Evaluation of Particulates Generated During Trimming and Cutting of Spray Polyurethane Foam Insulation

MARK SPENCE
Spence Consulting, LLC
1232 Holyrood Street
Midland, MI 48640

CYNTHIA GRAHAM
Huntsman LLC
8600 Gosling Road
The Woodlands, TX 77381

ABSTRACT

A study was initiated to evaluate the potential exposure of workers to inhalable and respirable particulates during the post-application trimming and cutting of open cell and closed cell sprayed polyurethane foam (SPF) insulation in interior applications. The primary purpose of the study was to establish sampling and analytical techniques which would be appropriate and practical for further field evaluations of worker exposure in actual SPF insulation applications. This study employed a protocol under controlled laboratory conditions designed to simulate an extreme case trimming situation.

SPF insulation was applied to sections of timber drywall assemblies to simulate actual interior wall application. Extra spray was applied so that the resulting foam extended well past the studs to provide adequate foam to lengthen times for trimming and cutting in this study. Once the wall sections had cured for 1-2 hours, short-term (11-17 min) task personal exposure sampling and source air sampling was conducted during trimming and cutting. Various trimming tools, categorized as "low" or "high" dust potential, were used for both types of foam. The "high dust potential" and "low dust potential" categories were evaluated separately.

Results demonstrated that "inhalable" particulate concentrations were above the OSHA PEL & ACGIH TLV® concentrations and "respirable" particulate concentrations were below the OSHA PEL & ACGIH TLV® concentrations in most cases. In all cases MDI and pMDI were not detected.

INTRODUCTION/ BACKGROUND

This study was initiated in response to questions of potential exposure to foam dust during trimming of SPF insulation. This study was intended to be an initial evaluation of the potential exposure of workers to inhalable and respirable polyurethane (PU) dust and polymeric methylene diphenyl diisocyanate (pMDI) during the post-application trimming and cutting of SPF foam. The primary purpose of the study was to establish sampling and analytical techniques which would be appropriate and practical for further field evaluations. Therefore the study employed a protocol under controlled laboratory conditions designed to simulate an extreme-case trimming situation. Trimming tools were chosen after contractors were polled as to common tools and methods used.

MATERIALS & METHODS

Generic Foam Systems

Open-cell foam – a nominal 0.5 pounds per cubic foot (pcf), polyether polyol-based polyurethane foam system typical of those currently used in interior wall spray applications.

Closed-cell foam – a nominal 2.5 pcf, polyester / polyether polyol-based rigid polyurethane foam system typical of those currently used in interior and exterior wall and roof spray applications.

Trimming Tools

Foam Planer – pneumatically-operated, wire-brush Tough Mechanics planer (planer brush: 9 cm diameter, 60 cm long)
Sander – Bosh 1028VSR hand-held electric drill with Norton "Stick and Sand" sanding disk (5" (12.7 cm) diameter) with Norton 40 grit sanding disk
Hand Saw – 36" x 1" (91 cm x 2.5cm) blade; 8 teeth per inch
Hand Scraper #1 – Husky #482 526 "14-in-1" Paint Tool, 3" (7.6 cm) blade
Hand Scraper #2 – Groomex #63306 dog shedding blade

Trimming Technique Groups

Trimming tools were grouped into "high dust potential" and "low dust potential" categories for the foam type on which they might be used in actual SPF insulation application based on subjective understanding of the techniques. The resulting groupings are shown in Table I.

