NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2005-0030-2968
Headlee Roofing
Mesa, Arizona

March 2008

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 M. Hall, Judith Eisenberg, Chad Dowell, 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 DataChem 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 United Union of Roofers, Waterproofers, and Allied Workers Local 135 to evaluate exposures to dust during saw cutting of cement tile among employees of Headlee Roofing, Mesa, Arizona. Employee exposures to dust and noise were evaluated during a site visit in January 2005, and medical screening of employees for silicosis was performed in February 2005.

What NIOSH Did

- We evaluated worker exposures to dust and crystalline silica.
- We compared a saw with local exhaust ventilation (LEV) to a saw that wasn't ventilated to see if the saw with LEV could reduce dust exposures.
- We evaluated worker exposures to noise.
- We observed work practices, fall protection, and personal protective equipment (PPE).
- We screened employees from Headlee Roofing and three other Phoenix roofing contractors for silicosis using a medical questionnaire, lung function testing, and chest x-ray.

What NIOSH Found

- Most employees were overexposed to silica and noise.
- The ventilated saw did not control worker exposures to silica to acceptable levels.
- Employees were not aware of the workplace hazards.
- Most roofers who participated in the medical screening had normal lung function.
- None of those with abnormal lung function 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 Headlee Roofing Managers Can Do

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

What Headlee Roofing Employees Can Do

- Use dust control measures.
- Use respirators and hearing protection properly.
- 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.

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 #2005-0030-2968

CDC Workplace Safety and Health

NIOSH

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SUMMARY

On November 15, 2004, 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) for employees of Headlee Roofing in Mesa, Arizona. The request listed silica and noise as potential hazards to roofers. This is one of four HHEs examining silica and noise exposures among roofers in Arizona.

On January 11–13, 2005, NIOSH investigators conducted an HHE at a residential work site in Mesa, Arizona. Dust and noise measurements were taken during residential roofing operations. In addition, bulk samples of tile dust were collected to determine the silica content.

NIOSH investigators selected four homes where employees were cutting and laying tiles throughout the day and took noise measurements and simultaneous full-shift personal breathing zone (PBZ) air samples for total and respirable dust. They also evaluated a saw equipped with local exhaust ventilation (LEV) and a saw not equipped with LEV typically used by the workers, using PBZ sampling and real-time monitoring of particle size and particle counts.

Noise exposures for all seven roofers exceeded the NIOSH recommended exposure limit. Two employees exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit, and all seven employees exceeded the OSHA action limit.

The 8-hour time-weighted averages (TWA) for the total dust samples ranged from 1.2 to 5.4 mg/m^3. The eight PBZ respirable dust concentrations ranged from 0.32 to 1.8 mg/m^3, with a mean of 1.3 mg/m^3. The 8-hour TWAs for respirable dust ranged from 0.2 to 1.8 mg/m^3. Respirable silica samples ranged from 0.057 to 0.27 mg/m^3, with a mean of 0.2 mg/m^3. The respirable silica 8-hour TWAs ranged from 0.04 to 0.25 mg/m^3. The LEV-equipped saw was not effective in reducing worker exposures to acceptable levels during cutting operations.

Medical screening was conducted February 22–24, 2005. Employees from all four roofing companies were invited to participate if they had at least 5 years of experience as a roofer. The medical screening

included a questionnaire, lung function test (i.e., spirometry), and a chest x-ray. Of the 118 employees who participated in all three tests, six were from Headlee Roofing.

Most roofers who participated in the medical screening had normal lung function. None of those with abnormal lung function had moderate or severe impairments. After controlling for the effects of smoking, NIOSH investigators found that lung function decreased with increasing years of dry cutting cement tiles. No chest x-rays showed findings consistent with silicosis.

NIOSH investigators determined that an occupational health hazard due to exposures to respirable silica and noise existed for employees of Headlee Roofing. 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. The employer should develop a training program regarding the potential health hazards of respirable silica exposure and institute a medical monitoring program per the OSHA Special Emphasis Program for Silicosis. Additional recommendations are included at the end of this report.

Keywords: NAICS: 238160 (Roofing Contractors), silica, quartz, dust, total dust, respirable dust, respirable silica, silicosis, noise, construction, roofing, fall protection, lung function, heat stress

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INTRODUCTION

On November 15, 2004, 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 Headlee Roofing in Mesa, Arizona. The request listed silica and noise as potential hazards that workers may be exposed to when performing roofing operations.

On January 11–13, 2005, NIOSH investigators conducted a survey at four residential building construction sites in Mesa, Arizona. At that time, they took dust and noise measurements during residential roofing operations. In addition, bulk samples of tile dust were taken to determine the silica content.

The medical screening component of this HHE was conducted on February 22–24, 2005. Participants were asked to complete a medical questionnaire, spirometry, and chest x-ray. This report includes environmental and medical findings for Headlee Roofing employees and group medical findings for all roofers evaluated by NIOSH in a series of four HHEs investigating respirable silica and noise exposure to roofers.[1,2,3]

BACKGROUND

Headlee Roofing provides roofing installation services to residential and commercial properties in the greater Phoenix area. The company employs approximately 75 workers, and Spanish is the primary language for many of these employees.

The work shift is typically 7:00 a.m. to 4:00 p.m. for 5 to 6 days per week, but may start and end earlier during the summer. Roof installation includes three phases. The first phase 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, formed into barrel or S-shapes, or formed to resemble slate. Workers use hand-held gas-powered saws equipped with diamond-tipped blades to cut the tiles and fit them into various parts of the roof (e.g., valleys, hips, cupolas, turrets, around vent pipes, at the ends of the roof, etc.). At the completion of the roof installation, the roof is cleaned of debris by using gas-powered leaf blowers.

