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NIOSH HEALTH HAZARD EVALUATION REPORT

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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 Steven A. Lee of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical Support was provided by Ardith Grote, Division of Applied Research and Technology (DART); and Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Suzanne Eugster. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Exposure to Crystalline Silica among Rock Drillers

This NIOSH Health Hazard Evaluation (HHE) was requested by management at Rocky Mountain National Park (RMNP) in north-central Colorado. It was conducted in July and September 2003, to evaluate exposure to respirable crystalline silica among trail builders who use rock drills.

What NIOSH Did

- We visited the RMNP to evaluate exposure to silica during rock drilling.
- We collected air samples for total dust, respirable dust, respirable crystalline silica and carbon monoxide (CO).
- We compared the air concentrations of these substances during the use of a 75-pound gas-powered rock drill and a 30-pound rock drill.

What NIOSH Found

- Much higher levels of airborne dust and respirable crystalline silica were emitted when using the large drill compared to the small drill.
- Overexposure to crystalline silica would occur if the large rock drill was used without respiratory protection.
- Low exposure to respirable crystalline silica occurs when using the small rock drill and respirators are not necessary.
- Low levels of CO are emitted by both types of rock drills.

What Managers Can Do

- Whenever possible, limit the use of the large rock drill by encouraging the use of the small rock drill.
- When the larger rock drill must be used, strictly enforce the use of respiratory protection in accordance with RMNP's written respiratory protection program.
- Provide rock drillers with medical monitoring that includes a chest X-ray, pulmonary function test, and an annual evaluation for tuberculosis.

What the Employees Can Do

- Pour water in the drill holes of the small rock drill.
- Do not eat, drink, or smoke in the drilling area.
- Wash your hands before eating, drinking or smoking.

CDC Workplace Safety and Health

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NIOSH

Health Hazard Evaluation Report 2003-0275-2926
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Steven A. Lee

SUMMARY

In June 2003, the U.S. Department of Interior (DOI) asked NIOSH to evaluate exposure to airborne crystalline silica among rock drilling workers at Rocky Mountain National Park (RMNP) in north-central Colorado. Although employees had not reported any symptoms related to rock drilling, DOI management wanted documentation of worker exposure along with recommendations on the use of respiratory protection during the use of two types of portable gas-powered rock drills.

The park employs 45 trail workers to build new hiking trails and to maintain 360 miles of existing trails. Holes are drilled into large rocks so they can be split and used as steps for steep sections of trail. Crews of five or six workers per project use either a 75-pound drill or a 30-pound drill for splitting rocks. The larger drill forces compressed air through the drill shank as a means of keeping the drill hole free of dust. Water can not be used as a dust suppression method because it causes the drill bit to bind in the rock. The smaller drill does not have an air-flushing mechanism and water may be applied to the drill holes. The large drill can drill holes about four times faster than the small drill. Workers wear powered air-purifying respirators when using the large rock drill, since few other control options are available in remote areas.

Exposure to airborne total dust, respirable dust, respirable crystalline silica (quartz and crystobalite), and carbon monoxide (CO) was evaluated for five workers during three days of sampling with maximum wind conditions of three miles per hour. Two bulk samples of rock dust contained 15% and 23% quartz. No crystobalite was found in any of the air or bulk samples. When workers used the large drill, maximum 8-hour time-weighted average (TWA) air concentrations were as follows: airborne total dust, 4.8 milligrams per cubic meter (mg/m^3); respirable dust, 0.63 mg/m^3; and respirable quartz, 130 micrograms per cubic meter ($\mu g/m^3$). These results indicate that overexposure to quartz occurs if workers use the large drill without respiratory protection. All other measured contaminants were below recommended evaluation criteria. Using the small drill, 8-hour TWA exposure to total dust ranged up to 0.18 mg/m^3, respirable dust ranged up to 0.12 mg/m^3, and exposure to respirable quartz was non-detectable (< 30 $\mu g/m^3$) during both wet and dry drilling. Low exposure to CO (up to 9 parts per million, 8-hour TWA) was found during the use of both drills.

Overexposure to crystalline silica occurs when the large air-flushing, gas-powered rock drill is used on quartz-containing rock. Recommendations are provided to minimize exposure through personal hygiene, training, respiratory protection, and medical monitoring.

