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Attention: 8(e) Coordinator

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Dear Sir or Madam:

The attached information is submitted in accordance with the EPA's interpretation of Section 8(e) of the Toxic Substances Control Act by the Chemical Manufacturers Association Hexamethylene Diisocyanate (HDI) Panel (Panel) on behalf of the following producers/manufacturers of HDI: Bayer Corporation, Lyondell Chemical Company and Rhodia Inc.

A pre-publication copy of the study "Qualitative Assessment of Isocyanate Skin Exposure in Autobody Shops" was provided to the HDI Panel and is included in this submission. The study indicates that latex rubber gloves may not provide adequate protection against dermal sensitization following exposure to HDI (CAS# 822-06-0). The Panel believes that current EPA guidance is not sufficient to adequately determine whether this information is reportable under TSCA Section 8(e). However, the Panel is aware that EPA could consider this information to constitute a substantial risk. For this reason, it is being submitted to EPA under 8(e) out of an abundance of caution. This submission should therefore discharge any 8(e) responsibilities that might exist, and should be processed in accordance with the EPA's "substantial risk" procedures.

If you have any questions regarding this letter, please contact Sarah Loftus, Manager of the HDI Panel at 703/741-5607 or Sarah_Loftus@cmahq.com.

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Sincerely Yours,

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Qualitative Assessment of Isocyanate Skin Exposure in Autobody Shops

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ABSTRACT

Background Little is known about the extent of human isocyanate skin exposure in autobody shops and the effectiveness of personal protective equipment. Animal studies suggest skin exposure to isocyanates may be an important risk factor for respiratory sensitization leading to asthma. This study provides initial data on HDI skin exposure in three autobody shops.

Methods Three autobody shops with different operational sizes and paint systems were examined for the presence of isocyanates on environmental surfaces and workers' skin and for the breakthrough of personal protective equipment. Semi-quantitative detection for contamination of isocyanates was conducted using a wipe-sampling technique. Assessment focused on the painters and their tasks although other autobody repairers were also evaluated.

Results Environmental surfaces such as workbenches and spray gun cleaning equipment were found to be contaminated with isocyanates. Painters had frequent contact with contaminated surfaces, often without wearing gloves. Moderate to heavy contamination of some skin surfaces was found with painters from 2 out of the 3 shops. The latex gloves used for skin protection showed significant breakthroughs even after a single painting session.

Conclusions Contaminated environmental surfaces and dermal exposure to isocyanates were documented in several autobody shops. Latex gloves are not adequate protection for workers using isocyanate paints. Further research better quantifying skin exposure and its potential relationship to respiratory sensitization and asthma is warranted.

KEY WORDS Isocyanates, HDI, skin exposure assessment, personal protective equipment, wiping sampling detectors, respiratory sensitization, occupational asthma.

INTRODUCTION

Isocyanate compounds are a group of highly reactive, low molecular-weight aromatic and aliphatic chemicals, the most common of which are toluene diisocyanate (TDI), methylene bisphenyl isocyanate (MDI), and hexamethylene diisocyanate (HDI). They are widely used, especially in the manufacture of polyurethane foam and in spray paints [Tarlo et al., 1997]. The world production of isocyanates is estimated to be 3 billion pounds annually [NIOSH, 1996]. The U.S. consumption has risen 34% since 1991, reaching almost 2 million tons in 1994 [Whitford, 1995]. It is estimated that 280,000 U.S. workers are occupationally exposed or potentially exposed to isocyanates in various industries [NIOSH, 1996]. With dramatically expanded use of polyurethane paints, plastics, foams and coatings, the diisocyanates have emerged as the most common identified cause of occupational asthma in developed countries. It is estimated that about 5 - 20 % of exposed workers develop asthma [Seguin et al., 1987; Mapp et al., 1988; Tornling et al., 1990]. A number of studies have described cases of asthma in autobody spray painters [Cockcroft and Mink, 1979; Belin et al., 1981; Clarke, 1981; Malo et al., 1983; Nielsen et al., 1985; Selden et al., 1989]. However, exposure characterization in autobody workers, particularly spray painters, has been very limited [Pisaniello and Muriale, 1989; Janko et al., 1992; Lesage et al., 1992].

