HETA 95-0405-2600
Spence's Carstar
Denver, Colorado

Charles McCammon

PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Charles McCammon, of the NIOSH Denver Field Office, Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Bambi L. Sorensen and Robb Menzies. Desktop Publishing by Bambi Sorensen and Pat Lovell.

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Health Hazard Evaluation Report 95-0405-2600
Spence’s Carstar
Denver, Colorado
September 1996

Charles McCammon

SUMMARY

On June 24, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the President of Spence’s Carstar in Denver, Colorado, for help in assessing worker exposure to isocyanates during spray painting of automobiles. Spence’s Carstar is an autobody repair shop whose other concerns for worker exposure included solvents, total dusts, noise, carbon monoxide (CO), and metals. An initial survey was conducted in September 1995 and an interim report was issued in January 1996. To assess effects of seasonal variation, a second survey was conducted on March 8, 1996. This report summarizes the exposures from both surveys.

Activities in the shop include frame straightening, panel repair/replacement, body filling, painting, and detailing. Spence’s uses the BASF Corp. Diamont™ and Solo ™ isocyanate catalyzed paints. The paints contain hexamethylene-1,6-diisocyanate (HDI) polymer and very small amounts of the monomer (<0.006%). Some of the hardeners also contain isophorone diisocyanate (IPDI) polymer and monomer. All of the various components contain solvents, especially the reducers which are all solvents.

Personal breathing zone (PBZ) and area airborne concentrations of isocyanate (HDI only) monomer and oligomers, various solvents (including n-butyl acetate, toluene, xylene, and acetone), total dust (paint over spray), carbon monoxide, and noise levels were measured. All but one of the monomer samples collected in both time periods were below the analytical limit of detection of 2 micrograms (µg) per sample. One personal sample collected in March 1996 was 750 micrograms per cubic meter (µg/m^3) for an 8-minute sample, which is in excess of the NIOSH ceiling recommended exposure limit (REL) of 140 µg/m^3. The oligomer samples from both time periods ranged from below the limit of detection (2 µg per sample) to 667 µg/m^3 (time-weighted average [TWA] concentrations for the two painters ranged from 38 to 65 µg/m^3). The TWA concentrations were below the industry recommend TWA of 500 µg/m^3.

Air samples for solvents (n-butyl acetate, toluene, xylene, or acetone) did not exceeded their respective NIOSH REL or Occupational Safety and Health Administration Permissible Exposure Limit (PEL), nor did the mixture summation exceed any evaluation criteria. Generally, the concentrations of organics measured in March were higher than those in September. Area total dust samples ranged from 1.3 to 3 milligrams per cubic meter (mg/m^3). Most of these samples were collected in the spray booth. PBZ total dust samples ranged from not-detected (0.02 mg/filter) to 9 mg/m^3. All samples were below the OSHA PEL of 15 mg/m^3. Generally, the results from September were higher than those collected in March. The CO concentrations averaged 25 parts per million (ppm) for the 8-hr sampling period. The peak CO concentration was 173 ppm and the highest 15-minute average was 80 ppm. The high peaks were associated with moving vehicles in and out of the shop. A personal noise monitor was placed on a body repair worker and a worker in the paint prep area. The time-weighted average noise level (using the OSHA criteria) in the body repair area was 86 dB(A), resulting in a 63% dose of the maximum allowable noise exposure. The maximum peak level measured was 132 dB(A). In the paint prep area, the TWA noise level was 74 dB(A) for an 11% dose and a peak level of 138 dB(A). The body repair measurement was in excess of the NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH) evaluation criteria, and at the OSHA action level.

A potential health hazard exists from exposure to noise, and to peak concentrations of CO during the cold weather months. Concentrations of isocyanates, solvents, and total dust were below their respective evaluation criteria. The use of air-purifying respirators was deemed sufficient for the exposures documented. Recommendation are presented for control of exposures to CO and to help reduce other exposures.

Keywords: SIC 7531(automotive body shops), isocyanates, solvents, total dust, carbon monoxide, noise, respirators

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INTRODUCTION

On June 24, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the President of Spence's Carstar in Denver, Colorado, for help in assessing worker exposure to isocyanates during spray painting of automobiles. Spence's Carstar is an autobody repair shop whose other concerns for worker exposure included solvents, total dusts, noise, carbon monoxide (CO), and metals. An initial survey was conducted in September 1995 and an interim report completed in January 1996. To assess seasonal variations, a second survey was conducted on March 8, 1996. This report summarizes both investigations.

BACKGROUND

The repair work at Spence's includes frame straightening, panel repair/replacement, body filling, painting and detailing. Repair and most body work is conducted in a shop located on the northeastern edge of the building complex. Detailing, frame straightening, some body work, prepping, and painting is performed in the south and western part of the complex. Most paint spraying, especially all top coat spraying, is conducted in a paint spray booth located in the center of the western portion of the complex. Just south of the spray booth is a paint mixing room where the paint components are stored and mixed. A flexible spray booth utilizing curtains and a down draft flow system is just north of the main spray booth. The main spray booth is a down-draft system which also has the capacity to be heated to accelerate paint drying. No painting is conducted outside either the main booth or the flexible booth except for the application of an occasional primer coat.

