Sealing	97	20.00	12.50	0.32
13	commercial	outdoor	Insulation	125	75.12	40.08	0.24
13	commercial	outdoor	Insulation	120	20.00	8.00	0.09
13	commercial	outdoor	Insulation	77	45.16	17.08	0.28
13	commercial	outdoors	Insulation	60	64.71	5.28	0.34
14	residential	indoors	Sealing	44	120.10	70.10	0.69
14	residential	indoors	Sealing	73	430.00	260.00	0.05
16	commercial	outdoors	Insulation	71	32.93	19.05	
16	commercial	outdoors	Insulation	76	11.15	5.67	
17	residential	indoors	Sealing	60	57.50	28.50	3.05
17	residential	indoors	Sealing	55.5	37.42	14.42	1.31
18	residential	indoors	Sealing	119	140.13	65.57	2.25

[25] The MDI concentrations are the averages of the analytical results obtained from the two sampling trains surrounding the installer's zone (see Methodology).

	Site	Work	Process	Duration (min)	MDI concentration (µg/m³)		
					Monomer	Oligomers	Vapours
19b	residential	indoors	Insulation	106	304.86	165.05	
19b	residential	indoors	Insulation	86	397.73	214.48	
19b	residential	indoors	Insulation	97	348.31	189.23	14.00
19a	residential	indoors	Insulation	78	571.10	310.58	36.48
19a	residential	indoors	Insulation	75	591.28	330.60	26.00
19a	residential	indoors	Insulation	90	309.61	174.81	19.50
20	residential	indoors	Insulation	54	116.22	69.12	
21	residential	indoors	Sealing	37	54.50	17.00	1.02
21	residential	indoors	Insulation	57	225.00	86.50	2.65
21	residential	indoors	Sealing	47	81.00	30.50	2.05
				µ	**114.8**	**59.3**	**4.0**
				s	**147.0**	**82.6**	**9.0**
				Median	**54.8**	**20.1**	**0.33**

Two series of analytical results were rejected.

Table A-3b: Analytical results of samples collected outside the spraying zone (assistants)

	Site	Work	Process	Duration (min)	MDI concentration (µg/m³)		
					Monomer	Oligomers	Vapours
25	commercial	outdoors	Insulation	69	84.00	56.00	
25	commercial	outdoors	Insulation	58	41.00	29.00	
25	commercial	outdoors	Insulation	109	4.00	0.26	
26	commercial	outdoors	Insulation	67	30.00	20.00	0.02
27	commercial	outdoors	Insulation	125	50.00	20.00	0.04
28	residential	indoors	Insulation	113			2.90
28	residential	indoors	Insulation	115			3.70
28	residential	indoors	Insulation	67			7.00
30b	residential	indoors	Sealing	74	5.00	2.00	0.25
30b	residential	indoors	Sealing	77	20.00	9.00	0.20
30a	residential	indoors	Sealing	38	3.00	0.69	0.12
30a	residential	indoors	Sealing	80	2.00	0.33	0.09
30a	residential	indoors	Sealing	107	4.00	1.00	0.23
33	commercial	outdoors	Insulation	71	32.93	19.05	
33	commercial	outdoors	Insulation	76	11.15	5.67	
34b	residential	indoors	Insulation	107	150.00	85.00	
34b	residential	indoors	Insulation	244			8.90
34b	residential	indoors	Insulation	81	170.00	99.00	
34b	residential	indoors	Insulation	101	150.00	82.00	11.00
34a	residential	indoors	Insulation	82	130.00	78.00	15.00
34a	residential	indoors	Insulation	69	170.00	93.00	9.30
34a	residential	indoors	Insulation	95	25.00	14.00	3.70
35	residential	indoors	Insulation	51	88.00	60.00	
36	residential	indoors	Sealing	39	40.00	13.00	0.97
36	residential	indoors	Insulation	57	120.00	33.00	0.04
36	residential	indoors	Sealing	47	130.00	50.00	0.01
37	commercial	outdoors	Insulation	121	75.19	29.50	
37	commercial	outdoors	Insulation	90	95.00	60.00	
				µ	**67.9**	**35.8**	**3.3**
				s	**58.5**	**33.0**	**4.6**
				Median	**45.5**	**24.5**	**0.25**

