NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2003-0209-3015
Diversified Roofing Inc.
Phoenix, Arizona

November 2006

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the 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 employers 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.

HETAB 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 Ronald Sollberger, Judith Eisenberg, Randy Tubbs, Chandran Achutan, Robert McCleery, and Charles Mueller of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Walter Alarcon, Carlos Aristeguieta, and Manuel Rodriguez of DSHEFS; Diana Freeland, David Spainhour, and Jim Taylor of the Division of Respiratory Disease Studies (DRDS); Kevin Ashley of the Division of Applied Research and Technology (DART); and Maria Lioce-Mata of the NIOSH Office of the Director. Review of spirometry results was provided by Paul Enright of DRDS. Interpretation of x-rays was provided by Lee Petsonk and Anita Wolfe of DRDS. Mobile x-ray equipment was provided by Professional Health Services (Havertown, Pennsylvania). Analytical support was provided by Data Chem Laboratories, Inc., (Salt Lake City, Utah). Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

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.

Highlights of the NIOSH Health Hazard Evaluation

NIOSH received a request for a health hazard evaluation (HHE) from the Roofers Union Local 135 to evaluate exposures to dust during saw cutting of cement tile among employees of Diversified Roofing Inc., Phoenix, Arizona. In addition, employee exposures to noise and carbon monoxide were evaluated and employees were screened for silicosis during site visits in April and June 2003, and February 2005.

What NIOSH Did

- We collected samples of cement tile dust, ran spot checks on noise and carbon monoxide (CO) levels, and gathered data on dust particle size.
- We measured the levels of exposure to dust, silica, CO, and noise.
- We asked employees questions about their work, use of personal protective equipment (PPE), and health symptoms.
- We screened employees from Diversified Roofing and three other Phoenix roofing contractors for silicosis using a medical questionnaire, lung function testing, and chest x-ray.

What NIOSH Found

- All employees could be overexposed to silica and noise.
- Employees rarely wore hearing protection or respirators, which were not mandatory.
- Employees were not aware of the workplace hazards.
- Most roofers who participated in the medical screening had normal lung function.
- Of those with abnormal lung function, none had moderate or severe impairments.
- Lung function decreased with increasing years of performing dry-cutting of cement tiles.
- No chest x-rays showed findings consistent with silicosis.

What Diversified Roofing Inc. Managers Can Do

- Establish engineering controls such as local exhaust ventilation and work practice controls to reduce airborne silica levels.
- Implement a mandatory respiratory protection program until controls are in place and proven effective.
- Develop and enforce a hearing conservation program.
- Conduct environmental monitoring to ensure that dust control measures are effective.
- Provide training on workplace hazards, use of PPE, and dust control measures.
- Implement OSHA-mandated silica medical surveillance protocols.

What Diversified Roofing Inc. Employees Can Do

- Use dust control measures.
- Use respirators and hearing protection when required.
- Tell management about health and safety concerns.
- Attend training programs provided by the company.
- Tell your doctor that you might be exposed to respirable silica at work and contact him/her right away if you develop shortness of breath or cough.

CDC Workplace Safety and Health

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 Final Report #2003-0209-3015

NIOSH

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SUMMARY

On March 31, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the United Union of Roofers, Waterproofers, and Allied Workers Local 135 at Diversified Roofing Inc. in Phoenix, Arizona. The request stated that employees were exposed to hazardous levels of dust, particularly crystalline silica, while cutting cement tiles. A concern was also raised about the lack of training and use of personal protective equipment.

An initial site visit was conducted on April 29-30, 2003. This visit included observations of the tile cutting process, collection of bulk samples of tile dust, and spot measurements of dust, noise, and carbon monoxide (CO) levels. A second site visit was conducted on June 16-18, 2003. Respirable and total dust, respirable silica, noise, and CO were monitored on employees performing roof installation. All employees who were monitored were asked questions on general health symptoms, work practices, and use of personal protective equipment.

Eight full-shift personal noise samples, eight full-shift personal breathing zone (PBZ) air samples for CO, sixteen full-shift PBZ air samples for respirable dust and silica, and nineteen full-shift PBZ air samples for total dust were collected over the 2 days. The noise exposure results showed that all of the employees' exposures were over the NIOSH Recommended Exposure Limit (REL), 63% (5 of 8) exceeded the Occupational Safety and Health Administration (OSHA) Action Level, and 38% (3 of 8) were over the OSHA Permissible Exposure Limit (PEL) for noise. The CO exposure results showed that all of the employees' exposures were below the REL time-weighted average; one employee's exposure exceeded the NIOSH ceiling level. The respirable silica (quartz) exposure results showed that 88% (14 of 16) of the employees' levels exceeded the NIOSH REL and American Conference of Governmental Industrial Hygienists threshold limit value, and 75% (12 of 16) exceeded the OSHA PEL for respirable silica. The total dust exposures ranged from 0.68 milligrams per cubic meter (mg/m^3) to 13 mg/m^3. The respirable dust exposures ranged from 0.23 mg/m^3 to 2.3 mg/m^3.

During the initial site visit informal employee interviews revealed that the duration of employment ranged from a few weeks to 7 years. Most of the employees reported wearing hard hats and eye protection

regularly; respirators and hearing protection were infrequently worn. None of the employees reported that they knew the hazards of silica overexposure even though some employees reported respiratory symptoms consistent with silica overexposures, such as difficulty breathing and/or cough.

A follow-up visit was conducted February 22-24, 2005, to perform the medical screening component of the HHE. Employees were invited to participate if they had at least 5 years experience as a roofer. Duration of dry cutting was used as a marker for duration of respirable silica exposure. The medical screening included a questionnaire, lung function test (i.e., spirometry), and a chest x-ray. NIOSH personnel read the questionnaire aloud to participants in their primary language. Spirometry results were reviewed by a NIOSH pulmonologist. The chest x-rays were interpreted by NIOSH certified B-readers according to the standards set forth by the International Labor Organization for grading work-related lung disease chest x-rays.

Most roofers who participated in the medical screening had normal lung function. Of those with abnormal lung function, none had moderate or severe impairments. After controlling for the effects of smoking, it was found that lung function decreased with increasing years of dry cutting cement tiles. No chest x-rays showed findings consistent with silicosis. Previous air sampling confirmed that all employees on the roof when tile cutting was occurring could be overexposed to respirable silica, placing them at risk for silicosis.

It is vital to institute OSHA-mandated employee protection programs to protect workers from further exposure to respirable silica. Employee monitoring for silicosis should also be started as per the recommendations set forth in OSHA's Special Emphasis Project for Silicosis.

NIOSH investigators determined that an occupational health hazard due to exposures to respirable silica and noise existed for workers at Diversified Roofing Inc. Recommendations for controlling workplace exposures include reducing or eliminating exposures by implementing engineering controls and enforcing the use of personal protective equipment under the OSHA respirator program guidelines. Employees need education regarding the potential health hazards of respirable silica exposure, and an employee monitoring program as per the OSHA Special Emphasis Program on silica should be implemented. Additional recommendations are included at the end of this report.

Keywords: NAICS 238160 (Roofing Contractors), respirable silica, silicosis, roofers, dust, lung function, noise, carbon monoxide

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INTRODUCTION

On March 31, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Union of Roofers, Waterproofers, and Allied Workers Local 135 to conduct a health hazard evaluation (HHE) at Diversified Roofing Inc. in Phoenix, Arizona. The request stated that during cutting of cement tiles there was concern that employees were exposed to hazardous levels of dust, including crystalline silica. Another issue regarded the Union's concern that inexperienced employees were inadequately protected from dust because of Diversified's voluntary respirator program.

On April 29, 2003, NIOSH investigators conducted an initial survey at a work site located at the Anthem Country Club in Anthem, Arizona, a construction site where Diversified employees were working. At that time, dust, noise, and carbon monoxide (CO) measurements were taken using direct-reading instrumentation during tile cutting operations in the work area. In addition, bulk samples of tile dust were taken to determine the percent silica content. A copy of Diversified's written respiratory protection program was obtained for review.

A second site visit was made on June 16-19, 2003. On June 16, 2003, NIOSH representatives and union officials went to the worksite at the Anthem Country Club to select locations for environmental monitoring. The locations included houses that had tile cutting ongoing throughout the entire work shift. On June 17 and 18, 2003, employees installing tile roofs on three houses were monitored for exposures to respirable and total dust and silica, and employees working on another house were monitored for noise and CO exposures. These employees were also asked questions to gather information on their use of personal protective equipment (PPE), understanding of hazards, and health symptoms they may have been experiencing.

The medical screening component of this HHE was completed on February 22-24, 2005. All participants completed a medical questionnaire, spirometry, and chest x-ray. This report includes environmental and medical findings for Diversified Roofing Inc. and group medical findings for all roofers evaluated by NIOSH in a series of health hazard evaluations that investigated roofer exposure to respirable silica during dry cutting of cement roofing tiles at four Phoenix area roofing contractors of which Diversified was one.

BACKGROUND

Diversified Roofing Inc. provides roofing installation services to residential and commercial properties in the greater Phoenix area. The company employs 375-400 workers. Although Diversified was a unionized shop at the time of the HHE request, that relationship ended in 2005. Spanish is the primary language for many employees.