METHODS

Industrial Hygiene

The sampling strategy consisted of selecting home sites each day where employees would be cutting and laying tiles throughout the day. Noise measurements and simultaneous full-shift personal breathing zone (PBZ) air samples were collected for total and respirable dust. In addition, on two houses, NIOSH investigators evaluated a local exhaust ventilation (LEV) equipped saw (RedMax® cut-off saw, Model HC510DV) and a non-LEV saw (Partner® cut-off saw, Model K650, typically used by the workers). The LEV-equipped saw had a dust collection mechanism that was belt-driven by the motor. As the revolutions per minute (rpm) increased on the saw, the fan drive belt speed increased and created more air velocity within the dust collection mechanism. A hose and collection bag were attached to the LEV-equipped saw to capture the dust. Real-time monitoring of particle size and particle counts was conducted during brief trials of tile cutting with the LEV-equipped saw. Two short-term PBZ air samples each for respirable dust and silica were also collected on the worker cutting tile during LEV-equipped saw and non-LEV saw operations.

A worker was instructed on how to operate the LEV-equipped saw according to the manufacturer's recommendations. For efficient cutting operations and dust collection performance, the manufacturer recommends placing the saw on the cutting surface and pulling it in a backward motion when cutting (not pushing it in a forward direction). On the first day of the evaluation the worker performed cutting operations by placing the saw on the tile and moving it backward as instructed. On the second day of the evaluation the worker operated the LEV-equipped saw the same way that he operated the non-LEV saw, which included making cuts by pushing the saw forward thus potentially reducing the dust collection potential of the LEV-equipped saw.

Bulk samples of tile dust were also collected at each house. In addition, NIOSH investigators observed fall protection practices as the roofers worked.

Noise

Quest® Electronics Model Q-300 noise dosimeters were used to collect daily noise exposure measurements. The dosimeter was secured on the workers' belts and the dosimeter's microphone attached to their shirt, halfway between the collar and the point of the 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.

Total and Respirable Dust

Simultaneous PBZ air samples for total and respirable particulate were collected and analyzed according to NIOSH Manual of Analytical Methods (NMAM) methods 0500 and 0600,[4] respectively. Samples were collected on 37 millimeter (mm), 5 micrometer (µm) polyvinyl chloride (PVC) filters, at a flow rate of 2 liters per minute (Lpm) for total particulate, and 1.7 Lpm using a 10-mm nylon cyclone pre-selector for respirable particulate. In addition, the respirable particulate samples were analyzed for silica content by x-ray diffraction using NIOSH method 7500.

Particle Size Analysis

Particulate concentration and particle size data were collected with a real-time light-scattering aerosol spectrometer (Grimm Model 1105, Labortechnik GmbH & CoKG, Ainring, Germany). The aerosol spectrometer measures the size distribution of particles in eight different size ranges. Particles are sized based on the amount of light scattered by individual particles. The aerosol spectrometer operates at a flow rate of 1.2 Lpm. The data collected with the aerosol spectrometer were downloaded to a Microsoft Excel® spreadsheet. Because the calibration of the aerosol spectrometer varies with aerosol properties, the output of the instrument is viewed as a measure of relative concentration. Integrated samples for total particulate as previously described were collected near the aerosol spectrometer sampling probe and used for calibration purposes. The calibration sample and aerosol spectrometer data were used to obtain a conversion factor. The conversion factor was obtained by taking the total dust sample result and dividing it by the integrated aerosol spectrometer concentration result. The conversion factor was then used to adjust the concentration values to obtain more accurate results.

Using the adjusted data from the aerosol spectrometer, the mass gain, mass fraction (MF), cumulative mass fraction (CMF), CMF less than indicated size, concentration, average respirable fraction, and respirable MF were calculated for each size range. The total percentage of particles in the respirable size range was also calculated as well as the total and respirable concentration values.

Particle Counts

A hand-held particle counter (HHPC-6, ART Instruments, Inc., Grants Pass, Oregon) was used to count particles in six different size ranges (0.3µm, 0.5µm, 0.7µm, 1.0µm, 2.0µm, and 5.0µm). The particle counting data were collected during tile cutting operations with the LEV-equipped saw and the non-LEV saw.

Short-Term Respirable Dust and Silica Samples

Short-term respirable dust samples were collected during LEV-equipped saw and non-LEV saw operations on 37 mm, 5-µm PVC filters, at a flow rate of 4.2 Lpm using a high-flow respirable cyclone pre-selector (Model GK 2.69, BGI Inc., Waltham, MA). Samples were analyzed gravimetrically and for silica content (by x-ray diffraction) by NIOSH methods 0600 and 7500 respectively.

Bulk Samples

One bulk sample of tile dust was collected at each of the four houses where workers performed roofing operations during this survey. The samples were analyzed for silica (quartz and cristobalite) using x-ray diffraction per NIOSH method 7500.[4]

Medical

Medical screening was conducted on February 22–24, 2005. Employees were initially recruited during January 2005. 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 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 was conducted by NIOSH certified spirometry technicians. Spirometry is a form of lung function testing that measures multiple parameters of an exhaled breath that 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 interpretations differed, the film was given to a third B-reader, and the final interpretation was taken as the majority opinion.

Statistical Analysis

The data from the medical screening component were analyzed in two ways. The first analysis involved only data from employees of Headlee Roofing. The second analysis used the data from all four contractors. Descriptive statistics were calculated for company-specific data, and linear regression analysis was performed on the combined data set to examine the relationship between years of dry-cutting cement tiles and lung function while controlling for effects of smoking. SAS Version 9.1.3 (Cary, North Carolina) was used for all statistical analysis. The significance level (p) was 0.05.

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),[5] (2) the American Conference of Governmental Industrial Hygienists' (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 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.

In particular, silicosis is a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs and 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 which are 10 µm or less in diameter. Particles 10 µm or below are considered to be respirable particles and classified as those which have 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.[8] 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.[9] 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) concluded in 1996 that there was "sufficient evidence in humans for the carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources."[10] 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.[11]

When proper practices are not followed or controls are not maintained, respirable crystalline silica exposures can exceed the NIOSH REL, the ACGIH TLV, or the OSHA PEL.[5,6,7] NIOSH recommends an exposure limit of 0.05 mg/m^3 to reduce the risk of developing silicosis, lung cancer, and other adverse health effects.

