HETA 98–0088–2753
U.S. Postal Service
Vehicle Maintenance Facility
Chicago, Illinois

Calvin K. Cook, M.S.
Robert Malkin, D.D.S., Dr. PH

PREFACE

The Hazard Evaluations and Technical Assistance Branch of National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Calvin K. Cook and Robert Malkin of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Zulfiqar Chaudry. Analytical support was provided by Data Chem Laboratories, Inc. and Omega Specialty Instrument Company. Desktop publishing was performed by Ellen Blythe. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at the Vehicle Maintenance Facility and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self–addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800–356–4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

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.

National Institute for Occupational Safety and Health
Exposures in the Vehicle Maintenance Facility

In August 1998, NIOSH investigators conducted a health hazard evaluation at the U.S. Postal Service Vehicle Maintenance Facility. We looked into employee concerns about exposure to vehicle exhaust and paint vapors.

What NIOSH Did

We looked at worker exposures in the repair bay and autobody paint shop.

We tested the air for vehicle exhaust emissions and paint vapors. Chemicals we tested for were nitric oxide and nitrogen dioxide from vehicle exhaust, and hexamethylene diisocyanate (HDI) from paint.

We tested the tail-pipe exhaust ventilation systems and roof ventilators that removed exhaust emissions from the repair bay.

We looked at the written respiratory protection program for the paint shop.

We looked for possible safety hazards.

What NIOSH Found

Painters were over–exposed to HDI.

Nitric oxide and nitrogen dioxide levels were low.

The airflow in the tail–pipe exhaust ventilation systems was too low.

Most roof ventilators were not working.

Painters did not wear supplied–air respirators as recommended by NIOSH.

There was not an emergency eyewash station in the paint shop.

Flammable storage cabinets were not grounded for fire prevention.

What U.S. Postal Service Vehicle Maintenance Facility Managers Can Do

Replace broken and missing parts of the tail-pipe exhaust ventilation systems, and repair broken roof ventilators.

Update the written respiratory protection program to require painters to use air-supplied respirators.

Install an eyewash station plumbed to a tempered water supply.

Ground flammable storage cabinets for fire prevention.

Communicate and enforce safe work practices and procedures to employees.

What the U.S. Postal Service Vehicle Maintenance Facility Employees Can Do

When working on an idling vehicle, always use a tail-pipe exhaust system.

Properly store and maintain respirators.

Do not store paint supplies in personal lockers.

Wear gloves for hand protection when using HDI–containing paint.

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 98-0088-2753

National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 98–0088–2753
U.S. Postal Service
Vehicle Maintenance Facility
Chicago, Illinois
September 1999

Calvin K. Cook, M.S.
Robert Malkin, D.D.S., Dr. PH

SUMMARY

On January 16, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from employees working at the U.S. Postal Service Vehicle Maintenance Facility located in Chicago, Illinois. The request stated that employees were experiencing headaches, sneezing, coughing, unspecified respiratory problems, fatigue, and eye irritation that they believed were caused by exposures to vehicle exhaust. Workers were also concerned about their exposures to paint vapors containing 1,6–hexamethylene diisocyanate (HDI) and about the effectiveness of existing ventilation systems.

Site visits were conducted on June 18–19, 1998, and on August 26–28, 1998, consisting of both a medical and industrial hygiene component. A visual inspection was made during the site visit of June 19, 1998, and ventilation measurements were made to evaluate the design and performance of the facility's tail–pipe exhaust systems and roof ventilators. In the facility's repair bay and paint shop a general inspection was made to identify potential safety and health hazards. Personal protective equipment and employee work practices were evaluated. Material safety data sheets, previous industrial hygiene reports, safety training records, and management's written respiratory protection program were reviewed.

Air sampling was performed on the visit of August 26–28, 1998, to measure vehicle exhaust components (nitric oxide [NO] and nitrogen dioxide [NO_2]) and HDI in the paint shop. Short–term air sampling for NO_2 revealed concentrations up to 0.68 parts per million (ppm), below the NIOSH 15–minute short–term exposure limit of 1 ppm. Full–shift air sampling revealed NO concentrations up to 0.73 ppm, well below the NIOSH recommended exposure limit of 25 ppm as an 8–hour time–weighed average concentration. Air sampling revealed painters' short–term exposures to HDI as high as 692 micrograms per cubic meter ($\mu g/m^3$), exceeding a Swedish ceiling limit of 200 $\mu g/m^3$ for HDI–based polyisocyanate and the United Kingdom Health and Safety Executive (UK–HSE) ceiling limit of 70 $\mu g/m^3$ for *total* HDI. Painters were exposed to these elevated HDI concentrations while using full–faced air–purifying respirators, rather than using supplied–air respirators as recommended by NIOSH and the paint manufacturer.

Qualitative ventilation measurements indicate the two tail–pipe exhaust systems in the repair bay did not meet minimum airflow exhaust criteria recommended by the American Conference of Governmental Industrial Hygienists. The inspection of the tail–pipe exhaust system revealed missing cone hoods, damaged flexible ducts, and inoperative crank–pulley mechanisms. Only two of six roof ventilators serving the repair bay were working during the evaluation.

Safety deficiencies were discovered that included the absence of an emergency eyewash near corrosive materials, improper storage of chemical supplies and respirators, and flammable storage cabinets not grounded for fire prevention.

The medical evaluation consisted of a walk–through tour of the facility, interviews with eight workers, and a symptom and exposure questionnaire. Symptoms reported in the interviews included asthma, headaches, fatigue, rashes, and eye irritation. A questionnaire was given to 77 workers; workers receiving the questionnaire included mechanics, painters, body shop workers, and office workers, and the areas where they worked included the paint shop, repair bay, and offices. Sixty–two workers (81% of the 77 answering the question) reported smelling diesel exhaust and the relationship to symptoms could not be evaluated because of the small number (5) who reported not smelling diesel exhaust. Forty–six workers (60%) reported smelling vehicle paint vapors when they worked. Smelling vehicle paint was statistically associated with chest tightness (odds ratio [OR]= 7.1, 95% confidence interval [CI] 1.5–34.2), difficulty breathing (OR=4.1, 95% CI 1.0–16.2), irritated eyes (OR=3.9, 95% CI 1.3–11.2), and morning phlegm (OR=3.7, 95% CI 1.1–12.8).