Table I. SPF Insulation Trimming Technique Groups

Trimming Technique	Dust Potential	½ lb (Open Cell) SPF	2.5 lb (Closed Cell) SPF
Hand Saw	low	X	n/a
Hand Scraper (#1 & #2)	low	X	X
Foam Planer	high	X	X
Sander	high	n/a	X

Monitoring Equipment

Samples were collected using SKC Aircheck 52 personal air sampling pumps. The sampling media was attached to the sampling pumps, the sampling pumps were flow calibrated using a Bios Dry-Cal DC-lite Model 717-01 calibrator.
Inhalable Particulate - Inhalable particulate samples were collected using IOM personal samplers, conductive plastic version (SKC Cat. # 225-70A). The sampler consists of a sample cassette, which contains the 25-mm sample filter, and a housing, which connects to the sampling pump and into which the loaded sample cassette is placed. The sample cassettes were loaded with 25-mm PVC membrane filters (5 µm pore size, SKC Cat. # 225-8-04) and pre-weighed as a unit by the analytical lab.
Respirable Particulate - Respirable particulate samples were collected using pre-weighed 37-mm PVC membrane filters (5 µm pore size) in three-piece polystyrene cassettes (SKC cat. # 225-803) fitted with a GS-3 conductive plastic cyclone pre-selector (SKC cat. # 225-100).
pMDI - 1,2-PP coated 13-mm glass fiber filters were prepared by the BMSEAL and pre-loaded into polypropylene cassettes.

Trimming procedure

SPF insulation was applied to sections of timber drywall assemblies which had been placed in a spray booth with a water cascade. Extra spray was applied so that the resulting foam extended well past the studs to provide adequate foam for extended trimming and cutting times. The foams were applied using a Graco "Reactor H25" spray unit fitted with 50 feet of hose and using a Graco "fusion" spray gun.

After curing for 1-2 hours post-spraying, the SPF insulation in wall sections were cut and trimmed flush with stud surfaces. Trimming was conducted in an environmental chamber (interior dimensions: 254 cm high, 284 cm wide, 325 cm deep) with the doors open but no additional ventilation. Observations with a smoke tube showed very slight air currents in random directions. Temperatures and humidity inside the chamber during trimming and cutting were 71.6 – 73.0 °F (22.0-22.8 °C) and 41-46 %, respectively.

Trimming was carried out for time periods calculated to ensure that sample volumes were sufficient to ensure that sample detection limits would be relevant to occupational exposure guidelines. Trimming was conducted in duplicate 15-20 minute sessions for each of the six trimming groups indicated in Table I.

Exposure Monitoring

Background samples for inhalable particulate, respirable particulate, and pMDI were taken before the start of trimming each day. The samples were collected in the center of the environmental chamber by mounting the sampling equipment on a tripod about 24" (60 cm) above the floor.

During each trimming session, personal exposure monitoring on the worker doing the trimming was conducted for all three types. In addition, inhalable particulate source sampling was conducted by holding the sampler 12-24 inches from the trimming area.

The sampling devices were assembled, flow calibrated, and located in the worker's breathing zone before each trimming session. Immediately after each trimming session, the sampling devices were retrieved, flow checked, and worked up as described below for later analysis. All handling of sample cassettes was done using powder-free nitrile laboratory gloves to avoid adding weight to the cassettes from fingerprints. The trimmed foam was removed and area was cleaned by sweeping before the next trimming session.

INHALABLE PARTICULATE

Inhalable particulate samples were collected and analyzed according to NIOSH Method 500. To conduct sampling, a loaded cassette was removed from its numbered transport clip, placed in the bottom of the IOM housing, and the housing top screwed in place. The housing was then connected to the tubing from the sampling pump to be used; the flow was set to approximately 2 L/min (using calibration adapter SKC Cat. # 391-01), and recorded to a precision of two decimal places as specified in the instructions for the device.

Following sampling, the sample flow was again measured and recorded, then the sample cassette was removed from the IOM housing and replaced in the transport clip. A numbered sample label was applied and the sample was placed in a zipper bag for analysis. All handling of IOM sample cassettes was done using powder-free nitrile laboratory gloves to avoid adding weight to the cassettes from fingerprints.

Analysis consisted of gravimetric determination of the mass captured by the sample cassette; the reporting limit was 200µg.

