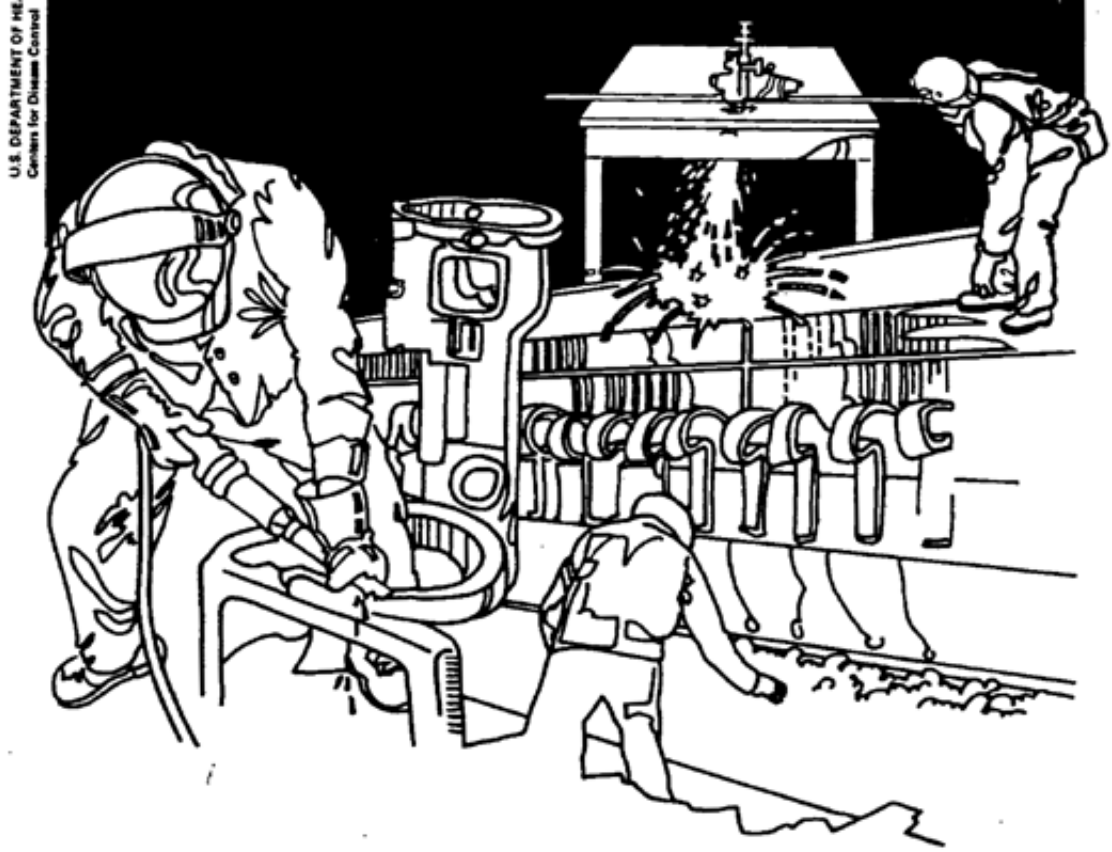
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 90-011-2034
XOMOX CORPORATION
CINCINNATI, OHIO

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APRIL 1990
XOMOX CORPORATION
CINCINNATI, OHIO

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I. SUMMARY

On October 11, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from a management representative of Xomox Corporation in Cincinnati, Ohio. The purpose of the request was to determine the exposures to workers using a polyurethane foam system in the shipping department. The foam, Instapak® 40 which is manufactured by Sealed Air Corporation, was used as packaging material for the shipping of valves to customers of Xomox. Instapak® 40 is a two-component system which contains 4,4'-diphenylmethane diisocyanate (MDI) and polymethylenepolyphenyl isocyanate (MDI prepolymer), and is applied with a spray gun. The actual packaging of valves takes approximately 30-45 minutes, during which Instapak® 40 is used for about 5 minutes. Thus, MDI enters the work atmosphere as a point source emission and the exposure is intermittent in nature.

Time-weighted average (TWA) and short term exposure monitoring were performed in the packaging area using NIOSH Method 5521. TWA air sampling equipment was located in the packaging station work area, and in surrounding work areas at varying distances from the polyurethane foam application area. All of the TWA air samples measured non-detectable levels of MDI and MDI prepolymer. Conversely, the short term exposure sampling did measure substantial levels of MDI, but did not detect any MDI prepolymer. Concentrations of MDI ranged from non-detectable to 320 micrograms of MDI per cubic meter of air (ug/m^3), with 2 of the 7 samples being above the OSHA and NIOSH ceiling limits for MDI of 200 ug/m^3. These data demonstrate that a potential for short term overexposure to MDI exists when spraying the polyurethane foam (Instapak® 40).