NIOSH investigators concluded that a potential health hazard exists among painters using HDI–based paints when supplied–air respirators are not worn. Although air sampling did not identify over–exposures to exhaust components (NO and NO_2), the ventilation exhaust system in the repair bay did not meet minimum airflow exhaust criteria and a visual inspection revealed many missing and inoperative parts. Recommendations are offered in this report to improve exhaust ventilation, respiratory protection, and general safety in the workplace.

Keywords: SIC 4311 (United States Postal Service) vehicle maintenance, diesel exhaust, gasoline exhaust, nitric oxide, NO, nitrogen dioxide, NO_2, spray paint, 1,6–hexamethylene diisocyanate, HDI, ISO–CHEK®, mechanics, painters, autobody.

TABLE OF CONTENTS

INTRODUCTION

On January 16, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request from a group of employees to conduct a health hazard evaluation (HHE) at the U.S. Postal Service Vehicle Maintenance Facility (VMF) in Chicago, Illinois, to evaluate occupational exposures to vehicle exhaust and paint vapors. The request was prompted by employees' concerns about the ineffectiveness of the existing ventilation system designed to control vehicle exhaust. The request stated that while at work some employees experienced headaches, sneezing, coughing, unspecified respiratory problems, fatigue, and eye irritation. In response to the request, NIOSH investigators made an initial survey in June 1998, and a follow–up survey in August 1998.

On June 18–19,1998, the initial survey began with an opening conference with VMF management and American Postal Workers Union (APWU) representatives, followed by a walk–though inspection of the VMF that included gathering information about the facility's processes, evaluating existing ventilation controls, interviewing affected employees, and reviewing records pertinent to the HHE. Based on potential health and safety problems observed during the walk–through survey, a follow–up visit was made on August 26–28, 1998, to conduct air sampling for components of vehicle exhaust such as nitric oxide (NO) and nitrogen dioxide (NO_2) gases, and to offer a questionnaire to all employees present at work those days. Air sampling was also done in the paint shop to measure 1,6–hexamethylene diisocyanate (HDI), a chemical agent in the paint used at the VMF. HDI was monitored because it is known to cause allergic sensitization of the respiratory tract in some individuals.[1]

BACKGROUND

Occupying a three–story 900,000–square foot building, the VMF is responsible for maintaining a fleet of about 2,500 vehicles that comprise a variety of light, medium, and heavy duty delivery trucks powered by either gasoline or diesel fuel. There are approximately 150 employees over three shifts (the day shift being the largest) including mechanics, painters, bodyshop workers, vehicle drivers, dispatchers, and office workers.

The work areas of concern regarding vehicle exhaust were the repair bay located on the third level and the vehicle parking areas on the first and second levels. Mechanics in the repair bays reported being exposed to exhaust from idling vehicles. Drivers in the vehicle parking areas reported being exposed to vehicle exhaust during cold startup periods and vehicle traffic. The repair bay had two overhead tail–pipe exhaust ventilation systems that served 24 individual work stations for mechanics—one system served 16 work stations and the other served 9 work stations. Above each work station was a retractable flexible duct (4.5 inch in diameter) controlled by crank–pulley mechanisms. The inlet of the flexible duct was attached to an idling vehicle's tail–pipe and directed exhaust gases to the roof outdoors. There were 10 additional workstations in use on the far west end of the repair bay that were not served by a tail–pipe exhaust system. The repair bay also had six auxiliary roof ventilators that directed exhaust to the roof outdoors. The tail–pipe exhaust systems and roof ventilators were manually controlled by on–off switches located near centralized work stations. In place was a continuous carbon monoxide (CO) monitoring system with sensors located on each of the facility's three levels. Original design specifications for the exhaust ventilation systems and the CO monitoring system were not provided during the HHE.

Vehicles undergoing auto body repairs were spray painted in the paint shop located adjacent to the repair bay on the third level. The paint shop included a large paint booth (about 35 x 65 feet) and a holding area for vehicle drying. The paint booth was equipped with a wet scrubber exhaust ventilation system designed to control paint vapors and particulates. (According to management, this scrubber is slated for replacement.) Located at the entrance of the paint booth was a large, sliding door that separated the paint booth and holding area. Painters were instructed to have the sliding door closed and have the wet scrubber turned on during spray painting. However, according to employees, these procedures were not always followed.

Spray painting was performed by a crew of three painters. A two–component paint was prepared by mixing an acrylic enamel with a urethane binder containing an aliphatic polyisocyanate resin and 1,6–HDI monomer. Personal protective equipment routinely worn by painters were full–faced air purifying respirators (equipped with organic vapor cartridges) and Tyvek® coveralls. Although not typically used by the painters, a supplied–air respirator equipped with a 100–foot hose leading to a compressor was available. The duration of painting tasks varied from only 15 minutes up to an 8–hour work day.

NIOSH medical investigators toured the facility on June 18–19, 1998, and interviewed eight employees (mechanics, drivers, body and fender workers, painters, drivers, and a union steward) selected by the APWU and the requestor on the basis of the severity of their symptoms and their willingness to be interviewed. The purpose of these interviews was to determine the severity of symptoms so that a decision could be made regarding the need for further study.

Three of the 8 interviewed workers reported asthma. One worker's asthma was newly diagnosed, and this individual was unable to continue working in the facility. Another had asthma as a child, was asymptomatic for over 25 years, but had a re–occurrence of symptoms in the last 3 years. The third had pre–existing asthma and felt that exposure to diesel exhaust fumes made the asthma worse. Other reported symptoms included headaches (3 workers), fatigue (2 workers), rashes (2 workers), and eye irritation (3 workers). Three workers reported that diesel exhaust fumes made their symptoms worse and symptoms were worse in the winter when the doors to the garage were closed. Three reported that paint fumes made their symptoms worse, and specifically blamed the paint booth and isocyanate–containing auto paint. Two workers did not report any symptoms.

