Highway Repair: A New Silicosis Threat

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Objectives. We describe an emerging public health concern regarding silicosis in the fast-growing highway repair industry.

Methods. We examined highway construction trends, silicosis surveillance case data, and environmental exposure data to evaluate the risk of silicosis among highway repair workers. We reviewed silicosis case data from the construction industry in 3 states that have silicosis registries, and we conducted environmental monitoring for silica at highway repair work sites.

Results. Our findings indicate that a large population of highway workers is at risk of developing silicosis from exposure to crystalline silica.

Conclusions. Exposure control methods, medical screenings, protective health standards, and safety-related contract language are necessary for preventing future occupational disease problems among highway repair workers. (*Am J Public Health.* 2004;94:876–880)

The United States is currently engaged in a massive public works effort to repair the national highway system's deteriorating infrastructure.[1,2] The Federal Highway Administration and state transportation agencies are responsible for improvements to the national highway system and its support roads. The national highway system is composed of 163 000 miles of rural and urban roads and includes the interstate system, other urban and rural principal arteries, and strategic highway network connectors. The Transportation Equity Act for the 21st Century (TEA-21) was enacted on June 9, 1998, and is the latest in a series of legislation that authorizes federal surface transportation programs for highways, highway safety, and transit.[3]

Because the interstate system is nearly completed, the focus has shifted from constructing new highways to preserving and improving existing highways. Much of the pavement on the interstate system was constructed 20 to 40 years ago, with some older highways having been incorporated into the system. Data on interstate pavement condition are taken from the Highway Performance Monitoring System (HPMS) and are used to track the condition and the performance of US highway systems. The 1994 HPMS report to Congress (the most recent) showed that more than half of the highway system's pavement was rated as fair to poor, indicating a need for resurfacing or other rehabilitation in the near future.[4]

Traditional methods of highway surface repair involved patching damaged areas with asphalt, an approach that usually resulted in failure within months of the repair. In the mid-1980s, a new method of cut-and-repair road maintenance that uses newly developed quick-setting concrete material, resulted in more permanent repairs. This new method utilizes large crews to cut, break up, and remove large sections of concrete road before patching begins. These operations, sometimes completed during overnight work shifts, result in the generation of large amounts of dust.

Our article describes the potential risk of silicosis for workers in the fast-growing highway repair industry. We reviewed silicosis surveillance data from the National Institute for Occupational Safety and Health (NIOSH) Sentinel Event Notification System for Occupational Risks (SENSOR) and crystalline silica exposure data from highway repair projects collected during the 1999 road construction season.

Background

Silicosis is a disabling, nonreversible, and sometimes fatal lung disease caused by inhaling dust containing extremely fine particles of crystalline silica.[5,6] Crystalline silica is found in materials such as concrete, masonry, and rock. Working with materials that contain crystalline silica can produce airborne respirable dust, causing lung damage. Silicosis is a disease with a long latency period and usually takes 20 years or more to develop. Symptoms of silicosis include shortness of breath, wheezing, chest tightness, and cough, although initially there may be no symptoms. In addition to causing silicosis, inhalation of crystalline silica particles has been associated with other diseases, such as chronic obstructive pulmonary disease, connective tissue disease, renal disease, tuberculosis, and lung cancer.

The dangers of silica exposure and silicosis are well established in the mining,[7–9] iron and steel manufacturing,[10,11] and pottery industries.[12–14] The danger to construction workers is less clear, although certain occupations (e.g., masonry, abrasive blasting) have well-documented associations with silicosis.[15–19] Since 1985, silicosis surveillance has been conducted in several states under the NIOSH SENSOR program.[20] The New Jersey Department of Health and Senior Services (NJDHSS) is 1 of 3 state agencies that conduct surveillance of silicosis under SENSOR (Michigan and Ohio are the other 2 states). The SENSOR states obtain reports of silicosis from hospital discharge data, physician records, death certificates, and other sources.[21] Recently, California, New York, Maine, New Mexico, and North Carolina have begun silicosis surveillance under various NIOSH surveillance grants.