Spence's uses the BASF Corp. R-M™ Diamont™ and Solo™ isocyanate catalyzed paints. In general, the paints are composed of a base, a reducer, and a hardener. The percentage and make-up of each component varies depending on the type of paint coat, i.e., a primer, base, color, or top (clear) coat. The paints contain hexamethylene-1,6-diisocyanate (HDI) polymer and very small amounts of the monomer (<0.006%). Some of the hardeners also contain isophorone diisocyanate (IPDI) polymer and small amounts of monomer (<1%). All of the various components contain solvents, especially the reducers which are all solvents.

When painting, multiple thin layers of the different paints are applied. When base metal is exposed, these areas are first covered with a primer. Once the vehicle is ready for final painting, several base coats are applied, the paint is allowed to sit a short while (10-20 minutes), then the color paint is applied, again in several thin coats. Lastly, the clear top coat is sprayed on until a uniform gloss is achieved. The vehicle is then allowed to sit overnight or in a heated booth for 1-2 hours to allow the paint to dry.

New, high volume, low pressure (HVLP) spray guns are used to reduce the amount of paint over-spray. However, most of the painters still used the conventional spray gun to some degree, especially when applying the clear coats of paint. While most painting was done in the spray booth, sometimes, due to the number of cars being painted and the limitations on drying times, many of the various primer, base, and color coats were applied in a secondary temporary booth. Rarely, a primer coat was applied outside either booth. Most of the clear coats were applied in the main spray booth to insure a dust-free finish coat.

METHODS

Isocyanates

Air samples for isocyanates were collected in 20 milliliters (mL) of an absorbing solution in a midget impinger at a flow rate of 1.0 liter per minute using MSA Model G sampling pumps. The absorbing solution contained a reactive chemical dissolved in dimethyl sulfoxide. The samples were analyzed by high performance liquid chromatography (HPLC) according to NIOSH Analytical Method #5522.[1] Since it is difficult to attach midget impingers in the breathing zone of workers, particularly since they had to bend over and move around, the impingers were attached to the sampling pumps on the worker's belt. Bulk samples of the various paint components were analyzed by HPLC to determine the amount of free isocyanate monomer present.

Isocyanate wipe samples were collected on work surfaces and worker's hands using colorimetric SWYPE™ skin and surface wipe tests developed by Colorimetric Laboratories, Inc (CLI, Des Plains, Illinois). Perma-Tec™ glove breakthrough indicators also developed by CLI were used to detect any isocyanates penetrating through gloves worn by workers.

Total Dust

Air samples for total dust were collected on 37-millimeter pre-weighed PVC filters housed in plastic cassettes. Air was drawn through the filters at a flow rate of 2 liters per minute using battery operated Gilian model HFS 513A high flow pumps. The filters were analyzed gravimetrically according to NIOSH Analytical Method # 0500.[1]

Organic Compounds

Air samples for organic compounds (n-butyl acetate, xylene, toluene, and ethyl acetate) were collected on standard 150-milligram charcoal tubes at 200 milliliters per minute using battery operated Gilian model LFS 113D-C sampling pumps. The samples were analyzed by gas chromatography according to NIOSH Analytical Methods #1450 and 1501.[1] One charcoal tube sample from each location was screened by gas chromatography/mass spectrometry (GC/MS) to determine what specific organic compounds were present in the air and approximate concentrations of each.

Carbon Monoxide

Carbon monoxide (CO) concentrations were measured with a Draeger Model 190 Datalogger®. This instrument uses an electochemical sensor for CO. It was calibrated on the day of use and electronically zeroed in the field.

Noise

Personal noise measurements were taken with Quest® Technologies Model M-27 Noise Logging Dosimeters. The unit stores and interprets data for a variety of different thresholds and exchange rates allowing comparison to different recommended evaluation criteria.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest concentrations of exposure to 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 even though their exposures are maintained below these concentrations. 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 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 recommended exposure limits (RELs)[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®)[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[4] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those concentrations specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term. A brief discussion of the toxicity and evaluation criteria for the substances monitored follows:

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[5-10]

The NIOSH REL for CO is 35 parts per million (ppm) for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not be exceeded.[2] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with carboxyhemoglobin (COHb) concentrations in excess of 5%.[2] The ACGIH recommends an 8-hour TWA TLV of 50 ppm, with a ceiling level of 400 ppm. Currently, the ACGIH recommends a TLV of 25 ppm as an 8-hour TWA.[3] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure. In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[11]

Organic Solvents

Exposure to organic solvents can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. As many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is considered a primary route of exposure. Overexposure to many organic solvents can result in irritation, central nervous system depression, headache, nausea, and possible effects on the liver, kidney, or other organs.[12-14] Many industrial solvents are primary irritants, and can cause defatting of the skin and dermatitis. Solvents are among the leading causes of occupational skin disease.[14] Biological effects of exposure can range from practically non-toxic (e.g., some Freons™) to highly toxic (e.g., carbon tetrachloride) or carcinogenic (e.g., benzene).[6] The ability to detect the presence of a solvent by the sense of smell will vary widely depending on the specific substance, and individual sensitivity. Substances are considered to have good warning properties if an average person with normal sensory perception can detect the presence of the chemical at a level below its occupational exposure limit. The following table summarizes the principle health effects associated with these solvents and the NIOSH RELs and odor detection thresholds for these compounds.