Hexamethylene diisocyanate (HDI) is the most common form of diisocyanate present in autobody paints. Available exposure data has shown high levels of airborne HDI monomer and polyisocyanate oligomers during spray painting [Janko et al., 1992; Rudzinski, 1995]. Exposure assessment has focused on the measurement of airborne levels due to the fact that the spray operations generate a significant amount of aerosol that may be an important inhalation hazard. However, there are numerous opportunities for skin exposure. Autobody workers regularly mix and apply paints. Direct skin contact with isocyanate-containing paint products, airborne

isocyanates and/or contaminated environmental surfaces may also result in significant skin exposure [NIOSH, 1996].

Experience with isocyanates has shown that monomeric, prepolymeric and polyisocyanate species are all capable of producing asthma in exposed workers [Seguin et al., 1987; Liss et al., 1988; Vandenplas et al., 1992]. The mechanism, by which exposure to these isocyanates causes asthma is, however, not clear. It has been assumed that the primary route of exposure and sensitization is via the respiratory tract. However, recent animal studies have suggested that dermal exposure to diisocyanates may also produce respiratory sensitization [Karol et al., 1981; Erjefalt and Persson, 1992; Rattray et al., 1994]. Toluene diisocyanate (TDI) was found to induce pulmonary sensitization in guinea pigs after dermal exposure [Karol, 1981]. Intradermal or topical exposure to diphenylmethylene diisocyanate (MDI) was also found to be effective in inducing sensitization of the respiratory tract [Rattray, 1994]. Although similar studies have not been done with HDI, it is likely that skin exposure to HDI can also result in respiratory tract sensitization. Thus, it is important that not only airborne exposure to isocyanates be characterized, but that skin exposure also be assessed.

One problem that hinders isocyanate skin exposure assessment is that little effort has been made to develop an isocyanate dermal exposure sampling and analysis method. Recently Colorimetric Laboratories, Inc. (CLI) has developed a direct reading colorimetric sampler that qualitatively detect surface and skin contamination by aliphatic and aromatic isocyanates. An independent validation by Miles Laboratory (an unpublished report available from CLI) showed the method has a limit of detection of 10 - 25 μg (very light color). The color change was more easily observed at 50 μg. A more intense color developed at 200 μg level (Miles Lab Report). This method by CLI has also been recommended by Occupational Safety and Health Administration (OSHA) Salt Lake City Technical Center (SLCTC) for use in autobody shops (OSHA, 1997).

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As part of an on-going cross-sectional epidemiologic study of the relationship of respiratory exposure to HDI and the development of asthma (Survey of Painters and Repairers of Autobodies by Yale or SPRAY), an exposure assessment strategy to assess airborne exposure to HDI has been developed. Because of the apparent risk of dermal exposure and possible sensitization via the dermal route, a pilot study of surface and skin exposure to HDI was conducted in 3 shops. The objectives of this initial study were to 1) identify environmental surfaces contaminated with HDI in autobody shops; 2) qualitatively and semi-quantitatively assess skin exposure of workers in the shops; 3) identify possible determinants of skin contamination and 4) identify HDI breakthrough of gloves and coveralls used in the autobody shops.

MATERIALS AND METHODS

Each of the 3 shops was evaluated for surface contamination, skin exposure and breakthrough of personal protective equipment (PPE) on a single day. The days sampled represented typical painting days in terms of the car type and size being painted, job difficulty and the type of paints used.

Evaluation of Environmental Surface Contamination

Surfaces that might be contaminated with isocyanate paints were identified. Selected surfaces included work benches for paint mixing, balance and computer panels for the weighing and formulating of base coat paints, spray gun knobs, thinner container knobs for gun cleaning, spray booth door handles, respirator surfaces and their hoses, and glove surfaces.

