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I. SUMMARY

On July 25, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the Gas Workers Union Local 18007. The request was for NIOSH to evaluate possible health effects and lack of adequate personal protection among employees of Peoples Gas Light and Coke Company, Chicago, Illinois, exposed to methyl ethyl ketone (MEK) and 4,4'-diphenylmethane diisocyanate (MDI) in encapsulation systems used to seal joints in underground gas mains.

On April 17, 1990, field investigators from NIOSH held an opening conference and visited sites where the systems were being applied. On April 18, 1990, the NIOSH investigators performed medical interviews and personal breathing zone and area air sampling at three application sites where a total of five joints were being sealed. Air sampling was conducted above and below road level for MEK, MDI, and MDI polyisocyanate. One of these sites contained 12" mains, and the other sites had 6" mains. The PLCS Flexapress L. P. Bell Joint Encapsulation System (PLCS) was used during one joint encapsulation on a 6" main, and the ALH Systems Inc. Series Four Encapsulation Kit (ALH) was applied during the other joint encapsulations investigated during the NIOSH survey.

Personal breathing zone exposure concentrations for MEK, both above and below road level, ranged from none detected (ND) to 126.4 parts per million (ppm). The MEK exposure concentrations below road level were <0.3 ppm, 75.9 ppm, and 126.4 ppm. The MEK concentrations above road level ranged from ND to 2.0 ppm, with 4 of 7 samples having no detectable concentrations of MEK. These data demonstrate that MEK exposure concentrations were significantly reduced when work activities were performed above ground.

Area air sampling below road level measured MEK concentrations ranging from 12.7 to 511.8 ppm. One of these samples detected a MEK concentration above the OSHA and NIOSH short-term exposure limits of 300 ppm. This indicates that workers entering the holes may be overexposed to short-term concentrations of MEK.

At each application site, two area air samples for MDI and MDI polyisocyanate were collected, one below road level, and one above road level approximately 3-4 feet from the hole. No MDI or MDI polyisocyanate was detected in any of the air samples collected during the NIOSH survey. However, the minimum detectable concentrations of MDI polyisocyanate in the ALH and PLCS encapsulation systems were high due to sampling and analytical limitations [185 and 1230 micrograms per cubic meter of air ($\mu g/m^3$), respectively]. Therefore, workers who enter the holes may be exposed to hazardous levels of MDI polyisocyanate that were not detected due to limitations in the method used in this survey. Exposure limits for MDI polyisocyanate have not been defined by OSHA or NIOSH.

Twelve of 21 employees interviewed reported experiencing eye, nose, and throat irritation when they used the paint primer. Cramped work spaces, especially when repairing pipes below street level, made it difficult to avoid inhalation and dermal exposure to the chemicals.

No worker interviewed could confirm that he had been fit tested or properly trained to wear respiratory protection. Observations made onsite indicated the workers had not been trained in the appropriate procedures for donning respiratory protective devices. In addition, the latex gloves provided by the manufacturers of the PLCS and ALH encapsulation systems are inadequate to protect workers from dermal exposure to the liquid chemicals in these systems.

While personal breathing zone sampling did not measure short-term overexposure to MEK, the area air sample for MEK of 512 parts per million (ppm) demonstrates that a potential health hazard exists during the installation of the encapsulation systems below road level. The data demonstrate that the use of extension tools to install the encapsulation systems greatly reduces workers' inhalation exposure to MEK, and potentially to the other hazardous components in these systems. No detectable concentrations of MDI were measured in 11 air samples collected both above and below road level. The sampling and analytical method was not sufficient to rule out exposure to MDI polyisocyanate. Dermal exposure to MEK and the other components in the encapsulation systems may be occurring from inappropriate glove-use when handling and mixing these liquid chemicals. Recommendations for reducing the respiratory and dermal exposures are provided in Section IX of this report.

Keywords: SIC 4932 (Utilities, Gas & Other Services), SIC 4931 (Utilities, Electric & Other Services), methyl ethyl ketone, MEK, 4,4'-diphenylmethane diisocyanate, MDI, MDI polyisocyanate, natural gas mains, joint encapsulation systems, acute exposure hazards.

II. INTRODUCTION

On July 25, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Gas Workers Union (GWU) Local 18007 concerning possible health effects among employees exposed to methyl ethyl ketone (MEK) and 4,4'-diphenylmethane diisocyanate (MDI) in compounds used to encapsulate joints in underground natural gas mains. In the request, the GWU Local 18007 was concerned that Peoples Gas, Light and Coke Company (hereinafter referred to as Peoples Gas) was not providing workers with adequate protection from the chemicals used during the encapsulation procedure.