METHODS

Industrial Hygiene Evaluation

On August 27, 1998, a total of eight air samples were collected for NO and NO_2 during the first shift. Full–shift personal breathing–zone (PBZ) measurements were collected on two mechanics working in the repair bay. Full–shift area air samples were collected near the center of the first and third levels. To assess vehicle exhaust concentrations generated on the first level during the start of the work–shift, four short–term area air samples for NO_2 were collected consecutively for 15–minute periods. Air samples for NO and NO_2 were collected on triethanolamine–treated sorbent tubes, using air sampling pumps pre– and post calibrated at a flowrate of 0.20 liters per minute (Lpm). Samples were analyzed by manual visible spectrophotometry, in accordance with the NIOSH Manual of Analytical Method 6014.[2]

On August 28, 1998, five short–term PBZ air samples were collected on first–shift painters (wearing full–faced air–purifying respirators) for 10–minute periods. Two area air samples also were collected in the spray paint booth and at the entrance of the vehicle holding area leading to the repair bay for 30–minute periods. Diisocyanates, including HDI, exist in many different forms in the workplace. The capability to measure all diisocyanate–containing substances in air, such as the *monomer* or *oligomer* (polyisocyanate) forms, is important when assessing a worker's *total* isocyanate exposure. In accordance with the ISO–CHEK® sampling and analytical method for diisocyanates, each air sample was collected using a two–stage filter cassette connected to an air sampling pump (pre– and post calibrated at 2 Lpm).[3] Each cassette contained a 5 micrometer (µm) Polytetrafluoroethylene (PTFE) filter to collect the oligomeric aerosol followed by a glass fiber filter to collect the monomeric vapor phase. Samples were analyzed by an ultraviolet detector and a spectrofluorometer in series.

During each of the initial and follow–up surveys, a visual inspection and ventilation measurements were made to evaluate the performance and design of the tail–pipe exhaust system and roof exhaust ventilators serving the third level. A thermal anemometer was used to make ventilation airflow measurements of the tail–pipe exhaust systems. Eight–point traverse measurements for air velocity (in feet per minute) were made at the inlet of each work station's flexible duct. Air velocity data were used to calculate the volumetric flowrate in units of cubic feet per minute (cfm) of each exhaust duct, then compared to minimum airflow criteria recommended by the American Conference of Governmental Industrial Hygienists' (ACGIH).

To determine whether exhaust gases were being re–entrained into the building, all exhaust terminals and sanitation stacks on the roof were identified and their distances determined with respect to outdoor air intakes. Qualitative airflow measurements were made using ventilation smoke tubes to determine whether work areas were under positive, negative, or neutral pressures. Airflow measurements were made at the entrances of the paint booth and holding area to determine how these areas were affected by the wet scrubber exhaust system being turn on and off. The dispatch office was also evaluated for qualitative airflow.

A general inspection was made to identify potential safety hazards in the repair bay and paint shop. Pertinent documents were reviewed that included material safety data sheets (MSDSs) for paint supplies, previous industrial hygiene reports, employee safety training records, and management's written respiratory protection program.

Medical Evaluation

During the follow–up visit of August 26–28, 1998, a questionnaire survey was conducted to evaluate the presence of chronic respiratory disease. Approximately 150 employees worked in the VMF on three different shifts and approximately 75 of them were vehicle maintenance employees including mechanics, auto painters, and auto body workers (an additional approximately 35 mechanics were assigned to locations not in the VMF building and were not surveyed) and the remaining were dispatchers or office workers. Since the dispatchers and office workers are working in the facility and are potentially exposed to vehicle exhaust, NIOSH investigators included them in the questionnaire survey. Working from a roster of employees supplied by management, auto maintenance workers present at work on the days of the survey were brought in groups to a central area to complete a self–administered questionnaire, and dispatchers and office workers were given the questionnaire in their work area by the NIOSH investigators. The purpose of the study and its voluntary nature was explained to most workers before they answered the questionnaire. NIOSH investigators were available in the work area to answer any questions and assist the employees. Some questionnaires were left with supervisors to give to specific employees who were working the night shift (11 p.m.–7 a.m.) or were not present that day. The participants returned these by mail to NIOSH investigators.

Symptoms relating to cough, cough and phlegm, phlegm, shortness of breath, and wheezing were asked on the questionnaire and were based on questions from the American Thoracic Society respiratory symptoms questionnaire (ATS–DLD–78).[4] For this study, chronic cough was considered to be present if the cough occurred at least four times a day at least four days a week for at least three months of the year. Participants were asked if they wheezed when they had a cold, occasionally when they did not have a cold, or wheezed on most days and nights. A participant was considered to have wheezing for the questionnaire if they answered positively to any of those questions.

A marker of exposure (yes/no) of individual workers was determined from the questionnaire by asking workers whether they smelled vehicle exhaust or vehicle paint vapors. According to management and the union, most workers were able to distinguish between diesel and gasoline exhaust and were aware of automotive paint vapors. Replying that diesel exhaust was never smelled or mostly gasoline exhaust was smelled was considered a negative response to smelling diesel exhaust, while smelling mostly diesel exhaust, or smelling gasoline and diesel exhaust equally was considered a positive response. Although area samples for NO and NO_2 were collected as an indicator of vehicle exhaust for measuring exposure to diesel, the sampling design was not appropriate for assigning exposures to an individual. There were no personal monitors for paint fume among workers other than painters. Thus, smelling exhaust or paint was used as the indicator of exposure for purposes of analyzing the symptom data.

Analysis of the questionnaire was done using SAS Version 6.12 and Epi Info Version 6. Logistic regression was used to determine odds ratios (OR) for univariate analyses. The odds ratio is used to measure the association between a disease and an exposure and measures the odds of having a particular disease or symptom given a particular exposure. When the **OR is 1 or less**, we say that people with the exposure are no more likely to have the disease than people without the exposure. When the **OR is greater than 1**, we say that people with the exposure are more likely to have the disease than people without the exposure. We also calculated the confidence interval (CI) for the OR. A CI that does not include the number 1 means that the evidence of an association between a disease and an exposure is unlikely to have occurred by chance. Statistical associations were also assessed by chi–square analyses and, if the people in the analysis were few (less than five participants in a cell), Fisher's exact tests were performed. A "p" value that is less than 0.05 is said to be statistically significant.

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 levels 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 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 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 increases 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),[5] (2) the ACGIH® Threshold Limit Values (TLVs®),[6] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[8] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short–term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term.

Vehicle Exhaust—Gasoline and Diesel

A typical light–duty, gasoline–powered vehicle gives off gaseous exhaust that is comprised of nitrogen, carbon dioxide (CO_2), and water vapor (99.5 to 99.9%). The remainder contains the pollutants such as hydrocarbons, aldehydes, CO, oxides of nitrogen (NO and NO_2), and lead. Vehicle exhaust vary according to gasoline composition, particularly with the use of reformulated gasoline or alternative clean fuels.[9]

The vehicle exhaust from diesel–powered engines consists of both gaseous and particulate fractions. The gaseous constituents include CO_2, CO, NO, NO_2, oxides of sulfur, and hydrocarbons (e.g., ethylene, formaldehyde, methane, benzene, phenol, 1,3–butadiene, acrolein, and polynuclear aromatic hydrocarbons).[9] Particulates (soot) in diesel exhaust are composed of solid carbon cores or elemental carbon that are produced during the combustion process and that tend to form chain or aggregates. Elemental carbon constitutes a large portion of the diesel particulate mass, and serves as a carrier of cancer–causing polycylic aromatic compounds. NIOSH recommends that diesel exhaust be regarded as a "potential occupational carcinogen," based on findings of carcinogenic and tumorigenic responses in rats and mice exposed to diesel exhaust.