RESPIRABLE PARTICULATE

Respirable particulate samples were collected and analyzed following NIOSH Method 600. To conduct sampling, the top section of a 37-mm filter cassette assembly was removed and the GS-3 cyclone was press-fitted onto the middle section of the cassette. The flow rate through the filter cassette / cyclone assembly was then set to approximately 2.75 L/min (using calibration jar SKC Cat. # 225-111), and recorded to a precision of two decimal places as specified in the instructions for the device. The calibrated filter cassette / cyclone assembly was mounted in a holder (SKC cat. # 225-1) to facilitate locating it in proper orientation in the worker's breathing zone.

Following sampling, the sample flow was again measured and recorded, and then the GS-3 cyclone was removed from the filter cassette inlet and the polystyrene cassette top was placed back on the cassette. A numbered sample label was applied and the sample was placed in a zipper bag for analysis. The cyclone was wiped with a lint-free wipe and any contents in the grit pot emptied to prepare it for reuse.

Analysis consisted of gravimetric determination of the mass captured by the sample filter; the reporting limit was 30 µg.

INORGANIC PARTICULATE

Following gravimetric analysis, the membrane filters from both the inhalable and respirable particulate samples were heated for two hours in a furnace at 765 °C, then cooled and re-weighed to determine the proportion of mass found that was inorganic.

POLYMERIC MDI

Polymeric MDI was determined according to Bayer Material Science Environmental Analytical Laboratory (BMSEAL) Method 1.7.7. The method is based on OSHA method 42, in which air is drawn through a glass fiber filter which has been treated with 1,2-pyridyl piperazine (1,2-PP). Isocyanates react with the amine functional groups on the 1,2-PP to form a stable derivative which serves as a sensitive analyte in subsequent liquid chromatography / ultraviolet detection (LC/UV) analysis.

To conduct sampling, the outlet nozzle of a pre-loaded 13-mm cassette was attached to the flexible tubing from the sampling pump to be used. The flow rate through the cassette was set to approximately 2 L/min as specified in the method and recorded to a precision of two decimal places.

Following sampling, the sample flow was again measured and recorded, then the filter cassette was opened and the 13-mm glass fiber filter was transferred using tweezers to a 4-mL glass vial. Using a pipettor (Gilson Pipetman 0-5 mL adjustable), 2.0 mL of a 90:10 solution of acetonitrile (Honeywell B&J high purity): dimethyl sulfoxide (Fisher lot 061838) was added to the vial. The vial was capped with a polyseal cap and shaken well. The cap was sealed with pressure tape and a numbered sample label applied to the vial. The vials were packed in a DOT-approved shipping container for return to BMSEAL for analysis.

Polymeric MDI (pMDI) is a mixture composed of MDI monomers (45-55%) and a series of larger, multiple-phenyl-ring, multi-isocyanate homologues of MDI (45-55%). Because characterized standards are only available for MDI and the pMDI mixture, the BMSEAL method employs instrumental calibration for these two analytes. In the case of pMDI, the three-phenyl-ring triisocyanate homologue of MDI is used as the calibration peak for the entire mixture. Thus, pMDI values reported by this method include the MDI mass; to estimate the total mass of the multiple-phenyl-ring, multi-isocyanate MDI homologues in the sample, the MDI result may be subtracted from the pMDI result. The method reporting limit was 0.1 µg for MDI and 3 µg for pMDI.

Two quality assurance samples which had been spiked with known amounts of pMDI were prepared by the BSEAL laboratory and included with the sampling equipment sent to the field. These samples were prepared in the field as if they had been field samples, following the desorption procedure described above and returned to the laboratory for analysis. In addition, two of the sampling filters were desorbed without having air drawn through them to serve as field blanks.

Calculations

AIR VOLUMES

Sample air volumes were determined by multiplying the sampling time (in min) for each sample by the mean sample air flow rate (mean of pre- and post-sampling flow rate measurement (in L/min; nominal flow rates listed later in the descriptions of the specific methods). Sample masses reported by the laboratory (in mg or µg, depending on the specific method) were divided by the sample volume (in m^3; 1000 L = $1m^3$) to give the reported concentration results (in mg/m^3 or $\mu g/m^3$, depending on the specific method).