Table A-3c: Analytical results outside the spraying zone (other workers)

	MDI concentration (µg/m³)		
	Monomer	**Oligomers**	**HS vapours**
			0.14
			0.26
			3.8
			6.1
			0.51
			11.0
			3.0
			4.3
			5.6
			2.5
			0.14
			0.01
			0.01
			0.03
			0.03
			0.35
			0.16
			0.18
			0.08
			0.01
			0.05
			0.14
			0.04
			0.05
	60	20	
			0.10
			0.37
	50	10	
	20	1.39	
	50	25	
	20	20	
	20	8	
			0.12
	20	15	
	25	12	
			0.13
			0.02
µ:	**33.1**	**13.9**	**1.4**
s:	**17.1**	**7.6**	**2.6**
Median	**22.5**	**13.5**	**0.1**

Table A-3d: Analytical results post-spraying by floor

Location	Time (min)	MDI concentration HS vapours (µg/m³)	Average
Same floor as foam spraying	30	1.90	
		0.36	
		0.01	
		0.06	
		0.02	
		0.29	
		0.44	
		0.07	
		0.01	0.350
	60	0.23	
		0.23	
		0.02	
		0.02	
		0.02	
		0.03	
		0.02	0.078
	120	0.04	
		0.01	
		0.01	
		0.08	
		0.01	0.029
	240	0.06	
On another floor than foam spraying	30	0.02	
		0.58	0.302
	60	2.40 *	
		0.39	
		0.06	0.951
	120	0.01	
		0.01	
		0.04	0.022

*: This sampling was carried out over the 60-minute period after the end of spraying.

APPENDIX 4: DATA FROM THE STATISTICAL ANALYSIS OF THE MDI RESULTS

Table A-4a: Results of the statistical analysis by determining factor for the daily average exposure by task (monomer MDI)
Table A-4b: Results of the statistical analysis by determining factor for the average concentration of the samples by task (Monomer MDI)
Table A-4c: Results of the statistical analysis by determining factor for the average daily exposure by task (MDI oligomers)
Table A-4d: Results of the statistical analysis by determining factor for the average concentration of the samples by task (MDI oligomers)

Table A-4a: Results of the statistical analysis by determining factor for the average daily exposure by task (monomer MDI)