The NJDHSS maintains a registry of reported silicosis cases and collects the medical and occupational data necessary for determining whether a case meets an epidemiological case definition. Cumulative data on silicosis are collected and are analyzed by NIOSH to determine incidence, causes, and trends of the disease. An integral component of the New Jersey surveillance system for silicosis is the follow-up of work sites identified through case reports. NJDHSS industrial hygienists conduct on-site evaluations, assess the risk of exposure to silica, and recommend control measures to prevent exposure.

The NJDHSS began a hazard surveillance project in 1998 to investigate highway repair as a possible source of silica exposure. Interest

TABLE 1—Participants in the New Jersey Silica Partnership

NJ Dept of Health and Senior Services
NJ Dept of Transportation
NJ Dept of Labor, OSHA Onsite Consultation Service
Federal Dept of Labor, OSHA
NIOSH, Division of Respiratory Disease Studies
NIOSH, Division of Engineering Control Technology
Utility and Transportation Contractors Association
Association of General Contractors
Laborers' Health and Safety Fund of North America
Laborers' International Union, Locals 172 and 472
NJ State Safety Council
Ten different highway construction contractors

Note. OSHA = Occupational Safety and Health Administration; NIOSH = National Institute for Occupational Safety and Health.

in this industry stemmed from a sentinel case of silicosis identified by NJDHSS in 1993. The case involved an individual who worked for 2 road construction companies from 1955 to 1990. This person was 63 years old when he was first diagnosed with silicosis. His work history indicated exposure to silica dust without respirator use during highway-building activities. Although the sentinel case pointed to exposure as a result of building roads versus repairing highways, a link between the highway construction industry and silica exposure was established. A review of the Occupational Safety and Health Administration's (OSHA) Integrated Management Information System database revealed that few data were available on silica exposure from highway construction. A pilot project was initiated with the New Jersey Department of Transportation (NJDOT) to perform industrial hygiene air sampling at highway repair sites. Air sampling was performed at a bridge deck repair site during the 1998 summer construction season; levels of silica dust indicated that workers were potentially overexposed.

In January 1999, the New Jersey Silica Partnership (Table 1) was formed to address issues associated with silica exposure among New Jersey road and highway workers. The primary goal of this effort was to quantify silica exposure from dust-producing tasks undertaken during road construction and repair work. The silica exposure data were used to support the development of protective language for NJDOT contracts similar to the health and safety language for reducing lead exposure that currently appears in NJDOT contracts for overpass- and bridge-painting operations.

METHODS

The materials used to build roads, such as concrete, asphalt, and masonry products, contain silica sand as well as other types of crystalline silica. Road construction and repair workers are potentially exposed to airborne silica dust from activities that create airborne dust, such as sawing, breaking, and grinding concrete and other materials that contain silica.

We reviewed all confirmed silicosis cases from the New Jersey, Michigan, and Ohio silicosis registries containing work histories coded with construction Standard Industrial Classification (SIC) codes[22] for SENSOR case reports from 1993–1997. In addition to identifying the workplace associated with each case, we collected data on occupation, age at diagnosis, year of first exposure, and duration of exposure. We reviewed case data to determine whether a link could be established between highway and road construction and silicosis.

In April 1999, NJDHSS industrial hygienists began a 6-month effort to collect air-sampling data for various tasks performed in road construction and repair. A protocol was developed and was distributed to 10 contractors who had been awarded highway repair contracts from the NJDOT. Personal samples of respirable crystalline silica dust were collected at a flow rate of 1.7 L/min with a battery-operated sampling pump. The pump was attached to the employee's waist and was connected via Tygon tubing to a preweighted 37-mm, 5-μm pore-size polyvinyl chloride filter in a filter cassette; a 10-mm Dorr-Oliver nylon cyclone was placed in the employee's breathing zone in accordance with NIOSH method 7500.[23] Samples were analyzed by an OSHA-accredited laboratory in accordance with OSHA method ID-142.[24]

At each worksite survey, workers involved in specific highway repair tasks were selected for silica air sampling. These dust-producing tasks were targeted after discussions with the contractors and the industrial hygienist's visual observation of dust generated from the various tasks during the initial survey. Eight-hour time-weighted-average sample results were compared with exposure standards established by OSHA and the American Conference of Industrial Hygienists (ACGIH) for crystalline silica. The OSHA permissible exposure limit (PEL) varies from 0.1 mg of respirable dust per cubic meter of air (mg/m^3) to almost 5 mg/m^3 depending on the percentage of crystalline silica in the dust. In 2000, the ACGIH adopted a threshold limit value (TLV) of 0.05 mg/m^3 for respirable crystalline silica.[25] The 0.05 mg/m^3 level is equal to the recommended exposure limit (REL) established by NIOSH in 1974.[26]