The OSHA PEL for respirable dust containing 1% quartz or more in general industry is expressed as an equation:

$$\text{Respirable PEL} = \frac{10\ mg/m^3}{\%\ \text{Silica} + 2}$$

If, for example, the dust contains no crystalline silica, the PEL is 5 mg/m^3, and if the dust is 100% crystalline silica, the PEL is 0.1 mg/m^3. For tridymite and cristobalite, OSHA uses half the value calculated using the formula for quartz.

The current OSHA PEL for respirable dust containing crystalline silica (quartz) for the construction industry is measured by impinger sampling. The PEL is expressed in millions of particles per cubic foot (mppcf) and is calculated using the following formula:[12]

$$\text{Respirable PEL} = \frac{250\ \text{mppcf}}{\%\ \text{Silica} + 5}$$

Since the PELs were adopted, the impinger sampling method has been rendered obsolete by gravimetric sampling.[13] OSHA is not aware of any government agencies or employers in this country that are currently using impinger sampling to assess worker exposure to dust containing crystalline silica, and impinger samples are generally recognized as less reliable than gravimetric samples. OSHA currently instructs its compliance officers to apply a conversion factor of 0.1 mg/m^3 per mppcf when converting between gravimetric sampling and particle count standard when characterizing construction operation exposures.[14] Arizona OSHA reports respirable dust concentrations in mg/m^3 even though the workers fall under the OSHA construction standard.[15] Therefore, in this report dust concentrations are presented in mg/m^3 instead of mppcf. The ACGIH TLVs for cristobalite and respirable quartz are 0.025 mg/m^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.[16] 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 Hertz (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.[17]

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)[18] stipulates that a worker can be exposed to a maximum 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:

$$F(e) = T1/L1 + T2/L2 + \dots + Tn/Ln,$$

where F(e) indicates the equivalent noise exposure factor, T indicates the period of noise exposure at any essentially constant level, and L indicates 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.[19]

In August 2002, OSHA published an advanced notice of proposed rulemaking on a hearing conservation program for construction workers.[20] 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)[21] 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,[22] and the ACGIH 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-hour 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.

Fall Protection

The OSHA safety and health regulation for construction, 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.[23] 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." 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 job site.

RESULTS

Industrial Hygiene

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 the OSHA criterion 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:

$$TWA = 16.61 \times \log_{10} (Dose/100) + 90,$$

and the NIOSH equation is:

$$TWA = 10.00 \times \log_{10} (Dose/100) + 85.$$

Because of these criteria differences, different equivalent TWA values will be calculated for the same noise environment.

Each roofing crew was composed of 1 to 4 roofers. Portable Partner® K650 Active III or Stihl® TS 400 cut-off saws with 12" diamond-tipped blades designed to cut concrete and masonry were taken up on the roof by each of the crews. A Homelite® Yard Broom II leaf blower was used by the January 12 crew. One of the four crews was observed wearing foam E.A.R.® hearing protection devices (HPDs) while on the roof. Noise data are presented in Table 1 for the 3 survey days. Full-shift TWA noise values (based on the recorded time) calculated according to the three criteria revealed that the NIOSH REL was exceeded for all seven measurements. The exposures for the roofers ranged from 93.4 to 99.8 dBA. For the two OSHA criteria, levels for two employees exceeded the PEL of 90 dBA, and levels for all seven employees exceeded the AL of 85 dBA.

Total and Respirable Dust

Nine PBZ total dust and eight PBZ respirable dust samples were collected on workers as they performed roofing operations. Some workers performed cutting operations more than others during the evaluation. Table 2 shows the concentrations of total dust in the PBZ samples. Table 3 shows the concentrations of respirable dust. The PBZ total dust concentrations ranged from 1.8 to 12 mg/m^3, with a mean of 7.1 mg/m^3. The 8-hour TWAs for the total dust samples ranged from 1.2 to 5.4 mg/m^3. The eight PBZ respirable dust concentrations ranged from 0.32 to 1.8 mg/m^3 with a mean of 1.3 mg/m^3. The 8-hour TWAs for respirable dust ranged from 0.2 to 1.8 mg/m^3. In addition, two area total dust samples located on the ground at breathing zone height were collected at the front and side of the house, and one respirable dust sample was collected on the ground at breathing zone height at the front of the house. These samples were collected to determine dust and silica concentrations at ground level where other construction workers may be working around the house. The two area total dust samples collected at ground level (at breathing zone height) indicated concentrations of 0.40 and 0.028 mg/m^3. The respirable dust sample collected at the ground level (at breathing zone height) indicated a concentration of 0.024 mg/m^3. All of the concentrations were well below all applicable occupational exposure levels.

Results of the silica analyses are also presented in Table 3. The quartz content in the respirable dust samples ranged from 12.9% to 21.7%. Seven of eight respirable dust 8-hour TWA sampling results exceeded the general industry OSHA PEL, and the NIOSH and ACGIH criteria. Two samples exceeded the construction industry OSHA PEL. The NIOSH and ACGIH exposure criteria are based on the respirable silica concentration in the sample.

Particle Size Analysis

See Tables 4–7 for the particle size analysis data. On the first day of the evaluation (January 11, 2005), particle size analysis was conducted during cutting operations for approximately 22 minutes with the LEV-equipped saw and approximately 15 minutes with the non-LEV saw. The total dust air sample concentration was 23 mg/m^3 during cutting operations with the LEV-equipped saw. The particle size analysis indicated that 10% of the concentration was in the respirable size range, which provides a respirable concentration of 2.3 mg/m^3. The mass median aerodynamic diameter (MMAD) was 13 µm (MMAD is the particle size where 50% of the particles are larger and 50% of the particles are smaller in diameter) with a geometric standard deviation (GSD) of 2.2 during operations with the LEV-equipped saw. The total dust air sample result obtained during cutting operations with the non-LEV saw indicated a concentration of 33 mg/m^3. The particle size analysis conducted during operations with the non-LEV saw had an MMAD of 14.2 µm and a GSD of 2.0, with 7% in the respirable size range (respirable concentration of 2.3 mg/m^3). When comparing the LEV-equipped saw to the non-LEV saw operations, NIOSH investigators noted a 30% reduction in total dust concentrations and a 4% reduction in respirable dust concentrations. Table 8 summarizes these results.