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (µg/m³)	Minimum (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
Installer	Indoors		B-2	DAE-mono	7	76.4	10.9	27.5	14.0	23.7	21.3	2.09	0.86	Yes	71.5	260.2	12%	2.4	37.4
	Outdoors	summer		DAE-mono	7	31.9	4.3	14.7	14.0	9.4	11.9	2.12	0.88	Yes	40.8	152.5	3%	0.1	21.1
Assistant	Outdoors			DAE-mono	5	36.8	4.3	15.7	13.0	12.9	11.9	2.32	0.98	Yes	47.7	410.0	4%	0.2	32.6
Installer	Indoors	winter		DAE-mono	5	76.4	10.9	29.4	13.3	28.1	21.3	2.35	0.83	Yes	87.0	773.2	15%	2.8	48.3
Installer	Indoors	winter	B-2	DAE-mono	5	76.4	10.9	29.4	13.3	28.1	21.3	2.35	0.83	Yes	87.0	773.2	15%	2.8	48.3
	Outdoors		A-1	DAE-mono	5	31.9	4.3	13.5	13.0	11.3	10.1	2.36	0.89	Yes	41.7	374.7	3%	<0.1	29.6
			A-1	DAE-mono	6	48.1	4.3	19.3	13.5	17.4	13.1	2.71	0.92	Yes	67.8	529.6	9%	1.1	36.1
		summer	A-1	DAE-mono	6	48.1	4.3	19.3	13.5	17.4	13.1	2.71	0.92	Yes	67.8	529.6	9%	1.1	36.1
	Indoors	summer		DAE-mono	11	243	9.4	71.2	38.9	80.5	42.2	2.90	0.94	Yes	243.8	848.5	43%	25.0	62.9
Installer	Indoors			DAE-mono	12	243	10.9	62.1	33.3	79.4	34.1	2.97	0.88	Yes	204.0	668.2	36%	19.6	55.2
		summer		DAE-mono	18	243	4.3	49.2	24.1	68.1	25.8	3.09	0.95	Yes	164.9	410.3	27%	15.4	43.1
Installer	Indoors	summer		DAE-mono	7	243	13.1	85.4	38.9	97.4	47.6	3.22	0.89	Yes	326.3	2541.0	48%	24.9	71.4
	Indoors		B-2	DAE-mono	9	76.4	1.5	22.0	13.3	23.3	13.2	3.23	0.96	Yes	90.6	460.2	12%	3.3	34.2
	Outdoors			DAE-mono	16	36.8	0.3	15.1	13.5	11.7	9.8	3.32	0.86	No	70.3	201.8	8%	2.6	21.7
Assistant				DAE-mono	11	93.7	1.5	24.5	13.0	27.9	13.1	3.48	0.98	Yes	102.0	438.7	14%	4.5	33.2
	Indoors	winter		DAE-mono	7	76.4	1.5	21.8	11.5	26.4	11.5	3.66	0.97	Yes	97.1	944.4	13%	2.7	38.4
	Indoors			DAE-mono	18	243	1.5	52.0	31.0	68.3	25.5	3.67	0.97	Yes	215.8	616.5	30%	17.3	45.6
			B-2	DAE-mono	18	76.4	0.3	18.7	12.4	18.9	10.5	3.75	0.93	Yes	92.3	268.4	12%	4.5	25.1
				DAE-mono	34	243	0.3	34.6	15.7	53.1	16.1	3.77	0.97	Yes	144.0	291.3	19%	11.7	29.9
Installer			B-2	DAE-mono	14	76.4	0.3	20.6	13.7	19.7	12.2	3.77	0.87	No	108.2	390.9	14%	5.6	30.7
Installer	Outdoors			DAE-mono	11	36.8	0.3	14.8	14.0	11.8	8.9	3.90	0.85	Yes	83.4	409.2	10%	2.6	28.0
		winter		DAE-mono	16	76.4	0.3	18.2	11.2	19.8	9.6	3.94	0.94	Yes	92.0	306.8	11%	4.0	25.6
		winter	B-2	DAE-mono	16	76.4	0.3	18.2	11.2	19.8	9.6	3.94	0.94	Yes	92.0	306.8	11%	4.0	25.6
			A-2	DAE-mono	6	243	9.4	103.3	72.7	100.5	55.8	3.96	0.92	Yes	536.3	9142.1	53%	27.1	76.9

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (µg/m³)	Minimum (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
	Indoors		A-2	DAE-mono	6	243	9.4	103.3	72.7	100.5	55.8	3.96	0.92	Yes	536.3	9142.1	53%	27.1	76.9
		summer	A-2	DAE-mono	6	243	9.4	103.3	72.7	100.5	55.8	3.96	0.92	Yes	536.3	9142.1	53%	27.1	76.9
Installer				DAE-mono	23	243	0.3	39.5	17.3	61.6	17.9	3.97	0.93	Yes	173.4	445.3	22%	12.7	36.0
	Outdoors	winter		DAE-mono	9	36.8	0.3	15.4	7.8	13.9	8.4	4.44	0.86	Yes	97.2	766.2	11%	2.8	32.7
	Outdoors		B-2	DAE-mono	9	36.8	0.3	15.4	7.8	13.9	8.4	4.44	0.86	Yes	97.2	766.2	11%	2.8	32.7
Assistant	Indoors			DAE-mono	6	93.7	1.5	31.7	19.8	35.8	14.2	4.90	0.97	Yes	194.0	5135.2	21%	6.0	50.5
Installer	Outdoors	winter		DAE-mono	7	36.8	0.3	13.6	7.8	12.8	7.0	4.94	0.88	Yes	97.0	1594.6	11%	2.0	36.0
Installer	Outdoors		B-2	DAE-mono	7	36.8	0.3	13.6	7.8	12.8	7.0	4.94	0.88	Yes	97.0	1594.6	11%	2.0	36.0
Installer	Outdoors	winter	B-2	DAE-mono	7	36.8	0.3	13.6	7.8	12.8	7.0	4.94	0.88	Yes	97.0	1594.6	11%	2.0	36.0

