American Chemistry Council
Diisocyanates Panel
Considerations for Modifications to NIOSH 5521 and OSHA 47 Air Sampling Methods for Diphenylmethane Diisocyanate (MDI)

PURPOSE

The purpose of this document is to provide considerations for modifications to the current air sampling methods for MDI - NIOSH Method 5521 and OSHA Method 47 - specific to situations in which reactive MDI aerosols may be present, such as spray applications. These modifications can improve the ability of the method to sample and derivatize MDI when present in both vapor and aerosol form. The information provided in this document is not a directive or an industry standard. The document is intended as guidance. Users should independently determine what constitutes an appropriate practice relative to their own needs and circumstances.

1. SUMMARY OF THE METHOD

1.1 Analyte: 4,4'-Methylene diphenylisocyanate (MDI, Methylene di-*p*-phenyl diisocyanate); CAS [101-68-8]. (NOTE: this method may also be applied to the determination of 2,4'-MDI if appropriate reference material is obtained for preparing spiking solutions and calibration standards. Chromatographic conditions would have to be adjusted based upon the calibration standards.)

1.2 Matrix: Air

1.3 Procedure: Adsorption of MDI into an impinger solution of 1-(2-pyridyl) piperazine (1, 2-PP) in toluene at a flow rate of 1 L/min for 0.25 to 4-hour time intervals; evaporation of the solvent and desorption of the residue into acetonitrile/DMSO and analysis using reverse-phase liquid chromatography with UV or fluorescence detection (HPLC/UV or FLD).

1.4 Basis and Validation: This method is an adaptation of NIOSH Method 5521 (Ref 7.1); the validation conducted for that method applies to this method. Several of these adaptations were made to improve the ability of the method to sample and derivatize MDI when present in both vapor and aerosol form; validation of the sampler for MDI aerosol/vapor mixtures has also been investigated (Ref. 7.3). The areas of the method in which changes were made from NIOSH 5521 are:

- The method is written for MDI only,
- 1,2 – (Pyridyl) piperazine is used as the derivatizing agent,

- A backup filter is recommended to capture particles (<2 microns) that may pass through the impinger,
- LC column and conditions are updated, and
- Detection of the LC eluents is by Fluorescence or Ultraviolet rather than by electrochemical and ultraviolet.

Working standards and spiking solutions may be made using either MDI or a previously prepared sample of the 1,2-PP derivative of MDI (MDIP).

2. SAFETY

2.1 Good laboratory practices dictate that each analyst should be thoroughly acquainted with potential hazards of the reagents, products, and solvents before commencing laboratory work. SOURCES OF INFORMATION INCLUDE: SAFETY DATA SHEETS, LITERATURE AND OTHER RELATED DATA. Safety information on reagents may also be obtained from the supplier. Disposal of reagents, reactants, and solvents must be in compliance with local, state, and federal laws and regulations.

2.2 Exposure to airborne concentrations of MDI above the occupational exposure limit (OEL = 5 parts per billion as an 8-hr average) can irritate (burning sensation) the mucous membranes in the respiratory tract - nose, throat, lungs - causing runny nose, sore throat, coughing, chest discomfort, shortness of breath and reduced lung function As a result of repeated overexposures (above the OEL) or exposure to a single large dose, certain individuals may develop sensitization to MDI (asthma or asthma-like symptoms) that may cause them to react to a later exposure to MDI at levels below the OEL. Upon direct skin contact, MDI can cause irritation of the skin, with symptoms of reddening, itching, and swelling. Direct splashing of liquid MDI into the eye can cause irritation with symptoms of reddening, tearing, stinging, and swelling. Refer to the SDS for more information including first aid measures.

2.3 Toluene is a highly flammable liquid and vapor. Exposure to toluene causes central nervous system depression; headache, dizziness, and is an eye, skin, and respiratory irritant. Prolonged overexposure or repeated unprotected exposure (i.e., inhalation of vapors, direct skin contact) may cause damage to the liver and kidneys. Toluene is suspected of damaging fertility or an unborn child. It may be fatal if swallowed and enters the airways. Refer to the SDS for more information including first aid measures.