RESULTS

Surveillance Case Data

Five hundred seventy-six confirmed silicosis cases in New Jersey, Michigan, and Ohio were reported to NIOSH for the years 1993 through 1997. Silicosis cases were identified by first determining potential silica exposure from the work history; then confirmation was obtained through either a positive chest x-ray reading for silicosis by a NIOSH certified "B reader" or a medical record radiology report with findings consistent with silicosis.[27] Work history data indicated 45 (8%) of the confirmed cases resulted from work in the construction industry under SIC codes 15, 16, and 17. Twelve (27%) of the construction cases were coded under SIC 16, "heavy construction other than building construction." SIC 16 includes road, bridge, tunnel, elevated-highway, water, sewer, and utility line construction. SIC 16 also includes miscellaneous heavy construction, such as dam, power plant, marine, and golf course construction. Highway repair contractors are usually small, multitask companies that engage in a wide range of construction activities.

Industry, occupation, age at diagnosis, year of first exposure, and duration of exposure for silicosis case reports under SIC 16 are shown in Table 2. Five of the 12 SIC 16 cases (42%) involved work in tunnel construction. Three cases (25%) specifically identified road construction and maintenance as the primary source of exposure. The New Jersey road-construction case indicated new-highway construction in which exposure began in the 1950s, well before the introduction of the modern cut-and-patch repair method. Case 1 in Ohio occurred in a laborer with an 8-year

TABLE 2—Highway Construction Silicosis Case Data—New Jersey, Michigan, Ohio: 1993–1997

Construction Type (SIC 16)	Occupation	Age at Diagnosis, y	Year of First Exposure	Duration of Exposure, y
New Jersey				
Road	Maintenance	63	1955	34
Tunnel	Laborer	75	1946	11
Tunnel	Driller	65	1928	23
Tunnel	Sandhog[a]	49	1938	...
Tunnel	Welder	...	...	...
Tunnel	Sandhog	61	1969	18
Michigan				
Heavy	Truck driver	...	1970	24
Heavy	Equipment operator	...	1976	8
Sewer	Laborer/sandblaster	...	1954	27
Ohio				
Road	Laborer	37	...	8
Road	Maintenance	...	...	...
Sewer	Laborer	80	1958	15

Note. SIC 16 = Standard Industrial Classification (SIC) code 16: heavy construction other than building construction.
[a]Tunnel worker.

duration of work involving the use of a jackhammer on bridge surfaces, although no information was provided about when exposure occurred. Road maintenance was listed as the occupation on the death certificate for case 2 in Ohio but no data were provided on year of first exposure or duration of exposure. Two cases in Michigan potentially involved road construction; again, however, the work histories were incomplete.

Air-Monitoring Data

Monitoring for airborne crystalline silica was completed for 9 highway repair sites involving 7 contractors. These contractors were listed according to the following Dun & Bradstreet MarketPlace industry classifications: concrete construction (roads, highways, sidewalks; SIC codes 1611–0202), general contractor (highway and street construction; SIC codes 1611–9901), and highway- and street-paving contractor (SIC codes 1611–0204). A total of 52 samples were collected for 7 of the 9 typical tasks: operating a jackhammer, sawing concrete, milling concrete, cleaning up concrete, drilling dowels, milling asphalt, and cleaning up asphalt. Samples were not collected for scabbling (small-scale surface milling) and grooving (surface depth cutting). The percentage of crystalline silica contained in the dust of an air sample was used to calculate the OSHA PEL for each respective sample.