Surface Sampling and Detection Procedures SWYPE™ surface sampling pads from Colorimetric Laboratories, Inc. (Des Plaines, IL) specific for the detection of aliphatic isocyanates were used according to manufacturer's specifications. A pair of poly nitrile medical examination gloves were worn during the sampling and changed after each surface sampling. Surface areas evaluated were lightly sprayed with the provided developing solution to ensure the surface was wet. After 30 seconds of spraying, the surface SWYPE™ pad was used to wipe the surfaces. Two to three minutes were allowed for the color development. A red-orange color indicated aliphatic isocyanates contamination. The color change was recorded in the following scheme: - no color change (no contamination detectable), <+very light color (estimated to be less than 5 μg), +light orange (estimated to be around 5 - 50 μg), ++moderate red-orange (estimated to be around 50 μg), +++heavy red-orange (estimated to be around 100 μg), ++++deep red-orange (estimated to be around 200 μg), >++++very deep red-orange (estimated to be >200 μg).

As a positive control for the color development, the isocyanate-containing hardeners and spray paints, which were mixed with hardeners, were also tested for the color change. Base coat

paints without hardeners and surfaces of mixing balance and the computer screen where the base coats were mixed, were used as controls.

Evaluation of Skin Contamination

Selection of Workers and Tasks One designated spray painter in each shop was selected for skin wipe sampling and evaluation of paint-related tasks. Two to three non-paint workers were also selected for non-paint tasks. Most tasks spray painters and repairers performed in their daily work, including both paint tasks and non-paint tasks, were sampled. Paint tasks included paint mixing, priming, sealer coating, base coating, clear coating, un-taping of painted car, spray gun cleaning, and sanding dry isocyanate paints. Non-paint tasks included car cleaning and washing, shop floor cleaning, mechanical work (battery repair, light and muffler change, and engine fixing up, etc.), frame and sheet metal working, bondo work, buffing, compounding and finishing, and office work. In each shop, tasks selected were based on the actual tasks available on the day.

Sampling Procedures SWYPE™ detectors for skin contamination were used. Each SWYPE™ wipe sample was taken after the worker had completed the target task. For painters, three wipe samples were taken after each task including one for the whole left arm, one for right arm and one in the face. If gloves were not worn during the task, arm wiping also included the hand. The whole skin area of a naked arm (hand) or face was wiped once with the cloth portion of the skin SWYPE™ pad. The skin SWYPE™ was then placed in a cup with 1 mL of developing solution, clothe end down and color detection strip up. A red-orange color change occurred if contamination by aliphatic isocyanates was present. Color change was recorded as noted above for the detection of surface contamination.

Evaluation of Personal Protective Equipment (PPE)

Selection of Subjects, PPE and Tasks Only spray painters were selected for PPE breakthrough evaluation. All breakthrough testing for gloves used the latex exam gloves worn by workers in the shops. One sample was also taken under the painter's coverall (protective clothes). Tasks selected for PPE evaluation were painting-related or priming-related, including formulating of base coat paints, mixing of paints and primers, priming, base coating, sealer coating, clear coating and spray gun cleaning.

Sampling Procedures Permea-Tec pads from the CLI Laboratory were used. Workers were instructed to wear the first pair of gloves they used for their work. One or more Permea-Tec patches (pad side out) were placed on the inner part of fingers, palm, (or leg under the coverall,). Another pair of gloves to be evaluated was worn outside the first and the sampling pads. After working for a certain time period, the outside pair of gloves was removed for evaluation of color change. If permeation or penetration by the solvent containing aliphatic isocyanates occurred, a reaction turned the pad to a red-orange color. Otherwise, 10 drops of tap water were used to wet the pad for color change. The color report was based on the similar judgement as in surface and skin analysis. The evaluation was based on the sampling after a single coating session of 2 to 15 minutes or after a car job of several coating sessions with paint mixing and spray equipment cleaning.

Collection of Task Information

A sampling log was developed to collect information related to wipe samplings. It included the location of surface sampling, possible sources of contamination, type of contamination, how often the painter had contact with it and gloves worn during the contact. Information on the location and duration of each task, type and quantities of paints and hardeners used, type of spray guns used, gloves or coveralls worn and ventilation was also collected.