The employees are organized in crews of three to five, typically consisting of a foreman, a "second man," and laborers, cutters, and drivers. The work shift is typically 6:00 a.m. to 3:00 p.m. for 5 to 6 days per week, but may start and end earlier during the summer. The roof installation includes three phases: the first is laying sticks and paper on the roof, the second is setting the tiles by stacking them in various areas of the roof, and the third is cutting and nailing the tiles in place. The tiles come in various colors and can be molded to look like wood shingles. They may be barrel-shaped or S-shaped, or made of slate (the job site had the slate shaped tiles that were "uncolored," which is actually a tan-brown color). At least one hand-held gas-powered cutting saw is used per crew. Generally the foreman or the second man cuts the tile while the laborers and drivers lay and nail the tiles in place. Dust is generated during the cutting of tiles to fit for size at the channels and valleys on the roof, at cupolas or turrets, and at the ends of the roof. At the completion of the roof installation, a cleanup of the roof is done by using a gas-powered leaf blower to remove dust and debris from the tiles, also creating dust exposures to the employees for short periods of time. Approximately 800 roofs are installed per month at the Anthem Country Club, and roof installation has been estimated to continue at this location until the year 2008.

Personal air monitoring for silica exposure was conducted in 1999 by a private consulting firm; the results showed that levels of respirable dust and silica during tile cutting were below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL). Based on these results, the company did not require the use of respiratory protection; use and purchase of respirators was the personal decision of each employee.

METHODS

Initial Site Visit (April 2003)

Bulk Sampling

Two bulk samples of tile dust were taken from both houses visited on the initial site visit. The samples were analyzed for silica (quartz and cristobalite), using x-ray diffraction, per NIOSH Manual of Analytical Methods (NMAM) Method 7500.[1]

Particulate Sampling

Real-time sampling for airborne particulates was conducted with an optical particle counter (OPC) (GRIMM Technologies, Inc.). The instrument operates at a flow rate of 2 liters per minute (Lpm), and is able to measure particle sizes ranging from 0.23 to greater than 20 micrometers (µm). Data are integrated over one-minute intervals and stored on a card that can be downloaded to a computer.

Data were collected to monitor the particulates generated by distinct events during roofing tile cutting and clean-up on top of newly constructed houses. The measurements were collected in the general vicinity of the worker's breathing zone. Start and stop times for significant operations were recorded during each sample collection period. The data collected revealed information on the mass distribution of particles, which is reported as a concentration in milligrams of particulate per cubic meter of air (mg/m^3). Estimates were made of the mass median aerodynamic diameter (MMAD) and the associated geometric standard deviation (GSD) based on the integrated particle size discrimination provided by the instrument. The density of the roofing tile particulate was assumed to be 1.0 gram per cubic centimeter (g/cm^3).

Carbon Monoxide and Noise Sampling

Carbon monoxide levels were measured with a Biometrics, Inc., ToxiUltra Single Sensor Gas Detector with a CO sensor. The instrument was placed in the employee's shirt pocket during tile cutting and when using the leaf blower. Noise levels were measured with a Quest® Technologies Model 215 sound level meter set on the A-scale, slow response. The instrument was held near the employee's ear during tile cutting and clean-up with the leaf blower.

Second Site Visit (June 2003)

Sampling Strategy

The sampling strategy consisted of selecting four home sites each day, where employees would be cutting and laying tiles throughout the day. On three of the houses, simultaneous personal air samples (samples collected in the breathing zone of employees) were collected for total and respirable dust. On the fourth house, employee exposures to noise and CO were evaluated simultaneously.

Simultaneous personal air samples for total and respirable particulate were collected and analyzed per NIOSH Methods 0500 and 0600[1], respectively. Samples were collected on 37-mm, 5-µm polyvinyl chloride (PVC) filters, at a flow rate of 1 to 2 Lpm for total particulate, and 1.7 Lpm using a 10-mm nylon cyclone sampler for respirable particulate. Samples were analyzed gravimetrically. In addition, the respirable samples were analyzed for silica content by x-ray diffraction using NIOSH Method 7500.[1]

Personal air samples were collected for CO using ToxiUltra CO monitors, which were calibrated before and after use according to the manufacturer's recommendations. The instruments were operated in the passive diffusion mode, with a 60-second sampling interval and a nominal range from zero to 500 parts per million (ppm).

Noise

Quest® Technologies Model Q-300 Noise Dosimeters were used to collect the daily noise exposure measurements from the roofers who volunteered for the NIOSH evaluation. The dosimeter was secured on the employees' belts and the dosimeter's microphone attached to their shirts, halfway between the collar and the point of their shoulder. A windscreen provided by the dosimeter manufacturer was placed over the microphone during recordings. The dosimeters were worn by the roofers for their entire work shift. The noise information was downloaded to a personal computer for interpretation with QuestSuite® Professional computer software and the dosimeters were reset for the next day. The dosimeters were calibrated before and after the work shift according to the manufacturer's instructions.

Employee Interviews

Employees were informally asked questions about their job, health symptoms, and PPE use. Twenty-four of the twenty-five employees who participated in the personal exposure monitoring survey participated in the interviews; one employee chose not to be interviewed.

Medical Screening (February 2005)

A follow-up visit was conducted February 22-24, 2005, to perform medical screening. Employees were initially recruited during January 2005 visits. Recruitment flyers in English and Spanish were distributed to all workers present. These flyers explained the purpose of the medical screening and recruited workers with at least 5 years of work experience as a roofer cutting cement roofing tiles. This criterion was chosen based on initial exposure data that indicated levels of respirable silica that could pose a risk for the development of chronic silicosis.

The medical screening consisted of a medical questionnaire, spirometry and chest x-ray. Informed consent was obtained from all participants in their primary language. To address language and literacy issues, NIOSH personnel read the questionnaire aloud in the participant's primary language. The medical questionnaire covered past medical, occupational, and smoking history; symptoms that could be consistent with silicosis or other conditions that have been associated with silicosis; and previous medical evaluations.

Spirometry, or lung function testing, was conducted by NIOSH certified spirometry technicians. Spirometry is a form of lung function testing that measures multiple parameters of an exhaled breath which are then compared to an expected set of values for a participant's age, gender, height, weight and ethnicity. The two spirometry parameters measured were the FEV1, the forced exhaled volume in one second, and the FVC, the forced vital capacity. The absolute values of the FEV1 and FVC along with their ratio are used to classify findings into obstructive, restrictive, or mixed patterns of lung function. Obstructive patterns are found in diseases such as chronic bronchitis when mucus physically blocks the inside of the airways. Restrictive patterns are found in conditions that prevent full inflation of the lungs as in the case of morbid obesity or fluid in the space between the lungs and the chest cavity.

Participants were coached in their primary language on how to properly perform the exhalation required for this test. Real-time computer displays of each exhalation curve ensured that the runs were technically adequate for interpretation. Computer interpretations of the exhalation curves were reviewed by a NIOSH pulmonologist.

Chest x-rays were performed by technicians with mobile x-ray equipment supplied by Professional Health Services. All x-rays were interpreted by NIOSH certified B-readers in a median read protocol. B-readers are physicians who pass a proficiency test every 4 years to demonstrate the ability to correctly grade work-related lung disease chest x-rays in accordance with the standardized set of films produced by the International Labor Organization in Geneva, Switzerland. Each x-ray was read by two B-readers. If their interpretation differed, the film was given to a third B-reader, and the final interpretation was taken as the majority opinion.

The data from the medical screening component were analyzed in two ways. The first analysis involved only data from Diversified employees. The second analysis used the combined data from employees of all four contractors. Results include descriptive statistics as well as linear regression analysis which examined the relationship between years of dry cutting cement tiles and lung function while controlling for any effects of smoking. SAS Version 9.1.3 (Cary, North Carolina) was used for all statistical analyses.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employs 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 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),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, OSHA PELs.[4] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

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 [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. 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.