Chemical	**NIOSH REL**	**Odor Threshold & Description**[16]	**Principle Health Effects**[8,15-17]
ethyl acetate	400 ppm	1 ppm sweet/fruity	central nervous system depression, dizziness, eye irritation
methyl-ethyl ketone (2-butanone)	200 TWA 300 ppm STEL	17 ppm sweet, sharp	headache, dizziness, numbness of extremities, dermal and eye irritation
toluene	100 TWA 150 ppm STEL	1.6 ppm sour, burnt	eye/respiratory irritation, fatigue, headache, narcotic effects
xylene	100 TWA 150 ppm STEL	20 ppm sweet	eye/respiratory irritation, narcosis, headache, dermal effects
acetone	250 ppm TWA	62 ppm sweet, fruity	eye irritation, nausea, headache, central nervous system depression
N-butyl acetate	200 STEL 150 ppm TWA	7 ppm sweet, fruity	eye/respiratory irritation, narcosis

Note: TWA = time-weighted average concentration for up to 10 hours/day
C = ceiling limit not to be exceeded
STEL = short-term exposure limit - 15 minute average

Note that many solvents have similar toxic effects. When there are exposures to two or more substances that act upon the same organ system, their combined effect is evaluated. Unless there is scientific evidence to the contrary, the effects are considered to be additive (as opposed to potentiating, synergistic, or antagonistic), and are calculated as follows:

$$\text{Combined REL} = \frac{C_1}{REL_1} + \frac{C_2}{REL_2} + \ldots \frac{C_n}{REL_n}$$

Where: C = measured atmospheric concentration
REL = corresponding recommended exposure limit

If the sum of the above fractions exceeds 1.0, the combined REL is considered to be exceeded.

Isocyanates

The unique feature common to all diisocyanates is that they consist of two -N=C=O (isocyanate) functional groups attached to an aromatic or aliphatic parent compound. Because of the highly unsaturated nature of the isocyanate functional group, the diisocyanates readily react with compounds containing active hydrogen atoms (nucleophiles). Thus, the diisocyanates readily react with water (humidity), alcohols, amines, etc.; the diisocyanates also react with themselves to form either dimers or trimers. When a diisocyanate species reacts with a primary, secondary, or tertiary alcohol, a carbamate (-NHCOO-) group is formed which is commonly referred to as a urethane. Reactions involving a diisocyanate species and a polyol result in the formation of cross-linked polymers; *i.e.*, polyurethanes. Hence, they are widely used in surface coatings, polyurethane foams, adhesives, resins, elastomers, binders, sealants, etc. Diisocyanates are usually referred to by their specific 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. Commercial-grade TDI is an 80:20 mixture of the 2,4- and 2,6- isomers of TDI, respectively.

In general, the type of exposures 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 at room temperature, creating a vapor inhalation hazard. Conversely, the higher molecular weight diisocyanates do not readily volatilize at ambient temperatures, but are still an inhalation hazard if aerosolized or heated in the work environment. The latter is very important since most 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, prepolymer and oligomer forms of these monomers were developed, and have replaced the monomers in many product formulations. An example is biuret of HDI, which actually consists of three molecules of HDI monomer joined together to form a higher molecular weight oligomer 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 oligomer (polymethylene polyphenyl isocyanate). Experience with both the monomeric and oligomeric forms of diisocyanates has shown that the occurrence of health effects is dependent on exposure, not molecular weight.

Exposure to the diisocyanates produces irritation to the skin, mucous membranes, eyes, and respiratory tract. High concentrations may result in chemical bronchitis, chest tightness, nocturnal wakening, pulmonary edema, and death.[18,21] The most common adverse health outcome associated with diisocyanate exposure is increased airway obstruction (asthma), and to a lesser extent dermal sensitization and hypersensitivity pneumonitis.[19-21]

Diisocyanate-induced sensitization

Probably the most debilitating health effects from workplace exposure to diisocyanates are respiratory and dermal sensitization. Exposures can lead to sensitization depending on the type of exposure, the exposure concentration, the route of exposure, and individual susceptibility. Dermal sensitization can result in such symptoms as rash, itching, hives, and swelling of the extremities.[18,21] Respiratory sensitization from exposure to diisocyanates results in the typical symptoms of asthma. Estimates of the prevalence of diisocyanate-induced asthma in exposed worker populations vary considerably; from 5% to 10% in diisocyanate production facilities,[22,23] to 25% in polyurethane production plants,[22,24] and 30% in polyurethane seatcover operations.[25]