Keywords: 7999 (Recreational Services) respirable crystalline silica, quartz, rock drillers, trail builders, hiking trails, silicosis, gas powered rock drills, respiratory protection, carbon monoxide.

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INTRODUCTION

In June 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the U.S. Department of Interior (DOI) to evaluate exposure to crystalline silica among trail workers during rock drilling operations at Rocky Mountain National Park (RMNP), Estes Park, Colorado. Employees had not reported any adverse health effects associated with rock drilling but the DOI wanted documentation of exposure along with some assurance that the personal protective equipment being used was adequate to safeguard the health of the workers.

In July and September 2003, NIOSH conducted three visits to evaluate trail workers' exposure to contaminants while using two types of gas-powered rock drills at RMNP. Airborne concentrations of respirable crystalline silica, total dust, respirable dust, and carbon monoxide (CO) were assessed, and employee interviews were conducted.

BACKGROUND

Located in north-central Colorado, RMNP became the nation's tenth national park in 1915. It has more than 360 miles of hiking trails through ecosystems ranging from montane forest to alpine tundra. The park currently employs 45 trail crew workers to build new trails and maintain existing ones. These employees work in teams of five or six people per project. Trail-building tools include level bars, hammers, sledge hammers, shovels, pickaxes, chisels, wedges, and drills. Steps for steep sections of trail are constructed of rocks collected from the area and shaped to the proper size. Workers split large rocks by drilling several bole holes into them with a gas-powered drill and them hammering a series of wedges into the holes until the rock splits. There is usually only one worker at a time operating a drill for the trail crew. Trail workers rarely drill for more than three hours because the drills are heavy and it takes substantial effort to control them.

Two types of gas-powered drills are used by RMNP trail crews. The Pionjar® rock drill weighs about 75 pounds and is powered by a single-cylinder, air-cooled, 185 cubic centimeter (cc) two-stoke motor fueled by gasoline mixed in a 12:1 ratio with 2-stroke oil. The hammer piston, chuck, and 18-inch drill bit rotate at about 250 revolutions per minute (rpm). To keep the drill hole clear of cuttings, flushing air is drawn in during the downward stroke of the hammer piston, and then compressed and forced out through the chuck and drill shank at 20-30 pounds per square inch. Water cannot be used as a dust suppression method when the Pionjar® drill is used because it causes the drill bit to bind up in the rock.

The Pico 14® rock drill weighs about 30 pounds and is powered by a single-cylinder, air-cooled, 28 cc two-stroke motor fueled with gasoline mixed in a 25:1 ratio with 2-stroke oil. The drill rotates at about 275 rpm and there is no flushing air to keep the drill hole clear of cuttings. Although the manufacturer recommends pouring water into the drill hole to help clear dust from the hole and improve the effectiveness of the drill, workers at RMNP often use the drill without water in remote areas where none is available.

METHODS

On July 7, 2003, the NIOSH investigator conducted an evaluation of a rock driller's exposure to total dust, respirable dust, respirable crystalline silica, and CO during four hours of drilling a total of 18 holes with the Pionjar® drill. Personal breathing-zone (PBZ) particulate air samples were collected on pre-weighed polyvinyl chloride (PVC) filters at a flow rate of 2.5 liters per minute for both the total and respirable air samples. An SKC Aluminum Cyclone® was used for collecting the respirable dust samples. Also, one area air sample for respirable dust and respirable crystalline silica was collected about 10 to 12 feet downwind of the rock driller. The filters were analyzed for total weight by gravimetric analysis according to NIOSH Method 0500[1], followed by analysis for quartz and crystobalite using x-ray diffraction according to NIOSH Method 7500.[1] Bulk samples of rock dust were analyzed for quartz and crystobalite using x-ray diffraction according to NIOSH Method 7500.[1] Exposure to CO was measured using Biosystems Toxi-Ultra. These dataloggers continuously monitor by diffusion through an electrochemical sensor specific for CO. The monitors were worn in the breathing zone of the employees during drilling. Each instrument was pre- and post-calibrated using 50 parts per million (ppm) CO span gas. The units displayed the 8-hour time-weighted average (TWA), the maximum 15-minute exposure, and the maximum peak exposure for each worker.