Table A-4b: Results of the statistical analysis by determining factor for the average concentration of samples by task (MDI monomer)

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (µg/m³)	Minimum (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
	Outdoors	summer		Conc mono	7	70.8	30.0	45.3	39.3	15.8	43.1	1.40	0.92	Yes	75.2	135.9	31%	12.7	57.3
	Outdoors		A-1	Conc mono	5	70.8	30.0	48.3	50.0	18.3	45.4	1.49	0.86	Yes	87.5	242.1	39%	15.2	68.4
			A-1	Conc mono	6	106.8	30.0	58.1	55.4	28.9	52.4	1.65	0.94	Yes	119.0	332.7	52%	26.7	76.5
		summer	A-1	Conc mono	6	106.8	30.0	58.1	55.4	28.9	52.4	1.65	0.94	Yes	119.0	332.7	52%	26.7	76.5
Assistant	Outdoors			Conc mono	5	83.6	21.7	44.4	36.5	24.3	39.8	1.67	0.98	Yes	92.7	345.2	31%	10.7	62.8
	Indoors	summer		Conc mono	11	480.5	38.0	160.3	106.8	132.0	127.2	1.98	0.89	Yes	389.6	863.8	91%	73.4	97.8
			A-2	Conc mono	6	480.5	88.0	214.7	135.9	161.5	172.9	2.01	0.89	Yes	546.6	2313.4	96%	72.1	99.8
	Indoors		A-2	Conc mono	6	480.5	88.0	214.7	135.9	161.5	172.9	2.01	0.89	Yes	546.6	2313.4	96%	72.1	99.8
		summer	A-2	Conc mono	6	480.5	88.0	214.7	135.9	161.5	172.9	2.01	0.89	Yes	546.6	2313.4	96%	72.1	99.8
		summer		Conc mono	18	480.5	30.0	115.6	92.3	116.9	83.5	2.18	0.93	Yes	300.8	564.5	74%	57.8	85.3
	Outdoors			Conc mono	16	83.6	3.8	42.3	37.3	25.6	33.3	2.27	0.89	Yes	128.0	262.3	30%	17.1	47.1
Installer	Indoors	summer		Conc mono	7	480.5	38.0	188.2	116.2	161.6	139.0	2.33	0.93	Yes	559.2	2466.4	88%	62.6	97.6
Installer	Outdoors			Conc mono	11	83.6	3.8	41.4	38.0	27.3	30.8	2.55	0.9	Yes	143.3	427.9	29%	14.4	50.3
Installer	Indoors		B-2	Conc mono	7	313.5	24.1	98.3	47.9	103.8	65.6	2.56	0.93	Yes	307.3	1593.6	61%	35.4	81.4
Installer	Indoors			Conc mono	12	480.5	24.1	155.9	111.5	146.0	103.1	2.67	0.95	Yes	519.4	1518.1	76%	56.6	89.2
	Outdoors	winter		Conc mono	9	83.6	3.8	40.0	21.7	32.0	27.3	2.81	0.91	Yes	149.0	622.7	27%	11.7	50.4
	Outdoors		B-2	Conc mono	9	83.6	3.8	40.0	21.7	32.0	27.3	2.81	0.91	Yes	149.0	622.7	27%	11.7	50.4
Installer	Outdoors	winter		Conc mono	7	83.6	3.8	36.4	21.7	31.3	24.0	2.97	0.94	Yes	143.8	968.9	24%	8.6	51.3
Installer	Outdoors		B-2	Conc mono	7	83.6	3.8	36.4	21.7	31.3	24.0	2.97	0.94	Yes	143.8	968.9	24%	8.6	51.3
Installer	Outdoors	winter	B-2	Conc mono	7	83.6	3.8	36.4	21.7	31.3	24.0	2.97	0.94	Yes	143.8	968.9	24%	8.6	51.3
Installer	Indoors	winter		Conc mono	5	313.5	24.1	110.8	47.9	122.7	67.8	3.00	0.91	Yes	413.3	6866.1	60%	30.6	84.0
Installer	Indoors	winter	B-2	Conc mono	5	313.5	24.1	110.8	47.9	122.7	67.8	3.00	0.91	Yes	413.3	6866.1	60%	30.6	84.0
Installer			B-2	Conc mono	14	313.5	3.8	67.3	38.0	80.4	39.7	3.02	0.98	Yes	245.1	716.3	41%	25.2	58.9