2.4 Acetonitrile is extremely flammable and can cause respiratory irritation. Prevent contact with the skin or eyes. Work in a well-ventilated area from any source of ignition. Refer to the SDS for more information including first aid measures.

2.5 Exposure to dimethyl sulfoxide (DMSO) can occur primarily by skin contact. DMSO readily penetrates the skin and may significantly enhance absorption of other dissolved chemicals into the body. Skin absorption may cause Central Nervous System effects such as headache, nausea, and dizziness. DMSO's ability to increase absorption of other chemicals is its most significant occupational hazard. Direct contact with DMSO may also

cause skin and eye irritation (burning sensation). Refer to the SDS for more information including first aid measures.

3. APPARATUS

3.1 Portable battery operated pumps, capable of maintaining a flow rate of approximately 1 L/min.

3.2 Spill-resistant, 25 mL midget glass impingers and impinger holders, SKC catalog #225-36-4 and 225-20, or equivalent.

3.3 13-mm Swinnex filter holders with polytetrafluoroethylene (PTFE) washers, P/N SX00-013-00, obtained from Millipore, P/N 4317 from Pall, or 225-32 from SKC or equivalent.

3.4 Fluoroelastomer Fluran™ tubing, ¼" ID, Thermo Fisher Scientific, catalog # 14-170-8B or silicone Silastic® tubing, catalog #11-189-13A, or equivalent.

3.5 10 mL Reuseable Luer-Lok Glass Syringe, Fisher catalog # 14-823-10C, or equivalent.

3.6 10 cm long, 14 gauge, stainless steel, Luer-Lok Cannula to fit the syringe in 3.5, Fisher catalog #01-290-29.

3.7 Repipet dispenser, 2 mL.

3.8 Mechanical flatbed shaker capable of producing 160+ cycles per minute.

3.9 HPLC system equipped with pump, autosampler and detectors.

3.10 Discovery® RP-AmideC16 HPLC Column, 5 µm particle size, 10 cm x 4.6 mm, Sigma-Aldrich catalog number 569323-U, or equivalent.

3.11 30 mL glass vials and PTFE-lined caps.

4. REAGENTS

4.1 4, 4'-Methylene diphenylisocyanate (MDI, Methylene di-*p*-phenyl diisocyanate) CAS [101-68-8], 99 %.

4.2 The 1,2-PP derivative of MDI (MDIP): N, N'-(Methylenediphenylene)bis[4-(2-pyridinyl)-1-piperazinecarboxyamide], available from Sigma-Aldrich (1 mg/mL in DMSO, Cat. No. 48147), or equivalent, or synthesized following the procedure in OSHA Method 47 (Ref 7.2).

4.3 Toluene (HPLC grade).

4.4 Desorbing solution: 90/10 (v/v) Acetonitrile (HPLC grade)/Dimethyl sulfoxide (DMSO).

4.5 1-(2-Pyridyl)piperazine (1,2-PP), CAS [34803-66-2], 99.5 + %, Cat No. 408166, obtained from the Sigma Aldrich Chemical Company, or equivalent.

4.6 Diethyl phthalate, CAS [84-66-2], 99%, Cat. No. D9,962-5, obtained from Sigma Aldrich Chemical Company, or equivalent.

4.7 Standard preparation solvent, 3mM 1,2-PP, CAS [34803-66-2] in acetonitrile (HPLC grade) prepared by diluting approximately 0.49 grams 1,2-PP into 1 liter of acetonitrile.

4.8 Ammonium Acetate, CAS [631-61-8], 98%, Cat. No. 15,852-6, obtained from Sigma Aldrich Chemical Company, or equivalent.

4.9 Glacial Acetic Acid, CAS [64-19-7], 99.7%, obtained from Fisher Scientific, or equivalent.

5. PROCEDURES

5.1 Preparation of the Impinger Solution

5.1.1 Weigh 50 mg of 1,2-PP in a 500 mL volumetric flask. Add ~100 mL of toluene and swirl to dissolve the PP. Dilute to the mark with toluene. The concentration of this solution is 0.1 mg/mL 1,2-PP in toluene.