All five of the workers on the trail crew were privately asked "have you experienced any health problems that you think might be related to your work?"

On September 3, 2003, potential exposure to airborne total and respirable dust, respirable crystalline silica, and CO were measured during two hours of operation of a Pionjar® drill during which nine holes were drilled. These exposures were also evaluated for a worker using a Pico 14® drill; however, the drill broke after only 20 minutes of operation. On September 11, 2003, a set of air samples was collected on a rock driller during two hours of drilling two holes without using water in the drill holes. Another set of particulate air samples were collected during two hours of drilling three holes using water.

Wind velocities were measured each day using either a TSI VelociCalc® Model 8360 thermal anemometer or a Skywatch® Meteos anemometer.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[1] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[2] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[3] 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 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)

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs. 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, but may appear in a shorter period of time if exposure concentrations are very high.[5] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 $\mu g/m^3$, as TWAs, for up to 10 hours per day during a 40-hour work week.[6] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen.[7-9] The OSHA PELs and the ACGIH TLV®s for respirable quartz and cristobalite are 100 and 50 $\mu g/m^3$, as 8-hour TWAs, respectively.[3,4]

Carbon Monoxide

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline. CO displaces oxygen in the blood and combines with hemoglobin to form carboxyhemoglobin (COHb). The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[10]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not been exceeded. The NIOSH REL of 35 ppm is intended to protect workers from health effects associated with COHb levels in excess of 5%.[10] The ACGIH recommends a TLV of 25 ppm as an eight-hour TWA, which is intended to protect workers from health effects associated with COHb levels in excess of 3.5%.[11] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure which is intended to protect workers from health effects associated with COHb levels in excess of 7.5%.[4]

Particulates, not otherwise classified

Often the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate ACGIH TLV criterion is now *"particulates, not otherwise classified (n.o.c.),"* [or *"not otherwise regulated"* (n.o.r.) for the OSHA PEL].

The OSHA PEL for total particulate, n.o.r., is 15 mg/m^3 and 5 mg/m^3 for the respirable fraction, determined as 8-hour averages. The ACGIH recommended TLV for exposure to a particulate, n.o.c., is 10 mg/m^3(total dust, 8-hour TWA). These are generic criteria for airborne dusts which do not produce significant organic disease or toxic effect when exposures are kept under reasonable control.[3]

RESULTS

During each of the NIOSH visits, wind velocities were less than three miles per hour. Two rock drillers had PBZ, 8-hour TWA concentrations of quartz of 120 and 130 $\mu g/m^3$, when they used the Pionjar® drill (Table 1). Airborne total dust PBZ 8-hour TWA concentrations during the same operations were 2.5 and 5.8 mg/m^3, and respirable dust PBZ 8-hour TWA concentrations were 0.63 and 0.45 mg/m^3. The area air sample collected downwind of one drilling operation had an 8-hour TWA quartz concentration of 53 $\mu g/m^3$, but no other employees were working that close to the drill during the NIOSH visits. No crystobalite was detected in any of the air samples. Drilling workers were exposed to 8-hour TWA CO concentrations of 9 and 3 ppm. The highest 15-minute TWA exposures to CO among the two workers when using the Pionjar® drill were 22 and 8 ppm.

When using the Pico 14® drill, workers were exposed to airborne total dust 8-hour TWA concentrations ranging up to 0.18 mg/m^3, and respirable dust 8-hour TWA concentrations ranging up to 0.12 mg/m^3 (Table 1). Exposure to respirable quartz was below the sampling and analytical limit of detection (<30 $\mu g/m^3$). One

8-hour TWA exposure to CO was 8 ppm. The location of last two sets of samples collected while using the Pico 14® drill was in a narrow pass with high rock ledges on each side, providing a semi-enclosed worst-case scenario for potential exposure to dust.

The type of rock being drilled during each of the NIOSH visits consisted of hard granite with very few striations or seams. Two bulk samples of rock dust collected from drill holes had quartz concentrations of 15% and 23%. Crystobalite concentrations in the bulk samples were below the analytical limit of detection (< 1%).