TIME-WEIGHTED VALUES

These short-term task results cannot be compared directly with the occupational exposure limits -- all of which are referenced to a 8-hour time-weighted average – unless it is assumed that a worker's complete 8-hour work shift is spent conducting these tasks. In the case of SPF application, estimates from industry workers knowledgeable about how SPF installation is conducted are that a worker would typically spend approximately 2 hours per work day on trimming tasks. Therefore, taking as an example a situation where a worker conducted SPF trimming tasks for 2 hours (and assuming that there is no other task that contributes to their inhalable particulate exposure), the worker's 8-hour time-weighted average would be calculated from a 15-minute task sample result of 10 mg/m^3 as:

$$10\ mg/m^3 \times (120\ min \div 480\ min) = 2.5\ mg/m^3\ (TWA_8)$$

This consideration in comparisons with occupational exposure limits applies to the results for all the monitoring conducted in this study (inhalable particulate, respirable particulate, and pMDI) since all samples were short-term task samples of 11-17 minutes.

RESULTS

Observations

The subjective grouping of trimming techniques into "low dust potential" and "high dust potential" was supported by visual observations. The pneumatically-powered foam planer generated by far the most observable foam particulate, followed by the sander. None of the three hand techniques (saw, scraper #1, and scraper #2) generated noticeable airborne particulate; their use resulted primarily in relatively large pieces of foam which fell to the floor as they were generated.

Measurements

The detailed results of the air sampling conducted during SPF insulation trimming are given in Tables II - IV below.

INHALABLE PARTICULATE

The inhalable particulate results largely mirror the subjective observations reported above: the results are highest for the pre-identified high dust potential trimming techniques with both foam types. The results for these short-term (11-17 minute) task samples were a factor of about 30 above the 8-hour time-weighted average (TWA_8) occupational exposure limits for inhalable particulate (OSHA PEL = 15 mg/m^3 ($TWA_{8)}$ and the ACGIH recommendation for inhalable particulate, not otherwise specified = 10 mg/m^3 (TWA_8) [note: no NIOSH REL established]).

The inhalable particulate results for the low dust potential techniques gave results below the 8-hour time-weighted average occupational exposure limit concentration in the case of the open cell foam, but the mean concentration for the low dust potential techniques with the closed cell foam had a mean that was almost 20 times higher. This was due to one of the two replicate results of inhalable particulate being 25 times the first replicate. This single result greatly skewed the mean. While the replicate trimming operations were done by different workers, there was no differences observed in the way they did the trimming that would account for such a large difference in the sample results. Interestingly, this is the only trimming situation where the source inhalable particulate results were lower than the personal inhalable particulate results. It is also interesting to note that the respirable particulate results were higher for the replicate with the lower inhalable particulate results.

RESPIRABLE PARTICULATE

Trimming of the open cell foam by high dust potential techniques resulted in respirable particulate results for these short-term tasks above the occupational exposure limit concentration (OSHA PEL = 5 mg/m^3 (TWA_8), ACGIH recommendation for respirable particulate, not otherwise specified = 3 mg/m^3 (TWA_8) [note: no NIOSH REL established]). Even so, the mean in this case exceeded the ACGIH concentration by a factor of just 2.5. All other trimming scenarios were below the occupational exposure limits. This result indicates that the particulate generated by all the trimming techniques is predominantly large.

INORGANIC PARTICULATE

Ashing of the PVC membrane filters from both the inhalable and respirable samples gave results that ranged from -9 – 0.9% ash. Since the range for four blank membrane filters that were ashed ranged from -2 – 0.7% ash, this result indicates that all of the gravimetrically measured mass was organic in nature. The ashing differential determination is designed to be a simple way to estimate the proportion of the mass measured that is not attributable to SPF.