Measurement and Analysis of Airborne Isocyanates

In order to observe the skin exposure in relation to airborne exposure to isocyanates, air samples were also taken in the three shops and analyzed for HDI monomer and polymers. IOM samplers with stainless steel cassettes were used for sampling. A single quarts filter, 25 mm in diameter and impregnated with 1-9-anthacenyl)piperazine (MAP) as the derivatizing agent, was used in the sampling cassettes, which was pre-prepared in the laboratory and cold shipped to the field. After sampling, samples were further extracted with MAP in the field and cold shipped to the laboratory for analysis by high performance liquid chromatography.

Sampling focused on the painting tasks, which included clear coating, sealer coating, base coating, priming and mixing paints. Sampling on non-painting tasks were also conducted in near spray and far spray locations. Near spray locations were in a same room within 10 feet of isocyanate-containing painting source. Far spray locations were the far corners in a same room more than 10 feet away from the painting source. Mostly stationery sampling was taken at the breathing zone level except for Shop 1 and 3 where personal sampling was also conducted during spray coatings inside the booth. Sampling was taken at 2 liters per minute. Spray and priming samples were taken with the task duration for about 2 to 15 minutes. Sampling for mixing paints was conducted by turning the pump on and off in the mixing area for mixing sessions. Near spray sampling was taken only when the nearby painting/priming was in session. Far spray sampling was taken for 6 - 8 hours. Airborne and skin wipe samplings were taken on the same day only in Shop 3.

RESULTS

General Shop Information

Table I summarizes the details of each shop surveyed. It can be seen that Shop 1 and 2 had smaller numbers of employees, cars painted daily and yearly revenues than Shop 3. Each shop used a different paint system. All had hardeners added to the sealer coats, clear coats and primers, but not to base coats. The hardeners all contained HDI monomers and polymers. Workers in each shop used respirators from different manufacturers. Spray painters all used the latex medical exam gloves and worked in mechanically ventilated spray booths for painting, although the brands of the gloves and booths varied.

Airborne Exposure Levels of HDI

Table II presents airborne levels of HDI in the three shops where skin exposure was assessed. There was an exposure gradient among different task operations. Concentrations were the highest in clear and sealer coatings, followed by those in priming. Although isocyanate-containing hardeners were not added to the basecoat paints, basecoating still resulted in HDI levels. Airborne exposure to HDI during mixing task was generally low. Airborne exposures to oligomers were much higher than to the monomer. Airborne exposure to both oligomers and monomer were in similar magnitude in Shop 1 and Shop 2, but much higher in Shop 3. Currently, OSHA does not have permissible exposure limits for HDI. NIOSH recommends 34 $\mu g/m^3$ for full-shift TWA and 140 $\mu g/m^3$ for ceiling as recommended exposure levels. American Conference of Governmental Industrial Hygienists recommends 34 $\mu g/m^3$ for full-shift TWA and does not have ceiling values. Guideline values do not distinguish monomers from oligomers. The exposure levels in the 3 shops were all above the guideline values and were comparable to the levels measured in the State of Oregon [Janko et al., 1992].

Surface Contamination

Most paint-related surfaces such as the spray gun knob, spray gun washer knob, and some mixing benches and painters' glove surfaces were contaminated with aliphatic isocyanates (Table III). More surfaces in Shops 2 and 3 were found contaminated than in Shop 1. Respirator surfaces were not found contaminated. As positive controls, the isocyanate-containing hardeners and coats all demonstrated a very deep red-orange color change (> ++++), whereas base coat paints without isocyanates, the mixing balance and computer screen revealed no positive color change.