On April 17, 1990, field investigators from NIOSH held an opening conference which was attended by both union and management representatives, and visited sites where the encapsulation procedures were performed. On April 18, 1990, the NIOSH investigators conducted medical interviews, and performed personal breathing zone and area air sampling at three sites where a total of five joints were being sealed. One of these sites contained 12" mains; the other sites had 6" mains. During the NIOSH site visit, two similar encapsulation systems were used by Peoples Gas: the PLCS Flexapress L. P. Bell Joint Encapsulation System (PLCS), and the ALH Systems Inc. Series Four Encapsulation Kit (ALH). Both systems were designed for use on iron, steel and polyvinyl chloride (PVC) pipes with a maximum pressure of 2 pounds per square inch.

III. BACKGROUND

The City of Chicago has thousands of joints where two pipes join in a gas main, and any number of these can be leaking at a given time. Because of this, crews are continually digging out the joints, and applying either the ALH or PLCS systems to encapsulate the joints and prevent gas leaks. On a typical day, 180 crews are involved with this activity, with each crew consisting of 2-4 workers. A union representative estimated that a crew can seal up to 4 joints per workshift.

Both encapsulation systems are similar in composition and method of application. First, the asphalt and dirt covering the joint is removed, producing a hole which is 1' wide × 1' long × 4' deep for a 6" main, and 3' × 3' × 4' for a 12" main. The exposed joint is then cleaned by sandblasting and/or brushing, and a primer consisting of MEK and a MDI-based polyisocyanate is applied using a brush. After this, either a rubber (ALH) or nylon (PLCS) sleeve is strapped around the joint, with the sleeve's spout pointing upward. Next, a two-component resin is mixed and poured into the spout. When the sleeve and spout are completely filled, the spout is sealed and the sleeve is inspected for a proper fit. The two components of the resin systems consist of a base (a polyol blend), and a hardener (MDI and MDI polyisocyanate). Both systems supply latex gloves for handling the sealant chemicals. Tools with extension handles are also available, allowing the encapsulation systems to be applied and installed without the workers entering the holes.

After a joint has been excavated, two workers (a laborer and a mechanic) perform the installation of the sleeve and application of the encapsulation chemicals. Typically, the laborer cleans the joint, applies the primer, pours the resin, and plugs the spout. The mechanic mixes the chemicals, installs and tightens the sleeve, and inspects the seal prior to burying the encapsulated joint. During the NIOSH site visits, the extension tools were not used, and were

not available on the equipment trucks used by the crews. Instead, the workers would enter the holes (arms and head first) to apply the primer, to install and tighten the sleeve, and to pour the resin during the encapsulation of joints on 6" mains. On the day of the NIOSH exposure monitoring (April 18, 1990), a manager for Peoples Gas requested that the encapsulations at the last Oakley Street site be performed using the extension tools. Since these tools were not available on-site, Peoples Gas delivered them from a remote location.

During the opening conference, the representatives of Peoples Gas stated they had a written respiratory protection program, and that respirator usage at a job was left to the discretion of the workers. During the NIOSH site visits, respirators were worn only on two occasions. The first was the encapsulation of a 12" main on Sheridan Road during the morning of April 18, 1990. The second was upon the request of a manager for Peoples Gas at the Oakley Street sites. The workers at these sites were not familiar with the supplied respiratory protection, and were trained onsite by Peoples Gas and their consultant on the proper method for donning a half-facepiece respirator with organic vapor cartridges. No qualitative or quantitative fit testing was performed on the workers prior to respirator usage.

IV. EVALUATION DESIGN AND METHODS

A. *Industrial Hygiene Evaluation*

Short-term personal breathing zone air samples for MEK were collected from both the laborer and mechanic at each application site. In addition, one area air sample for MEK was collected below the road level (approximately 2 feet into the hole); two area air samples for MDI were collected, one below road level, and one above road level approximately 3 feet from the hole. All air samples for MEK and MDI were collected according to NIOSH Method 2500 and OSHA Method 47, respectively.

1. NIOSH Method 2500-MEK[1]

Air samples for MEK were collected by drawing sample air through an ambersorb sorbent tube using calibrated, battery-powered pumps. The sample air was drawn through the sorbent tubes at a nominal flowrate of 0.2 liters per minute. After the sampling, the front and back sections of the sorbent tubes were separated prior to sample preparation and analysis. Sample desorption for MEK was performed by extracting sections of the ambersorb tubes in 1 milliliter of carbon disulfide for 30 minutes, with 1 microliter per milliliter of benzene added as an internal standard. The samples were analyzed using a gas chromatograph mated with a flame ionization detector. The analytical limit of detection (LOD) for this method was 0.01 milligrams of MEK per sample; the limit of quantitation (LOQ) was 0.03 milligrams of MEK per sample. No breakthrough of MEK was detected in the back-up sections of the ambersorb tubes.