On the basis of this survey, the NIOSH investigators conclude that a health hazard exists from short term exposure to MDI when applying the Instapak® 40. Recommendations are made in Section VII of this report to either eliminate the use of the polyurethane foam system, or to use engineering controls and personal protective equipment to protect the workers.

KEYWORDS: SIC 3491 (Industrial Valves), 4,4'-diphenylmethane diisocyanate, MDI, polyurethane foam, Instapak® 40, respiratory protection, short term exposures.

II. INTRODUCTION

On October 11, 1989, NIOSH received a request for a health hazard evaluation from the Safety Coordinator for Xomox Corp. in Cincinnati, Ohio. Specifically, the requester was concerned with exposures to the foam system used to package valves in the shipping department.

An industrial hygiene survey was performed on January 25, 1990, and consisted of area air sampling for the major toxic components of the foam system. Response letters were forwarded to both management and employee representatives on February 20, 1990, and included recommendations that smoking be prohibited in all work areas, and that a second shift worker with respiratory problems be removed from all MDI exposure areas until evaluated by an occupational medicine physician.

III. BACKGROUND

Xomox Corp. (hereinafter referred to as Xomox) is a manufacturer of industrial valves in a variety of sizes and applications. Finished valves are boxed prior to shipment, and the boxes are packaged with styrofoam packaging material. Some valves are painted with a certain type of paint that reacts with the styrofoam, marring the painted surface of the valve. To alleviate this problem, the valves requiring this paint are packaged with a polyurethane foam system.

The polyurethane foam system used by Xomox is Instapak® 40, a two-component system marketed by Sealed Air Corporation.[1] Component A of Instapak® 40 consists of 50% 4,4'-diphenylmethane diisocyanate (MDI), and 50% polymethylenepolyphenyl isocyanate (MDI prepolymer). The two components mix during the spray application of the system, exiting the spray gun as a liquid. The components of the liquid quickly react, forming an expanding foam which fills all spaces in the box or crate.

Observations made by the NIOSH investigators found the packaging activity to proceed as follows: the box is assembled, the valves and parts to be shipped are placed in the box, the foam is applied and allowed to react, the box is sealed and moved to the shipping dock. The packaging operation requires approximately 30-45 minutes to complete; the application of the foam usually takes about 5-10 minutes. Since the foam is only applied during a brief portion of the total packaging operation, MDI enters the workroom air as a point source emission and the exposure is intermittent in nature. The foam system is also used to fill plastic bags which are used as packaging pillows for certain valve sizes or orders. The packaging station is located in the shipping department and is typically staffed by 2-4 workers. Adjacent to this area is a garage door that is opened on an infrequent basis. During the NIOSH survey, the door was open from 6:10 a.m. to 8:15 a.m.

IV. EVALUATION DESIGN AND METHODS

Because of the nature of the exposure, both time-weighted average (TWA) and short term exposure monitoring were used to sample MDI and MDI prepolymer. The TWA sampling was performed using area air sampling equipment located in the foam application area, the packaging area, and in other adjacent work areas. The short term exposure sampling was performed by holding the air sampling equipment in or near the breathing zone of the worker(s). Air sampling for MDI and MDI prepolymer was performed according to NIOSH Method 5521,[2] which utilizes a midget impinger containing 15 milliliters (ml) of a solution of 1-(2-methoxyphenyl) piperazine dissolved in toluene. Air was sampled at a nominal flowrate of 1.0 liter per minute (Lpm) using a calibrated, battery-powered sampling pump. Upon completion of sampling, the impinger solutions were transferred to 20 ml glass vials, and shipped refrigerated to the analytical laboratory. The impinger solutions were reacted with 25 microliters (ul) of acetic anhydride, then evaporated to dryness in a nitrogen atmosphere. The residues, which consist of the urea derivatives formed when 1-(2-methoxyphenyl) piperazine reacts with MDI, were redissolved in 5 ml of methanol, and 25 ul aliquots were injected into the high performance liquid chromatograph (HPLC). The ureas were qualitated and quantitated by using the ratio of the outputs from an electrochemical (potential of +0.8 volts versus Ag/AgCl) and an ultraviolet (wavelength of 242 nanometers) detectors. This methods limit of detection (LOD) for MDI and MDI prepolymer is 0.3 micrograms per sample (ug/sample); the limit of quantitation (LOQ) is 1.0 ug/sample.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are

often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, including recommended exposure limits (RELs), 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs®), and 3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs). Often, the NIOSH RELs and ACGIH TLVs® are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs® usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in the report, it should be noted that industry is legally required by the Occupational Safety and Health Act of 1970 to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. In addition to this, some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA, where there are recognized toxic effects from high short-term exposures.