During the LEV-equipped saw operation on January 12, 2005, an area air sample was not collected in conjunction with the direct reading monitor due to air sampling pump failure. During this time period the same conversion factor obtained on January 11, 2005 with the LEV-equipped saw was used to adjust the dust monitor data.

Particle size analysis was conducted the second day of the evaluation (January 12, 2005) during cutting operations for approximately 29 minutes with the LEV-equipped saw and approximately 21 minutes for operations with the non-LEV saw. The dust monitor total dust concentration collected during tile cutting operations with the LEV-equipped saw was 45 mg/m^3. The MMAD was 14.5 µm and the GSD was 2.0. Seven percent of the concentration was in the respirable size range (respirable concentration of 3.2 mg/m^3). Sampling during the non-LEV saw operations showed a total dust concentration of 57 mg/m^3, MMAD of 14.9 µm, and a GSD of 1.9, with 5% of the concentration falling within the respirable size range (respirable concentration of 3.0 mg/m^3). There was a 21% reduction in total dust concentrations and a slight increase in respirable dust concentrations when comparing the LEV-equipped saw versus the non-LEV saw operations. However, because of the limited amount of dust concentration data, a complete assessment of the control's effectiveness could not be made.

Particle Counts

The particle counting data collected on the first day of our evaluation (01/11/05) showed reductions of 33% (at the particle size of 0.3 µm) to 57% (at the particle size of 10 µm) with the LEV-equipped saw compared to the non-LEV saw. The particle counting data collected the second day of our evaluation (01/12/05) showed smaller reductions of 5% at the particle size of 0.3 µm, and 7% at 10 µm. However, data analysis on the other size ranges between 0.3 and 10 µm showed increases in the particle counts when comparing the LEV-equipped saw data with the non-LEV saw data.

Short-Term Respirable Dust and Silica Samples

Short-term respirable samples were collected during LEV-equipped saw and non-LEV saw operations. On the first day, the short-term sample collected during LEV-equipped saw operations had a respirable dust concentration of 5.3 mg/m^3 and a respirable silica concentration of 0.75 mg/m^3. During non-LEV saw operations the respirable dust concentration was 5.3 mg/m^3 and the respirable silica concentration was 0.74 mg/m^3.

On the second day the short-term sample collected during LEV-equipped saw operations had a respirable dust concentration of 5.3 mg/m^3 and a respirable silica concentration of 1.1 mg/m^3. During non-LEV saw operations the respirable dust concentration was 17 mg/m^3 and the respirable silica concentration was 2.2 mg/m^3.

Bulk Samples

Bulk samples of tile dust contained 13% to 24% quartz. Cristobalite was not detected in any of the bulk samples.

Fall Protection

Employees were consistently observed working without fall protection during this evaluation.

Medical

Results for Headlee Roofing Employees

Medical questionnaire: Six employees of Headlee Roofing involved in cement tile installation participated in the medical screening. The mean age was 44 (range 25 to 58) years. One third identified themselves as Hispanic. Four participants were current or former smokers. The mean number of years dry cutting was 16 with a range of 8 to 25 years for the five Headlee employees who were reached by phone.

One Headlee employee reported shortness of breath while walking fast. He was a smoker. No employees reported shortness of breath requiring them to walk more slowly on level ground than others of similar age or getting short of breath while at work. These categories were not mutually exclusive, and employees could answer more than one.

Spirometry: One Headlee participant had abnormal spirometry results. This abnormality was categorized as a borderline obstructive pattern. This participant was the one who reported shortness of breath on the questionnaire.

Chest x-ray: No chest x-rays were interpreted as consistent with silicosis. None required immediate notification for other abnormalities. Two had non-specific findings noted by the B-reader, which included calcified granulomas or nodes on one film and a note of scar tissue on a second. These results were relayed to the participants in their notification packets.

Further statistical analysis was not performed due to the small number of participants from Headlee. However, since the work conditions, job tasks, and materials used were similar for all four contractors, the results obtained from the analysis of the grouped results (i.e., a slight decrease in both spirometry parameters versus years roofing) are relevant to each company.

Grouped Results for all Four Roofing Contractors

One hundred eighteen participants completed all three testing stations: medical questionnaire, spirometry, and chest x-ray. An additional five completed only one or two stations.

Medical questionnaire: 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. When reviewing the questionnaire, investigators noted apparent confusion regarding the responses to the question that asked for duration of dry cutting. Therefore, NIOSH investigators attempted to contact all the participants by phone using Spanish-fluent NIOSH personnel to confirm responses. Of the 123 participants, they were only able to reach 68. 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.

Nineteen (16%) reported some shortness of breath. Of the 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. The diagnoses given to those who were treated included sinusitis/pneumonia, asthma, and “smoking related” disease.

The medical questionnaire included inquiries regarding participants’ past exposure to mycobacterium 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. Two 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 [Bacillus of Calmette and Guerin] vaccination status, which may produce a false positive skin test for TB.) No participant had a prior diagnosis of silicosis, scleroderma, or systemic lupus erythematosis. Positive responses came in for rheumatoid arthritis (1) and renal disease (2). Scleroderma, sarcoidosis, systemic lupus erythematosis, rheumatoid arthritis, and renal disease have been associated with silicosis in the medical literature.

Spirometry: Eighteen (15%) of the combined group of participants had abnormal spirometry results: 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 of 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. These 58 participants represented those employees whose employment was confirmed by a second telephone interview. The variable “years dry cutting” was used as a marker for years of exposure to respirable silica. Because 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%) were notified of non-silicosis related findings on their chest x-rays that could indicate the presence of a potential malignancy, infectious process, or structural abnormality.