2. OSHA Method 47-MDI and MDI Polyisocyanate[2]

Samples for MDI and MDI polyisocyanate were collected using glass fiber filters coated with 1-(2-pyridyl)piperazine. Sample air was drawn through the filters using a calibrated, battery-powered pump at a nominal flowrate of 1.0 liter per minute. After sampling, each filter was desorbed with 4 milliliters of 10% dimethyl sulfoxide

in acetonitrile and sonicated for 45 minutes. A 15 microliter aliquot of each sample was injected into a high performance liquid chromatograph with an ultraviolet detector. Media standards for MDI were prepared using laboratory grade MDI, and media standards for MDI polyisocyanate were prepared using bulk samples of the hardener component of the ALH and PLCS resin system. The analytical LOD for MDI was 0.1 microgram per sample; the analytical LOQ was 0.3 microgram per sample. The analytical LOD for MDI polyisocyanate was 3 micrograms per sample, and the analytical LOQ was 8 micrograms per sample. The first major peak other than MDI was used to identify and quantitate MDI polyisocyanate.

3. Sampling and Analytical Limits of Detection

When using air samples to determine exposures, the possibility arises that the toxic substance being sampled will not be detected. When this occurs, these samples are reported in the data tables as "ND" meaning none detected. In order to interpret ND values, a sampling and analytical LOD is calculated using the LODs discussed in the previous paragraphs of this section and an average sample volume. For this survey, the NIOSH investigators averaged the sample volumes for each street location; e.g., Rasher, Oakley, and Sheridan, and used these in the calculations. The minimum detectable concentrations (MDC) can be found in the bottom portion of Tables 1, 2, and 3, and the units are the same as the concentration units for that specific chemical and/or substance. Whenever a ND is encountered in the data tables, this indicates that the actual exposure or concentration is less than the MDC listed for that chemical in the table.

B. *Medical Evaluation*

The medical component of this investigation consisted of a review of the Occupational Safety and Health Administration (OSHA) illness and injury logs for 1988 and 1989, of personal interviews with 21 workers from the street crews, and of the observation of work practices. The medical director was also interviewed concerning the Peoples Gas onsite medical department.

V. EVALUATION 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). The OSHA standards 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 this 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. Since some chemicals or substances have recognized toxic effects associated with acute exposures, recommended short-term exposure limits (STEL) or ceiling values have been developed which are intended to supplement the TWA. Typically, STELs are higher exposures when compared to TWAs, but the exposure duration is usually 15 minutes or less.

A. *Methyl Ethyl Ketone*

Short-term (acute) effects of exposure to MEK may occur immediately upon exposure or shortly thereafter. Acute exposure to MEK at 100 ppm can cause slight nose and throat irritation, at 200 ppm eye irritation, and at 300 ppm headache and throat irritation.[3,4] Dermal contact with MEK may irritate the skin, producing a rash or burning feeling. Workers have developed a dermatitis of the face with exposure to the vapor alone.[3] Exposure to high concentrations of MEK can cause dizziness, nausea, lightheadedness, headache, blurred vision, and incoordination. Higher levels may result in a loss of consciousness.[4] However, ketones (the group of chemicals into which MEK falls) have good warning properties in that irritation or a strong odor usually occurs at levels below those that cause central nervous system depression.

With regards to reproductive effects of exposure to MEK, there have been no studies which look at reproductive outcomes or fetal loss in humans. MEK has been shown to be teratogenic in laboratory rats and mice, producing such defects as cleft palate, missing vertebrae, fused ribs, and fused toes, but this was at very high doses of oral intake (3000 parts per million), which also caused materal toxicity.[6] (A teratogen is a substance which causes birth defects in the offspring of exposed pregnant females). These findings in rodents are thought to be subject to interpretation, as some scientists view delayed bone formation as a birth defect and others do not. The reported activity of MEK to delay fetal development at high doses in only one species does not appear to be sufficient evidence to regard it as an occupational reproductive hazard.[7]

MEK may potentiate substances known to cause neurological problems. Although not highly neurotoxic itself, repeated exposure to MEK, in conjunction with certain other

solvents (for example, methyl n-butyl ketone), may also cause numbness and weakness in the hands and feet.[8]

The OSHA PELs, ACGIH TLVs, and NIOSH RELs for MEK are 200 ppm for an 8-hour TWA exposure and 300 ppm for a 15-minute STEL.[9-11]