5.1.2 The 1,2-PP degrades slowly over time and the decomposition is accelerated by exposure to light and heat. The decomposition products can cause interference in the chromatography. Use high purity 1,2-PP reagent which is stored in a freezer. Store the 1,2-PP solution in the freezer prior to shipping. It can be shipped at ambient temperatures, however, minimize exposure to light and heat as much as possible.

5.1.3 The impinger solution may be used for up to one month.

5.2 Preparation of QC Spikes

5.2.1 For the low loading level (~ 2 µg) inject 1 µL of MDI spiking solution (~20 mg of MDI [or ~ 50 mg MDIP] in 10 mL of acetonitrile) into 15 mL of the impinger solution in the 30 mL vials used for the samples. For the high loading level (~20 µg) inject 10 µL of MDI spiking solution into 15 mL of the impinger solution in a vial.

5.2.2 Include a laboratory blank (15 mL of impinger solution) and the spiked impinger solutions with samples for analysis.

5.3 Sampling Procedures

5.3.1 Attach the outlet of an impinger containing 15 mL of the 0.1 mg/mL 1,2-PP solution to a 13 mm Swinnex filter cassette, then connect to a pump with tubing. Note that during sampling toluene will condense in the tubing and it may flow back into the impinger-filter train. Plasticizers from the tubing may cause interferences in the chromatography. Fluran® fluoroelastomer or Silastic® silicone tubing is recommended for this reason. If this tubing material is not available and other tubing is used, make a loop in the tubing to prevent the toluene from re-entering the impinger. A trap or carbon tube in-line may also be used to prevent the toluene vapors from entering and potentially damaging the sampling pump.

5.3.2 Calibrate the sampling pump with the impinger and filter cassette in line to a flow rate of 1.0 L/min.

5.3.3 Connect the impinger to the worker's shirt lapel with an impinger-holder and attach the pump to the worker's belt.

5.3.4 Start the pump and record the time. Periodically check the level of solution in the impinger. Replenish the solution if the level falls below ~5 mL.

5.3.5 At the end of the sampling period, stop the pump and record the time. Do not exceed 4 hours sampling time.

5.3.6 For the samples, detach the impinger and transfer the impinger solution to a glass vial using a glass syringe and cannula. Add ~2 mL of fresh impinger solution or toluene to the impinger using a clean syringe and cannula. Rinse the impinger and transfer the rinse to the vial containing the sample. This process can be repeated if necessary to thoroughly rinse the impinger. Cap the vial securely and tape the lid to prevent it from loosening during shipping. Rinse the syringe and cannula used for the sample to a waste vial before processing the next sample or blank.

5.3.7 Perform a post-sampling flow check with a representative sampling train (impinger with back-up filter).

5.3.8 For every ten samples, a blank should be prepared by transferring a 15 mL aliquot of the impinger solution to a vial.

5.3.9 The samples and blanks should be shipped to the laboratory. Ship according to DOT regulations. *See Appendix A for general shipping guidance.*

5.4 Preparation of the Samples for Analysis

5.4.1 Evaporate the toluene in the samples and blanks by either of the methods outlined in 5.4.1.1 and 5.4.1.2. Make sure that all of the toluene is evaporated

because it can otherwise cause interferences in the chromatographic analysis of the samples. Be sure to use fresh caps for the bottles after evaporation to avoid toluene contamination.

5.4.1.1 The vials containing the samples and blanks are opened and placed in a heater block or water bath set at 65°C. Nitrogen is gently blown into the vials to aid in evaporating off the toluene. Take the vials to dryness.

5.4.1.2 Alternatively, the vials can be placed in a vacuum oven at 65°C. Evacuate the oven and maintain the vacuum until all the toluene has evaporated. A cold trap should be used to keep the toluene from entering the vacuum pump.

5.4.2 Allow the samples to cool to room temperature then add 2.0 mL of 90/10 acetonitrile/DMSO to each bottle. Shake the samples for 30 minutes and then filter an aliquot of each sample using 0.45 µm pore-size Teflon filters into autosampler vials.