None of the five rock drilling workers interviewed by the NIOSH investigator reported having any health problems that they associated with their work. Personal protective equipment worn by trail workers during rock drilling included safety glasses, ear plugs, leather boots, and leather gloves with anti-vibration gel inserts. When using the Pionjar® drill, workers are required to wear a 3M Airstream® AS-200 loose-fitting, face shield, powered air purifying respirator (PAPR) with a high efficiency particulate air (HEPA) filter. RMNP has a written respiratory protection program stating that this respirator is required when using the Pionjar® drill along with criteria for proper storage, cleaning, maintenance, training, inspection, repair, and medical approval of workers assigned to wear respirators.

DISCUSSION

When workers used the Pionjar® drill, PBZ, 8-hour TWA quartz concentrations were above both permissible and recommended exposure limits. However, workers wore loose-fitting PAPRs with HEPA filters during the drilling operation. These respirators have a protection factor of 25, meaning that a properly worn and maintained respirator should reduce a person's actual exposure to an airborne contaminant by a factor of 25. Without a large increase in manpower to carry portable local exhaust ventilation equipment, no other control options are feasible when using the Pionjar® drill in remote locations.

The Pionjar® drill is much larger and more powerful than the Pico 14® drill. The Pionjar® can drill a hole in 8 to 12 minutes, while the Pico 14® requires 30 to 40 minutes to drill a hole. There was a dramatic visual and measured difference in the amount of airborne dust generated by these two types of rock drills. The flushing air mechanism of the Pionjar® drill caused a large thick white cloud of airborne dust during its use. In contrast, the Pico 14® drill, when operated dry, gradually built up a small pile of rock dust around the top of the drill hole with no visible airborne dust emissions. The only visual difference between wet and dry drilling was some additional accumulation of dust on the boots and pant cuffs of the operator during dry drilling. No exposure to airborne quartz was detected during the use of either wet or dry methods. However, a sampling and analytical limit of detection of 30 $\mu g/m^3$ is fairly high (60% of the NIOSH REL). It is probable that wet drilling has the potential to produce lower exposure than dry drilling even though both methods generate exposures below the limit of detection.

Exposure to CO was well below all permissible and recommended occupational exposure limits during the use of both types of drills.

CONCLUSIONS

The Pico 14® drill may be used with either wet or dry methods without respiratory protection, although wet drilling is preferable when possible. The Pionjar® drill should not be used without respiratory protection; therefore, the advantages of using the faster, more powerful drill must be weighed against the increased expense and regulatory burden of maintaining an effective respiratory protection program.

RECOMMENDATIONS

1. The Pico 14® drill should be used instead of the Pionjar® drill whenever possible. Also, the Pico 14® drill should be used with wet methods when water is available.

2. If the Piojar® drill must be used, the operator should continue to use a respirator in accordance

with RMNP's written respiratory protection program. Coworkers should avoid working within 20 feet downwind of Piojar® drilling operations unless they don respiratory protection.

3. Workers should not eat, drink, or use tobacco products in the drilling area and drillers should wash their hands and faces before eating, drinking, or smoking.

4. To avoid contaminating cars, homes, or other work areas, drillers should change into clean clothes before leaving the worksite.

5. Information about the adverse health effects of exposure to crystalline silica should be included when training rock drillers.

6. Rock drillers should have a medical examination before job placement and at least every three years thereafter. The exam should include the collection of data on worker exposure to crystalline silica and signs and symptoms of respiratory disease, a chest X-ray, pulmonary function testing, and an annual evaluation for tuberculosis.[12]

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Table I

Eight-Hour TWA Air Concentrations of Total Dust, Respirable Dust, and Quartz

Date/Job/ Location	Sample Duration (min.)	Total Dust (mg/m^3)	Respirable Dust (mg/m^3)	Respirable Quartz ($\mu g/m^3$)
7/23 PBZ Pionjar® drilling	300	2.5	0.63	120
7/23 Area, 12 ft. from Pionjar®	300	-	0.42	53
9/3 PBZ Pionjar® drilling	110	4.8	0.41	130
9/3 PBZ Pico 14® drilling	20	ND	ND	ND
9/11 PBZ Pico 14® dry drilling	120	0.18	0.083	ND
9/11 PBZ Pico 14® wet drilling	150	0.17	0.12	ND

TWA - time-weighted average

mg/m^3 - milligrams per cubic meter

$\mu g/m^3$ - micrograms per cubic meter

PBZ - personal breathing zone

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