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 acronym; e.g., TDI for 2,4- and 2,6-toluene diisocyanate, HDI for 1,6-hexamethylene diisocyanate, MDI for 4,4'-diphenylmethane diisocyanate, NDI for 1,5-naphthalene diisocyanate, etc.[12]

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 be more volatile, creating a vapor inhalation hazard. Conversely, the higher-molecular-weight diisocyanates do not readily volatilize, but are still an inhalation hazard if aerosolized or heated. The latter is very important since many reactions involving diisocyanates are exothermic in nature, thus providing the heat for volatilization. In an attempt to reduce the vapor hazards associated with the lower-molecular-weight diisocyanates, pre-polymer and oligomer forms of these monomers were developed and have replaced the monomers in many product formulations. An example of this is biuret of HDI, which actually consists of three molecules of HDI monomer combined to form a higher molecular weight molecule with characteristics similar to those found in HDI monomer. Also, many MDI product formulations actually contain a combination of MDI monomer and MDI polyisocyanate (polymethylenepolyphenyl isocyanate).

Diisocyanates cause irritation to the skin, mucous membranes, eyes, and respiratory tract. High concentrations may result in chemical bronchitis, chest tightness, nocturnal dyspnea, pulmonary edema, and death.[12,13] The most important and most debilitating health effects from exposure to diisocyanates are respiratory and dermal sensitization. The latter can result in such symptoms as rash, itching, hives, and swelling of the extremities. With respiratory sensitization, the response is an asthmatic reaction (airway obstruction) characterized by difficulties in breathing; e.g., coughing, wheezing, shortness of breath, and tightness in the chest.[13] In fact, respiratory sensitization from exposure to diisocyanates has traditionally been referred to as "diisocyanate-induced asthma." Estimates of the prevalence of diisocyanate-induced asthma in exposed populations of workers vary considerably; from 5% to 10% in diisocyanate production facilities,[14,15] to 25% in polyurethane production plants[14,16] and 30% in polyurethane seatcover operations.[17] Recent evidence indicates that a specific immunological mechanism is involved. Diisocyanates, when inhaled, may act as sensitizing antigens, evoking the body to produce high serum concentrations of antibodies. Specific IgE and IgG antibodies to TDI, MDI, HDI, and/or to polyisocyanate/oligomer forms of MDI and HDI conjugated to human serum albumin (HSA), have been measured in both exposed workers, but are not always detected in sensitized workers.[19-30] Workers exposed to diisocyanates/MDI, even levels

below recognized occupational exposure limits and standards, may have elevated serum concentrations of these antibodies. Considerable evidence exists indicating that sensitized workers, with IgG or IgE antibodies specific for a diisocyanate-HSA conjugate, will exhibit cross-reactivity when challenged with other diisocyanates.[31-34] This cross-reactivity occurs independent of workplace exposure to the other diisocyanates. Currently, the measurement of specific antibodies to diisocyanate-protein conjugates is considered an indicator of diisocyanate exposure,[35] but requires other diagnostic tools to determine and confirm cases of diisocyanate-induced sensitization (asthma).

Development of diisocyanate-induced sensitization depends on the type of exposure, the exposure concentration, the route of exposure, and individual susceptibility. Once exposed to diisocyanates, the sensitized worker may then develop an asthmatic reaction immediately or several hours after re-exposure, or the asthmatic reaction may occur months after the first exposure, or even after several years of exposure.[14,16,36-37] After sensitization, any exposure, even to levels below any occupational exposure limit, could produce an asthmatic response, which may be life-threatening. This asthmatic reaction may occur minutes after exposure (immediate), several hours after exposure (late), or a combination of both immediate and late components after exposure (dual).[36,37] Recurrent nocturnal asthma has been described in workers sensitized to TDI and MDI.[26,39] An improvement in symptoms may be observed during periods away from the work environment (weekends, vacations).[14,36,37] Of utmost importance in the treatment of the worker with diisocyanate-induced asthma (sensitization) is cessation of diisocyanate exposure.[36,37,40]

The percentage of sensitized workers with persistent symptoms of asthma after years of no exposure may be 50% or higher. Workers with persistent asthma after cessation of diisocyanate exposure are more likely to have had a significantly longer duration of symptoms prior to diagnosis, larger decrements in pulmonary function, and a severe degree of nonspecific bronchial hyperreactivity at diagnosis.[36,37] These findings suggest that prognosis is improved with early diagnosis of diisocyanate-induced respiratory sensitization and cessation of diisocyanate exposure.