A worker suspected of having diisocyanate-induced sensitization will present with symptoms of traditional acute airway obstruction; e.g., coughing, wheezing, shortness of breath, tightness in the chest, nocturnal awakening, etc.[18,20] Upon first exposure to diisocyanates, the worker may develop an asthmatic reaction immediately or several hours after exposure, after the first months of exposure, or after several years of exposure.[18,20,23,26,27] Some evidence exists which suggests that the onset of sensitization occurs after a mean exposure interval of two years.[28] After sensitization, any exposure, even to concentrations below any occupational exposure limit or standard, can 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).[20,26] The late asthmatic reaction is the most common, occurring in approximately 40% of diisocyanate-sensitized workers.[29] Recurrent nocturnal asthma has been described in workers sensitized to TDI and MDI.[30,31] An improvement in symptoms may be observed during periods away from the work environment (weekends, vacations).[18,20,26]

The percentage of sensitized workers with persistent symptoms of asthma after years of no exposure may be 50% or higher. Studies have shown that workers with persistent asthma have a significantly longer duration of symptoms prior to diagnosis, larger decrements in pulmonary function, and a severe degree of nonspecific bronchial hyperactivity at diagnosis.[26] These data suggest that prognosis is improved with early diagnosis of diisocyanate-induced respiratory sensitization and early removal from diisocyanate exposure. This emphasizes the need to minimize workplace exposure concentrations, and for active medical surveillance of all workers potentially exposed to diisocyanates.

Prevention and treatment

Whenever there is a potential for a hazardous exposure to diisocyanates, traditional industrial hygiene practice dictates that the following hierarchy of controls, in decreasing order of desirability and effectiveness, be implemented to protect worker health:

1. Elimination of the toxic substance from the workplace.

2. Substitution of the toxic substance with a less toxic substance.

3. Installation of engineering controls designed to reduce exposure.

4. Use of administrative controls to reduce exposure.

5. Use of personal protective equipment to reduce exposure.

In many instances, it is not possible to eliminate or substitute a diisocyanate from a production process without altering the integrity of the desired product. Thus, most strategies for reducing diisocyanate exposure center on the use of engineering controls and personal protective equipment. Local exhaust ventilation and/or process isolation are commonly used controls for diisocyanate exposure reduction. Personal protective equipment should only be used when engineering controls are not feasible, in the interim when engineering controls are being installed or repaired, or when engineering controls have not sufficiently reduced exposures. NIOSH recommends that whenever there is a potential for exposure to diisocyanates, including concentrations below the NIOSH REL, that the employer provide the worker with supplied-air respiratory protection.[18] Air-purifying respirators are not approved for diisocyanates owing primarily to the fact that diisocyanates have poor odor warning properties. However, several studies have demonstrated that air-purifying respirators with combined dust/mist and organic cartridges effectively trap TDI, HDI, and MDI.[32-34] Personal protective equipment should also be used to prevent skin and eye contact with diisocyanates.

OSHA currently has standards for only two of the diisocyanates, TDI and MDI. OSHA recommends a ceiling limit of 0.02 parts per million (ppm) [140 micrograms per cubic meter, ug/m^3] for both TDI and MDI. For MDI, NIOSH recommends a TWA of 0.005 ppm (35 ug/m^3) and a 10-minute ceiling of 0.02 ppm [200 ug/m^3]. NIOSH considers TDI a carcinogen and recommends exposure be limited to the lowest feasible concentration.

For HDI, NIOSH recommends a TWA of 0.005 ppm [35 ug/m^3] and a 10-minute ceiling limit of 0.02 ppm [140 ug/m^3]. For isophorone diisocyanate (IPDI), NIOSH recommends a TWA of 0.005 ppm [45 ug/m^3] and a ceiling limit of 0.02 ppm [180 ug/m^3] with a skin designation. This indicates the potential for dermal absorption and skin contact should be avoided.

Neither NIOSH nor OSHA have recommended exposure limits for the polymeric isocyanate groups (oligomers). The United Kingdom Health and Safety Commission set a standard in 1982 for total isocyanate group per cubic meter of air. This standard is 20 ug of isocyanate group/m^3 for a TWA and 70 ug/m^3 for a 10-minute ceiling.[35] Miles Laboratories recommends in their Material Safety Data Sheet (MSDS) for the Glasurit HDI-based paints that a limit of 500 ug/m^3 be followed for the polymeric isocyanates.