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (µg/m³)	Minimum (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
Installer				Conc mono	23	480.5	3.8	101.2	60.7	120.0	57.8	3.08	0.98	Yes	366.9	791.3	54%	40.8	67.5
				Conc mono	34	481	3.1	88.4	55.4	103.0	51.1	3.14	0.97	Yes	335	614.9	5%	39.0	61.1
Assistant				Conc mono	11	155.6	3.1	61.7	50.0	47.7	39.4	3.30	0.9	Yes	281.0	1136.3	41%	23.8	61.5
			B-2	Conc mono	18	313.5	3.1	58.9	33.1	73.8	31.8	3.36	0.97	Yes	233.2	620.3	35%	21.6	50.8
		winter		Conc mono	16	313.5	3.1	57.8	26.2	77.8	29.4	3.50	0.98	Yes	230.8	693.3	33%	19.4	50.0
		winter	B-2	Conc mono	16	313.5	3.1	57.8	26.2	77.8	29.4	3.50	0.98	Yes	230.8	693.3	33%	19.4	50.0
	Indoors			Conc mono	18	480.5	3.1	129.4	101.1	127.7	74.6	3.57	0.92	Yes	606.6	1697.6	62%	45.9	75.5
	Indoors		B-2	Conc mono	9	313.5	3.1	77.7	38.0	98.8	37.2	4.11	0.98	Yes	379.5	2688.7	41%	21.9	63.2
	Indoors	winter		Conc mono	7	313.5	3.1	80.7	28.2	112.6	32.3	4.84	0.98	Yes	432.4	6869.7	39%	18.0	64.0
Assistant	Indoors			Conc mono	6	155.6	3.1	76.2	94.4	59.4	39.2	5.08	0.8	Yes	566.8	16155.4	44%	20.3	69.9

Table A-4c: Results of the statistical analysis by determining factor for the average daily exposure by task (MDI oligomers)