For this survey NO and NO_2 were measured as markers for vehicle exhaust in the work environment, because these gases are easily measured, and may be responsible for many of the health effects reported by VMF employees. Inhalation exposure to NO_2 may cause irritation of the eyes, nose, throat, and pulmonary edema.[1] NO causes cyanosis in animals, presumably from the formation of methemoglobin in blood.[1] On the basis of information from animal and human studies, ACGIH has established TLVs® for NO_2 of 3 parts per million (ppm) as an 8–hour TWA and 5 ppm as a 15–minute STEL. The NIOSH REL for NO_2 is 1 ppm as a 15–minute STEL, while the OSHA PEL is a 5 ppm ceiling limit. The NIOSH REL, ACGIH TLV®, and OSHA PEL for NO are all 25 ppm as a TWA.

Diisocyanates

Diisocyanates are a class of low molecular weight compounds containing the isocyanate group—NCO. They are widely used in the manufacture of polyurethanes which are 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 (the one used at the VMF), 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 *polyisocyanate* 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 *polyisocyanate* with similar characteristics to those found in HDI *monomer*. Experience with both the *monomeric* and *polyisocyanate* forms of diisocyanates has shown that the occurrence of health effects is dependent on the level of exposure, not molecular weight.

Health Effects

Exposure to isocyanates is irritating to the skin, mucous membranes, eyes, and respiratory tract.[10,11] The most common adverse health outcome associated with isocyanate exposure is asthma due to sensitization; less prevalent are contact dermatitis (both irritant and allergic forms) and hypersensitivity pneumonitis (HP).[11,12,13] Contact dermatitis can result in symptoms such as rash, itching, hives, and swelling of the extremities.[10,11,13] A worker suspected of having isocyanate–induced sensitization/asthma will exhibit the traditional symptoms of acute airway obstruction, *e.g.*, coughing, wheezing, shortness of breath, tightness in the chest, and nocturnal awakening.[10,12,13] An isocyanate–exposed worker may first develop an asthmatic condition (*i.e.*, become sensitized and symptomatic) after a single (acute) exposure, but sensitization usually takes a few months to several years of exposure.[10,12,14,15,16] An asthmatic reaction may occur within minutes after exposure (immediate), or several hours after exposure (late), or there may be a combination of both immediate and late components (dual).[12,15] The late asthmatic reaction is common, occurring in approximately 40% of isocyanate–sensitized workers.[17] After sensitization, any exposure, even to levels below current occupational exposure limits, can produce an asthmatic response which may be life threatening. The scientific literature contains limited animal data suggesting that dermal exposure to diisocyanates may produce respiratory sensitization.[18,19,20,21] This finding has not been documented in dermally exposed workers.

HP also has been described in workers exposed to isocyanates.[22,23,24,25] Currently, the prevalence of isocyanate–induced HP in the worker population is unknown, but is considered to be less common than isocyanate–induced asthma.[13] The initial symptoms associated with isocyanate–induced HP are flu–like, including shortness of breath, non–productive cough, fever, chills, sweats, malaise, and nausea.[12,13] After the onset of HP, prolonged and/or repeated exposures may lead to an irreversible decline in pulmonary function and lung compliance, and to the development of diffuse interstitial fibrosis.[12,13]

HDI Exposure Criteria

NIOSH and ACGIH have established full–shift TWA exposure criteria for the HDI *monomer* form at 35 micrograms per cubic meter ($\mu g/m^3$) and 34 $\mu g/m^3$, respectively. Applicable to the short–term air sampling data collected during this HHE, a NIOSH ceiling limit of 140 $\mu g/m^3$ is established for the HDI *monomer* form. There are no NIOSH, ACGIH, or OSHA exposure criteria for the HDI *polyisocyanate* form; however, a Swedish standard has adopted a ceiling limit of 200 $\mu g/m^3$. The United Kingdom Health and Safety Executive (UK–HSE) has taken a different approach by developing a non–specific exposure criteria of 70 $\mu g/m^3$ based on *total* diisocyanates in a volume of air.

RESULTS

Industrial Hygiene Results

Air Sampling

Table 1 contains the air sampling results for oxides of nitrogen. A full–shift PBZ air sample collected on a mechanic revealed full–shift TWA concentrations up to 0.24 ppm for NO and 0.13 ppm for NO_2. These concentrations were well below the NIOSH REL of 25 ppm for NO and the ACGIH TLV® of 3 ppm for NO_2, both as an 8–hour TWA. Area air samples collected on the first and third floors revealed full–shift TWA concentrations up to 0.73 ppm for NO and 0.33 ppm for NO_2. Four short–term area air samples collected on the first floor revealed 15–minute TWA concentrations for NO_2 up to 0.68 ppm, less than the NIOSH 15–minute STEL of 1 ppm. During winter months when the VMF's windows and overhead doors are normally closed, it is conceivable that short–term NO_2 concentrations on the first level could meet or exceed the NIOSH 15–minute STEL.

Presented in Table 2 are the results for isocyanate sampling. On August 28, five short–term PBZ air samples collected revealed painters' exposures to HDI *monomer* concentrations up to 6.1 $\mu g/m^3$, well below the NIOSH ceiling limit of 140 $\mu g/m^3$. Two of five short–term PBZ air samples collected revealed HDI *polyisocyanate* concentrations as high as 692 $\mu g/m^3$, above the Swedish ceiling standard of 200 $\mu g/m^3$. Four of five short–term PBZ air samples collected revealed exposures to *total* isocyanates (*monomer* plus *polyisocyanate*) as high as 349 $\mu g/m^3$, nearly five times the UK–HSE ceiling limit of 70 $\mu g/m^3$ developed for *total* isocyanates. An area air sample collected in the paint booth revealed a *total* HDI concentration of 33 $\mu g/m^3$. Only trace concentrations were measured at the entrance of the holding area, leading to the repair bay.