MDI / pMDI

In all trimming groups with both foam types, MDI and pMDI were not detected in the personal and source samples. This was true even in the case of the samples taken during the high dust potential techniques, where foam dust was observed inside the sampler after sampling and was included with the filter in the desorbed sample. The detection limit for these short-term task samples was a factor of at least 20 below the OSHA PEL (and NIOSH REL) of 200 µg/ m^3 (Ceiling) and a factor of at least 5 below the 8-hour time-weighted average occupational exposure limit (ACGIH TLV® for MDI = 51 µg/ m^3 (TWA_8), NIOSH REL for MDI = 50 µg/ m^3 (TWA_8)).

The samples were spiked with a solution containing 4.65 µg pMDI which had specifications of 40-45% monomer (MDI). The results of the spikes showed 95-110% accountability for the pMDI amount spiked, and MDI monomer results which were 37-41%. These results demonstrate that the method was functioning as validated and could be expected to detect any pMDI that was present above the detection limit.

Table II. Inhalable Particulate Sampling Results

Trimming Task	Worker	Sample type	Air Concentration (mg/m^3)		Notes
			As sampled	Background corrected	
Open cell foam – low dust potential	1	Personal	ND (<6)*	ND (<6)	Hand saw 65% of time Hand scraper 35% of time
	1	Source	15	9.3	
	2	Personal	11	5.3	
	2	Source	30	24.3	
MEAN		Personal	7	4.1	
		Source	23	17	
Open cell foam – high dust potential	1	Personal	53	47.3	Pneumatic planer 100% of time
	1	Source	380	374	
	2	Personal	490	484	
	2	Source	520	514	
MEAN		Personal	272	266	
		Source	450	444	
Closed cell foam – low dust potential	1	Personal	10	4.3	Curry comb 50% of time Hand scraper 50% of time
	1	Source	9.8	4.1	
	2	Personal	250	244	
	2	Source	45	39.3	
MEAN		Personal	130	124	
		Source	27	22	
Closed cell foam – high dust potential	1	Personal	180	174	Pneumatic planer 100% of time
	1	Source	720	714	
	2	Personal	420	414	
	2	Source	540	534	
MEAN		Personal	300	294	
		Source	630	624	
Background	Day 1	Area	5.6	-	
	Day 2	Area	5.9	-	
MEAN		Area	5.8	-	
Occupational Exposure Limits : ACGIH : 10 mg/m^3 TWA_8 OSHA PEL : 15 mg/m^3 TWA_8 NIOSH REL : None Established					

*ND = Not Detected; less than reporting limit listed in parenthesis

Table III. Respirable Particulate Sampling Results

Trimming Task	Worker	Sample type	Air Concentration (mg/m^3)		Notes
			As sampled	Background corrected	
Open cell foam – low dust potential	1	Personal	0.88	0.4	**Hand saw 65% of time Hand scraper 35% of time**
	2	Personal	ND (0.7)*	ND (0.7)	
MEAN		Personal	0.6	0.4	
Open cell foam – high dust potential	1	Personal	5.4	5.0	**Pneumatic planer 100% of time**
	2	Personal	10	9.6	
MEAN		Personal	7.7	7.3	
Closed cell foam – low dust potential	1	Personal	3.5	3.1	**Curry comb 50% of time Hand scraper 50% of time**
	2	Personal	0.96	0.5	
MEAN		Personal	2.2	1.8	
Closed cell foam – high dust potential	1	Personal	1.5	1.1	**Pneumatic planer 100% of time**
	2	Personal	1.4	1.0	
MEAN		Personal	1.5	1.0	
Background	Day 1	Area	0.72	-	
	Day 2	Area	ND (0.3)	-	
MEAN		Area	0.4	-	
Occupational Exposure Limits : ACGIH : 3mg/m^3 TWA$_8$ OSHA PEL : 5 mg/m^3 TWA$_8$ NIOSH REL : None Established					