Skin Contamination

Shop 1 Table IV presents the result of skin contamination in Shop 1. Three brief (< 7 min) clear coating sessions were conducted in the booth before each skin wipe sample was taken from the painter. The painter wore no protective clothes, but did wear powdered latex exam gloves. None of the painting sessions resulted in any skin contamination at detectable levels with SWYPE™ samples (Tasks 1-3), possibly due to the short duration of painting. The painter was also tested while not wearing gloves when mixing clear coat paints and un-taping the painted car (Tasks 4-5). A slight contamination was found on one of his hands during the paint mixing. Sanding bondo was tested as one of the non-paint tasks in this shop on another worker (Task 6). No color change was detected.

Shop 2 Painting work conducted in Shop 2 on the day of sampling was a large van. It consisted of two sessions of sealer coating, a base coating and a clear coating (Table V). Since isocyanates were not used in base coating in this shop, no sampling was attempted for base coating. The painter did not wear any protective clothes. With these longer (20 - 55 min) paint

sessions, skin contamination was noted during the 2 sealer coats and 1 clear coat applications (Tasks 1-3). Un-taping the van without any gloves also resulted in slight contamination of one hand (Task 4). Light contamination was also found on another worker who did a 4-minute priming outside the booth when no gloves were worn (Task 6). No skin contamination was detected for sanding the primer (Task 7).

Shop 3 Three paint sessions were carried out inside the booth in this shop and each was tested for skin contamination (Table VI). The painter was very well protected in nylon body and head coveralls, gloves and half mask supply air-breathing apparatus. The first two sessions were very brief and resulted in no skin contamination (Tasks 1-2). The third involved 5-minute sealer coating followed by 9-minute clear coating on the van (Task 3). After this third job, moderate skin contamination was detected on the un-covered face around eyes. A number of other non-paint tasks, such as sanding dried primer, mechanical work, car cleaning and office work (Tasks 4-8), were tested in this shop where no gloves were worn. No skin contamination was detected.

Evaluation of PPE

Gloves and coverall breakthrough may allow the direct contact of skin with contaminated surfaces in autobody shops. In Shop 1, no breakthrough of the latex gloves used in the brief painting tasks was found (Table VII). In Shop 2, moderate breakthrough was detected after the latex gloves were worn for 2.5 hours. In Shop 3, moderate to heavy breakthrough of the latex gloves was detected, even when the duration was only several minutes. One sample taken on the leg under the painter's coverall in Shop 3 did not reveal any breakthrough of the coverall.

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DISCUSSION

This study demonstrates that many of the environmental surfaces in these 3 autobody shops, especially those painters routinely and frequently had contact with, were contaminated with isocyanates. The spray gun itself and the cleaning tools were heavily contaminated after paint sessions in all three shops surveyed. For the workbenches, paint contamination appeared to be sporadic and likely depended on the work practices of the painter. Although a quantitative relationship between the direct contact with contaminated surfaces and the skin exposure has not been established in this study, skin contamination by isocyanates to various extents in painting sessions was well documented, despite the use of personal protective equipment. Currently little is known about the dynamics of dermal absorption of isocyanates in humans. Contaminated skin, however, may result in the risk for dermal sensitization that induces asthma.

Surface and skin contamination by isocyanates may be affected by several factors, such as the type of hardeners used, job size and spray duration, effective use of personal protective equipment (gloves and coveralls), type of spray booth ventilation and airborne exposure levels. Since isocyanates were only contained in hardeners, contamination of surface and skin would be significantly less if no hardeners were used. Although this study only surveyed 3 shops, it suggests that larger job size with longer spray duration resulted in more skin contamination as shown in Shop 2 (20 - 55 min coatings). In addition, good work place hygiene and work practices, such as preventing hardeners and hardener-containing paints from collecting on the workbench surfaces, avoiding standing in between the spray source and the booth exhaustion. In Shop 1, the painter maintained a tidy bench and kept the spray source away from breathing zone. Although he was not wearing any gloves and protective clothing, HDI was not detected on his skin. In Shop 2, the painter did not maintain this position while spraying a large van. The result was a significant skin contamination.

Overall it appears that more surface and skin contamination was detected in those tasks where the airborne exposures were found to be high, such as spray coatings and priming. However, it is not clear if there was a direct correlation between the airborne exposure and the skin contamination with such a small sample size. Further studies may better characterize determinants of surface contamination and skin exposures.