Silica (Quartz, Cristobalite)

Silica, or silicon dioxide (SiO_2), occurs in a crystalline or non-crystalline (amorphous) form. In crystalline silica, the SiO_2 molecules are oriented in a fixed pattern versus the random arrangement of the amorphous form. The more common crystalline forms in workplace environments are quartz and cristobalite, and to a lesser extent, tridymite. Occupational exposures to respirable crystalline silica (quartz and cristobalite) have been associated with silicosis, lung cancer, pulmonary tuberculosis, and airway diseases. Silicosis is a fibrotic disease of the lung caused by the deposition of fine crystalline silica particles in the lungs. It is the disease most often associated with exposure to respirable crystalline silica. This lung disease, which is sometimes asymptomatic, is caused by the inhalation and deposition of respirable crystalline silica particles that are 10 µm or less in diameter. Particles 10 µm or below are considered respirable particles and classified as having the potential to reach the lower portions of the human lung (alveolar region). Although particle sizes 10 µm and below are considered respirable, the human body and its clearance mechanisms are capable of deposition of a certain portion of these sizes before they reach the alveolar region.[5] Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure (chronic), but may appear in a shorter period of time (acute) if exposure concentrations are very high. Acute silicosis is typically associated with a history of high exposures from tasks that produce small particles of airborne dust with a high silica content.[6] Even though the carcinogenicity of crystalline silica in humans has been strongly debated in the scientific community, the International Agency for Research on Cancer (IARC) in 1996 concluded that there was "sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources."[7] A NIOSH publication also lists several other serious diseases from occupational exposure to crystalline silica. These include lung cancer and non-carcinogenic disorders including immunologic disorders and autoimmune diseases, rheumatoid arthritis, renal diseases, and an increased risk of developing tuberculosis after exposure to the infectious agent.[8]

The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 0.05 mg/m^3, as TWAs, for up to 10 hours per day during a 40-hour work week.[2] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen, and NIOSH is currently reviewing the data on carcinogenicity.[8] The OSHA PEL for respirable quartz for an 8-hour TWA is based on calculating the percent of quartz in each respirable dust sample using the following formula: PEL = 10 mg/m^3 ÷ (% quartz + 2).[4] For cristobalite, it is one-half the value calculated from the respirable dust formula for quartz. The ACGIH TLVs for respirable quartz and cristobalite are 0.025 mg/m^3 as 8-hour TWAs.[3]

Noise

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.[9] 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.[10]

The A-weighted decibel (dBA) is the preferred unit for measuring sound levels to assess worker noise exposures. The dBA scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. 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. Because the dBA scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and hundredfold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean. A TWA exposure refers to the average noise exposure during a normal 8-hour workday.

The OSHA construction standard for occupational noise exposure (29 CFR 1926.52)[11] stipulates that a worker can be exposed to a maximum PEL of 90 dBA for 8 hours per day. Times permitted at noise levels from 90 to 115 dBA are given in Table D-2 of the standard. These levels are based on a 5 dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dBA for no more than 4 hours, to 100 dBA for 2 hours, etc. The standard provides a formula to calculate the equivalent noise exposures for conditions where noise levels vary throughout the day:

F(e) = (T(1)divided by L(1))+(T(2)divided by L(2))+ ... + (T(n) divided by L(n)) where:

F(e) = the equivalent noise exposure factor,

T = the period of noise exposure at any essentially constant level,

L = the duration of the permissible noise exposure at the constant level (Table D-2).

If the value of F(e) exceeds unity (1) the exposure exceeds permissible levels. When noise levels exceed the PEL, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment shall be provided and used to reduce sound levels to less than permissible levels.[12]

In August 2002, OSHA published an advance notice of proposed rulemaking on a hearing conservation program for construction workers.[13] In the notice, OSHA is considering rulemaking to revise the construction noise standards to include a hearing conservation component for the construction industry that provides a similar level of protection to that afforded to workers in general industry. The OSHA general industry standard for occupational exposure to noise (29 CFR 1910.95)[14] also specifies a maximum PEL of 90 dBA for 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity exchange rate. 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 Table G-16a of the OSHA general industry noise regulation. 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 general industry regulation has an additional action level (AL) of 85 dBA; an employer shall administer a continuing, effective hearing conservation program when the 8-hour TWA value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o). In conclusion, the OSHA noise standard states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dBA, feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. NIOSH, in its Criteria for a Recommended Standard,[15] and the ACGIH[3] propose exposure criteria of 85 dBA as a TWA for 8 hours, 5 dB less than the OSHA standard. The criteria also use a more conservative 3 dB time/intensity trading relationship in calculating exposure limits. Thus, a worker can be exposed to 85 dBA for 8 hours, but to no more than 88 dBA for 4 hours or 91 dBA for 2 hours. Twelve hours exposures have to be 83 dBA or less according to the NIOSH REL. Like the

PEL, a worker is allowed a daily noise dose of up to 100% during a 24-hour period under these criteria.

Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless gas that can be a product of the incomplete combustion of organic compounds. Carbon monoxide combines with hemoglobin and interferes with the oxygen-carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death. The NIOSH REL for CO is 35 ppm for up to a 10-hour TWA. NIOSH also recommends a ceiling limit of 200 ppm that should not be exceeded at any time during the workday. The OSHA PEL for CO is 50 ppm for an 8-hour TWA. The ACGIH TLV for CO is 25 ppm as an 8-hour TWA.[3]

Animal studies have demonstrated that CO potentiates noise-induced hearing loss (NIHL) when there is a simultaneous exposure to noise and CO that results in a greater NIHL than for noise exposure alone. Carbon monoxide reduces oxygen supply to tissues, and acute exposure to high-level CO can cause temporary hearing loss at high frequencies. If CO exposure reduces or abolishes the recovery process during a rest period between noise phases, these rest periods will no longer be of any benefit to the ear, and hearing loss will persist. If the combined exposure induces cellular damage that cannot be recovered, the rest periods between the noise phases will also not be of any benefit.[15] The potentiation of NIHL by CO appears to saturate as noise severity is increased such that at the most severe conditions used, the effects of CO on NIHL are obscured totally by the noise effect.[16,17,18]

RESULTS

Initial Site Visit (April 2003)

Bulk Samples

Results of the two bulk samples of tile dust showed that they contained 18% and 19% quartz. Neither sample contained cristobalite.

Particle Size Analysis

The MMAD value indicates the diameter at which half of the total mass of particles is larger and half is smaller. Monitored tasks had MMADs of 9 µm or larger. This indicates that the particles generated are at the upper end of the potential respirable range and have a better chance of being removed from the air stream before entering the alveolar region. The respirable mass fractions reflect the percentage of total mass in the respirable range, less than 10 µm. The respirable mass fractions ranged from 11% to 17%.

The total particulate concentration measured with the OPC while an employee was cutting roofing tiles in a roof valley was 100 mg/m^3. The MMAD was graphically estimated at 9.0 µm with a GSD of 2.4. The respirable mass fraction of the sample mass was approximately 17%. The total particulate concentration measured with the OPC while an employee was cutting roofing tiles to be used on a roof turret was 107 mg/m^3. The MMAD was graphically estimated at 9.0 µm with a GSD of 2.3. The respirable mass fraction of the sample mass was approximately 15%. The total particulate concentration measured with the OPC while an employee was blowing tile dust off the roof with a leaf blower was 6.0 mg/m^3. The MMAD was graphically estimated at 13 µm with a GSD of 2.7. The respirable mass fraction of the sample mass was approximately 11%.

Carbon Monoxide and Noise Sampling

Results from the ToxiUltra CO monitor used to collect samples on two employees for approximately 30 minutes each during tile cutting and use of the leaf blower ranged from zero to 70 ppm. Noise level results from the sound level meter during tile cutting ranged from 106 to 110 dBA and dropped to 87-88 dBA while the saw engine was idling; results during use of the leaf blower ranged from 97 to 101 dBA.

Second Site Visit (June 2003)

Respirable and Total Dust

Nineteen total dust and respirable dust samples were collected; however, three respirable dust samples were voided due to operator error, leaving sixteen respirable dust samples for which the results are reported. The concentrations of the total and respirable dust in personal breathing zone (PBZ) samples are shown in Tables 1 and 2, respectively. The 19 total dust concentrations ranged from 0.68 to 13 mg/m^3, with a mean of 5.9 mg/m^3. The 16 respirable dust concentrations ranged from 0.23 to 2.3 mg/m^3, with a mean of 1.2 mg/m^3.

Respirable Silica

Results of the silica analyses are also presented in Table 2. The quartz content in the respirable dust samples ranged from 9.5% to 17.6%. The OSHA PEL for silica uses a formula that reflects the combination of two components: (1) the level of respirable dust (i.e., dust small enough to penetrate to the air exchange regions of the lung, and (2) the percent and type of crystalline silica (e.g., quartz or cristobalite) in the dust. Twelve of the 16 samples (75%) exceeded the OSHA PEL. The NIOSH and ACGIH exposure criteria are based on the respirable quartz concentration in the sample. Fourteen of the 16 samples (88%) exceeded the NIOSH REL and ACGIH TLV. The foremen and second men, who performed the majority of the tile cutting during the survey, had the highest exposures. The laborers, who rarely conduct tile cutting, but are often in close proximity during tile cutting so they can lay and set the tiles, had exposures that exceeded the OSHA standard and NIOSH and ACGIH recommended levels. A couple of the employees were observed wearing disposable dust respirators at times during their work shift.

Noise

The Quest dosimeters collect data so that one can directly compare the information with the three different noise criteria used in this survey, the OSHA PEL (same PEL criterion for both construction and general industry) and AL, and the NIOSH REL. The OSHA criteria use a 90 dBA criterion and 5-dB exchange rate for the PEL and AL. The difference between the two is the threshold level employed, with a 90 dBA threshold for the PEL and an 80 dBA threshold for the AL. The threshold level is the lower limit of noise values included in the calculation of the criteria; values less than the threshold are ignored by the dosimeter. The NIOSH criterion differs from OSHA in that the criterion is 85 dBA, the threshold is 80 dBA, and it uses a 3-dB exchange rate. Because of the different 8-hour criteria and exchange rates, the dose equations used to calculate the equivalent TWA values are different for the NIOSH and OSHA criteria. The OSHA dose equation is:

$$TWA = 16.61 \times \log10 (Dose/100) + 90,$$

and the NIOSH equation is:

$$TWA = 10.00 \times \log10 (Dose/100) + 85.$$

Each roofing crew was composed of a foreman, second man, and two laborers. Two K-12 portable circular saws with 12” diamond blades designed to cut concrete and masonry were taken up on the roof by each of the crews. A leaf blower was used by the June 18 crew. None of the employees were observed wearing hearing protection devices (HPDs) while on the roof. Most cutting with the power saw was done by the foreman and second man on both crews. Noise data are presented in Table 3 for the two survey days. Full-shift TWA noise values calculated according to the three criteria revealed that the NIOSH REL was exceeded for all eight measurements. The exposures ranged from 87 to 102 dBA, with the highest values measured on the crew’s second man. For the two OSHA criteria, three employees exceeded the PEL of 90 dBA and five exceeded the AL of 85 dBA.