5.4.3 Analyze the samples and blanks according to the conditions given below.

5.5 Analysis Conditions and Instrumentation

5.5.1 The conditions and instrumentation given below are known to work well for this analysis. Any other set of conditions and instrumentation that are demonstrated to work by analysis of the calibration standards and a media blank may be used in place of those given here.

5.5.2 Prepare eluent by dissolving 7.7 grams of ammonium acetate into 10 L of purified water (0.01M Ammonium Acetate). Then adjust the pH of the solution to pH 6.0 - 6.2 by adding glacial acetic acid drop-wise.

5.5.3

Pump:	HPLC gradient pump
UV Detector:	254 nm (313 nm for confirmation wavelength)
Fluorescence Detector:	Excitation=240 nm Emission= 370 nm
Column:	Supelco Discovery® RP-AmideC16, 10 cm x 4.6 mm, 5 µm, catalog # 569323-U or equivalent
Autosampler:	10 µL injection volume
Eluent Program:	A=Acetonitrile B= 0.01M Ammonium Acetate, pH=6.0-6.2

Acetonitrile can be added at 5-20% to prevent microbial growth.

Time (min)	%A	%B	Flow (mL/min)
0	30	70	2.0
4.0	30	70	2.0
8.0	50	50	2.0
10.0	50	50	2.0
10.1	30	70	2.0

(Note: Running a higher concentration of acetonitrile after the end of each analytical run may be required if the derivatizing agents or other components tend to build up on the column as evidenced by changes in separation.

5.5.4 Retention time under these conditions: 4,4'-MDI: 8.0 min

5.5.5 Approximate limit of quantitation under these conditions: 0.1 µg

5.6 Preparation of Calibration Standards

5.6.1 Calibration standards may be prepared using MDI (as described below) or MDIP. (Note: A single stock solution may be used for calibration standards if a second stock solution is used for calibration verification.)

5.6.1.1 If MDIP is used, DMSO is a good solvent to use for making the concentrated stock solutions (5.6.2.1) for later dilution into acetonitrile.

5.6.1.2 The molecular weights of MDI (250.26) and MDIP (576.71) lead to a mass conversion factor of 0.4339 for expressing MDIP mass as MDI mass equivalent.

5.6.2 Prepare stock/standard solutions as follows:

5.6.2.1 Weigh ~15 mg (Stock A) and ~30 mg (Stock B) of solid MDI into separate 10-mL volumetric flasks and bring to volume with methylene chloride.

5.6.2.2 Allow the MDI to dissolve for ~ ½ hour with periodic agitation.

5.6.3 Prepare the following calibration standards from the stock standard solutions (Section 5.6.2.1)

5.6.3.1 Standard 1/100 A: inject 100 µL of Stock A (Section 5.8.2.1) into 9.9 mL of standard preparation solvent (concentrations = ~15 µg/mL).

5.6.3.2 Standard 1/1000 B: inject 10 µL of Stock B (Section 5.8.2.1) into 10 mL of standard preparation solvent (concentration= ~ 3 µg/mL).

5.6.3.3 Standard 1/1000 A: inject 10 µL of Stock A (Section 5.8.2.1) into 10 mL of standard preparation solvent (concentration= ~ 1.5 µg/mL).

5.6.3.4 Standard 1/10000 B: inject 1 µL of Stock B (Section 5.8.2.1) into 10 mL of standard preparation solvent (concentration= ~ 0.3 µg/mL).

5.6.3.5 Standard 1/10000 A: inject 1 µL of Stock A (Section 5.8.2.1) into 10 mL of standard preparation solvent (concentration= ~ 0.15 µg/mL).

5.6.3.6 Standard 1/100000 B: add 1 mL of Standard 1/10000 B (Section 5.8.3.4) into 9.0 mL of standard preparation solvent (concentration= ~0.03 µg/mL).

6. CALCULATIONS

6.1 Generate a calibration line from the standards.

6.2 Use the equation from the calibration to calculate the µg/sample for each sampler, correcting for the sample volume (2 mL).