B. Diisocyanates (MDI)

The unique feature of all diisocyanate-based compounds is that they contain two -N=C=O functional groups, which readily react with compounds containing active hydrogen atoms to form urethanes. The chemical reactivity of diisocyanates, and their unique ability to cross-link, makes them ideal for polymer formation. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, and sealants. Diisocyanates are usually referred to by their specific acronym; e.g. TDI for toluene diisocyanate, HDI for 1,6-hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, IPDI for isophorone diisocyanate, NDI for naphthalene diisocyanate, etc.[3]

In general, the potential respiratory hazards encountered during the use of diisocyanates in the workplace are related to the vapor pressures of the individual compounds. The lower molecular weight diisocyanates tend to volatilize, creating a vapor inhalation

hazard. Conversely, the higher molecular weight diisocyanates do not readily volatilize, but are still an inhalation hazard if aerosolized in the work environment. In an attempt to reduce the vapor hazards associated with the lower molecular weight diisocyanates, prepolymer and oligomer forms of these monomers were developed and replaced the monomers in many product formulations. An example of this is biuret of HDI, which actually consists of three molecules of HDI monomer joined together to form a higher molecular weight molecule with similar characteristics to those found in HDI monomer. Also, many product formulations that contain MDI actually contain a combination of MDI monomer and MDI prepolymer (polymethylenepolyphenyl isocyanate). It should be noted that the higher molecular weight diisocyanates still may generate vapor concentrations sufficient to cause respiratory and mucous membrane irritation if they are handled in poorly ventilated areas.[4]

Actual experience has shown diisocyanates to cause irritation to the skin, mucous membranes, eyes, and respiratory tract. Worker exposure to high concentrations may result in chemical bronchitis, chest tightness, nocturnal dyspnea, pulmonary edema, and death.[4,5] The most important and most debilitating health effect from exposure to diisocyanates is respiratory and dermal sensitization. Exposure to MDI can lead to this sensitization, depending on the type of exposure, the exposure concentration, the route of exposure, and individual susceptibility. After sensitization, any exposure, even to levels below any occupational exposure limit or standard, will produce an allergic response which may be life threatening. The symptoms for both respiratory and dermal sensitization may develop immediately or several hours after exposure, after the first few months of exposure, or may be delayed in onset until after several years of exposure.[6-9] The only effective treatment for the sensitized worker is cessation of all diisocyanate exposure.[10]

The dermal sensitization is similar to allergic dermatitis, including such symptoms as rash, itching, hives, and swelling of the extremities. In respiratory sensitization, the response is an asthmatic reaction characterized by difficulties in breathing; e.g. coughing, wheezing, shortness of breath, and tightness in the chest.[4] In fact, respiratory sensitization from exposure to diisocyanates has traditionally been referred to as "isocyanate asthma". Estimates of the prevalence of diisocyanate-induced asthma in exposed populations of workers vary considerably; from 5% in diisocyanate production facilities,[11] to 25% in polyurethane production plants[7,11] and 30% in polyurethane seatcover operations.[12] Recent evidence does indicate that a specific immunological mechanism is involved, though this response is not fully understood. Diisocyanates, when inhaled, may act as

sensitizing antigens, evoking the body to produce high serum concentrations of specific antibodies. High levels of MDI-specific IgG and IgE antibodies have been detected in the serum of sensitized workers. It should be noted that these antibodies are not always detected in sensitized workers. Also, workers exposed to diisocyanates/MDI, even to levels below the occupational health limits and standards, may also have elevated serum concentrations of IgG and IgE antibodies.[13-23] Presently, elevated antibody levels are considered indicators of exposure, and require other diagnostic tools to determine and confirm cases of diisocyanate-induced sensitization.

Presently, the OSHA PEL for MDI is a ceiling limit of 200 ug/m^3.[24] The ACGIH TLV® is 51 ug/m^3 which is an 8-hour time weighted average. The NIOSH recommended exposure limit is 50 ug/m^3 for up to a 10-hour, time-weighted average exposure, and a ceiling limit of 200 ug/m^3.[26]

VI. RESULTS AND DISCUSSION

The results from the air sampling for MDI and MDI prepolymer are shown in Tables 1 and 2. Table 1 presents the data from the TWA air sampling. Air sampling equipment was located at the packaging station work area, and in surrounding work areas and spaces at varying distances from the polyurethane foam application area. All of the TWA air samples measured non-detectable levels of MDI and MDI prepolymer. These data demonstrate that there is minimal secondary exposure; i.e. exposure to people in adjacent areas and/or who do not work with the polyurethane foam. The fact that the area air sampling in the shipping department did not reveal measurable concentrations of MDI or MDI prepolymer is probably due to the location of the air sampling equipment. Because of the design of the packaging station, the sampling equipment in this area was usually a minimum of 3-5 feet from the nozzle of the spray gun.