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (max) (µg/m³)	Minimum (min) (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation(GSD)	W test on log-transformed data	Lognormal l(α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
	Outdoors		A-1	DAE oli	5	11.9	2.1	5.8	5.2	4.12	4.6	2.2	0.89	Yes	16.5	118.0	0%	<0.1	12.6
	Outdoors	summer		DAE oli	7	12.6	2.1	7.6	7.8	4.56	6.1	2.2	0.82	Yes	22.2	87.5	0%	<0.1	10.5
Installer	Indoors		B-2	DAE oli	7	46.0	5.1	13.9	6.4	14.74	9.9	2.2	0.84	Yes	37.2	152.0	2%	<0.1	19.4
Assistant	Outdoors			DAE oli	5	18.7	2.1	8.3	5.2	6.85	6.2	2.4	0.97	Yes	25.9	241.2	1%	<0.1	20.9
			A-1	DAE oli	6	22.8	2.1	8.6	6.5	7.84	6.1	2.6	0.94	Yes	28.7	201.9	1%	<0.1	19.1
		summer	A-1	DAE oli	6	22.8	2.1	8.6	6.5	7.84	6.1	2.6	0.94	Yes	28.7	201.9	1%	<0.1	19.1
Installer	Indoors	winter		DAE oli	5	46.0	5.1	15.8	6.3	17.51	10.5	2.6	0.83	Yes	50.3	575.7	5%	0.3	33.9
Installer	Indoors	winter	B-2	DAE oli	5	46.0	5.1	15.8	6.3	17.51	10.5	2.6	0.83	Yes	50.3	575.7	5%	0.3	33.9
	Outdoors			DAE oli	16	18.7	0.3	7.6	5.5	5.83	5.1	3.0	0.91	Yes	30.7	80.2	2%	0.2	9.1
	Indoors	summer		DAE oli	11	139.9	6.4	37.7	14.6	46.36	20.7	3.0	0.9	Yes	128.0	467.4	21%	8.5	41.3
		summer		DAE oli	18	139.9	2.1	26.0	11.7	38.73	12.9	3.1	0.93	Yes	84.8	214.1	11%	4.4	25.0
Installer	Indoors			DAE oli	12	139.9	5.1	32.9	13.2	45.52	16.4	3.2	0.87	Yes	109.6	385.7	16%	6.1	35.1
Installer			B-2	DAE oli	14	46.0	0.3	10.2	6.0	11.55	6.0	3.3	0.91	Yes	43.6	140.2	4%	0.7	15.0
Installer	Outdoors			DAE oli	11	18.7	0.3	7.3	5.6	5.65	4.6	3.4	0.9	Yes	33.9	139.7	2%	0.2	14.0
Installer	Indoors	summer		DAE oli	7	139.9	6.4	45.2	14.6	56.34	22.7	3.5	0.86	Yes	174.9	1544.5	26%	9.3	52.5
			A-2	DAE oli	6	139.9	6.4	58.3	41.2	56.17	32.7	3.7	0.92	Yes	283.9	4263.0	37%	15.5	64.4
	Indoors		A-2	DAE oli	6	139.9	6.4	58.3	41.2	56.17	32.7	3.7	0.92	Yes	283.9	4263.0	37%	15.5	64.4
		summer	A-2	DAE oli	6	139.9	6.4	58.3	41.2	56.17	32.7	3.7	0.92	Yes	283.9	4263.0	37%	15.5	64.4
	Outdoors		B-2	DAE oli	9	18.7	0.3	7.5	5.4	6.94	4.4	3.7	0.91	Yes	38.2	236.5	3%	0.3	18.4
	Outdoors	winter		DAE oli	9	18.7	0.3	7.5	5.4	6.94	4.4	3.7	0.91	Yes	38.2	236.5	3%	0.3	18.4
Installer				DAE oli	23	139.9	0.3	20.7	7.8	34.97	9.0	3.8	0.95	Yes	79.0	195.0	9%	3.8	20.3
Installer	Outdoors		B-2	DAE oli	7	18.7	0.3	6.5	5.4	6.31	3.7	4.0	0.93	Yes	35.6	402.4	3%	0.2	21.7
Installer	Outdoors	winter	B-2	DAE oli	7	18.7	0.3	6.5	5.4	6.31	3.7	4.0	0.93	Yes	35.6	402.4	3%	0.2	21.7
Installer	Outdoors	winter		DAE oli	7	18.7	0.3	6.5	5.4	6.31	3.7	4.0	0.93	Yes	35.6	402.4	3%	0.2	21.7