The proper use of adequate personal protective clothing and correct type of clothing may provide good protection for painters and repairers and reduce the skin contamination by isocyanates. In Shop 3, the painter wore a nylon coverall and a head coverall. His arms were not contaminated in any paint sessions, although his un-protected face was moderately contaminated. However, it was observed that 2 out of 3 painters in this pilot survey did not wear protective clothing (coveralls) even though our skin wipe sampling was not conducted in hot weather. In warmer weather, skin contamination may be even more prevalent.

Our data also suggests that the latex gloves workers currently use in autobody shops do not adequately protect workers from skin contamination and exposure. The latex gloves were found broken on all 3 workers. The solvents which act as a vehicle for the isocyanates enhance their penetration even when they are not broken [Gunderson et al., 1989]. Nitrile non-latex gloves have been recommended by OSHA Salt Lake City Technical Center for the use in conducting the isocyanate sampling [OSHA, 1997], but this has not been required of the autobody shops. Latex medical exam gloves are currently used in most autobody shops although the brand may vary.

Although limited in size, this study has several strengths. It is the first documentation of surface and skin contamination by isocyanates in autobody shops we are aware of. It also demonstrates the feasibility of semi-qualitatively characterizing surface and skin contamination in large-scale epidemiologic studies. Our surface and skin contamination data, as well as the positive and negative controls we used in the field, suggest that this method can be used for semi-quantitative assessment.

The primary weakness of this study is the qualitative nature of this HDI detection technique used and the small sample size of shops and subjects. Thus, it is difficult to quantitatively characterize the levels of skin exposure. It is also difficult to determine the relationships between surface contamination, airborne isocyanate levels and other determinants of skin exposure. The isocyanate surface and skin contamination detected in this study demonstrates the importance of developing a more quantitative method to better characterize skin exposure.

In conclusion, although this pilot study is limited in size and uses a qualitative sampling and analysis method, it does document HDI contamination of a number of surfaces in autobody shops. In addition, we have shown evidence of substantial skin exposure in autobody shop workers. These findings, along with the recent animal data, suggest that dermal exposure to isocyanates has the potential to be an important determinant of sensitization and the development of asthma. Further studies to better quantify dermal exposure, to characterize exposure determinants, and eventually to determine the relationship between dermal as well as respiratory isocyanate exposure and the development of asthma are planned.

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TABLE I Shop Information

Shop number	1	2	3
Years of operation	30	27	13
Yearly revenue ($)	N/A [a]	600,000	1,800,000
Floor size (square feet)	16,000	4,000	9,200
Full-time employee	7	9	15
Designated painters	1	2	2
Cars painted/day	2	2 - 3	5 - 6
Cars painted outside booth/day	0	parts	parts
Number of spray booths	1	2	2
Booth/spray gun type	Devilbuss/HVLP	Devilbuss/HVLP	Devilbuss/HVLP
Paint brand	Du Pont	BASF Glasurit	Akzo Nobel
			Sikkens
Base coating	No hardener	No hardener	No hardener
Sealer coating	Sealer hardener	Sealer hardener	Sealer hardener
Clear coating	Fast hardener	Fast hardener	Fast hardener
Priming	Primer hardener	Primer hardener	Primer hardener
Type of isocyanates in hardeners	HDI Monomer	HDI Monomer	HDI Monomer
	HDI Polyisocyanates	HDI Polyisocyanates	HDI Polyisocyanates
		IPDI	
No. of workers wearing respirator	2	3	11
Type of respirator	SAR [b], Hood style	SAR	SAR
	Half mask cartridge	half mask cartridge	Full face cartridge
			dust masks
Type of gloves	Aker's latex	Aker's latex	Diamond Grip Latex
Shop ventilation	Natural	Natural + general	Mechanical exhaust
Booth ventilation type	Semi-down draft	Down draft	Down draft

[a] Not available

[b] Supplied air respirator

TABLE II Airborne exposure levels of HDI in autobody shops by task[a]