Airborne levels of crystalline silica associated with 7 major road repair tasks are shown in Table 3. Sample results indicated a significant risk of overexposure to crystalline silica for workers who performed the 5 highway repair tasks involving concrete. Mean sample results for these 5 tasks exceeded the ACGIH TLV for crystalline silica. Sample results in excess of the OSHA PEL were found for operating a jackhammer (88% of samples), sawing concrete and milling concrete tasks (100% of samples); cleaning up concrete tasks (67% of samples); and drilling dowels (100% of samples). No measured exposures in excess of the PEL were found for milling asphalt and cleaning up asphalt; however, of the 8 samples collected for milling asphalt, 6 (55%) results approached the OSHA PEL, and 1 was at 92% of the PEL. The percentage of samples exceeding the more stringent ACGIH TLV was even greater. No dust-control measures were in place during the sampling of these highway repair operations.

TABLE 3—Task-Based Silica Exposures: Sample Data

Task	No. of Samples	Range of Sample Results (mg/m^3)[a]	Mean (mg/m^3)[a]	SD	No. (%) of Samples Above OSHA PEL	No. (%) of Samples Above ACGIH TLV
Operating a jackhammer	25	0.03–0.63	0.276	0.161	22 (88)	24 (96)
Sawing concrete	6	0.15–0.50	0.348	0.144	6 (100)	6 (100)
Milling concrete	2	0.99–1.15	1.070	0.113	2 (100)	2 (100)
Cleaning up concrete	6	0.02–0.26	0.152	0.099	4 (67)	5 (83)
Milling asphalt	8	nd–0.07	0.041	0.027	0	4 (50)
Cleaning up asphalt	3	nd–0.02	0.007	0.012	0	0
Drilling dowels	2	0.05–0.16	0.107	0.076	2 (100)	2 (100)

Note. mg/m^3 = milligrams of respirable dust per cubic meter of air; OSHA PEL = Occupational Safety and Health Administration permissible exposure limit; ACGIH TLV = American Conference of Industrial Hygienists threshold limit value; nd = nondetectable (below lower detection limit).
[a]8-hour time-weighted-average samples.

DISCUSSION

Large-scale public works projects and silicosis share a common history. For example, the Hawk's Nest disaster[28,29] and water tunnel construction in New York City[30,31] led to epidemics of silicosis among the respective worker populations. Although highway maintenance construction does not fit the definition of a large-scale project, the ubiquity of maintenance projects throughout the United States could conceivably result in hazardous silica exposures for many more workers than those caused by large scale projects. In the United States, almost 1 million workers are employed in SIC 16 jobs—heavy construction other than building construction. Approximately 350 000 (39%) of these workers are employed in highway and street construction, with an additional 54 000 (6%) employed in bridge, tunnel, and elevated-highway construction. Recent congressional legislation has authorized substantial spending for rehabilitation of the national highway system. This emphasis on rebuilding road infrastructure creates a scenario in which large numbers of workers will be exposed to crystalline silica dust and silicosis incidence will increase.

Occupational disease surveillance case data from the New Jersey, Michigan, and Ohio SENSOR programs indicate that workers employed in certain occupations in the construction industry are at risk of developing silicosis. The disease evidence is less clear for highway construction workers, because the majority of identified cases in this group occurred in individuals working in tunnel construction. Only 3 (7%) of the 45 SENSOR-reported silicosis cases in the construction industry between 1993 and 1997 had work history data identifying exposure specific to highway construction work. A sentinel-event surveillance system such as SENSOR is limited in its ability to detect a long-latency chronic disease among the worker population because of the relatively short time that modern highway repair methods have been in use. This lack of sensitivity in identifying silicosis among a newly exposed population demonstrates the importance of using hazard-surveillance methods to identify populations at high risk and to target preventive interventions. Hazard surveillance refers to the ongoing assessment and evaluation of hazardous substance use in the workplace and of worker exposure to these hazardous materials.[32,33] High exposure to crystalline silica from routine activities is sufficient evidence of the need to develop and implement increased public health prevention activities for the identified industry.