Noise/Hearing Loss

Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[36] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[37]

The A-weighted decibel [dB(A)] is the preferred unit for measuring sound levels to assess worker noise exposures. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies. Because the dB(A) scale is logarithmic, increases of 3 dB(A), 10 dB(A), and 20 dB(A) represent a doubling, tenfold increase, and 100-old increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[38] specifies a maximum PEL of 90 dB(A)-slow response for a duration of eight hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. NIOSH, in its Criteria for a Recommended Standard,[39] proposes an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. In 1994, the ACGIH changed its TLV to a more protective 85 dB(A) for an 8-hour exposure, with the stipulation that a 3 dB exchange rate be used to calculate time-varying noise exposures.[10] Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to only 88 dB(A) for 4 hours or 91 dB(A) for 2 hours. In 1995, NIOSH also recommended a 3 dB exchange rate.

Time-weighted average noise limits as a function of exposure duration are shown as follows:

Duration of Exposure (hrs/day)	Sound Level dB(A) ACGIH	NIOSH	OSHA
16	82	82	85
8	85	85	90
4	88	88	95
2	91	91	100
1	94	94	105
1/2	97	97	110
1/4	100	100	115*
1/8	103	103	---
	***	***	**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

*** No exposure to continuous, intermittent, or impact noise in excess of a peak C-weighted level of 140 dB.

The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$\text{Dose} = 100 \text{ X } (C_1/T_1 + C_2/T_2 + ... + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in the above table. During any 24-hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and record keeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

RESULTS

A summary of the isocyanate results from September 1995 are presented in Table 1. All of the monomer samples were below the analytical limit of detection of 2 µg/sample. The less than values (<) in the table represent the lowest detectable concentrations for that sample based on the sample volume and the detection limit. HDI oligomer concentrations ranged from below the limit of detection to 667 µg/m^3. The highest oligomer concentrations measured were all personal samples for short time periods. The TWA oligomer concentration for the two painters were 65 and 38 µg/m^3. The painter’s individual oligomer exposures were higher, averaging 235 µg/m^3 for 132 minutes on one painter and 91 µg/m^3 for 94 minutes on the other painter. The samples collected in March are summarized in Table 1a. In general, the HDI oligomer concentrations were lower than in September. All but one of the monomer samples were below the limit of detection. This one personal sample averaged 750 µg/m^3 but the sample was collected for only 8 minutes. The sample is well in excesses of the NIOSH ceiling REL of 140 µg/m^3. The painter’s TWA for this day averaged only 14 µg/m^3. The oligomer concentrations were all below the industry recommended TWA standard of 500 µg/m^3.

Air samples for organics are summarized in Tables 2 (September 1995) and 2a (March 1996). None of the individual chemical concentrations (n-butyl acetate, toluene, xylene, or acetone) exceeded their individual RELs or PELs. Furthermore, the mixture summation of all organics (the best indicator for total organic exposure), for all samples during both sampling times was not in excess of any evaluation criteria. Generally, the concentrations of organics measured in March were higher than those in September.

Sample results for total dust are summarized in Tables 3 (September) and 3a (March). None of the samples exceeded the PEL of 15 mg/m^3. Generally, the results from September were higher than those collected in March.

The one CO monitor output collected in the paint preparation area is shown in Figure 1. The CO concentrations averaged 25 ppm for the 8-hr sampling period. The peak CO level was 173 ppm and the highest 15-minute average was 80 ppm. The high peaks were associated with moving vehicles in and out of the shop.

A personal noise monitor was placed on a body repair worker for 7 hours and 7 minutes and on a worker in the paint prep area for 6 hrs and 10 min. The average noise level in the body shop (using the OSHA criteria) was 86 dBA, resulting in a 63% dose of the maximum allowable noise exposure. The maximum peak levels measured was 132 dBA. The average noise level from the paint prep area was 74 dBA for a 11% dose and a peak noise level of 138 dBA.

DISCUSSION

The isocyanate results generally demonstrate low exposures to HDI monomer and oligomers. For both sampling periods, only one monomer sample was in excess of the NIOSH ceiling REL of 140 µg/m^3 but it was below the TWA REL of 35 µg/m^3. This sample was collected in March and for a very short time period (8 minutes). The oligomer samples were higher during the warmer time period (September) but were still below the TWA concentration recommended by the paint manufacturer (500 µg/m^3). The isocyanates samples indicate the potential for some exposure exists, but not generally at concentrations in excess of existing evaluation criteria.

Exposures to solvents were generally higher in the winter than in the summer. The highest exposure was at 61% of the allowable exposure for solvent mixtures. The highest exposures were consistently to n-butyl acetate and toluene. Use of protective gloves to reduce skin exposure (and absorption) of solvents was inconsistent. Gloves were mostly used when mixing paint and spray painting but were not always used during spray gun cleaning.

Total dust concentrations due to paint over spray (measured as area and personal samples) were consistently below the OSHA PEL even inside the spray booth. Samples collected during the warmer time period (September) were generally higher than those collected in March.

CO concentrations did not exceed the ceiling limit of 200 ppm. The average exposure for the 8-hr sample (25 ppm) equaled the ACGIH TLV of 25 ppm. The CO concentrations were high enough that some remediation is necessary to control exposure. Since cars moving into and out of the shop were the source of the CO, and since it is very difficult to control these moving sources, the best possible solution is to increase general building dilution ventilation. This increase in ventilation would also help reduce other exposures such as solvents, isocyanates (when sprayed outside the booth), and total dust.