All employees who participated in the medical screening component received a packet containing the following: a letter in both English and Spanish explaining in lay terms the results of their spirometry and chest x-ray, advising them if any further action was needed based on those results, recommending that they show the results of this testing to their family doctors, give their family doctor a copy of the "What Physicians Need to Know" document included in the packet, and advice to stop smoking if they were current smokers; copies of the actual spirometry results (flow chart and interpretation) and B-reading interpretation forms; a copy of the NIOSH publication No. 2004-108 "Silicosis-Learn the Facts" which is a booklet having English and Spanish texts; and lastly, a copy of the New Jersey Department of Health document "What Physicians Need to Know About Occupational Silicosis and Silica Exposure Sources" in both English and Spanish.

Discussion

Industrial Hygiene

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 influenced the exposures (Figures 1–7). Saw use resulted in noise levels greater than 100 dBA, while periods when the saws were turned off had noise levels closer to 80–90 dBA.

NIOSH investigators observed no HPD use in three of the four crews. Because the noise output of the portable saws is so intense, an HPD with a large noise reduction rating (NRR)[24] 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 that no saws were in use 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.

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 personal protective equipment (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.[25]

When comparing the LEV-equipped saw operations with the non-LEV saw operations, the limited real-time data and the short-term sample data indicated conflicting results. Particle sizing data indicated reductions of total dust and just a slight reduction of respirable dust on the first day and a slight increase in respirable dust on the second day. Particle counting data indicated reductions in particle counts during LEV-equipped saw operations on the first day (when compared to non-LEV saw operations). However, on the second day, particle counting data indicated only slight reductions for two particle sizes (0.3 µm and 10 µm) and indicated increases in particle counts for the other size ranges when comparing LEV-equipped saw versus non-LEV saw operations. Short-term sample results did not indicate reductions in respirable dust or respirable silica concentrations when comparing LEV-equipped saw to non-LEV saw operations on the first day. However, short-term sample results obtained when using the LEV-equipped saw for the second day indicated reductions for respirable dust and respirable silica concentrations. The data do not indicate that the LEV-equipped saw was effective at controlling worker exposures to acceptable respirable silica concentrations. The manner by which the saw was used did not affect its ability to capture and control the dust. Because of the limited amount of dust concentration data a complete assessment of the control's effectiveness could not be made. However, the reductions seen with some of the data indicate a potential to reduce exposures with saws equipped with LEV. Therefore, further research and evaluations of saws equipped with LEV are needed to identify more efficient control options and to help reduce exposures to respirable silica in this environment.

The best way to control worker exposures in the workplace would be substituting a less hazardous material in place of the hazardous material or using engineering controls to reduce exposures to acceptable concentrations. Less effective methods of reducing worker exposures would include administrative controls (e.g., job rotation and limiting the time a worker performs operations with hazardous material) and PPE (i.e., respirators).

Using a less hazardous material that does not contain silica whenever possible and feasible will help eliminate or minimize the amount of tile-cutting operations. Minimizing the amount of cutting will help reduce worker exposures to respirable silica. When cutting of cement tile is necessary, an appropriate engineering control (e.g., wet cutting or use of saws equipped with LEV) should be used. Thorpe et al. evaluated wet methods and LEV for use with hand-held cut-off saws when cutting concrete slabs. They found that a minimum flow rate of about 0.5 liters of water per minute was required to optimize dust suppression, and that LEV was also effective (they did not test the control device used in this report).[26] Yereb demonstrated the effectiveness of water for reducing silica exposures when brick and block were cut using a stationary masonry saw.[27]

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.

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.[28]

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." 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."[28]

Medical

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. Therefore, sick roofers would not be available to participate in this study because they would have already removed themselves from the job.

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 NIOSH investigators found no abnormalities consistent with silicosis on chest x-rays.

NIOSH investigators did find in the grouped results, however, a slight decrease in lung function related to years performing dry cutting of cement tiles. They 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' PBZ 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 NIOSH investigators cannot ascertain that this decrement is from silica exposure, it is prudent and good public health practice to limit further exposure.

CONCLUSIONS

Dry cutting of cement roof tiles with hand-held saws produces large amounts of dust in the respirable size range and hazardous levels of respirable quartz and noise. Any worker on the roof has the potential for overexposures to respirable quartz and noise. During this evaluation, the LEV-equipped saw did not reduce silica exposures to acceptable levels and was therefore not sufficiently effective.

During the NIOSH evaluation, respiratory protection, in the form of filtering facepiece (disposable) respirators, was available and was observed in use by employees. Until engineering controls and work practices are shown to reduce exposures below the occupational criteria, respiratory protection should be worn.

The medical screening revealed that workers at Headlee Roofing had no diagnosable silicosis by chest x-ray; however, one worker had pulmonary function test abnormalities. For the participants from all four roofing contractors as a whole, there were decrements in both measures of lung function (percent predicted FEV1 and percent predicted FVC) with increased number of years of dry cutting although only the decrease in the percent predicted FEV1 reached statistical significance.

RECOMMENDATIONS

The following recommendations are offered to prevent or minimize exposures to respirable silica, noise, and heat; prevent falls; 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 high efficiency particulate air (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.[29] (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).

4. Implement an exposure monitoring program to evaluate airborne silica levels every time a material or process changes, 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. Other sources for defining effective hearing loss prevention programs are also available.[30,31,32]

6. Require roofers to wear HPDs whenever saws are in use on a roof. The use should include all members of the crew. Several types of foam and premolded earplugs should be adequate to protect workers from saw noise. However, they will overprotect during times when saws are not used, and they are difficult to remove and insert 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 (in accordance with HCS 29 CFR 1910.1200), 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." 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" regarding worker exposure to silica and noise.

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.

9. Consult an occupational medicine physician to implement the employee medical monitoring program as outlined in OSHA's Special Emphasis Program for Silicosis. 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. Create a heat stress prevention program that will:[33]

- Assess employees for medical fitness before they begin hard work, 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
Noise Dosimeter Summary Results

Worker	Duration (hh:mm)	OSHA AL		OSHA PEL		NIOSH REL	
		TWA (dBA)	Dose (%)	TWA (dBA)	Dose (%)	TWA (dBA)	Dose (%)
Roofer #1	07:06	94.4	162.4	93.7	149.0	99.3	2413.1
Roofer #2	08:48	89.9	106.9	88.9	92.8	95.5	1208.5
Roofer #3	08:20	89.5	97.0	88.4	83.4	94.4	911.5
Roofer #4	09:00	87.7	82.1	86.3	67.5	93.4	783.4
Roofer #5	06:22	94.8	154.6	94.1	141.2	99.8	2408.3
Roofer #6	05:45	90.5	77.5	89.4	66.5	96.3	973.5
Roofer #7	05:49	88.7	60.3	87.2	49.0	94.0	573.5

The various dose percentages are the amounts of noise accumulated during a work day, with 100% representing the maximum allowable daily dose.