Concrete disturbance and removal during highway repair projects generate high levels of airborne crystalline silica dust. However, highway worker exposure to crystalline silica is variable. Highway repair work is conducted in an open-air environment in which weather conditions can affect exposure levels. Intense exposure can potentially occur when larger-scale projects are conducted in an assembly-line fashion and when tasks that generate dust, such as operating a jackhammer or sawing concrete, are performed continuously for a full 8-hour shift. Conversely, crews that work on small road-repair projects spend about half the shift removing the existing concrete and the remaining time doing relatively dust-free patch work, resulting in lower overall exposures to silica dust. A highway worker who performs a nonexposure task (e.g., a flagman) can potentially be exposed to dust generated by other tasks performed nearby. The amount of highway repair work contracted to a specific contractor is dependent on available projects and successful bidding. Companies involved in this type of work also specialize in types of construction work not involving concrete. Thus, employees may be exposed to silica dust on only an intermittent basis. Also, the highway worker may be a general laborer who is involved in other work than highway repair. Highway repair methods may vary in different parts of the country; for example, the Connecticut Department of Transportation will sometimes require the use of water to control dust during construction work. New Jersey projects do not use water because of potential problems with construction material performance, environmental concerns with slurry runoff, costs associated with vehicle cleanup and paint damage claims from passing motorists, and concerns about hazardous driving conditions on wet roadways.

The air-sampling results in Table 3 show levels of respirable silica dust above the OSHA PEL for 6 of the 8 tasks performed during highway repair. For typical tasks such as operating a jackhammer and sawing concrete, average silica exposures approached 3 times the regulatory limit, whereas sample results for milling concrete were more than 10 times this limit. Exposures were dramatically higher than the limits established by ACGIH for protection against silicosis. The recently adopted ACGIH TLV is at most one half the current OSHA PEL. One must consider that the OSHA PEL for crystalline silica is based on outdated toxicological information from the late 1960s. OSHA has placed crystalline silica on its Semiannual Regulatory Agenda (in the proposed rule stage[34]) to develop a comprehensive standard for exposure to crystalline silica.

The various exposure limits for crystalline silica have been established to prevent silicosis, but they do not address the risk of cancer associated with crystalline silica exposure. The International Agency for Research on Cancer has designated inhaled crystalline silica as a Class I carcinogen,[35] and the National Toxicological Program has designated it as a substance known to be a human carcinogen.[36] The ACGIH lists quartz silica as a "suspected human carcinogen."[37] Prudent occupational health practice dictates that exposures to known and suspected carcinogens be maintained at levels as low as reasonably achievable.

To reduce worker exposure, future activities addressing the silica exposure hazard must focus on prevention. Research on concrete, stone, and masonry jobs that involve drilling and sawing has demonstrated the efficacy of water in reducing dust levels to which workers are exposed.[38–40] A project carried out through the New Jersey Silica Partnership observed a significant reduction of dust generated by jackhammers during concrete breakup when a low-volume water spray or local exhaust ventilation were used.[41] Until feasible engineering controls are developed and effectively deployed, highway workers must rely on appropriate hazard awareness training and respiratory protection to control their exposures to crystalline silica dust. Highway workers should be required to wear half-mask air-purifying respirators fitted with high-efficiency N-100 or P-100 filters as part of a comprehensive respiratory protection program.

Continued research is needed to confirm the link between silicosis and highway repair work. Modern highway repair methods did not begin until the mid-1980s, and jobs that utilize these methods are increasing in number as the nation's highway infrastructure is rebuilt. A cohort of high-risk highway repair workers with long-term exposures could be medically screened for silicosis to further evaluate the disease potential among this occupational group.

The NJDOT has implemented a proposal to include silica safety and health language in highway repair contracts similar to the language for lead exposure in contracts for bridge-painting projects. This strategy has worked especially well in reducing lead levels in the blood of workers who are involved in bridge-painting operations.[42] In the continued absence of comprehensive federal regulations for silica exposure, Federal Highway Administration and state department of transportation contracts for highway repair should require basic preventive actions, such as dust control, exposure monitoring, respirator use, and training to protect highway repair workers from silicosis. ■

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Contributors

D.J. Valiante conceived the project and wrote the article. D.P. Schill directed the project and helped analyze the data. K.D. Rosenman helped conceive the project, and E. Socie reviewed interim data and provided data analysis. All authors provided substantive contributions to the article.

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Human Participant Protection

The disease surveillance component of this project was both reviewed and approved by the institutional review board of the New Jersey Department of Health and Senior Services. The environmental evaluation component of the study was exempt from institutional review board approval because no personal identifiers were involved. No informed consent was obtained, because study participants were not enrolled.

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