Carbon Monoxide

The CO results for the eight PBZ samples are shown in Table 4. The eight CO concentrations ranged from 4 ppm to 15 ppm as a TWA, and the CO ceiling concentrations ranged from 106 ppm to 273 ppm. None of the CO levels exceeded the NIOSH REL-TWA or the OSHA PEL; one foreman was exposed to CO concentrations that exceeded the NIOSH ceiling limit of 200 ppm.

Carbon Monoxide and Noise

Each member of the roofing crew wore a CO detector along with the noise dosimeter to determine if the CO levels were correlated with the higher noise exposures from saw usage. The clocks in each meter were synchronized each morning before they were placed on the employees. This allowed the NIOSH investigators to view the peak CO levels generated each minute of the shift with the noise levels for that same time interval. These data are graphically shown in Figures 1 – 8. The peak CO levels are represented by the lighter tracings and the noise levels by the darker traces at the top of each figure. A work activity log is shown for the second men (Figures 1 and 5) because they have the highest noise exposures and perform a lot of cutting on the roofing tiles. All eight crew members show CO peaks over the day that at times seem to correlate with the higher noise levels, presumably from the use of the saw. However, there is no one-to-one correspondence, and the highest CO peak on the first day of sampling occurs during the break period.

Employee Interviews

The informal interviews with employees revealed that seven reported difficulty breathing and eight reported a persistent cough, and others also reported recent fever, night sweats, and weight loss. None of the workers expressed an understanding of what silica is and the hazards involved in working with silica-containing materials.

Medical Screening (February 2005)

Combined Results for all Four Roofing Contractors

Questionnaire: One hundred eighteen participants completed all three testing stations: medical questionnaire, spirometry, and chest x-ray. All participants were male and between the ages of 19-58 years. The mean age of all participants was 32 years. One hundred eight (91%) identified themselves as Hispanic. Thirty-three (30%) were current smokers and 39 (36%) were former smokers. Upon review of the questionnaire, there appeared to be some confusion regarding the responses to the question that asked for duration of dry cutting. Therefore, we attempted to contact all the participants by phone using Spanish-fluent NIOSH personnel to confirm their responses. Of the 118 participants, we were only able to reach 68 of the participants. For the participants who were reached by phone, the mean duration of dry cutting was 7.5 years with a range of 0 to 27 years.

Of the 118 participants, 19 (16%) reported some shortness of breath. Of these nineteen, eleven reported shortness of breath while at work, two reported that their shortness of breath made doing their job tasks difficult, and three sought treatment for shortness of breath. Only four of the participants who reported shortness of breath listed the diagnoses given to them which included sinusitis/pneumonia, emphysema, asthma, and perforated lung.

The medical questionnaire included inquiries regarding participants' past exposure to tuberculosis (TB) and any subsequent diagnosis of this infection. These questions were included because persons with silicosis have an increased risk for developing active TB infection after exposure to the TB bacterium. Three had a self-reported history of a positive TB skin test, but none reported a prior diagnosis of TB. (We did not inquire about BCG vaccination status, which may produce a false positive skin test for TB.) No participant reported a prior diagnosis of silicosis or any of the connective tissue diseases that have been associated with it such as scleroderma or systemic lupus erythematosis. There were positive responses for other conditions that have been associated with silicosis with one participant indicating a diagnosis of rheumatoid arthritis and two participants reporting chronic renal disease.

Spirometry: Eighteen (15%) of the 120 participants that completed the spirometry testing had abnormal spirometry results as follows: three had borderline restrictive patterns, ten had borderline obstructive patterns, four had mild restrictive patterns, and one had a mild obstructive pattern. One participant could not generate acceptable curves for analysis. No participants had moderate or severe impairments on their spirometry results.

When controlling for smoking, there was a 0.6% decrease in the percent predicted FEV1 per year dry cutting (p=0.054) and a 0.3% decrease in the percent predicted FVC per year dry cutting (p=0.35) for the 58 participants having data for years dry cutting, smoking status and spirometry. The variable "years dry cutting" was used as a marker for years of exposure to respirable silica. Since percent predicted values were used, normal decreases in lung function that occur with age were already taken into account.

Chest x-ray: All 121 chest x-rays were read as technically adequate by the B-readers. No chest x-rays had a profusion score of 1/0 or higher, which is needed for that film to be read as consistent with silicosis. Nineteen participants (16%) required early notification for non-silicosis related findings on their chest x-rays that could indicate the presence of a potential malignancy, infectious processes, or structural abnormality.

Results for Diversified Roofing Inc. Employees

Questionnaire: Eighty-seven employees of Diversified Roofing Inc. involved in cement tile installation participated in the medical screening (denominator could not be calculated due to multiple differing estimates from both union and management of how many employees met the inclusion criterion). The mean age was 31 (range 19 to 48) years. Ninety-seven percent identified themselves as Hispanic. Of the 82 participants who supplied complete information on their smoking history, 68% were current or former smokers. The mean number of years dry cutting was 6 years with a range of 0 to 13 years for the 45 Diversified employees who were reached by phone.

Ten Diversified employees reported shortness of breath. Seven reported shortness of breath while walking fast, four reported shortness of breath requiring them to walk more slowly on level ground than others of similar age, and seven reported getting short of breath while at work. Two of these employees reported that the shortness of breath that occurred while working interfered with their job performance. These categories were not mutually exclusive and employees could answer more than one.

Spirometry: Eighteen percent (n=15) of Diversified participants had abnormal spirometry results. These abnormalities included two participants with a borderline restrictive pattern, eight with a borderline obstructive pattern, four with a mild restrictive pattern, and one with a mild obstructive pattern. One participant was unable to generate adequate exhalation curves for analysis. Of the ten employees who reported shortness of breath, only two had abnormal spirometry results and both were in the borderline category.

For the 42 Diversified employees contacted by phone, the analysis of both spirometry parameters, percent predicted FEV1 and percent predicted FVC, showed a statistically significant ($p<0.05$) decrease with years of dry cutting for both these lung function parameters after controlling for smoking status.

Chest x-ray: No chest x-rays were interpreted as consistent with silicosis. Fifteen had non-silicosis related findings e.g., possible cancer, infections or heart abnormalities for which we quickly notified affected individuals by both telephone and written letter.

DISCUSSION

Silica, Particulates, and Observations

The cement tiles used in this evaluation contain crystalline silica, and workers were exposed to silica concentrations in excess of the occupational exposure limits; therefore, a control system or program should be in place to prevent recurring high exposures. This system, in order of preference, can consist of engineering controls (e.g., wet cutting or use of saws equipped with local exhaust ventilation), work practice changes (e.g., positioning employees during tile cutting and roof cleaning to take advantage of wind and natural dilution ventilation, or implementing employee rotation for tile cutting jobs), and PPE. NIOSH recommends substituting less hazardous materials for crystalline silica whenever feasible. In addition, appropriate respiratory protection should be used when source controls cannot keep exposures below the REL or in the interim until such controls are in place. Medical surveillance of exposed employees should also be performed for evaluation of conditions related to silica exposure.[19]

Crystalline silica has been regulated under OSHA's Hazard Communication Standard (HCS) 29 CFR 1910.1200. (The construction standard 29 CFR 1926.59 states that the requirements applicable to construction work under this section are identical to those set forth in 1910.1200.) The HCS establishes uniform requirements to ensure that the hazards of all chemicals imported, produced, or used in the workplace are fully evaluated for possible physical or health hazards, and that this hazard information is transmitted to affected employers and exposed workers. Under the HCS, OSHA-regulated businesses must follow Federal guidelines concerning hazard communication and worker training.[20]

Dry cutting of cement tiles generates large amounts of dust when not controlled. Wet cutting, whether using water from a main or a portable water tank, has been shown to be the most effective method for controlling silica dust generated during sawing, because when wet, dust is less able to become or remain airborne.[21] Masonry saws with vacuum systems are commercially available; a vacuum pulls dust from the cutting point through a special fitting connected directly to the saw (fixed blade saws) or, alternatively, through a dust collection shroud connected to the back of the saw (plunge-cut saws). With any type of vacuum system, worker protection from respirable dust is only as good as the filter in the vacuum; the less efficient the filter, the more respirable dust will pass through the vacuum exhaust air. High efficiency particulate air (HEPA) filters will allow for maximum control because they are at least 99.97% efficient when tested with fine dust (0.3 μm). However, increasing the vacuum filter efficiency can result in decreased airflow, and lower airflow can reduce the amount of dust that a system captures at the cutting wheel. A larger filter will help minimize this problem, as will using a more powerful vacuum. HEPA filters tend to be more costly; by using pre-filters, you can extend the service life of the HEPA filter by protecting the fine particulate filter by initially capturing the larger dust.