Ventilation Evaluation

Qualitative ventilation measurements indicate the two tail–pipe exhaust systems in the repair bay did not meet minimum airflow exhaust criteria recommended by ACGIH. The tail–pipe exhaust system on the south end had flexible ducts that provided average volumetric flow rates that ranged from 90 cfm to 222 cfm, and the flexible ducts for the tail–pipe exhaust system on the north end provided volumetric flowrates that ranged from 95 cfm to 283 cfm. Overall, only 2 of 25 flexible ducts provided more than 200 cfm as recommended by ACGIH to effectively control exhaust emissions generated by vehicles with greater than 200 horsepower engines. For diesel–powered vehicles ACGIH recommends volumetric flowrates may be as low as 50 cfm and up to 1500 cfm, depending upon whether vehicles have normal aspirated or turbo charged engines.

The inspection of the tail–pipe exhaust system revealed missing cone hoods, damaged flexible ducts, and inoperative crank–pulley mechanisms that discourage workers from using the system. Only two of six roof ventilators serving the repair bay were working during the evaluation.

Qualitative airflow measurements showed the entrances of both the paint booth and holding area to be under neutral pressure when the exhaust system was turned off and under strong negative pressure when turned on. It is desirable to have these work areas under negative pressure to prevent paint vapors from migrating to other work areas. Measurements in the dispatch office showed airflow to be under positive pressure. In this case, it is desirable to have the dispatch office under positive pressure to inhibit vehicle exhaust from entering the work space.

Other Findings

Paints and chemical supplies (e.g., lacquer) were improperly stored in employees' personal lockers, and a respirator and cartridges were improperly stored in a flammable storage cabinet along with chemical paint supplies. Four flammable storage cabinets onsite were not grounded in accordance with the National Fire Protection Association (NFPA) guidelines for fire prevention.

Painters were not wearing gloves for protection against dermal exposure to the isocyanate–containing paint, which could cause allergic contact dermatitis.

An emergency eyewash or shower station was not present in the general vicinity of the paint shop for quick water flushing in the event of accidental chemical splash to the face and eyes, as required by OSHA's General Industry standard (Code of Federal Regulations [CFR], Part 1910.151) for medical services and first–aid.

Medical Survey

A total of 77 people participated in the study, representing approximately 52% of the approximately 150 workers assigned to the VMF building. Thirty–eight (49% of participants) were auto maintenance workers including mechanics, auto painters, and auto body workers out of approximately 75 workers in these jobs. A total of 39 non–auto maintenance workers participated and included 20 office workers or clerks and 19 people who listed their occupation as "other" (managers, transportation operations supervisors, garagemen, and stockroom workers). The average age of the participants was 47 years (range 26–68). Employees had been working in the building for an average of 15 years and had been working in the same occupation an average of 12 years. Twenty–one workers (28%) reported that they sometimes or always wore a respirator, and nine workers (43% of those responding that they wore a respirator) said that the respirator worn was a disposable dust mask. Six workers (9% of the 71 workers who answered the question) reported that they had asthma, and two of those reported that their asthma was first diagnosed when they were an adult.

Sixty–two workers (81%), including workers in every job title, reported smelling some diesel exhaust during the day. Three (4%) reported smelling only gasoline exhaust, 2 (3%) smelled no exhaust odor, and 10 workers (13%) stated that they smelled an odor, but could not distinguish the diesel from the gasoline exhaust. Diesel exhaust was smelled by workers in all job titles at the plant, but was most predominantly reported by painters, body workers, and mechanics. (Table 3). Of those workers smelling diesel, 30 (48% of the 62 answering the question) reported smelling it for 8 hours a shift. With only five workers not smelling diesel (an "unexposed" group), it was impossible to assess relationships between health effects and diesel exposure from the questionnaire.

Thirty–five workers (47% of the 74 workers answering the question) reported "ever" smoking cigarettes, and 26 (34% of the 74 workers answering the question on smoking) reported smoking cigarettes "now." Eight workers (31% of the smokers) reported that they smoked a cigarette at work. No one presently smoked a pipe and six workers (8% of the 73 workers answering the question), smoked cigars. Workers in the maintenance area were statistically no more likely to smoke (31%) than other workers (37%) (p=0.5). Smoking was not related to the symptoms of chronic cough (p=0.6), wheezing (p=0.9), phlegm in the morning (p=0.8), or chest tightness (p=0.7), and was not considered in further analyses.

Thirteen workers (18% of the 74 workers answering the question) reported that they "usually" cough, with "usually" defined as four or more days during the week and ten reported that they cough as much as four to six times a day at least four days during the week. Seven (9% of 76 workers answering the question) met the definition of a chronic cough and included 2 maintenance workers, 3 office workers, and 2 "others." Thirty–five (49% of 71 workers answering the question) reported that they wheezed at some time during the day and 12 (16% of the 74 workers answering the question) reported having a cough with phlegm.

Forty–six workers in all job duties (64% of the 72 workers answering the question) reported smelling vehicle paint at the worksite (Table 4). Smelling vehicle paint vapors at the worksite was statistically significantly associated with respiratory symptoms including having chest tightness, phlegm in the morning, irritated eyes, and difficulty breathing (Table 5). Job title was not related to any symptom, with the exception of an association between chest tightness and auto body work (Table 6).

DISCUSSION

Industrial Hygiene

Air Sampling

During the HHE, site visit painting activities were reportedly slow and did not reflect a typical workload for painters. Some work–days may require up to eight hours of continuous spray painting. The workload during the HHE only required about two hours of painting and, consequently, air samples were not collected to assess painters' full–shift exposures to HDI. Instead, the focus of air sampling on painters was to assess their short–term exposures to HDI for 10–minute periods. Even for only two hours of painting, air sampling data demonstrate that elevated isocyanate concentrations can be generated in the paint booth, and give reason for using the supplied–air respirator present on–site.

Taking into consideration the protection factor afforded by using full–faced air–purifying respirators, painters' actual exposures to HDI are *theoretically* estimated at about 10 times less than the measured concentrations. However, because isocyanates have poor warning properties and breakthrough can occur from overloaded cartridges, using air–purifying respirators can give painters a false sense of protection.

There was concern about possible isocyanate exposures to workers outside the paint shop. Although air monitoring for isocyanates was not performed outside the paint shop, it is unlikely that workers outside the paint shop are exposed to the isocyanate–based paint for the following reasons:

in the paint shop only trace concentrations were measured at the entrance of the holding area (leading to the repair bay and other work areas);

when the wet scrubber exhaust system was turned on the paint shop was under negative pressure, which prevents air contaminants from migrating to other work areas; and

after air contaminants in the paint shop are exhausted to the roof outdoors, there is no logical pathway for them to re–entrain into the building.