Table 2
Personal Breathing Zone Concentrations of Total Dust among Roofers

Date	Time (Minutes)	Concentration (mg/m^3)	8-hour TWA (mg/m^3)
01/11/2005	233	10	5.4
	140	1.9	
01/12/2005	92	12	4.7
	216	5.3	
01/12/2005	310	1.8	1.2
01/13/2005	67	12	3.6
	216	4.2	
01/13/2005	215	9.1	5.1
	66	7.6	

Note - If visible loading was detected on the filters, they were changed during the sampling period.

Table 3
Personal Breathing Zone Concentrations (mg/m^3) of Respirable Dust and Respirable Silica among Roofers

Date	Time (Minutes)	Respirable Silica	8-hour TWA Respirable Silica	Respirable Dust (% Quartz)	8-hour TWA Respirable Dust	Calculated OSHA PEL
01/12/2005	494	0.16	0.16	1.1 (14.6)	1.1	0.60
01/12/2005	467	0.23	0.22	1.8 (12.9)	1.8	0.67
01/12/2005	444	0.27	0.25	1.6 (16.7)	1.5	0.54
01/12/2005	311	0.06	0.04	0.32 (17.6)	0.20	0.51
01/12/2005	306	0.21	0.13	1.3 (16.2)	0.83	0.55
01/12/2005	308	0.23	0.15	1.3 (17.9)	0.83	0.50
01/13/2005	282	0.27	0.16	1.3 (21.7)	0.76	0.42
01/13/2005	281	0.21	0.12	1.6 (13.1)	0.94	0.66

The NIOSH REL is 0.05 mg/m^3 and the ACGIH TLV is 0.025 mg/m^3.

Table 4
Particle Size Analysis during LEV-equipped Saw Operations

Stage Number	Effective Cut Diameter	Size Range lower	Size Range upper	Size Interval Dp	Final Weight (mg)	Initial Weight (mg)	Net Gain (mg)	Mass Fraction	CMF	CMF< Indicated Size	Concentration (mg/m^3)	Average Respirable Fraction	Respirable Mass Fraction
1	15	15	>15		0.010551	0	0.0105506	0.38732	1.00000	0.613	8.79214	0	0
2	10	10	15	5	0.016818	0.010551	0.0062676	0.23009	0.61268	0.38259	5.22300	0.005	0.00115
3	7.5	7.5	10	2.5	0.020582	0.016818	0.0037634	0.13816	0.38259	0.24443	3.13618	0.0425	0.00587
4	5	5	7.5	2.5	0.024007	0.020582	0.0034257	0.12576	0.24443	0.11867	2.85476	0.1875	0.02358
5	3.5	3.5	5	1.5	0.026373	0.024007	0.0023658	0.08685	0.11867	0.03182	1.97148	0.455	0.03952
6	2	2	3.5	1.5	0.02705	0.026373	0.0006774	0.02487	0.03182	0.00696	0.56449	0.775	0.01927
7	1	1	2	1	0.027206	0.02705	0.0001552	0.00570	0.00696	0.00126	0.12930	0.97	0.00553
8	0.5	0.5	1	0.5	0.02724	0.027206	0.0000344	0.00126	0.00126	0.00000	0.02863	1	0.00126
Totals							0.02723999				22.7000		0.10
Total Aerosol Concentration 23 mg/m3													
Respirable Mass Fraction 0.10 or 10%													
Respirable Mass Concentration 2.2 mg/m3													