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (max) (µg/m³)	Minimum (min) (µg/m³)	Arithmetic mean (µg/m³)	Median (µg/m³)	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
				DAE oli	34	139.9	0.1	18.1	7.8	30.08	7.6	4.3	0.94	Yes	85.6	187.1	10%	4.7	18.4
			B-2	DAE oli	18	46.0	0.1	9.3	5.5	10.86	4.6	4.6	0.89	No	56.4	193.4	6%	1.6	16.4
		winter	B-2	DAE oli	16	46.0	0.1	9.3	5.3	11.52	4.2	5.0	0.91	Yes	58.9	240.5	6%	1.5	17.9
		winter		DAE oli	16	46.0	0.1	9.3	5.3	11.52	4.2	5.0	0.91	Yes	58.9	240.5	6%	1.5	17.9
	Indoors			DAE oli	18	139.9	0.1	27.5	10.8	39.08	11.0	5.4	0.89	No	175.6	685.5	18%	8.6	33.1
Assistant				DAE oli	11	52.9	0.1	12.9	6.4	15.84	5.4	5.8	0.9	Yes	98.2	770.3	10%	2.7	28.3
	Indoors		B-2	DAE oli	9	46.0	0.1	11.0	6.3	13.99	4.8	6.0	0.85	Yes	91.2	1094.0	9%	2.0	29.9
	Indoors	winter		DAE oli	7	46.0	0.1	11.5	5.2	16.03	4.0	7.6	0.89	Yes	112.8	3933.1	11%	1.9	35.7
Assistant	Indoors			DAE oli	6	52.9	0.1	16.8	8.1	20.62	4.9	10.6	0.92	Yes	235.8	30457.1	16%	3.6	45.2

Table A-4d: Results of the statistical analysis by determining factor for the average concentration of samples by task (MDI oligomers)

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (max)	Minimum (min)	Arithmetic mean (µg/m³)	Median	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
	Outdoors	summer		Conc Oli	7	39.2	15.0	23.4	22.6	8.46	22.2	1.4	0.94	Yes	39.2	71.6	1%	<0.1	13.9
	Outdoors		A-1	Conc Oli	5	39.2	15.0	22.3	20.0	9.95	20.9	1.5	0.87	Yes	40.0	109.5	1%	<0.1	23.2
Assistant	Outdoors			Conc Oli	5	42.5	12.1	22.7	20.0	11.95	20.5	1.6	0.96	Yes	45.3	155.0	3%	<0.1	29.5
			A-1	Conc Oli	6	50.6	15.0	27.1	21.3	14.56	24.2	1.7	0.9	Yes	55.5	157.2	7%	0.7	33.5
		summer	A-1	Conc Oli	6	50.6	15.0	27.1	21.3	14.56	24.2	1.7	0.9	Yes	55.5	157.2	7%	0.7	33.5
			A-2	Conc Oli	6	266.5	57.5	120.5	75.5	86.73	99.6	1.9	0.84	Yes	289.4	1102.0	85%	55.7	96.7
	Indoors		A-2	Conc Oli	6	266.5	57.5	120.5	75.5	86.73	99.6	1.9	0.84	Yes	289.4	1102.0	85%	55.7	96.7
		summer	A-2	Conc Oli	6	266.5	57.5	120.5	75.5	86.73	99.6	1.9	0.84	Yes	289.4	1102.0	85%	55.7	96.7
	Indoors	summer		Conc Oli	11	266.5	17.6	82.7	57.5	75.64	61.9	2.1	0.94	Yes	217.3	531.0	60%	39.8	77.4
		summer		Conc Oli	18	266.5	15.0	59.6	37.4	65.37	41.6	2.2	0.93	Yes	156.3	299.5	40%	26.0	55.7
Installer	Indoors	summer		Conc Oli	7	266.5	17.6	96.7	50.6	93.30	66.0	2.6	0.95	Yes	310.9	1623.4	61%	35.5	81.5
Installer	Indoors		B-2	Conc Oli	7	188.6	11.3	50.5	21.7	63.69	30.7	2.7	0.91	Yes	159.0	919.5	31%	12.4	57.0
Installer	Indoors			Conc Oli	12	266.5	11.3	81.5	50.1	84.59	49.6	2.9	0.94	Yes	283.1	898.8	49%	30.8	67.3
Installer	Indoors	winter		Conc Oli	5	188.6	11.3	60.1	21.7	75.11	33.3	3.3	0.9	Yes	234.6	4885.9	36%	13.5	66.4
Installer	Indoors	winter	B-2	Conc Oli	5	188.6	11.3	60.1	21.7	75.11	33.3	3.3	0.9	Yes	234.6	4885.9	36%	13.5	66.4
	Outdoors			Conc Oli	16	42.5	0.2	21.0	17.7	14.10	13.5	3.9	0.76	No	124.1	405.6	16%	7.0	32.0
Assistant				Conc Oli	11	81.9	0.7	31.8	23.6	25.91	18.6	4.0	0.87	Yes	183.7	938.1	23%	10.2	44.1
	Indoors			Conc Oli	18	266.5	0.7	67.5	50.1	73.21	34.7	4.2	0.91	Yes	371.8	1191.1	39%	25.5	55.3
				Conc Oli	34	266.5	0.2	45.6	26.1	58.35	22.3	4.3	0.91	No	245.1	532.2	28%	19.2	39.8
Installer				Conc Oli	23	266.5	0.2	52.2	28.7	68.28	24.3	4.5	0.9	No	291.5	819.1	31%	19.8	45.2
Installer	Outdoors			Conc Oli	11	42.5	0.2	20.3	15.3	15.46	11.2	4.9	0.8	No	150.9	962.7	17%	6.1	36.9
	Indoors		B-2	Conc Oli	9	188.6	0.7	39.8	17.6	59.14	16.0	5.0	0.97	Yes	226.7	2120.3	24%	9.3	46.8
Installer			B-2	Conc Oli	14	188.6	0.2	33.7	16.4	48.17	14.7	5.1	0.9	Yes	211.4	1016.1	22%	10.4	40.1