Exhaust Ventilation Systems

With the paint shop's wet scrubber exhaust system in operation, qualitative ventilation measurements showed both the paint booth and holding area to be under negative pressure, meaning air flowed toward these areas, thus inhibiting paint vapors from migrating to the repair bay or other areas of the facility. However, because the holding area is directly adjacent to the repair bay area, the desired inward airflow could be adversely affected by expected exhaust ventilation repairs and improvements that could create cross–drafts. Therefore, airflow patterns within the paint shop should be re–evaluated following exhaust ventilation improvements in the repair bay. If it is discovered that the desired airflow in the paint shop is adversely affected by cross–drafts created by exhaust ventilation in the repair bay, a solution would be to install a sliding door (identical to one located at the paint booth entrance) at the threshold between the holding area and repair bay. The presence of a sliding door (when closed) would provide a means to isolate the entire paint shop during operation, and eliminate potential cross drafts created by exhaust systems in the repair bay.

The overall ventilation design of the VMF was good regarding the placement of exhaust terminals and outdoor air intakes. All exhaust terminals (located on the roof of the build) and outdoor air intakes were separated more than 50 feet, a rule of thumb often followed to avoid re–entrainment of vehicle exhaust and paint vapors into the building.

CO Monitoring System

The design specifications for the facility's CO monitoring system was not provided during the HHE. Obtaining the specifications were essential for further evaluating the adequacy of the system. Discussions with management and employees suggest there were design problems with the system's audible alarms with respect to the location of sensors. The presence of a CO monitoring system is an important preventive measure for garage environments to ensure CO levels do not pose health problems in the workplace.

Medical Survey

Although NIOSH investigators were asked to evaluate the effects of diesel exhaust on respiratory function, this study was not able to do so. Only five participants did not report smelling diesel exhaust, and there were not enough environmental measurements to categorize participant exposures, since there was no "unexposed" group. However, a clear relationship was shown between smelling vehicle paint and some symptoms. Whether such a relationship existed with diesel exhaust exposure as well could not be determined from the data obtained at the VMF.

The medical study had several limitations that should be noted. A major limitation of the study was that we did not have a very high participation rate in the survey. It is possible the those who participated were more likely to have symptoms than those who did not, which would cause us to overestimate the occurrence of symptoms among all employees. Another limitation of the survey was that we were dependent on self–reports of exposure to paint based on detecting the odor of paint, and not on measurements of the air levels of the paint. The odor threshold of the particular paint is not known, but would probably be dependent on the volatility of the solvents in the paint, since HDI is not as volatile as many organic solvents.[26] People with symptoms may be more likely than people without symptoms to report odors if they believe their symptoms are related to the chemical odors.

Another limitation is that at the time of the evaluation, the interior walls of the VMF were being painted using a latex–based paint. The isocyanate–based paint was only used in the paint shop, although during interviews workers stated they could tell the difference between the smell of the two paints. However, confounding from the latex paint was still possible and some workers may have reported smelling the latex–based paint as the isocyanate–based paint. The latex–based paint was only used for a short period of time before the NIOSH study, and was unlikely, however, to account for long–term respiratory symptoms. According to the paint MSDS, latex paints are predominantly irritants and can result in conjunctivitis, headache, irritation of the nose, throat, and lungs, and gastrointestinal irritation including nausea and vomiting. This contrasts with the isocyanate–based paint, which can result in sensitization or allergic reactions and asthma.

We did not conduct air monitoring for vehicle exhaust components during the winter months (when windows and overhead doors are normally closed to conserve heat). Workers informed us that working conditions and symptoms were worse at those times. Whether a health effect would be seen from exposure to diesel exhaust at that time is not known. Increased cough, labored breathing, chest tightness, and wheezing[27] have been associated with exposure to diesel exhaust in bus garage workers; increased phlegm production, irritation and reduced pulmonary function tests have been reported in other publications.[28]

CONCLUSIONS

NIOSH investigators concluded that a potential health hazard existed among painters using HDI–based paints when supplied–air respirators are not worn. Although short–term air sampling did not identify over–exposures to vehicle exhaust components (NO and NO_2), the tail–pipe exhaust system in the repair bay did not meet minimum airflow criteria and had missing and inoperative parts. Safety deficiencies were discovered that included the absence of an emergency eyewash near corrosive materials, improper storage of chemical supplies and respirators, and flammable storage cabinets not grounded for fire prevention.

RECOMMENDATIONS

Exhaust ventilation systems should be in good operating condition to minimize worker exposures to exhaust emissions (particularly diesel) in the workplace. Until a new tail–pipe exhaust system can be installed in the repair bay, the performance of

the existing system can be improved by replacing missing cone hoods and repairing damaged flexible ducts and broken crank–pulley mechanisms. A new tail–pipe exhaust system should also have the capacity to serve the 10 workstations at the far west end. Inoperative auxiliary roof ventilators should also be serviced to maximize exhaust ventilation. The design and performance specifications of newly installed exhaust systems should meet those recommended by ACGIH for vehicle ventilation. A qualified industrial ventilation professional should be consulted.

Consider installing a sliding door at the threshold between the holding area and repair bay to isolate the entire paint shop when in use, thus eliminating potential cross–drafts created by exhaust systems in the repair bay.

As with the paint manufacturer, NIOSH recommends using a supplied–air respirator—one is already available for the paint shop. However, when using a supplied–air respirator with a compressor several precautions (listed in Appendix) should be taken to ensure the safety of the user and the respirator's purifying performance. Management's written respiratory protection program should be updated to include these precautions. The use of air–purifying respirators is not recommended for protection against diisocyanates.[10] These substances are known to have poor warning properties, and breakthrough could occur from overloaded cartridges, thus exposing a painter.

Painters should be required to wear gloves for hand protection when using isocyanate–containing paint. Gloves made of neoprene or butyl rubber material offers protection against HDI skin absorption.

An emergency eyewash station should be installed (and plumbed to a tempered water supply) in the general vicinity of chemical processes. This is particularly true in the paint shop where there is the potential for workers to experience chemical splashes to the face or eyes. OSHA's medical and first aid standard requires the provision of suitable facilities within the work area for quick drenching or flushing of the eyes or body where a worker may be exposed to injurious corrosive materials.