Noise exposures were below the OSHA exposure limits but were near the OSHA action level of 85 dBA as an 8-hr TWA (86 dBA for 7.12 hr). Noise levels did approach the NIOSH REL and the ACGIH TLV. Since body work that produces the highest noise levels is an inconsistent work practice, more measurements representing a wider variety of body work is recommended to increase the baseline monitoring.

CONCLUSIONS

Isocyanate exposures were generally below the various evaluation criteria. One sample did exceed the NIOSH ceiling RELs indicating a need for protective measures. NIOSH recommends air-supplied respirators whenever there is the potential for exposure to isocyanates. There are no NIOSH approved air-purifying respirators for isocyanates because isocyanates have no odor warning properties to indicate breakthrough of the cartridge. Studies have shown that combination dust/mist and organic cartridges effectively stop isocyanates and that the various solvents, particularly n-butyl acetate, will break through the cartridge long before the isocyanates.[32-34] Therefore, the combination dust/mist/organic air-purifying respirators should provide adequate protection against the small amounts of isocyanate present and the n-butyl acetate odor can be used to indicate breakthrough of the cartridges. Eye and skin protection also needs to be provided with isocyanate monomers.

Both solvent and total dust exposures approached, but did not exceed, the NIOSH/OSHA evaluation criteria. Use of the combination air-purifying respirators during painting would also provide sufficient protection for solvents and total dust. Use of gloves and eye protection will provide the needed skin and eye protection for the solvents. Eye protections in the entire shop should be a general requirement due to the potential for flying objects from body work (grinding and welding), detailing , painting , polishing, etc.

The CO concentrations measured during the winter months, when the shop was fairly airtight, equaled the ACGIH TWA. Since vehicles need to be moved around and in and out of the shop to keep the repair process going, the only real control option is to provide general building ventilation for the shop. The only exhaust in the building occurs through leakage into the spray booth and mixing room or if the exhaust fan in the southwest corner of the building is turned on during any painting outside the spray booth. Outside air needs to be brought into the building, tempered and partially exhausted. The American Society of Heating, Regfrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) recommends certain levels of outside air in their guideline "Ventilation for Acceptable Indoor Air Quality," standard ASHRAE 62-1989.[40] This guideline recommends 1.5 cubic feet per minute of outside air per square feet for auto repair shops and enclosed parking garages to control for CO.

RECOMMENDATIONS

The following recommendations are based on the environmental sampling results and the observations made during this investigation and are offered in the interest of improving employee health and safety for all employees at Spence's Carstar.

1. NIOSH recommends air-supplied respirators when there is the potential for exposure to isocyanates. However, if air-purifying respirators are used, there are a few items which should be noted. First, there are no NIOSH approved air-purifying respirators for isocyanates primarily because isocyanates have no odor warning properties. Studies have shown that combination dust/mist and organic cartridges effectively stop isocyanates and that the various solvents will break though long before any isocyanate.[32-34] Therefore, the odor property of n-butyl acetate could be used to determine when respirators need to be replaced. Eye and skin protection should be provided during spray painting. At a minimum, air-purifying respirators are indicated by the organic chemical and total dust exposures.

2. General ventilation for the entire shop is needed to control CO concentrations in the winter. This ventilation should meet the guidelines recommended by ASHRAE 62-1989.

3. A complete respiratory protection program needs to be implemented as per 29 CFR 1910.134. Many of the elements of the 10-point respirator plan are in effect, but all elements must be in place including medical testing of workers for the ability to wear respirators, respirator training, fit testing of respirators, and respirator maintenance.

4. Paint spraying should be conducted in the paint booth as much as possible. The concentrations of total dust and organics can be substantial, so the best way to control these exposures is to limit spraying to

the booth. When any spraying is done outside the booth, all employees in the area should be wearing their respirators.

5. No eating, drinking, or smoking should be allowed in the shop area. This rule was followed by most employees.

6. Gloves should be worn when mixing paint, cleaning paint guns, or any time when bulk paint and/or solvents may come into contact with the skin. Testing for isocyanate monomers with SWYPE^{TM} samples demonstrated isocyanate content in used solvent. This was confirmed by bulk sample analysis, therefore demonstrating the need to avoid skin contact with this solvent.

7. Noise levels should be re-measured during a variety of different body shop operations for several different days. If average noise levels exceed 85 dBA as a TWA, then a comprehensive hearing conservation program needs to be implemented.