Task	Location	Season	Foam	Parameter	Number (n)	Maximum (max)	Minimum (min)	Arithmetic mean (µg/m³)	Median	Standard deviation (s)	Geometric mean (µg/m³)	Geometric standard deviation (GSD)	W test on log-transformed data	Lognormal (α = 0.05) ?	95th percentile	UTL1, 95%,95%	Fraction exceeding PEV	CLlower 1,95% %>PEV	CLupper 1,95% %>PEV
			B-2	Conc Oli	18	188.6	0.2	29.5	14.4	43.64	12.1	5.2	0.93	Yes	179.2	673.8	19%	9.2	34.1
	Outdoors		B-2	Conc Oli	9	42.5	0.2	19.1	12.1	17.60	9.2	5.5	0.84	Yes	153.2	1645.5	16%	4.9	38.3
	Outdoors	winter		Conc Oli	9	42.5	0.2	19.1	12.1	17.60	9.2	5.5	0.84	Yes	153.2	1645.5	16%	4.9	38.3
		winter	B-2	Conc Oli	16	188.6	0.2	29.8	12.8	46.33	11.0	5.6	0.95	Yes	186.1	840.4	19%	8.6	34.8
		winter		Conc Oli	16	188.6	0.2	29.8	12.8	46.33	11.0	5.6	0.95	Yes	186.1	840.4	19%	8.6	34.8
	Indoors	winter		Conc Oli	7	188.6	0.7	43.6	13.4	67.53	14.0	6.2	0.98	Yes	283.8	7006.3	24%	8.3	50.8
Installer	Outdoors		B-2	Conc Oli	7	42.5	0.2	16.8	12.1	17.54	7.1	6.4	0.89	Yes	148.4	3815.3	14%	3.4	40.5
Installer	Outdoors	winter	B-2	Conc Oli	7	42.5	0.2	16.8	12.1	17.54	7.1	6.4	0.89	Yes	148.4	3815.3	14%	3.4	40.5
Installer	Outdoors	winter		Conc Oli	7	42.5	0.2	16.8	12.1	17.54	7.1	6.4	0.89	Yes	148.4	3815.3	14%	3.4	40.5
Assistant	Indoors			Conc Oli	6	81.9	0.7	39.5	45.3	32.76	17.1	6.8	0.83	Yes	400.2	20907.1	28%	10.1	57.3