6.3 Correct the sample concentration based on the method recovery.
$M^1 = (M*100)/\%\ R$

where: M^1= corrected mass of the analyte
M= uncorrected mass of the analyte
% R= appropriate recovery value (expressed as a percent).
The laboratory determined extraction efficiency.

7. BIBLIOGRAPHY

7.1 National Institute for Occupational Safety and Health (NIOSH), "NIOSH Method 5521: Monomeric Isocyanates," NIOSH Manual of Analytical Methods, Fourth Edition, 1994.

7.2 Occupational Safety and Health Administration (OSHA), "OSHA Method 47: Methylene Bisphenyl Isocyanate," OSHA Analytical Laboratory, Organic Methods Development Branch, Salt Lake City, UT, 1985.

7.3 NIOSH 1998. Chapter K: Determination of airborne isocyanate expos re. In: O'Connor PF, ed. NIOSH Manual of Analytical Methods, 4th ed. Cincinnati, OH : U.S. Dept. of Health

and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH). DHHS/NIOSH Publication #98-119.

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Appendix A – Shipping Guidance

Introduction

Since the procedure for the ACC Diisocyanates Panel modifications to NIOSH 5521 and OSHA 47 air monitoring methods for MDI involve sample collection in toluene and field desorption with an acetonitrile/dimethlysulfoxide solvent mixture, certain considerations apply for proper shipping of the solvent mixture to the field and the field-desorbed samples back to the laboratory. This guidance represents a summary of the best practices employed by those experienced with the method in the United States of America (as of the date of publication) and is intended to give the user some ideas on practices that have been found to be effective***. The user of this method is advised to check current regulations and the advice of those responsible for shipping in their organization when establishing the practices they will use.***

Shipping Liquid Samples to the Laboratory

As of the date of publication, limited liquid samples may be shipped to the laboratory for analysis without hazardous material boxes, labels or shipping documents according to the "small quantity exemption" in the US Department of Transportation regulations (49 CFR § 173.4). Below are some details for such shipments (current as of the date of publication of this Appendix), but always refer to 49 CFR § 173.4 for specific guidance:

- Shipment is by ground transport (highway or rail).
- Samples are contained in screw-cap glass vials which have a maximum solvent volume of 30mL (1 ounce).
    - Some headspace is left in the vials.
    - The cap of each vial is secured (for example, with tape or wire).
- The sample vials are packed in an inner container with cushioning and absorbent material sufficient to absorb the entire volume of solvent in the package.
- The inner packaging is contained in strong outer packaging that is marked with the statement, "This package conforms to 49 CFR 173.4 for domestic highway or rail transport only."
- The total weight of the package is no greater than 29 kg (64 pounds).

Examples of typical commercially-available packages meeting these characteristics are shown below:

Packaging must be appropriately labeled. Refer to 49 CFR § 173.4 for specific guidance.

It is important to note that the person shipping samples to the lab (i.e., the field industrial hygienist, or the person that will prepare the shipping papers and arrange to ship the liquid samples back to the lab) has appropriate Hazardous Materials or Dangerous Goods Training. Companies that ship hazardous materials are required by law to ensure their products are properly classified, described, packaged, marked, and labeled as prescribed by domestic and international standards. Hazmat training and documentation of training are mandatory requirements for employees who prepare hazardous materials for transport or sign shipping papers.

Shipping Impinger and Field Desorption Solvents to the Sampling Location

One option for shipping the impinger and field desorption solvents to the sampling location is to pre-fill the sample vials with the solvent in the lab and then ship them to the sampling location. The guidance provided above should be followed for shipping the liquid samples to the laboratory.

A second option is to ship the sample vials and packaging to the field empty and ship the impinger desorption solvents separately in a bottle and shipping package designed for such shipping. In this case, the shipment would not meet the container volume requirements of the DOT “small quantity exemption” and so would need to be shipped as a “fully regulated” hazardous material shipment (requiring UN specification packaging, marks, and labels with the Bill of Lading, etc.). Any unused impinger and field desorption solvents would need to be properly disposed of at the sampling location or shipped back to the laboratory in sample vials as described above.