Shop	Task Type	Number of Measurements	HDI Monomer GM ($\mu g/m^3$)	HDI Monomer GSD ($\mu g/m^3$)	HDI Oligomers GM ($\mu g/m^3$)	HDI Oligomers GSD ($\mu g/m^3$)
1	Clear coating in booth	3	0.72	1.59	161.88	7.46
	Base coating in booth	2	ND[b]	ND	19.05	2.35
	Mixing paints	2	ND	ND	2.16	1.07
	Near Spray	2	ND	ND	1.05	3.38
	Far Spray	2	ND	ND	2.08	13.51
2	Clear/sealer coatings in booth	6	0.23	3.18	97.23	9.33
	Priming outside booth	2	0.26	1.10	37.03	1.01
	Mixing paints	2	0.02	1.72	0.34	1.01
	Near Spray[c]	2	0.40	1.11	16.11	1.42
	Far Spray[d]	2	0.05	1.01	4.97	1.03
3	Clear/sealer coatings in booth	4	2.21	2.67	1418.40	2.18
	Priming outside booth	3	0.84	4.36	131.77	3.74
	Mixing paints	2	0.09	1.58	5.58	1.56
	Near spray	2	0.06	1.18	10.79	2.43
	Far spray	2	0.01	1.03	0.81	1.18

[a] Measurements in spray operations were taken by stationary sampling except for spray coatings in Shop 2 and Shop3;
[b] ND: not detected;
[c] Near spray samples were taken near the paint source;
[d] Far spray samples were taken away from the paint source.

TABLE III Surface Contamination Detection

Shop evaluated	Surface evaluated	Color change[a]
Shop 1	Mixing bench for painting	No
	Mixing bench for priming	No
	Spray gun knob for coating	+++
	Full face supplied air respirator hose	No
	Microfiche panel	No
Shop 2	Mixing bench for painting	++++
	Mixing bench for priming	No
	Spray gun knob for painting	+++
	Spray gun knob for priming	No
	Spray gun washer knob	+++
	Half mask respirator surface for priming	No
	Spray painter's gloves	++
	Spray painter's respirator	No
	Spray booth knob	No
Shop 3	Bench for paint mixing	+
	Spray gun knob for painting	+
	Half mask respirator surface for painting	No
	Spray painter's gloves	> ++++
	Base coat mixing balance	No
	Base coat paint	No
	Office table	No

[a] color change code

- no color change
<+ very light orange
+ light orange
++ moderate red-orange
+++ heavy red-orange
++++ deep red-orange
>++++ very deep red-orange

TABLE IV Skin Contamination in Shop 1

Tasks performed	Isocyanate type	Skin evaluated	Color change[a]
1) In-booth painting, 3 bumpers	HDI monomer and polymers	Left arm	No
6-minute clear coating		Right arm	No
Gloves, no coverall		Face	No
2) In-booth painting, 1 bumper	HDI monomer and polymers	Left arm	No
5-minute clear coating		Right arm	No
Gloves, no coverall			
3) In-booth painting, 1/2 car	HDI monomer and polymers	Left hand	No
7-minute clear coating		Right hand	No
Gloves, no coverall			
4) Mixing clear coats	HDI monomer and polymers	Left hand	±
About 2 minutes		Right hand	No
No gloves, no coverall			
5) Un-taping 1/2 painted car	Dried HDI paints	Left hand	No
Less than 3 minutes		Right hand	No
No gloves, no coverall			
6) Sanding bondo	No HDI	Left hand	No
5 minutes		Right hand	No
No gloves, no coverall			

[a] color change code

- no color change
<± very light orange
± light orange
++ moderate red-orange
+++ heavy red-orange
++++ deep red-orange
>++++ very deep red-orange