Employees should be made aware to properly store paints and chemical supplies only in flammable liquid storage cabinets or in the designated chemical storage room of the paint shop. Flammable liquid storage cabinets present in the paint shop should be properly grounded for fire prevention as recommended by the manufacturer and in accordance with OSHA general industry regulation 29 CFR 1910.106. Also, respirators and cartridges should never be stored in flammable liquid storage cabinets.

Employee work practices can be improved by updating written safety procedures, communicating the importance of following safety procedures, and enforcement by line supervisors. Placards posted in work areas may be beneficial to emphasize safe work practices.

Communication between VMF management should be improved so that employees feel free to report non–functioning personal protective equipment or ventilation systems that are essential to maintaining employee health. These issues can be discussed during safety meetings and briefings.

REFERENCES

1. Hathaway G, Proctor N, Hughes J [1996]. Chemical Hazards of the Workplace, Fourth Edition. Philadelphia, PA: JB Lippincott. Fishman ML.

2. NIOSH [1994]. NIOSH manual of analytical methods, 4th ed. Cincinnati, OH: U.S. Public Health Service, Public Health Service, Centers for Disease Control and Prevention, the National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

3. Lesage J and Perrault G. Sampling device for isocyanates, U.S. Patent # 4,961,916.

4. Ferris BG [1978]. Epidemiology standardization project. American Review of Respiratory Disease 118(6).

5. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92–100.

6. ACGIH [1999]. 1999 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental industrial Hygienists.

7. Code of Federal Regulations [1997]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

8. Public Law 91–596. Occupational Safety and Health Act of 1970, Sec. 5.(a)(1).

9. NIEHS [1993]. Environmental health perspectives supplements: health effects of gasoline. Research Triangle Park: U.S. Department of Health and Human Services, National Institutes of Health, National Institute for Environmental Health Sciences, DHHS (NIH) Publication No. 93–218.

10. NIOSH [1978]. Criteria for a recommended standard: occupational exposure to diisocyanates. Cincinnati, OH: U.S. Dept. of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78–215.

11. NIOSH [1990]. Pocket guide to chemical hazards. Cincinnati, OH: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90–117.

12. NIOSH [1986]. Occupational respiratory diseases. Cincinnati, OH: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86–102.

13. Levy BS, Wegman DH (editors) [1988]. *Occupational Health: Recognizing and Preventing Work–Related Diseases*. Second Edition. Boston/Toronto: Little, Brown and Company.

14. Porter CV, Higgins RL, Scheel LD [1975]. A retrospective study of clinical, physiologic, and immunologic changes in workers exposed to toluene diisocyanate. American Industrial Hygiene Association Journal 36: 159–168.

15. Chan Yeung M, Lam S [1986]. Occupational asthma. American Review of Respiratory Disease 133: 686–703.

16. NIOSH [1981]. Technical report: respiratory and immunologic evaluation of isocyanate exposure in a new manufacturing plant. Cincinnati, OH: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81–125.

17. McKay RT, Brooks SM [1981]. Toluene diisocyanate (TDI): biochemical and physiologic studies. American Review of Respiratory Disease 123: 132.

18. Karol MH, Hauth BA, Riley EJ, Magreni CM [1981]. Dermal contact with toluene diisocyanate (TDI) produces respiratory tract hypersensitivity in guinea pigs. Toxicology and Applied Pharmacology 58:221–230.

19. Erjefalt I, Persson CGA [1992]. Increased sensitivity to toluene diisocyanate (TDI) in airways previously exposed to low doses of TDI. Clinical and Experimental Allergy 22:854–862.

20. Rattray NJ, Bothman PA, Hext PM, Woodcock DR, Fielding I, Dearman RJ, Kimber I [1994]. Induction of respiratory hypersensitivity to diphenylmethane–4,4'–diisocyanate (MDI) in guinea pigs. Influence of route of exposure. Toxicology 88:15–30.

21. Bickis U [1994]. Investigation of dermally induced airway hyperreactivity to toluene diisocyanate in guinea pigs. Ph.D. Dissertation, Department of Pharmacology and Toxicology, Queens University, Kingston, Ontario, Canada.

22. Baur X, Dewair M, Rommelt H [1984]. Acute airway obstruction followed by hypersensitivity pneumonitis in an isocyanate (MDI) worker. Journal of Occupational Medicine 26:285–287.

23. Yoshizawa Y, Ohtsuka M, Noguchi K, Uchida Y, Suko M, Hasegawa S [1989]. Hypersensitivity pneumonitis induced by toluene diisocyanate: sequelae of continuous exposure. Annals of Internal Medicine 110: 31–34.

24. Selden AI, Belin L, Wass U [1989]. Isocyanate exposure and hypersensitivity pneumonitis—report of a probable case and prevalence of specific immunoglobulin G antibodies among exposed individuals. Scandinavian Journal of Work, Environment and Health 15:234–237.

25. Vanderplas O, Malo JL, Dugas M, Cartier A, Desjardins A, Levesque J, Shaughnessy MA, Grammar LC [1993]. Hypersensitivity pneumonitis–like reaction among workers exposed to diphenylmethane diisocyanate (MDI). American Review of Respiratory Disease 147: 338–346.

26. NIOSH [1994]. NIOSH Pocket Guide to Chemical Hazards. Cincinnati, OH: U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety, DHHS (NIOSH) Publication No. 94–116.

27. Morgan WK, Reger RB, Tucker DM [1998]. Health effects of diesel emissions. Annals of Occupational Hygiene 41(6):643–658.

28. Gamble J, Jones W, Minshall S [1987]. Epidemiological–environmental study of diesel bus garage workers: chronic effects of diesel exhaust on the respiratory system. Environmental Research 44, pp 6–17.