The time of year the survey was conducted (June) may have factored into the lack of observed PPE use as temperatures exceeded 116°F on both days of the survey. One study reported that the increased temperature imposed by wearing a disposable respirator results in increased physiological stress (e.g., increased heart rate and blood pressure), especially at high work loads.[22] It is known that respirator acceptance is related directly to comfort, and if comfort decreases (e.g., sweat accumulation in the respirator), then the respirator is more likely to be removed when it should be worn, thus compromising worker health.[23]

Respiratory protection, in the form of filtering facepiece (disposable) respirators, was available on the crew trucks and was observed in use by a couple of employees. Respiratory protection should be worn until engineering controls and work practices are shown to reduce exposures below the occupational criteria. Respirable quartz sample results indicate that the workers should wear, at a minimum, a half-mask, air-purifying respirator with a high-efficiency particulate filter (designated as an N-100, P-100 or R-100 series, where the N-100 can be used for non-oil aerosol environments and the P- and R-100 can be used for both oil and non-oil environments). Half-mask air purifying respirators have an assigned protection factor (APF) of 10, which means they can be used by workers when exposures are less than or equal to ten times the REL (<=0.5 mg/m^3). Respirators at a higher APF such as a full-facepiece air-purifying respirator with N-100, P-100, or R-100 filters (APF = 50) or a powered air purifying respirator (PAPR) with a loose-fitting or tight-fitting facepiece and high efficiency filters (APF = 25 for loose fitting and APF = 50 for tight-fitting) can also be considered. Ease of use, reuse, disposability, and safety issues (e.g., tripping hazards with PAPR hoses on the roof) are all factors that must be taken into consideration for respirator selection.

Even though NIOSH did not evaluate heat exposure, with ambient temperatures exceeding 116°F on both days of the survey, the company should implement a heat stress program that includes all employees.

Fall protection for the employees was not observed during the evaluation. Section 1926.501(b)(13) "Residential Construction," states that if an employee is exposed to falling 6 feet (1.8 meters) or more from an unprotected side or edge, the employer must select a guardrail system, safety net system, or personal fall arrest system to protect the worker.[24] Fall protection for residential construction has certain tasks identified that may be performed without the use of conventional fall protection provided the employer follows all guidelines in Appendix E of Subpart M covered in OSHA Instruction STD 3.1, "Interim Fall Protection Compliance Guidelines For Residential Construction." It permits employers engaged in certain residential construction activities to use alternative procedures routinely instead of conventional fall protection. An employer does not have to demonstrate that conventional fall protection is not feasible before using these procedures. A fall protection plan is required but it does not have to be written nor does it have to be specific to the jobsite. Alternative procedures are specified for different activities.[24]

Noise

All members of the roofing crew were exposed to excessive levels of noise on the surveyed days, according to the NIOSH criterion. Use of the saw had a great influence on the exposures. Saw use by the foremen and second men resulted in noise levels greater than 100 dBA for these individuals while noise levels during periods when the saws were turned off were closer to 80-90 dBA. The influence of the saw on the laborers' exposure appeared less but was still intense enough to exceed the NIOSH REL.

The use of HPDs was not observed in the two crews measured for noise and CO. HPDs were reported as being used by 8% of the interviewed employees. Because the noise output of the portable saws is so intense, an HPD with a large noise reduction rating (NRR)[25] value would be necessary to adequately protect the employee during the time when the saw was on. However, during times when gas-powered tools were not operational, the employee would most likely be overprotected to the 80-90 dBA exposures. Realistically, this would mean that the roofers would have difficulty hearing important signals, including conversations, during times when they were not overexposed to noise if they did not remove their HPDs each time a saw was not being used on the roof. A more appropriate HPD would be one that responds to the ambient noise environment and amplifies signals during periods of low noise exposure and attenuates during period of high exposure. Most of the devices of this type are configured as ear muffs, which may pose additional problems in the high-temperature environment in which these roofers work.

Carbon Monoxide and Noise

There appears to be a temporal relationship between CO peaks and high noise exposures, at least for the individuals who actually use the saws. However, the peaks are transient and do not remain high whenever the saw is in use. Also, the TWA values for CO were all below relevant evaluation criteria. To see if these short, peak exposures are putting the employees at additional risk of occupational hearing loss, audiometric data would have to be collected from the workforce over a period of years to see if unusual patterns of hearing loss were observed.

Medical Screening

Most roofers who participated were young and had unremarkable past respiratory medical histories, and none had previous medical evaluations consistent with a diagnosis of silicosis. This would be expected with the physically demanding nature of their daily job tasks such as climbing ladders, handling power tools on the roof, etc. However, this study was limited by the lack of pre-placement spirometry or chest x-rays for comparison.

The healthy worker effect is a phenomenon observed in physically demanding occupations. Because a worker must be in excellent physical condition to perform the job, it is unlikely that those who become ill due to work-related exposures or other causes would be able to continue working in that occupation. In this situation, the healthy worker effect would have resulted in sick roofers no longer able to work and thereby taking themselves out of the potential study participant pool.

Another important issue to consider when evaluating these results is that the latency period for chronic silicosis is 10-20 years or more. Between the healthy worker effect described above and the fact that the mean duration of dry cutting for our medical screening participants was 7.5 years, well below the latency period, it is not surprising that we found no abnormalities consistent with silicosis on chest x-rays.

We did find, however, a slight decrease in lung function related to years performing dry cutting of cement tiles. We used “duration of dry cutting” as an indicator of duration of exposure to respirable silica. Although other respirable substances (such as asbestos or coal dust) can diminish lung function, prior air sampling of the roofers’ personal breathing zone showed that the dust the workers were inhaling contained primarily respirable silica as described earlier in this report.

This decrease in lung function could indicate subclinical lung damage. Although we cannot ascertain that this decrement is from silica exposure, it is prudent and good public health practice to limit further exposure.

CONCLUSIONS

Dry cutting with hand-held saws produces large amounts of dust in the inhalable size range and hazardous levels of respirable quartz. Any crew worker has the potential for overexposures to respirable silica, noise, and CO. The environmental data support the implementation of control systems or programs, consisting of engineering controls, work practice changes, and PPE to prevent recurring high exposures to noise, CO, and respirable quartz. The data also show that employees should use appropriate respiratory protection to keep exposures below the respirable quartz occupational exposure limits until effective source controls are in place.

Our medical screening revealed that workers at Diversified had no diagnosable silicosis by chest x-ray, however, we found 15 workers with pulmonary function test abnormalities. For Diversified employees, there were statistically significant decrements in both measures of lung function (percent predicted FEV1 and percent predicted FVC) with increased number of years of dry cutting. Although these findings do not indicate clinical disease, they do suggest that workers need to be followed up medically as a preventive measure. If these workers do develop respiratory disease in the future, it is imperative that they inform their physicians of their work-related exposure to respirable silica so that silicosis can be included in their differential diagnosis.

Mandatory PPE (hard hats and safety glasses) was observed being used by all the employees during the survey. Use of PPE, when left up to the individual employee, was found to be infrequent (two employees were observed wearing respirators) or lacking (no employees were observed wearing hearing protection). Eleven employees did report that they wore respirators on the job, and two employees reported hearing protection use when interviewed. Some of the employees interviewed described health symptoms that were potentially consistent with exposures to silica (cough and difficulty breathing). The interviews also revealed that none of the workers reported knowledge of silica and its harmful effects.

RECOMMENDATIONS

The following recommendations are offered to prevent or minimize exposures to respirable silica, noise, and heat; monitor employees' respiratory health; and educate employees regarding the hazards of silica exposure.

1. Reduce dust levels. This can be accomplished by either wetting the material to be cut or extracting the dust by suction close to its point of production. Both can significantly reduce dust emissions during cutting activities. Tile cutting using a stationary saw positioned on the ground with local exhaust ventilation is another option to consider for reducing airborne dust levels.

2. Use a HEPA vacuum to clean debris from roofs when the tile cutting work is completed. Leaf blowers currently being used contribute to the airborne dust generated during the roof installation process.

3. Implement a respiratory protection program for all work crews until engineering controls are in place and proven effective in reducing worker exposures below the NIOSH REL and the OSHA PEL for silica. The data from this evaluation indicate that a respirator having an assigned protection factor of at least 10 is needed. The program should conform to the requirements in the OSHA standard 29 CFR 1910.134. (The construction standard 29 CFR 1926.103 states that requirements applicable to construction work under this section are identical to those set forth in 29 CFR 1910.134.)[26]

4. Implement an exposure monitoring program to evaluate airborne silica levels, on a periodic basis, every time there is a material or process change, and to measure the effectiveness of engineering controls.