Presently, the OSHA PEL and the ACGIH TLV for MDI are 200 and 51 $\mu g/m^3$, respectively.[11,12] The OSHA PEL is a ceiling limit while the ACGIH TLV is an 8-hour time weighted average. The NIOSH recommended exposure limit is 50 $\mu g/m^3$ for up to a 10-hour, time-weighted average exposure, and a ceiling limit of 200 $\mu g/m^3$.[12] There are no NIOSH, OSHA, or ACGIH exposure limits for MDI polyisocyanates.[10-12]

VI. RESULTS

A. *Environmental*

The data from the personal breathing zone and area air sampling are presented in Tables 1, 2, and 3. Sampling was performed at three locations in the Chicago area; a total of five encapsulations were performed. The ALH system was applied to three 6" and one 12"

mains, the PLCS system was applied to one 6" main. The amount of time required to apply the encapsulation systems ranged from 10 to 23 minutes for the 6" mains, and was 50 minutes for the 12" main. Thus, samples were collected during each specific encapsulation for comparison to short-term and ceiling evaluation criteria for MEK and MDI. The MEK concentrations in the air samples obtained on the laborers and mechanics ranged from none detected (ND) to 126.4 ppm. Area air sampling in the holes (below road level) ranged from 12.7 to 511.8 ppm. The MEK exposure concentration below road level ranged from ND to 126.4 ppm (n=3). The MEK concentration above road level ranged from ND to 2.0 ppm, with 4 of 7 samples not measuring detectable concentrations of MEK. Only one of the air samples for MEK was above the OSHA/NIOSH STEL of 300 ppm. This was an area air sample that detected a MEK concentration of 511.8 ppm below road level at the second Oakley Street application site.

As shown in Tables 1, 2, and 3, MDI was not detected in any of the air samples collected during the NIOSH survey. The MDCs for MDI ranged from 1.9 to 7.4 $\mu g/m^3$. Though it is not listed in the tables, MDI prepolymer was also not detected in any of the air samples. The MDCs for MDI polyisocyanate in the ALH and PLCS encapsulation systems were approximately 185 and 1230 $\mu g/m^3$, respectively.

B. *Medical Results*

1. Employee Interviews

Confidential interviews were conducted with 21 employees selected by serial sampling from available work crews. They were interviewed both at the Oakley work-site (where repair of the gas pipeline joints was occurring), and at the North Distribution Center for Peoples Gas Company, on Irving Park Road.

All employees interviewed were male and had more than 3 years on the job. Twelve employees reported that they experienced eye, nose, and throat irritation when they used the paint primer. To avoid the irritating effects, most reported that they held the small can of paint primer far away from their face. This practice was difficult when they were forced to work in cramped spaces. Three workers reported that when "down in the hole" (repairing the pipes below street level) they held their breath when using the paint and primer because of the noxious odor. Although they were given the option of wearing half-facepiece respirators with organic vapor cartridges when performing this work, no one interviewed could confirm that he had been fit tested or properly trained to wear the respiratory protection.

All employees denied shortness of breath, wheezing, cough, mucus production, chest tightness, history of asthma, or history of allergy. No employee had tingling, numbness, or weakness in the extremities. There were no reports of rashes.

2. Medical Department Interview

The employee medical surveillance program included only a minority of employees and depended upon the insurance coverage of the individual employee. Those employees participating in health maintenance organizations (HMO's) are not routinely screened for disease in the company medical department, because they are

considered to receive their medical care (both occupational health follow-up care, as well as general medical care) through their HMO's. The other employees, who are eligible for medical surveillance in the People's Gas medical department receive examinations that may vary according to seniority and age. There have been no documented cases of diisocyanate induced occupational asthma or hypersensitivity pneumonitis seen in the medical department at Peoples Gas. There have been no reports of employees with any work-related neurological findings or neurological disease.

3. Records

The OSHA 200 Log was reviewed for the period of January 1989 through April 1990 for the North, South, and Central Distribution Centers (these are the Centers which include the road crews who use the diisocyanate- and MEK-containing paint products). There were no entries in the log for any respiratory illness; no entries for illness which may have included constitutional symptoms such as dizziness, nausea, malaise; no reports of neurological symptoms such as numbness, tingling, or extremity weakness. All entries were for acute injuries, with the majority listed for injuries to back, knees, and hands.

VII. DISCUSSION

Personal breathing zone MEK concentrations from the air samples taken below road level were higher than those in samples taken above road level. These data suggest that the extension tools, when properly used, are an effective means of reducing exposures.