Table 1
Air Sampling Results for
Oxides of Nitrogen
U.S. Postal Service Vehicle Maintenance Facility
August 27, 1998

Sample Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Concentration, parts per million (ppm)	
				Nitric Oxide	Nitrogen Dioxide
Area – center of 1st floor	15	0.200	3	NS	0.39
Area – center of 1st floor	15	0.200	3	NS	0.68
Area – center of 1st floor	15	0.200	3	NS	trace
Area – center of 1st floor	15	0.200	3	NS	trace
Area – center of 1st floor	472	0.05	23.6	0.73	0.33
Mechanic – 3rd level	467	0.05	23.4	0.24	0.13
Mechanic – 3rd level	433	0.05	21.7	trace	trace
Area – center of 3rd level	436	0.05	21.8	0.27	0.12
Minimum Detectable Concentration (MDC)†				0.016	0.018
Minimum Quantifiable Concentration (MDQ)†				0.07	0.045
Exposure Criteria (expressed in parts per million)					
NIOSH Recommended Exposure Limit (REL); as 8–hr. TWA				25	NA
NIOSH 15–minute STEL				NA	1
OSHA Permissible Exposure Limit (PEL); as 8–hr. TWA				25	5
ACGIH Threshold Limit Value (TLV)®				25	3

Abbreviations:
NS = not sampled
NA = no available exposure criteria
PBZ = personal breathing–zone
† = assuming a 23.6 liter sample
trace = concentration is between the MDC and MQC

Table 2
Air Sampling Results for 1,6–Hexamethylene Diisocyanate
U.S. Postal Service Vehicle Maintenance Facility
August 28, 1998

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (liters per minute)	Sample Volume (liters)	Hexamethylene Diisocyanate (HDI) Concentration, expressed in µg/m³		
				HDI–Based Polyisocyanate	HDI–Based Monomer	Total Isocyanates
PBZ – Painter	10	2	20	27	2	15
PBZ – Painter	10	2	20	692*	5	346*
PBZ – Painter	10	2	20	169	6	88*
PBZ – Painter	10	2	20	151	2	77*
PBZ – Painter	10	2	20	244*	4	124*
Area sample – Paint Booth	30	2	60	64	4	34
Area sample – Holding Area	30	2	60	trace	trace	trace
Minimum Detectable Concentration (MDC)†				0.017	0.17	0.09
Minimum Quantifiable Concentration (MQC)†				0.05	0.5	0.28
Exposure Criteria – Short Term or Ceiling Limits (expressed in* µg/m³*)						
NIOSH REL – Ceiling				none	140	none
UK–HSE – Ceiling				N\A	N\A	70
Swedish–Ceiling				200	N/A	none

Abbreviations:

µg/m³	=	micrograms per cubic meter
REL	=	recommended exposure limit
UK–HSE	=	United Kingdom Health and Safety Executive
PBZ	=	personal breathing–zone
N/A	=	no available criteria
†	=	assuming a 60 liter sample
trace	=	concentration is between the MDC and MDQ
*	=	exceeded exposure criteria

Table 3
Job Title and Self– Reported Smelling of Diesel Exhaust
United States Post Office
Chicago, Illinois
August 26–28, 1998

Job Title	number (#) of workers responding	# smelling no exhaust	# Smelling mostly gasoline exhaust	# Smelling mostly diesel exhaust	# of workers at a particular job who smelled diesel and gas exhaust equally	# of workers at a particular job who smelled either mostly diesel exhaust or diesel and gas exhaust equally	% of workers with a specific job who smelled either diesel exhaust or diesel and gas exhaust equally
Painter	3	0	0	0	3	3	100
Body worker	7	0	0	4	3	7	100
Mechanic	27	1	0	5	21	26	96
Office worker	20	0	2	5	6	11	55
Other*	19	0	1	3	12	15	79

* includes garagemen, supervisors of transportation operations, stockroom workers, and managers

Table 4
Job Title and Self–Reported Smelling of Vehicle Paint
United States Post Office
Chicago, Illinois
August 26–28, 1998

Job Title	Number of workers responding	# Smelling auto paint	% of workers who smelled auto paint with that job title
Painter	3	3	100%
Body worker	7	5	71%
Mechanic	26	17	65%
Office worker	17	9	53%
Other	19	12	63%

Table 5
Symptoms Related to Reporting Smelling Vehicle Paint,
United States Post Office
Chicago, Illinois
August 26–28, 1998

Symptom	Number of Workers With Symptom	Percent of workers who smelled paint and reported symptom	Odds Ratio	95% confidence Interval
Chest tightness	18	89	7.1	1.5–34.2
Difficulty breathing	17	82	4.1	1.0–16.2
Irritated Eyes	38	76	3.9	1.3–11.2
Phlegm in the morning	21	81	3.7	1.1–12.8
Chronic cough	6	83	3.0	0.3–27.6
Cough with phlegm	12	83	3.2	0.7–16.4
Shortness of breath while hurrying on level ground	22	77	2.6	0.8–8.3
Wheezing	35	71	1.9	0.7–5.1
Phlegm during the day or at night	17	71	1.5	0.6–3.7

Table 6
Symptoms By Job Title
United States Post Office
Chicago, Illinois
August 26–28, 1998

Symptom	Painter		Body worker		Mechanic		Office worker		Other		p value*
	# of workers with symptom	% of workers with symptom	# of workers with symptom	% of workers with symptom	# of workers with symptom	% of workers with symptom	# of workers with symptom	% of workers with symptom	# of workers with symptom	% of workers with symptom	
Chest tightness	0	0	4	80	4	15	6	30	5	26	0.05**
Irritated Eyes	2	66	5	71	10	42	10	50	11	65	0.5
Difficulty breathing	0	0	2	33	6	27	5	25	5	20	0.9
Phlegm in the morning	0	0	1	17	8	33	7	35	7	41	0.6
Chronic cough	0	0	0	0	2	7	3	15	2	11	0.9
Wheezing	0	0	2	29	12	44	11	55	11	58	0.3
Shortness of breath while hurrying on level ground	0	0	2	33	6	24	10	50	6	32	0.3

* the “p” value indicates whether there is a difference between the prevalence of the symptom among the different jobs.
** there is an excess of chest tightness in body workers, 1 was expected and 4 were found

Appendix
Cautions in the Use of Supplied–Air Respirator

Source:
NIOSH Guide to Industrial Respiratory Protection[a]

The compressor intake should be properly located to intake ordinary uncontaminated ambient air.

The compressor intake should be remotely located from the compressor and all possible mobile exhausts to ensure that carbon monoxide is excluded from the intake. The intake should be remotely plumbed to a safe position at each worksite.

The compressor intake should be located to ensure that air with normal ambient air oxygen content (19.5%–23.5) is always available.

A continuous carbon monoxide monitor and alarm should be installed and functioning in the compressor output breathing air stream.

Air supply hose or lines should be restrained every 15 feet of their length.

Use compressor oil suitable for use in breathing applications.

The recommendations for oil suitable for use in compressors for breathing air applications should only be made by the compressor or breathing air system manufacturer.

[a] NIOSH [1987]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87–116.

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh

National Institute for Occupational Safety and Health

Delivering on the Nation's promise:
! Safety and health at work for all people through research and prevention