5. Institute a hearing loss prevention program. The OSHA construction standard for noise does not currently provide detailed guidelines for such a program. Therefore, the regulations set forth in the OSHA general industry standard should be met.[12] Other sources for defining effective hearing loss prevention programs are also available.[27,28,29]

6. Require roofers to wear HPDs whenever saws are in use on a roof. The use should include all members of the crew. The foam earplugs referenced by management in correspondence with NIOSH investigators following the site visit should be adequate to protect workers from saw noise. However, they will overprotect during times when saws are not used, and they are not amenable to easy removal and insertion throughout the work shift. Management should research different types of protectors that provide varying levels of amplification and attenuation depending on the surrounding noise conditions.

7. As required by the OSHA HCS, workers must be "provided with effective information and training on hazardous chemicals in their work area at the time of their initial assignment, and whenever a new physical or health hazard the employees have not previously been trained about is introduced into their work area."[20] This information can be

provided to the employees "by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets and employee training"[20] regarding worker exposure to silica, noise, and CO.

8. Assure compliance with the fall protection standard per the OSHA construction standard 29 CFR, Subpart M, Fall Protection, 1926.500(a), 1926.501, 1926.502, 1926.503.[24]

9. Consult an occupational medicine physician to implement the employee medical monitoring program as outlined in OSHA's Special Emphasis Program for Silicosis.[30] This includes a focused medical examination, lung function testing, and a chest x-ray to be done pre-placement, at regular intervals as determined by the supervising physician, and at termination. These records should be kept by the employers for 30 years post-termination due to the potentially long latency period for silicosis.

10. Educate employees regarding the potential adverse health effects that they may develop from exposure to respirable silica. Encourage symptomatic employees to seek treatment immediately and to inform their personal physicians of their workplace exposures to respirable silica. Symptoms consistent with this disease include shortness of breath, chest pain, exercise intolerance and cough.

11. Create a heat stress prevention program that will:[31]
    - Assess employees for medical fitness before they begin hard work and especially during the hot season.
    - Allow employees to get used to the heat (acclimate) before they work in it full time.
    - Train employees to know the dangers of and protect themselves from working in extreme heat.
    - Encourage employees to report any heat stress symptoms and signs.
    - Keep systematic records of employee reports of heat stress illnesses.
    - Teach employees to monitor their own and others' heat stress and strain signs.

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TABLES

Table 1
Personal Breathing Zone Concentrations of Total Dust
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17 & 18, 2003

Date	Time	House ID	Sample ID	Job description	Concentration (mg/m^3)*
June 17, 2003	0608 to 0903 0954 to 1325	RM-1	T-1 T-4	Foreman	9.9
	0552 to 0905 0957 to 1326	RM-1	T-2 T-5	Second man	5.7
	0611 to 0903	RM-1	T-3	Laborer	11
	0545 to 1330	CA-1	T-16	Foreman	9.4
	0544 to 1330	CA-1	T-17	Cutter/Second man	1.8
	0550 to 1320	CA-1	T-18	Laborer	2.0
	0602 to 1322	CA-1	T-19	Laborer	2.3
	0607 to 1324	RS-1	T-31	Foreman	8.0
	0602 to 1322	RS-1	T-32	Second man	5.2
	0558 to 1320	RS-1	T-33	Driver	0.68
June 18, 2003	0600 to 0912 0959 to 1314	RM-2	T-8 T-9	Foreman	4.7
	0602 to 0912 0957 to 1316	RM-2	T-10	Laborer	1.5
	0527 to 1302	CA-2	T-20	Foreman	5.8
	0530 to 1300	CA-2	T-21	Second man	12
	0535 to 1300	CA-2	T-22	Laborer	0.84
	0657 to 1302	CA-2	T-23	Laborer	0.98
	0536 to 0947 1045 to 1256	RS-2	T-35 T-38	Laborer	6.5
	0540 to 0946 1040 to 1255	RS-2	T-34 T-37	Foreman	11
	0534 to 0947 1043 to 1258	RS-2	T-36 T-39	Second man	13

*mg/m^3 = milligrams per cubic meter.

Note – if visible dust loading was detected on the filters, they were changed out at the morning lunch break.

Table 2
Personal Breathing Zone Concentrations of Respirable Dust & Respirable Quartz
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17 & 18, 2003

Date	Time	House ID	Sample ID	Job description	Respirable Quartz (mg/m^3)*	Respirable dust , mg/m^3 (% quartz)	Calculated OSHA PEL† (mg/m^3)
June 17, 2003	0545 to 1330	CA-1	RESP-16	Foreman	0.21	2.2(9.5)	0.87
	0544 to 1330	CA-1	RESP-17	Cutter/Second man	0.33	2.3 (14.4)	0.61
	0550 to 1320	CA-1	RESP-18	Laborer	0.06	0.34 (17.6)	0.51
	0550 to 1322	CA-1	RESP-19	Laborer	0.10	0.65 (15.4)	0.58
	0605 to 1324	RS-1	RESP-31	Foreman	0.12	1.2 (10.3)	0.81
	0601 to 1322	RS-1	RESP-32	Second man	0.15	1.2 (12.2)	0.70
	0558 to 1320	RS-1	RESP-33	Driver	Trace‡	0.23 (N/A)	N/A
June 18, 2003	0600 to 0912 0959 to 1314	RM-2	RESP-5	Foreman	0.18	1.4 (13.2)	0.66
	0602 to 0912 0957 to 1316	RM-2	RESP-6	Laborer	Trace‡	0.27 (N/A)	N/A
	0527 to 1302	CA-2	RESP-20	Foreman	0.10	0.71 (13.7)	0.64
	0530 to 1300	CA-2	RESP-21	Second man	0.24	1.6 (15.0)	0.59
	0535 to 1300	CA-2	RESP-22	Laborer	0.12	0.87 (13.8)	0.63
	0657 to 1302	CA-2	RESP-23	Laborer	0.06	0.42 (15.0)	0.59
	0540 to 0946 1040 to 1255	RS-2	RESP-34	Foreman	0.28	2.01 (13.8)	0.63
	0536 to 0947 1045 to 1256	RS-2	RESP-35	Laborer	0.21	1.5 (14.1)	0.62
	0534 to 0947 1043 to 1258	RS-2	RESP-36	Second man	0.32	2.1 (15.1)	0.59
NIOSH Recommended Exposure Limit					0.05	N/A	
ACGIH Threshold Limit Value					0.025	N/A	

*mg/m^3 = milligrams per cubic meter
†OSHA PEL = OSHA Permissible Exposure Limit
‡ "Trace" refers to concentrations between the minimum detectable concentration (MDC) and maximum quantifiable concentration (MQC). The MDC was 0.01 mg/m^3 and the MQC was 0.04 mg/m^3 based on a 700 L sample volume.
N/A = Not applicable

Table 3
Full-shift TWA Noise Exposures
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17 & 18, 2003

Date	Total run time (hh:mm)	Job classification	Noise exposures (dBA)*			All exposure criteria exceeded?
			OSHA PEL	OSHA AL	NIOSH REL	
June 17, 2003	08:03	Foreman	93.5	94.1	99.0	Yes
	08:01	Second man	96.8	97.1	101.7	Yes
	08:00	Laborer-1	80.1	82.4	89.1	Exceeded REL
	08:00	Laborer-2	82.1	84.3	92.5	Exceeded REL
June 18, 2003	07:35	Foreman	88.2	89.2	96.5	Exceeded REL and AL
	07:41	Second man	95.4	95.8	101.4	Yes
	07:37	Laborer-1	87.8	89.2	95.8	Exceeded REL and AL
	07:18	Laborer-2	78.2	81.4	86.6	Exceeded REL

*dBA = decibels on the A-weighted scale
OSHA PEL = OSHA Permissible Exposure Limit
OSHA AL = OSHA Action Level
NIOSH REL = NIOSH Recommended Exposure Limit

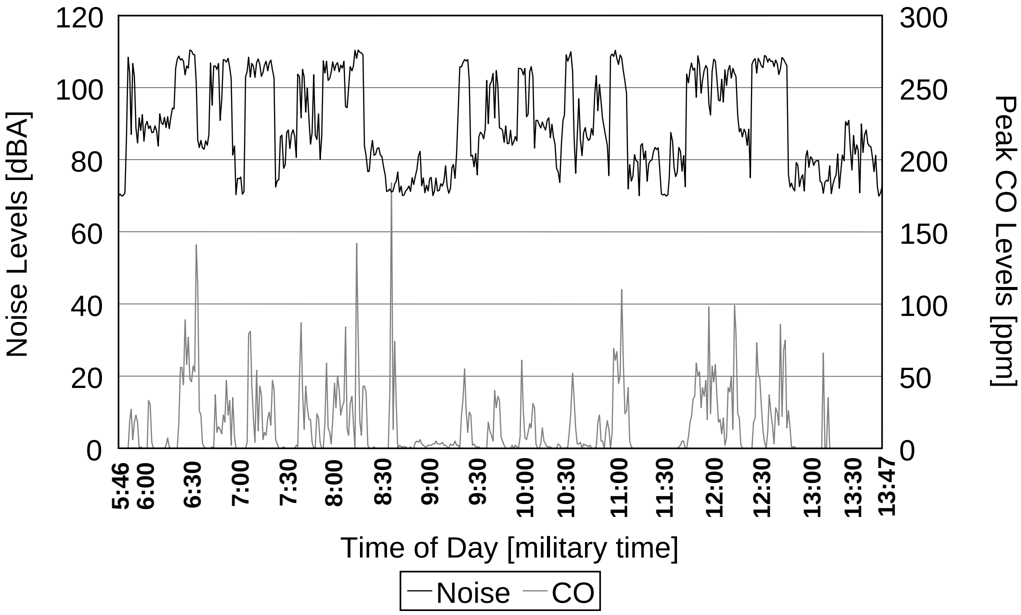
Table 4
Carbon Monoxide Concentrations
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17 & 18, 2003