Table 5
Particle Size Analysis during Non-LEV Saw Operations

FIGURES

Figure 1
Noise Dosimeter Data: Roofer #1

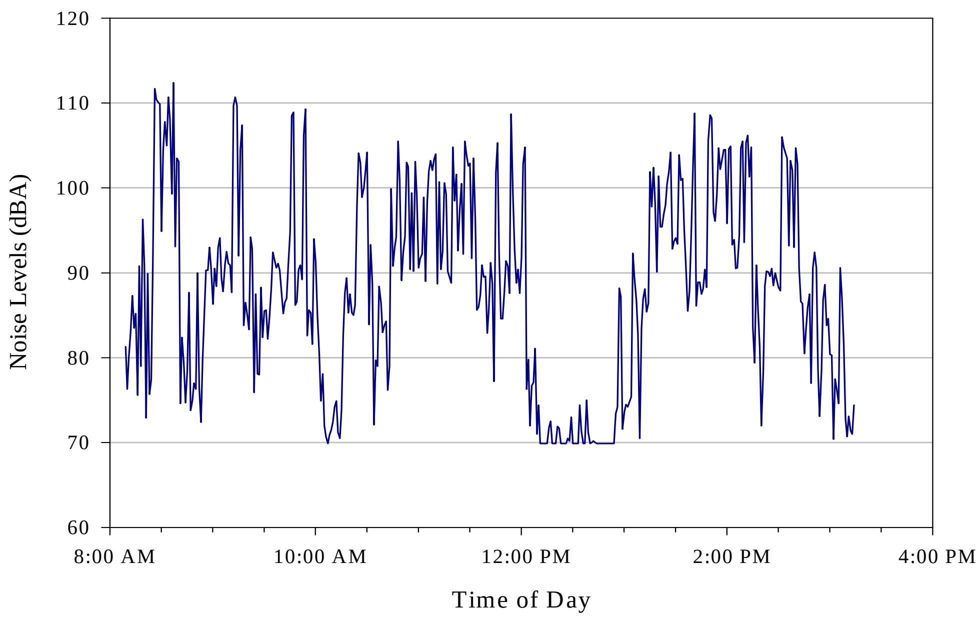


Figure 2
Noise Dosimeter Data: Roofer #2

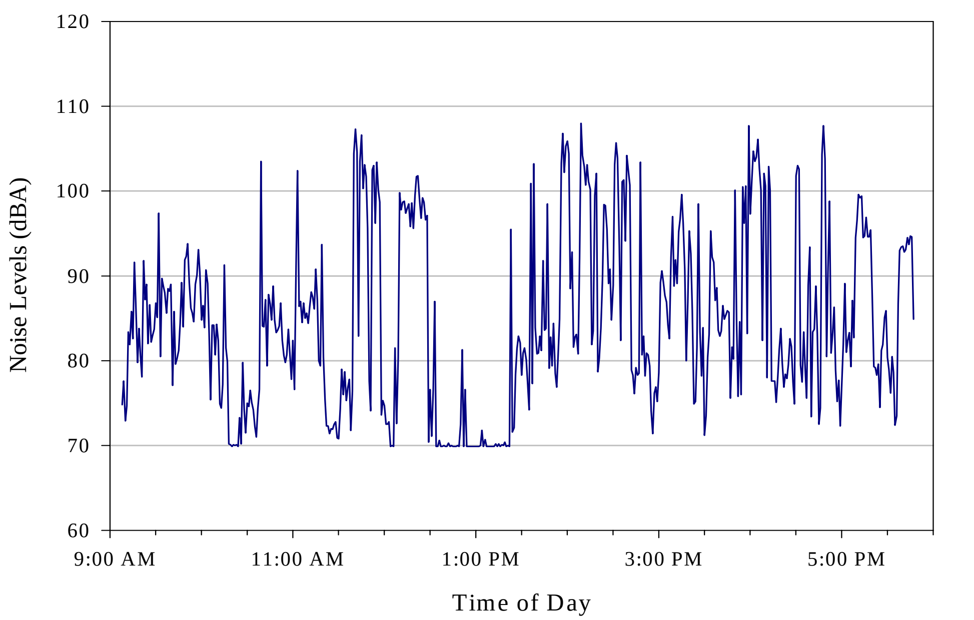


Figure 3
Noise Dosimeter Data: Roofer #3

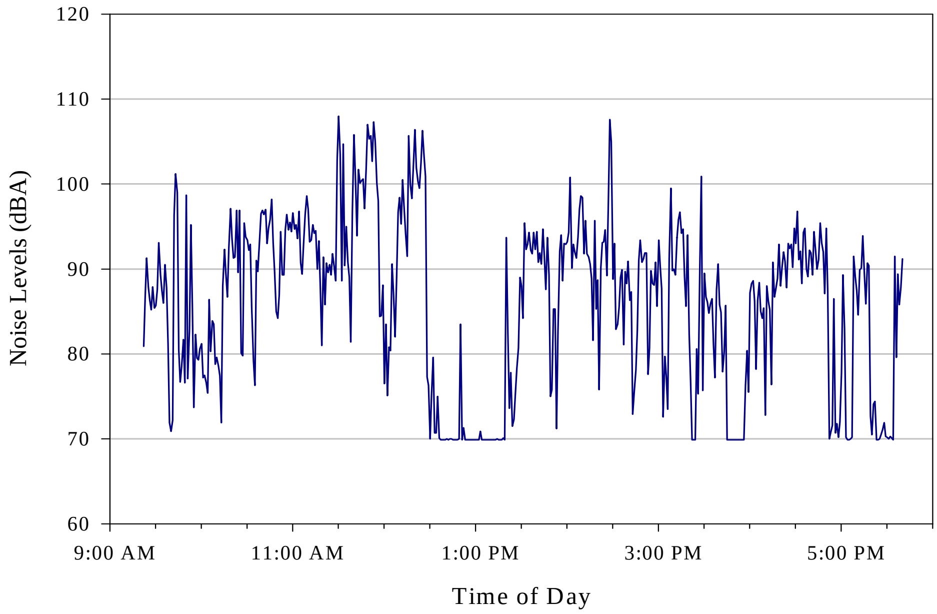


Figure 4
Noise Dosimeter Data: Roofer #4