During the NIOSH survey on April 18, 1990, the ambient temperature ranged from 52°F to 61°F. Considering the MEK concentration above the OSHA/NIOSH STEL of 300 ppm, and the fact that temperatures are higher in the summer months, it is possible that MEK concentrations could be higher during warmer temperatures due to increased volatility.

It is important when comparing 8-hour TWAs and STELs to measured airborne concentrations and exposures, to consider the reasoning behind the establishment of these two different types of evaluation criteria for the same toxic substance. In general, the 8-hour TWAs are designed to protect workers from the chronic effects associated with exposure to the substance. Conversely, STELs are set at levels that are intended to protect workers from adverse, acute effects associated with higher levels of exposure. In this case, we documented a MEK concentration within the hole greater than the NIOSH/OSHA STEL of 300 ppm. Consequently, unprotected workers entering these holes during or after application of the primer portion of these encapsulation systems could be exposed to MEK levels that could cause acute health effects. On the other hand, the workers entering the holes apparently were not overexposed to MEK based on an 8-hour TWA. This can be exemplified using a worst case scenario. Using the highest measured MEK concentration (an area air sample concentration of 511.8 ppm), a maximum of 4 encapsulations performed by a given crew (both union and management representatives estimated that a given crew performs 2-3 encapsulations per workshift), an estimated application time of 30 minutes per site/gas main joint (average application time was 23 minutes for the five application sites visited during the NIOSH survey), and assuming that the workers have zero MEK exposure when not applying the encapsulation systems, the calculated 8-hour TWA MEK exposure would be

approximately 128 ppm. This is below the OSHA/NIOSH standards of 200 ppm. The NIOSH investigators believe this calculated 8-hour TWA is a maximum value, and the actual 8-hour TWA MEK exposure in these workers should be lower than the calculated 128 ppm.

Although MDI polyisocyanate was not detected in the air samples, this does not mean the workers do not have potential exposure to this substance. The MDCs for MDI polyisocyanate in the ALH and PLCS encapsulation systems were 185 and 1230 $\mu g/m^3$, respectively. Considering this, workers entering the holes may be exposed to potentially hazardous levels of MDI polyisocyanate that were not detected due to limitations in the sampling and analytical methods used in this survey, and the short length of time required to encapsulate a joint. The latter limits the volume of the air that can be sampled during the task, and increases the minimum detectable concentration. However, the same measures used to protect workers from airborne MEK exposures should also protect them from exposure to MDI and MDI polyisocyanate.

Due to the nature of a NIOSH health hazard evaluation, data on workplace exposures and health effects are collected during a limited number of site visits. These data are used to make health hazard determinations on work environments that may contain significant degrees of temporal and spatial variation. In this case, only one area air sample detected a concentration of MEK, below road level, in excess of the OSHA/NIOSH STEL of 300 ppm. This indicates that a potential health hazard from exposure to MEK may exist when workers enter the holes. Work practices, i.e., the use of extension tools to install the encapsulation systems above ground, have been shown in this study to substantially reduce MEK exposures. Further exposure monitoring is needed to better define the MEK, MDI, and MDI polyisocyanate exposures and to characterize the variations in exposure. When the work activities require the workers to enter the holes, they should don respiratory protection devices to protect them from the potentially high short-term exposures. Any worker who installs these encapsulation systems should be clean-shaven, properly fit-tested, and provided with his/her own respirator. These respirators should be stored in resealable plastic bags when not in use, frequently cleaned and inspected for broken or worn parts that may compromise the device's integrity, and stored in an area where the respirator is protected from the outside environment.

As previously mentioned, Peoples Gas reported they had a written respiratory protection program, and use of a respirator was the decision of the worker. From a worker protection, the optional use of respiratory protection in the case of potentially toxic exposures is inappropriate. Workers who choose not to wear respiratory protection are offered no protection from the potential overexposure to MEK when entering the holes. The fact that the workers had to be shown how to properly don the respirators suggests that the workers did not receive adequate training in the use of respiratory protective devices.

The workers who handled the liquid chemicals wore the latex gloves included with encapsulation system kits. These wrist-length gloves are not adequate to protect workers from dermal exposure to MEK, MDI, and the other liquid chemicals in these kits. Any glove for preventing dermal exposure to a chemical that may be absorbed through the skin and/or produce dermatitis should protect the hands and forearms, and should be made of a material that is impermeable to the potential chemical exposures.

VIII. CONCLUSIONS

The NIOSH investigators concluded that a potential health hazard exists from short-term exposure to MEK when workers enter the holes. The NIOSH investigators were unable to determine if a health hazard exists from exposure to MDI polyisocyanate due to the inability of the sampling and analytical method used in this survey to detect low levels of the substance, given that the relatively short length of time required to encapsulate the joints limited the sample volume. No health hazard existed from short-term exposure to MDI, or from full-shift, TWA exposure to MEK in these holes.