Date	Total run time (hh:mm)	Job classification	Average CO[†] Concentration (ppm)*	Ceiling CO Concentration (ppm)	All exposure criteria exceeded?
June 17, 2003	08:03	Foreman	13	273	Exceeded NIOSH ceiling
	08:01	Second man	15	184	No
	08:00	Laborer-1	4	188	No
	08:00	Laborer-2	10	159	No
June 18, 2003	07:35	Foreman	4	154	No
	07:41	Second man	6	173	No
	07:37	Laborer-1	5	106	No
	07:18	Laborer-2	7	124	No
NIOSH Recommended Exposure Limit			35	200	
OSHA Permissible Exposure Limit			50		
ACGIH Threshold Limit Value			25		

[†]CO = carbon monoxide
*ppm = parts per million

FIGURES

Figure 1
Noise and CO Exposure – Second Man
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17, 2003



Work Activity Log					
Time	Activity	Time	Activity	Time	Activity
0551	Foreman Sawing	0748	All Saws Off	1009	Laborer #2 Sawing
0554	Second man Sawing	0757	Both Saws On	1015	Laborer #2 Saw Off
0605	Laborer #1 Sawing	0835	Break	1025	Foreman Sawing
0637	All Saws Off	0922	Second man Sawing	1047	Foreman Sawing
0645	Second man Sawing	0934	Foreman Sawing	1140	Foreman Sawing
0708	Foreman Sawing	0955	All Saws Off	1145	Both Saws Off
0726	All Saws Off	0958	Foreman Sawing	1240	Second man Sawing
0745	Both Saws On				

Figure 2
Noise and CO Exposure – Foreman
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17, 2003

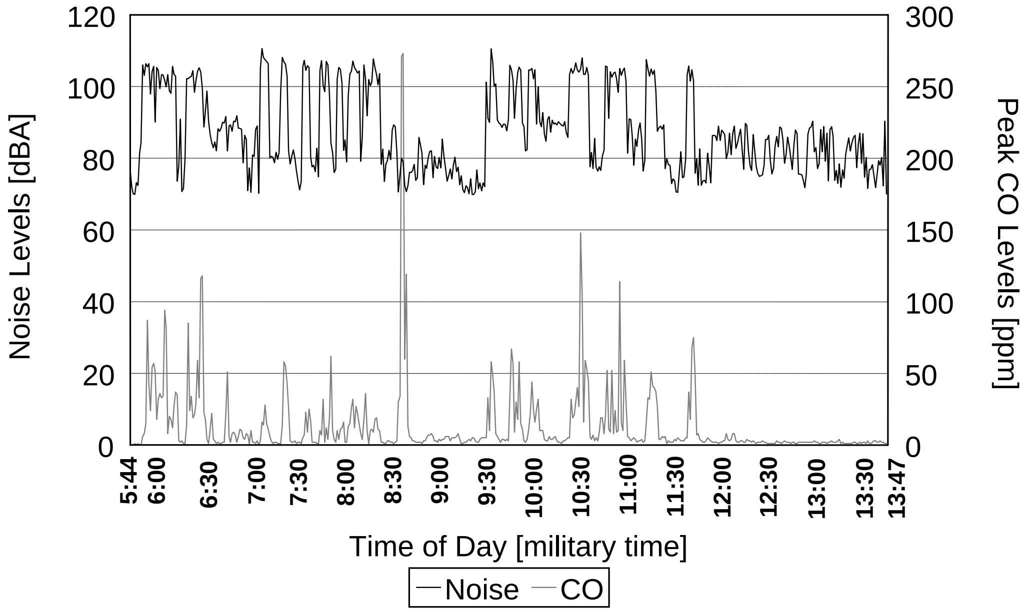


Figure 3
Noise and CO Exposure – Laborer #1
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17, 2003

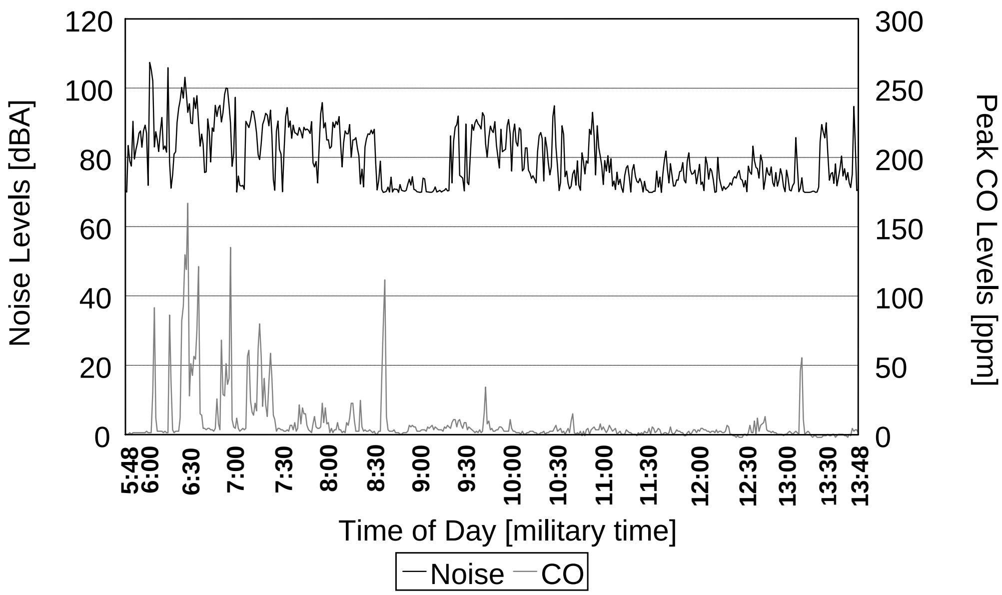


Figure 4
Noise and CO Exposure – Laborer #2
Diversified Roofing Inc.
HETA 2003-0209-3015
June 17, 2003

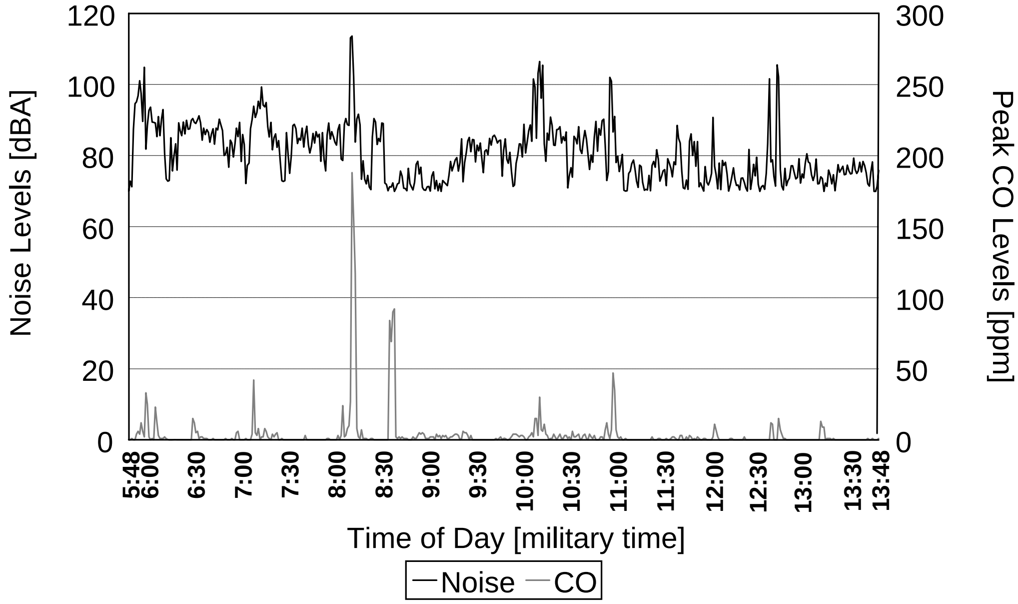
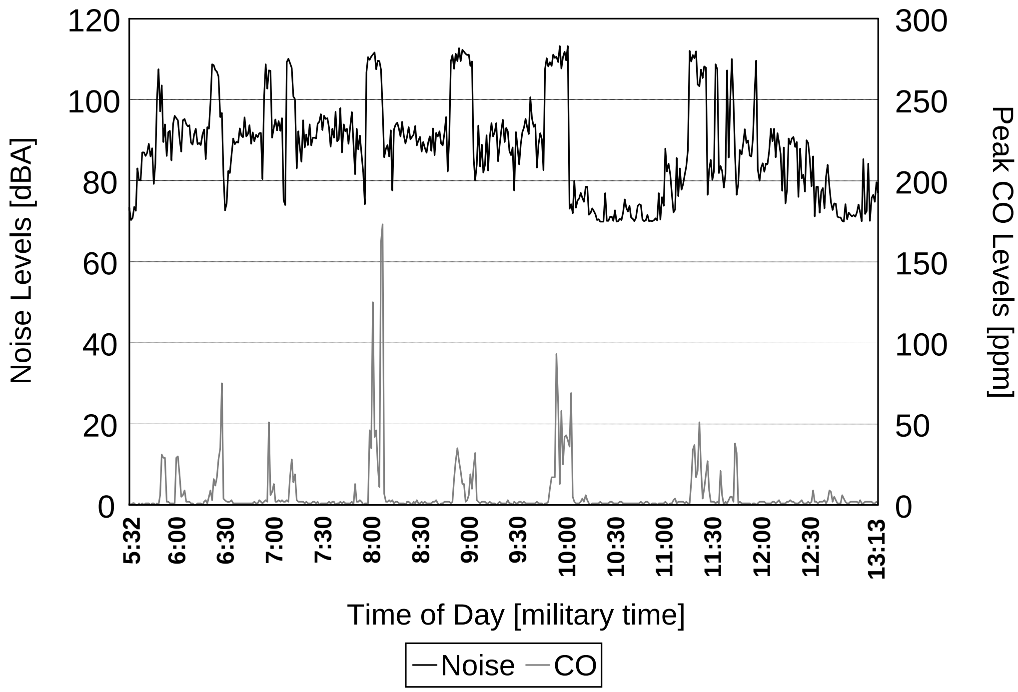