TABLE V Skin Contamination in Shop 2

Tasks performed	Isocyanate type	Skin evaluated	Color change[a]
1) In-booth painting, Whole van 20-minute sealer coating Gloves, no coverall	HDI monomer and polymer IPDI[b]	Left arm Right arm Face	++ ++ No
2) In-booth painting, Whole van 47-minute sealer coating Gloves, no coverall	HDI monomer and polymer IPDI	Left arm Right arm Face	+++ ++ +
3) In-booth painting, Whole van 55-minute clear coating Gloves, no coverall	HDI monomer HDI polymer IPDI	Left arm Right arm Face	+++ +++ ++
4) Un-taping Whole van No gloves, no coverall	Dried HDI/IPDI paints	Left hand Right hand	+ No
5) Out-booth priming Left rear panel 3 minutes Gloves, no coverall	HDI monomer HDI polymer	Left arm Right arm	No No
6) Out-booth priming 2 right rear panels 4 minutes No gloves, no coverall	HDI monomer HDI polymer	Left hand Right hand	+ No
7) Sanding primer Near spray No gloves, no coverall	HDI monomer HDI polymer	Left hand Right hand	No No

[a] color change code

- no color change
<+ very light orange
+ light orange
++ moderate red-orange
+++ heavy red-orange
++++ deep red-orange
>++++ very deep red-orange

[b] IPDI: isophorone-diisocyanate

TABLE VI Skin Contamination in Shop 3

Tasks performed	Isocyanate type	Skin evaluated	Color change[a]
1) In-booth painting, Left front fender 1-minute sealer coating Gloves, body coverall[c] Head coverall	HDI monomer and polymer HMDI[b]	Left arm/hand Right arm/hand Face	No No No
2) In-booth painting, Left front fender 1-minute sealer coating Gloves, body coverall Head coverall	HDI monomer and polymer HMDI	Left arm/hand Right arm/hand Face	No No No
3) In-booth painting, Large van, hood And two bumpers 5-minute sealer coating 9-minute clear coating Gloves, body coverall Head coverall	HDI monomer and polymer IPDI	Left arm Right arm Face	No No ++
4) Sanding priming Hood, 10 minutes No gloves, no coverall	HDI monomer and polymer HDI polymer	Left arm/hand Right arm/hand	No No
5) Mechanical work Near spray No gloves, no coverall	No HDI	Left hand Right hand	No No
6) Mechanical work Far spray No gloves, no coverall	No HDI	Left hand Right hand	No No
7) Car cleaning Far spray No gloves, no coverall	No HDI	Left hand Right hand	No No
8) Office work Two samples in separate rooms No gloves, no coverall	No HDI	Left hand Right hand	No No

[a] color change code

- no color change
<+ very light orange
+ light orange
++ moderate red-orange
+++ heavy red-orange
++++ deep red-orange
>++++ very deep red-orange

[b] HMDI: Dicyclohexylmethane 4,4-diisocyanate

[c] Coverall by Akron Nobel, 100% nylon

TABLE VII Gloves/Coverall Breakthrough Indication

Shop evaluated	Task involved	PPE evaluated	Color change[a]
Shop 1	In booth paint work	Gloves worn for 1 hour	
	Two clear coatings	Left thumb	No
	Some touch up	Left index finger	No
		Right palm	No
	In booth paint work,	Same gloves worn for	
	Two clear coatings	2 more hours	
	Some touch up	Left thumb	No
		Left index finger	No
		Right palm	No
Shop 2	In booth paint work	Gloves worn for 2.5 hours	
	A whole van	Right thumb	No
	67-minute sealer coating	Right index finger	++
	55-minute clear coating	Left palm	No
	28-minute base coating		
Shop 3	In booth paint work	Gloves worn for one paint work	
	Left front fender	Right thumb	No
	1-minute clear coating	Left index finger	++
		Left palm	No
	In-booth painting,	Gloves worn for one paint work	
	Big van, hood	Right thumb	++++
	And two bumpers	Left middle finger	++
	5-minute sealer coating	Right leg **under coverall**	No
	9-minute clear coating		

[a] color change code	- no color change	+++ heavy red-orange
	<+ very light orange	++++ deep red-orange
	+ light orange	>++++ very deep red-orange
	++ moderate red-orange	

C 02

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