IX. RECOMMENDATIONS

1. All efforts should be taken to prevent workers from having to enter the holes when encapsulating a joint using the ALH, PLCS, and other similar systems. The workers should use the extension tools when performing this activity, and Peoples Gas should insure that all crews are provided with these tools prior to leaving the facility at the beginning of the shift. If experience with these extension tools suggests they are awkward and difficult to use, then Peoples Gas should consider redesigning the tools to alleviate these problems. Workers using these tools should be consulted before initiating a tool redesign project.

2. Whenever workers enter the holes, they should be required to properly don an air-purifying respirator with organic vapor cartridges. Peoples should provide a respiratory protection program which meets the minimum requirements set forth in the OSHA Safety and Health Standards.[41] NIOSH recommends that this program be consistent with the recommendations found in DHHS (NIOSH) Publication No. 87-116, NIOSH Guide to Industrial Respiratory Protection.[42]

3. Whenever workers handle the liquid chemicals in these systems, they should don appropriate gloves and protective clothing to protect them from exposure to these chemicals. The clothing and gloves should be made of a material resistant to penetration by MEK and MDI, and should be elbow-length. Workers should also don safety goggles when handling these chemicals.

4. Workers should be educated about the effects of the chemicals they work with and the types of work practices that will minimize their exposure to chemicals, specifically MDI and MEK. The scope of the educational activities should include clear identification of work activities where exposures are likely and the recognition of signs and symptoms of exposure to MDI and MEK. Minimum requirements for such a program can be found in the OSHA Hazard Communication Standard (29 CFR 1910.1200).[43]

5. Peoples Gas should implement an exposure monitoring program for all workers potentially exposed to MEK, MDI, MDI polyisocyanate, and any other hazardous substances found or used at the workplace. This program should consist of sampling the air from the worker's breathing zone to measure his/her exposure to specific chemical substances. Exposure monitoring should be performed on an periodic basis, or whenever work processes, practices, and/or conditions are likely to lead to a change in exposures. Though not all workers have to be monitored, sufficient samples should be collected to characterize worker exposure and to measure the amount of variation in this exposure. All workers participating in the monitoring should be informed of the results, and the employer should maintain these records for a period of 30 years.

6. Annual medical examinations should be offered to workers potentially exposed to aerosols and vapors containing MDI, MDI polyisocyanate, or any other diisocyanate-containing compounds. These exams should include medical and work histories and clinical examination, giving particular attention to the respiratory tract and measurements of forced expiratory volume at 1 second (FEV1) and forced vital capacity (FVC). Spirometry should be done according to guidelines set forth by the American Thoracic Society.[43] These periodic examinations should also be utilized to make a judgement on the workers ability to wear a respirator.[44]

7. Employees found to have medical conditions that could be directly or indirectly aggravated by exposure to MDI or other diisocyanates (e.g. respiratory allergy, chronic upper or lower respiratory irritation, chronic obstructive pulmonary disease, or evidence of sensitization to diisocyanates) should be counseled on their risk from working with or around these substances. Chronic bronchitis, emphysema, disabling pneumoconiosis, and decreased ventilatory capacity similarly suggest an increased risk of adverse health effects from exposure to diisocyanates. All employees should also be advised that exposure to diisocyanates may result in delayed effects, such as coughing or difficulty in breathing during the night. The current Peoples Gas policy of removing employees suspected of diisocyanate sensitization from areas where diisocyanate-containing paints are used is appropriate and consistent with previous NIOSH HHE recommendations, if employees are transferred to other tasks/jobs without the loss of pay, benefits or seniority.

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Copies of this report have been sent to:

1. Peoples Gas Light and Coke Company, Chicago, Illinois
2. Gas Workers Union Local 18007, Chicago, Illinois
3. OSHA Region V
4. NIOSH

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 - MEK and MDI Concentrations Measured at the Two Rasher Street Locations -- 6" Mains / Peoples Gas, Light, and Coke Company - HETA 89-318 / April 18, 1990