Figure 5
Noise and CO Exposure – Second Man
Diversified Roofing Inc.
HETA 2003-0209-3015
June 18, 2003



Work Activity Log					
Time	Activity	Time	Activity	Time	Activity
0551	Second man Sawing	0723	Foreman Sawing	0944	Foreman Sawing
0554	Saw Off	0726	Saw Off	0949	Saw Off
0559	Foreman Sawing	0727	Laborer #2 Sawing	0949	Second man Sawing
0609	Saw Off	0731	Saw Off	1004	Saw Off
0615	Laborer #2 Sawing	0750	Foreman Sawing	1005	Break
0619	Saw Off	0800	Second man Sawing	1110	End Break
0624	Second man Sawing	0808	Both Saws Off	1118	Second man Sawing
0628	Saw Off	0813	Laborer #2 Sawing	1129	Saw Off
0638	Laborer #2 Sawing	0851	Second man Sawing	1135	Second man Sawing
0641	Saw Off	0904	Laborer #2 Sawing	1136	Saw Off
0653	Laborer #2 Sawing	0905	Second man Saw Off	1141	Second man & Laborer #2 Sawing
0654	Saw Off	0910	Both Saws Off	1142	Second man Saw Off
0656	Second man Sawing	0915	Laborer #2 Sawing	1142	Both Saws Off
0701	Saw Off	0920	Saw Off	1144	Second man Sawing
0704	Foreman Sawing	0923	Foreman Sawing	1200	Saw Off

Figure 6
Noise and CO Exposure – Foreman
Diversified Roofing Inc.
HETA 2003-0209-3015
June 18, 2003

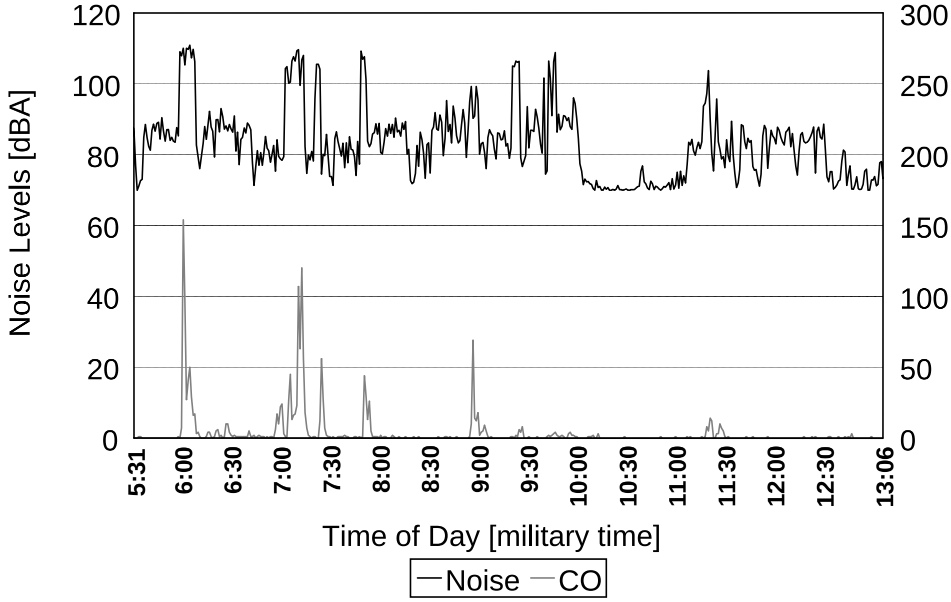


Figure 7
Noise and CO Exposure – Laborer #1
Diversified Roofing Inc.
HETA 2003-0209-3015
June 18, 2003

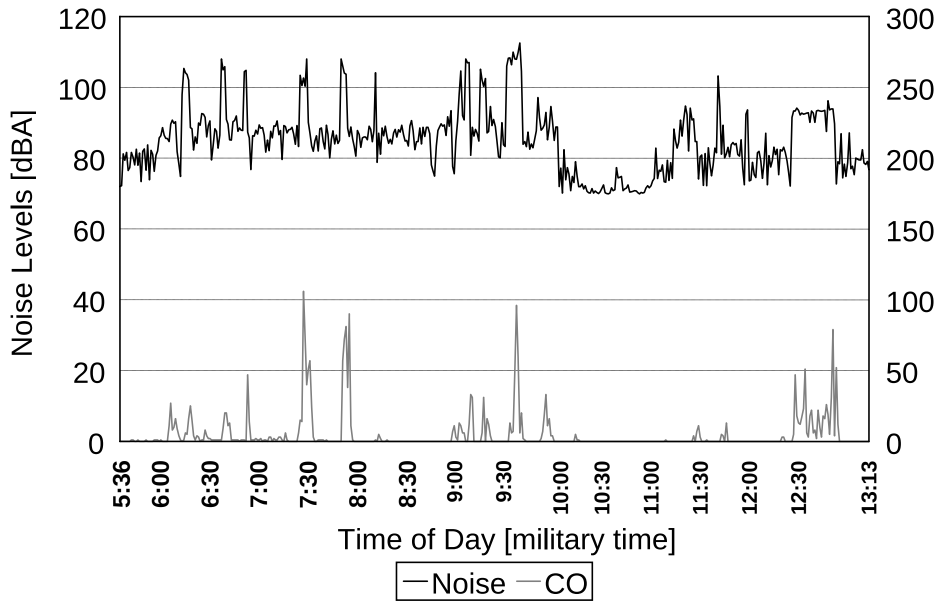
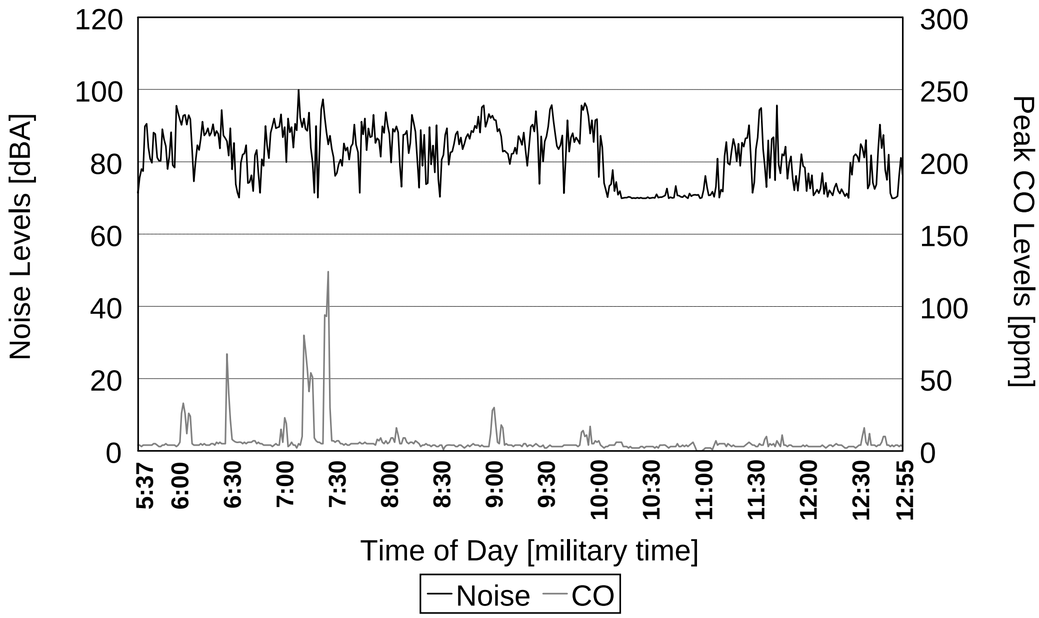


Figure 8
Noise and CO Exposure – Laborer #2
Diversified Roofing Inc.
HETA 2003-0209-3015
June 18, 2003



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