Conversely, Table 2 shows that the short term exposure sampling did measure substantial levels of MDI, but did not detect any MDI prepolymer. Concentrations of MDI ranged from non-detectable to 320 ug/m^3, with 2 of the 7 samples being above the OSHA and NIOSH ceiling limits for MDI of 200 ug/m^3. These data demonstrate that a potential for short term overexposure to MDI exists when spraying the polyurethane foam (Instapak® 40).

During the survey, Xomox provided the NIOSH investigators with a copy of their respirator program. In this program, Xomox states that an "American Optical Brand-Model R-5500 ... with R55A P/N 211961 cartridge will be used exclusively by operator when packaging with polyurethane foam", and that "respirators are to be worn whenever packaging with

polyurethane foam is being done". Upon contacting American Optical (AO), the NIOSH project officer was told by an AO representative that it is their policy to recommend only supplied-air respirators for workers exposed to isocyanates. Furthermore, the AO representative stated that the R55A cartridge is a dust, mist, and fume cartridge and should not be used for exposure to any diisocyanate. It should be noted that during the NIOSH site visit, no workers were observed using a respirator when applying the polyurethane foam.

VII. RECOMMENDATIONS

The following recommendations are offered per the conditions encountered and the data collected during the NIOSH survey:

1. Discontinue use of the polyurethane foam system as a packaging material. NIOSH recommends that alternative methods for packaging the valves be researched by Xomox. We suggest that the valves be tightly wrapped in plastic, or shrink wrapped, and then packaged with the styrofoam material. This should prevent the styrofoam from contacting the painted surface of the valve, provide an effective and alternative means to ship the valves, and eliminate the MDI-based foam system from the packaging process. Elimination of a toxic compound from the work environment is the most effective means for protecting the health of the worker.

If Xomox continues to use the polyurethane foam syatem, then NIOSH recommends the following steps to protect the workers from exposure to MDI:

2. Engineering controls, such as local exhaust ventilation, should be used to reduce exposure to MDI. These controls should be designed to effectively remove MDI from the breathing zone of the worker, and should be specifically designed for the packaging operation. Exhaust air from these controls should not be recirculated.

3. Only supplied-air respirators should be donned by workers in the packaging area. These respirators should be those approved by NIOSH and the Mine Safety and Health Administration, per federal regulations (30 CFR 11). The present air-purifying respirator used by Xomox offers no protection to workers exposed to MDI, and its use should be discontinued. Minimum standards for a respirator policy are in the OSHA General Industry Standards (29 CFR 1910.134).

4. A medical surveillance program should be provided to the workers exposed to MDI. This program should include the following:

    a. A preplacement examination that includes a comprehensive medical and work history, a smoking history, a physical examination with emphasis on the respiratory tract, a chest X-ray, and a pulmonary function test of forced vital capacity and forced expiratory volume in 1 second.

b. An annual medical exam which includes an update of the medical and work histories, a physical exam with emphasis on the respiratory tract, and a pulmonary function test.

c. If a worker develops respiratory problems which may be related to the work environment, he/she should be removed from all diisocyanate exposure until evaluated and diagnosed by an occupational medicine physician with experience in diagnosing diisocyante-induced sensitization.

5. The possibility of skin and eye contact with MDI-containing liquids should be minimized using proper personal protective equipment. NIOSH recommends that workers wear rubber or polyvinyl chloride gloves and goggles when handling and/or applying the polyurethane foam system.

6. Eating, drinking, and smoking should be prohibited in all work areas, including those where MDI is used. These activities should only be allowed in designated break areas that are separate from the work areas.

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X. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Safety Coordinator, Xomox
2. Employee Representative, Xomox
3. Account Representative, Sealed Air Corporation
4. NIOSH Cincinnati Region
5. OSHA Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Data From the NIOSH Survey
Time-Weighted Average Area Air Sampling for MDI and MDI Prepolymer

Xomox Corporation
HETA 90-011

January 25, 1990

Sample Location[1]	Sample Time	Sample Volume[2]	Concentration[3] MDI	MDI Prepolymer
Work Table (15')	0700-1031	209	ND	ND
File Cabinets (25')	0706-1130	264	ND	ND
Work Bench (15')	0700-1130	270	ND	ND
Storage Racks (10')	0702-1130	268	ND	ND
Sampling Set-up Table	0654-1130	271	ND	ND
Under Packaging Work Table, Component A Tank (4')	0704-1130	266	ND	ND
Near Garage Door (18')	0705-1130	265	ND	ND
NIOSH REL			50	
ACGIH TLV			51	
LOD in micrograms per sample			0.3	0.3
LOQ in micrograms per sample			1.0	1.0

1 Location of the area air samples. The numbers in parentheses are the distance of the sampling equipment from the spray nozzle.

2 Sample volumes expressed in liters of air.

3 Concentrations expressed in micrograms of MDI or MDI prepolymer per cubic meter of air.
ND - none detected