*ND = Not Detected; less than reporting limit listed in parenthesis

Table IV. MDI/pMDI Sampling Results

Trimming Task	Worker	Sample type	Air Concentration		Notes
			MDI (mg/m^3)	pMDI ($\mu g/m^3$)	
Open cell foam – low dust potential	1	Personal	ND* (<4)	ND (<200)	Hand saw 65% Hand scraper 35% of time
	2	Personal	ND (<6)	ND (<200)	
MEAN		Personal	ND (<5)	ND (<200)	
Open cell foam – high dust potential	1	Personal	ND (<10)	ND (<300)	Pneumatic planer 100% of time
	2	Personal	ND (<7)	ND (<200)	
MEAN		Personal	ND (<9)	ND (<250)	
Closed cell foam – low dust potential	1	Personal	ND (<6)	ND (<200)	Curry comb 50% Hand scraper 50% of time
	2	Personal	ND (<6)	ND (<200)	
MEAN		Personal	ND (<6)	ND (<200)	
Closed cell foam – high dust potential	1	Personal	ND (<5)	ND (<200)	Pneumatic planer 65% Sanding wheel 35% of time visible foam pieces on filter
	2	Personal	ND (<6)	ND (<200)	
MEAN		Personal	ND (<6)	ND (<200)	
Background	Day 1	Area	ND (<4)	ND (<100)	
	Day 2	Area	ND (<3)	ND (<90)	
MEAN		Area	ND (<4)	ND (<95)	
Occupational Exposure Limits		**ACGIH**	**51 TWA_8**	**None established**	
		OSHA PEL	**200 (ceiling)**	**None established**	
		NIOSH REL	**50 TWA_8 200 (ceiling**	**None established**	

*ND = Not Detected ; less than reporting limit listed in parenthesis

CONCLUSIONS & RECOMMENDATIONS

The following conclusions can be drawn from the results in this study:

- The sampling and analytical techniques used appear to be practical and adequately sensitive for use in field evaluations of SPF insulation trimming exposures.
- The inhalable particulate results were greater than the relevant occupational exposure guideline in all but one case, while the respirable particulate results were under the relevant occupational exposure guideline in most cases. The use of respiratory protection appropriate for particulates is indicated during SPF trimming operations.
- While the SPF insulation trimming operations in this study were designed to simulate extreme case field situation, pMDI was not detected in any of the samples, indicating that exposure to these SPF components from trimming is not likely to be a concern when trimming is conducted with at least one hour cure after application.
- Field studies are needed to determine usual trimming techniques and exposure during real-time SPF application and trimming.

ACKNOWLEDGMENTS

The authors would like to thank the Center for the Polyurethanes Industry (CPI, of the American Chemistry Council) for funding the study.

BIOGRAPHIES

.

Mark W. Spence

Mark Spence is a consultant specializing in health & safety programs for manufacturing operations and products in the chemical & plastics industry following a 30-year career with the Dow Chemical Company. Following assignments as industrial hygiene chemist and then Laboratory Director of Dow's AIHA-accredited Industrial Hygiene Laboratory, Mark served as a Senior Industrial Hygienist with Dow's Global Industrial Hygiene Expertise Center. While at Dow, Mark supported Dow's Polyurethanes business on industrial hygiene issues for 20 years. Mark has a Bachelor of Science degree in chemistry from Clarkson University, a Master of Science degree in chemistry from Michigan State University and is a Certified Industrial Hygienist.

Cynthia Graham

Cynthia Graham earned a Ph.D and a M.S. from the University of Pittsburgh, Graduate School of Public Health, Department of Environmental and Occupational Health and Toxicology. Currently, Cynthia serves as a toxicologist at Huntsman LLC in The Woodlands, TX. Cynthia has worked as an industrial toxicologist for over 10 years. Her specialty is immunotoxicology, evaluating the allergic responses to chemicals. She is currently a member of the Society of Toxicology, as well as various US and international organizations dealing with chemicals, including isocyanates and epoxy resins.