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Table 1
Summary of Air Sample Results for Hexamethylene Diisocyanates
Spence’s Carstar
Englewood, Colorado
HETA 95-0405
September 14, 1995

SAMPLE	**SAMPLE DESCRIPTION**	**ON**	**OFF**	**SAMPLE TIME (min)**	**VOLUME at 1 Lpm (m^3)**	**HDI CONCENTRATION (ug/m^3)**	
						Monomer	**Polymer**
ISC-41	Personal	9:39	10:53	74	0.074	<27	230
ISC-40	Personal	12:03	12:50	47	0.047	<43	319
ISC-42	Personal	1:50	2:05	15	0.015	<133	667
ISC-43	Personal	2:48	3:35	47	0.047	<43	64*
ISC-44	Personal	4:44	5:27	43	0.043	<47	93*
ISC-45	Area-Prep Booth	5:03	5:33	30	0.030	<67	<67

*Denotes value is between Limit of Detection (2 ug/sample) and Limit of Quantitation (8.2 ug/sample)
NIOSH Recommended Exposure Limit: HDI: 35 ug/m^3 for TWA, 140 ug/m^3 for 10-min Ceiling
OSHA Permissible Exposure Limit: none

Table 1a
Summary of Air Sample Results for Hexamethylene Diisocyanates
Spence's Carstar
Englewood, Colorado
HETA 95-0405
March 8, 1996

SAMPLE	**SAMPLE DESCRIPTION**	**ON**	**OFF**	**SAMPLE TIME (min)**	**VOLUME at 1 Lpm (m^3)**	**CONCENTRATION (ug/m^3)**	
						Monomer	Oligomer
ISP-70	Area- Paint Room	10:01	10:17	16	0.016	<125	<125
ISP-71	Personal-Clear coat	10:00	10:08	8	0.008	750	<250
ISP-72	Personal-Jamming Parts	11:01	11:10	9	0.009	<222	256*
ISP-73	Personal-Priming	11:29	11:51	22	0.049	<41	110*
		3:40	4:07	27			
ISP-74	Personal-Priming	11:28	12:00	32	0.045	<44	400
		4:20	4:33	13			
ISP-75	Area-Paint Booth	11:30	4:33	303	0.303	<7	<7
ISP-77	Personal	2:11	2:30	19	0.019	<105	<105

NIOSH Recommended Exposure Limit: HDI Monomer: 35 ug/m^3 for TWA, 140 ug/m^3 for 10-min Ceiling
OSHA Permissible Exposure Limit: none

Table 2
Summary of Air Sample Results for Organics
Spence’s Carstar
Englewood, Colorado
HETA 95-0405
September 14, 1995

SAMPLE	**SAMPLE DESCRIPTION**	**ON**	**OFF**	**SAMPLE TIME (min)**	**VOLUME at .2 Lpm (m^3)**	**CONCENTRATION** (mg/m^3)				Mixture TLV
						n-Butyl Acetate	Toluene	Xylene	Acetone	
CSC-40	Personal	9:39	10:53	74	0.0148	16	10	7.4	4.5	0.07
CSC-41	Personal	9:40	10:01	21	0.0042	7	10.7	3	8	0.06
CSC-42	Area-Inside Mix Room	9:07	5:25	498	0.0996	3.2	17.1	1.0	17	0.08
CSC-43	Personal	12:03	12:50	47	0.0094	12	5	4	2	0.04
CSC-44	Personal	1:50	2:05	15	0.0030	13	4	4	1	0.04
CSC-45	Personal	2:48	3:35	47	0.0094	9	13	2	10	0.07
CSC-46	Personal	4:45	5:27	42	0.0084	17	29	4	14	0.13
CSC-48	Area-Prep Booth	5:03	5:33	30	0.0060	9	35	1	28	0.16
NIOSH Recommended Exposure Limit - 8 hour TWA - mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	590 (250)	1.0
OSHA Permissible Exposure Limit - 8 hour TWA - mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	2400 (1000)	1.0

Table 2a
Summary of Air Sample Results for Organics
Spence’s Carstar
Englewood, Colorado
HETA 95-0405
March 8, 1996

SAMPLE	**SAMPLE DESCRIPTION**	**ON**	**OFF**	**SAMPLE TIME (min)**	**VOLUME at .2 Lpm (m^3)**	**CONCENTRATION** (mg/m^3)				Mixture REL/PEL
						n-Butyl Acetate	Toluene	Xylene	Ethyl Acetate	
CSP-30	Personal-Jamming Parts	11:01	11:10	9	0.0018	44	183	16	39	0.61
CSP-31	Area-Paint Booth	10:01	10:17	16	0.0032		1.0	1	-	0.00
CSP-32	Per-Prime, Color,Clear	9:15	10:19	64	0.0128	9.4	60.2	7.0	5	0.19
CSP-33	Area-Mixing Room	8:51	1:30	279	0.0558	20	91	7.0	12.5	0.30
CSP-34	Personal-Priming	11:29	11:51	22	0.0098	3	13	1	2	0.04
		3:40	4:07	27						
CSP-35	Area-Mixing Room	1:31	4:25	174	0.0348	2	3	-	-	<0.01
CSP-36	Personal-Priming	11:13	12:00	37	0.0204	3	48	16	6	0.17
		2:11	3:16	65						
CSP-37	Area-Paint Booth	11:30	4:33	303	0.0606	2	3	-	-	<0.01
CSP-38	Personal-Priming	11:28	12:00	32	0.0352	19	40	7	10	0.16
		2:09	4:33	144						
NIOSH Recommended Exposure Limit - 8 hour TWA - mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	1400 (400)	1.0
OSHA Permissible Exposure Limit - 8 hour TWA - mg/m^3 (ppm)						710 (150)	375 (100)	435 (100)	1400 (400)	1.0