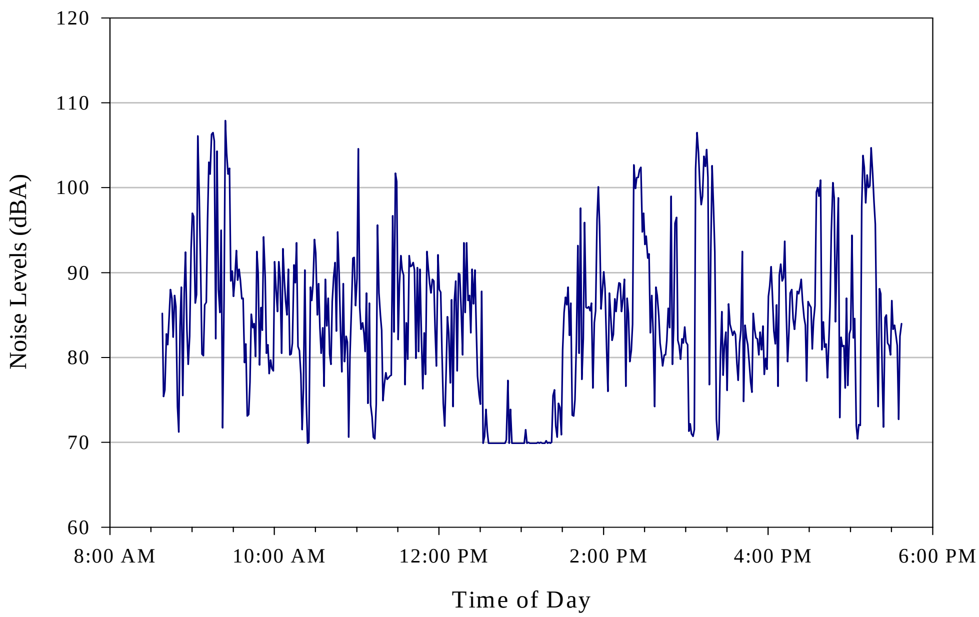


Figure 5
Noise Dosimeter Data: Roofer #5

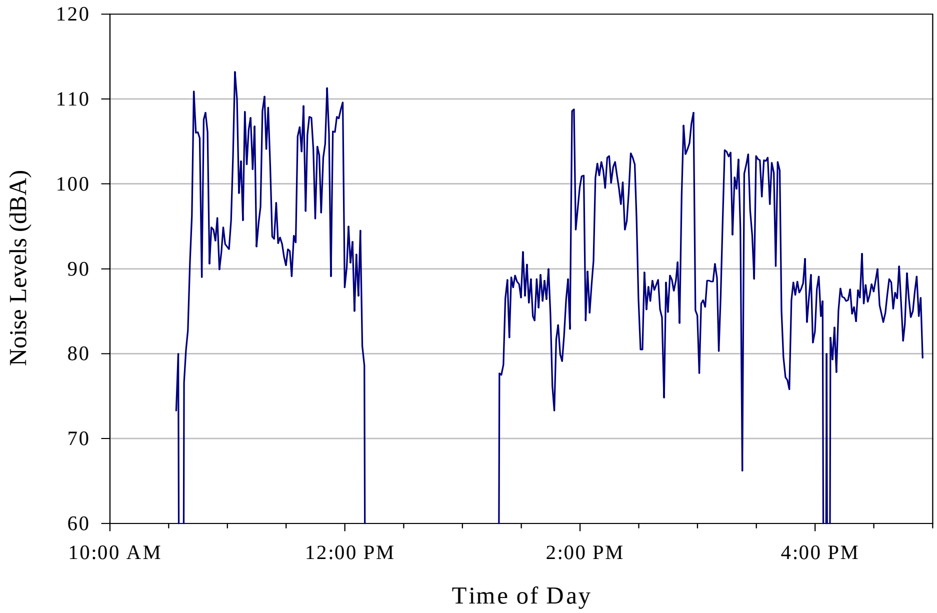


Figure 6
Noise Dosimeter Data: Roofer #6

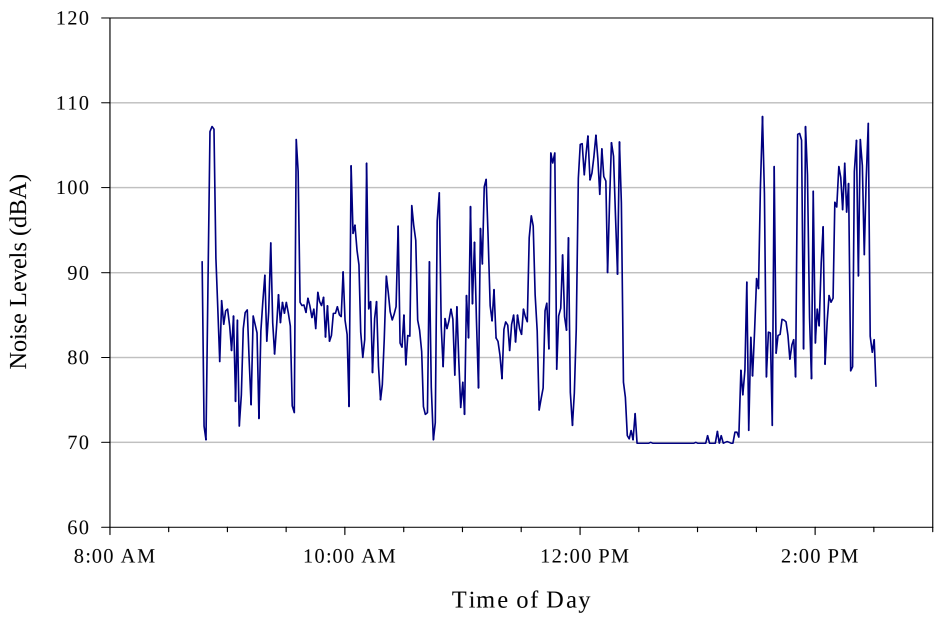
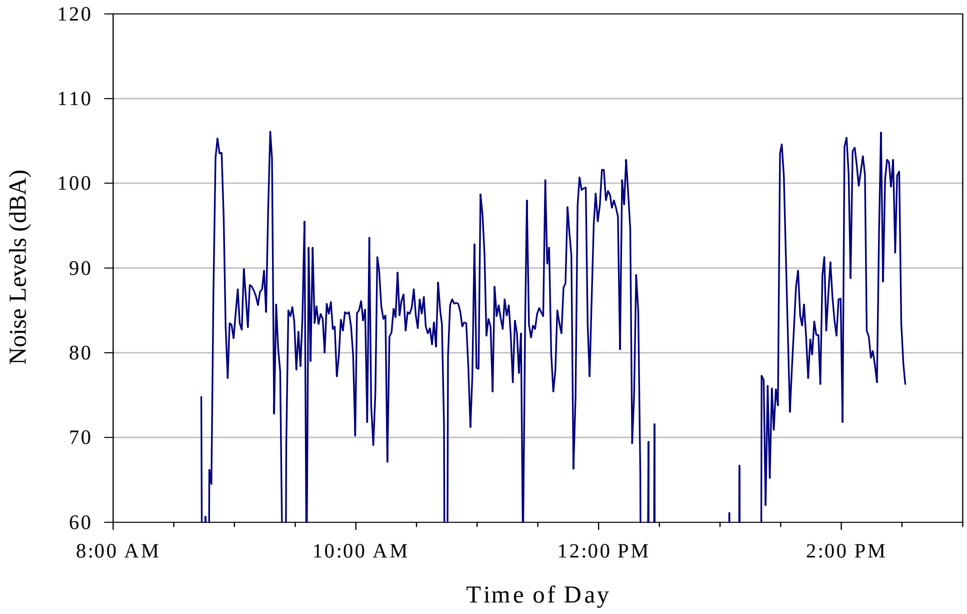


Figure 7
Noise Dosimeter Data: Roofer #7



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