System Type	Sample Type[1]	Above/Below Road Level	Sample Time	Sample Volume[2]	Conc. of MEK[3]	Conc. of MDI[4]
ALH	PBZ-L	Below	1132-1144	2.4	126.4	--
ALH	PBZ-M	Above	1132-1146	2.8	ND	--
ALH	AAS	Below	1132-1144	12.0	--	ND
ALH	AAS	Below	1133-1144	2.2	101.0	--
ALH	AAS	Above	1132-1146	14.0	--	ND
PLCS	PBZ-L	Below	1156-1210	2.8	75.9	--
PLCS	PBZ-M	Above	1156-1210	2.8	ND	--
PLCS	AAS	Below	1156-1210	14.0	--	ND
PLCS	AAS	Below	1156-1210	2.8	12.7	ND
PLCS	AAS	Above	1156-1210	14.0	--	ND
NIOSH REL: 8-hr. TWA					200.0	50.0
NIOSH REL: 15-min. STEL					300.0	--
OSHA PEL: 8-hr. TWA					200.0	--
OSHA PEL: 15-min. STEL					300.0	--
NIOSH Ceiling Limit: 10-min.					--	200.0
OSHA Ceiling Limit					--	200.0
Minimum Detectable Concentration (MDC)[5]					1.5	7.4

[1] PBZ-L: Personal breathing zone air sample from "Laborer." PBZ-M: Personal breathing zone air sample from "Mechanic." AAS: Area air sample.
[2] Sample volumes expressed in liters of air.
[3] Concentrations of MEK in parts per million (ppm).
[4] Concentrations of MDI in micrograms per cubic meter of air.
[5] MDC based on a sampling volume of 2.3 liters for MEK and 13.5 liters for MDI.
ND = not detected

Table 2
MEK and MDI Concentrations Measured at the Two Oakley Street Locations -- 6" Mains
Peoples Gas, Light, and Coke Company
HETA 89-318
April 18, 1990

System Type	Sample Type[1]	Above/Below Road Level	Sample Time	Sample Volume[2]	Conc. of MEK[3]	Conc. of MDI[4]
ALH	PBZ-L	Above	1456-1519	4.6	ND	--
ALH	PBZ-M	Above	1456-1519	4.6	1.7	--
ALH	AAS	Above	1456-1519	23.0	--	ND
ALH	AAS	Below	1457-1519	22.0	--	ND
ALH	AAS	Below	1457-1519	4.4	277.3	--
ALH	PBZ-L	Above	1532-1542	2.0	ND	--
ALH	PBZ-M	Above	1532-1542	2.0	2.0	--
ALH	AAS	Above	1532-1542	10.0	--	ND
ALH	AAS	Below	1532-1542	10.0	--	ND
ALH	AAS	Below	1532-1542	2.0	511.8	--
OSHA PEL/NIOSH REL: 8-hr. TWA					200.0	--
OSHA PEL/NIOSH REL: 15-min. STEL					300.0	--
NIOSH REL: 10-hr. TWA					--	50.0
OSHA/NIOSH Ceiling Limits					--	200.0
Minimum Detectable Concentration (MDC)[5]					1.2	6.2

[1] PBZ-L: Personal breathing zone air sample from "Laborers." PBZ-M: Personal breathing zone air sample from "Mechanics." AAS: Area air sample.
[2] Sample volumes expressed in liters of air.
[3] Concentrations of MEK in parts per million (ppm).
[4] Concentrations of MDI in micrograms per cubic meter of air.
[5] MDC based on a sampling volume of 2.8 liters for MEK and 16 liters for MDI.
ND = not detected

Table 3

MEK and MDI Concentrations Measured at the Sheridan Street Location -- 12" Mains Peoples Gas, Light, and Coke Company HETA 89-318 April 18, 1990

System Type	Sample Type[1]	Above/Below Road Level	Sample Time	Sample Volume[2]	Conc. of MEK[3]	Conc. of MDI[4]
ALH	PBZ-L	Above	1000-1051	10.2	1.7	--
ALH	PBZ-M	Below	0959-1051	10.4	ND	--
ALH	PBZ-L	Above	1000-1051	51.0	--	ND
ALH	PBZ-M	Below	0959-1051	52.0	--	ND
OSHA PEL/NIOSH REL: 8-hr. TWA (MEK)					200.0	--
OSHA PEL/NIOSH REL: 15-min. STEL (MEK)					300.0	--
NIOSH REL: 10-hr. TWA (MDI)					--	50.0
OSHA/NIOSH Ceiling Limits (MDI)					--	200.0
Minimum Detectable Concentration[5]					0.3	1.9

[1] PBZ-L: Personal breathing zone air sample from "Laborer."
PBZ-M: Personal breathing zone air sample from "Mechanic."
AAS: Area air sample.
[2] Sample volumes expressed in liters of air.
[3] Concentrations of MEK in parts per million (ppm).
[4] Concentrations of MDI in micrograms per cubic meter of air.
[5] MDC based on a sampling volume of 10 liters for MEK and 52 liters for MDI.
ND = not detected