Table 3
Summary of Air Sample Results for Total Dust
Spence’s Carstar
Englewood, Colorado
HETA 95-0405
September 14, 1995

SAMPLE	SAMPLE DESCRIPTION	ON	OFF	SAMPLE TIME (min)	VOLUME at 2 Lpm (m^3)	CONCENTRATION (mg/m^3)
95-2288	Personal	9:39	10:53	74	0.148	3.6
95-2289	Personal	9:40	10:01	21	0.042	3.1
95-2287	Personal	12:03	12:50	47	0.094	4.6
95-2286	Personal	1:50	2:05	15	0.030	9.0
95-2285	Personal	2:48	3:35	47	0.094	1.7
95-2284	Personal	4:45	5:27	42	0.084	3.0
95-2282	Area-Prep Booth	5:03	5:33	30	0.060	1.5

OSHA Permissible Exposure Limit = 15 mg/m^3 for Total Dust as an 8-hr TWA

Table 3a
Summary of Air Sample Results for Total Dust
Spence's Carstar
Englewood, Colorado
HETA 95-0405
March 8, 1996

SAMPLE	SAMPLE DESCRIPTION	ON	OFF	SAMPLE TIME (min)	VOLUME at 2 Lpm (m^3)	CONCENTRATION (mg/m^3)
95-3212	Personal-Prime, Color, Clear coat	9:15	10:19	64	0.128	0.4
95-3228	Personal-Bondo work	9:10	11:52	162	0.324	2.0
95-3225	Area-Paint Booth	10:01	10:17	16	0.032	1.3
95-3204	Personal-Jamming Parts	11:01	11:10	9	0.018	<1.1*
95-3231	Personal-Priming	11:13 2:11	12:00 3:16	37 65	0.204	0.6
95-3226	Personal-Priming	11:28 2:09	12:00 4:33	32 144	0.352	1.8
95-3202	Personal-Priming	11:29 3:40	11:51 4:07	22 27	0.098	1.1
95-3215	Area-Paint Booth	11:30	4:33	303	0.606	3.0
95-3203	Personal-Bondo work	1:06	4:25	199	0.398	0.9

* Sample was below the Limit of Detection of 0.02 mg/sample
OSHA Permissible Exposure Limit = 15 mg/m^3 for Total Dust as an 8-hr TWA

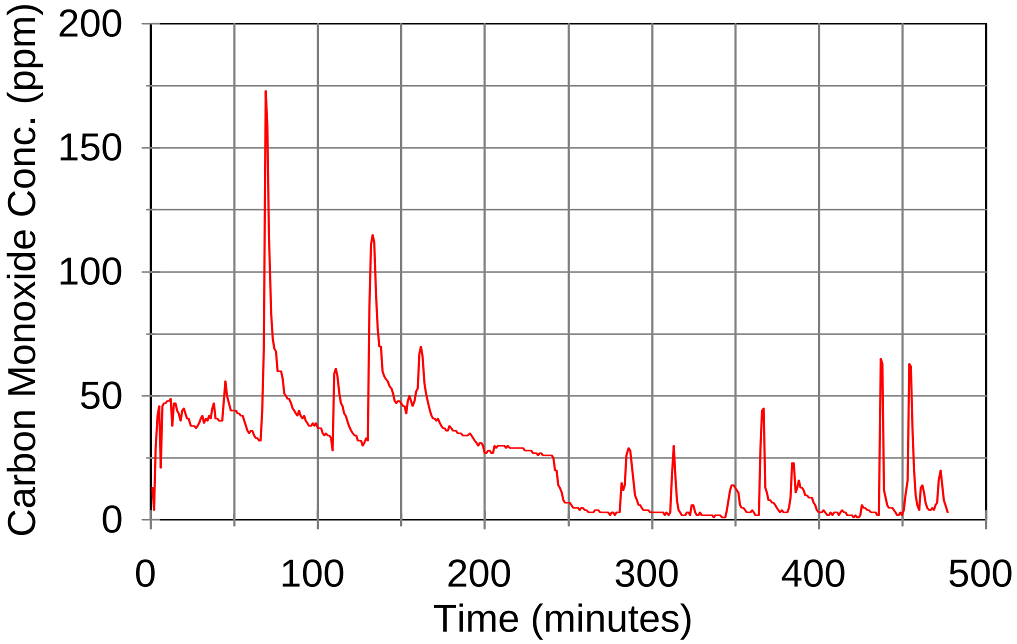

Figure 1: **Carbon Monoxide Concentrations in Paint Prep Area, Spence's, 3/8/96**

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