CDC

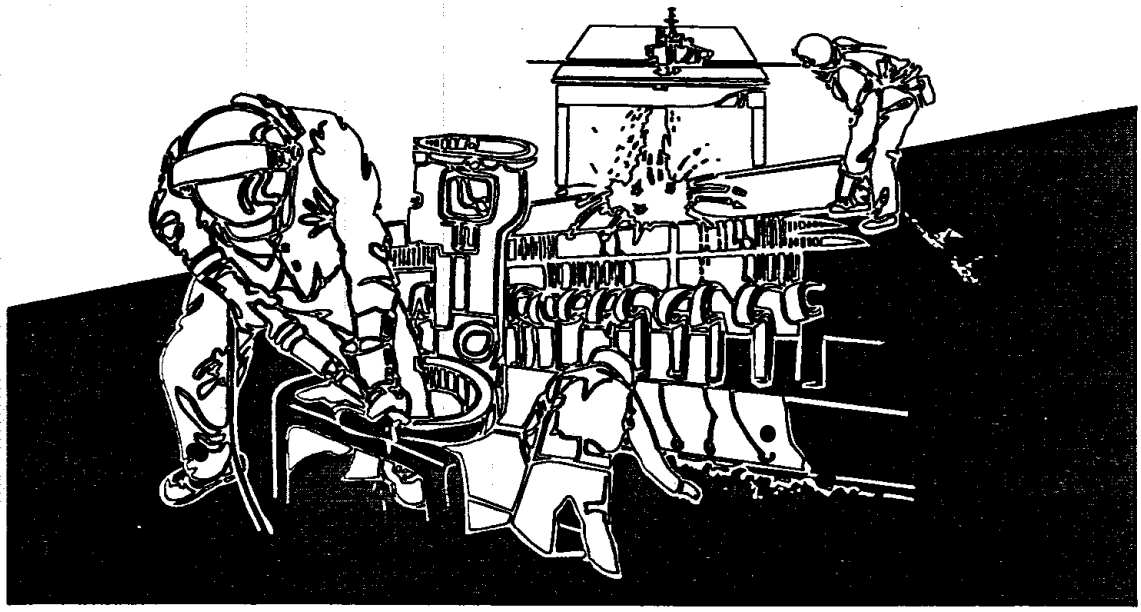
Centers for Disease Control And Prevention

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 91-0375-2779
J.S. Silica Company, Berkeley Springs
Berkeley Springs, West Virginia

Margaret S. Filios, SM RN

NIOSH HEALTH HAZARD EVALUATION REPORT



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

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 Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

NIOSH 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 the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Margaret S. Filios, SM, RN, of the Surveillance Branch, Division of Respiratory Disease Studies (DRDS). Assistance was provided by Jean Cox-Ganser, Ph.D., Field Studies Branch; and Ken Ream, DRDS. Analytical support was provided by Kathleen Fedan, BS, Field Studies Branch. Desktop publishing was performed by Terry Rooney.

Copies of this report have been sent to employee and management representatives at U.S. Silica Company; General Teamsters and Allied Workers, Local 992; International Brotherhood of Teamsters, A.F.L.-C.I.O; Mine Safety and Health Administration; West Virginia Bureau of Public Health; National Industrial Sand Association; PACE International; Glass, Molders, Pottery, Plastics & Allied Workers International; and the Laborers' Health and Safety Fund of North America. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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

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

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 91-0375
U.S. Silica Company, Berkeley Springs
Berkeley Springs, West Virginia
February 2000

Margaret S. Filios SM, RN

SUMMARY

In July 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Mine Safety and Health Administration (MSHA) to estimate the prevalence of silicosis among active and retired miners at U.S. Silica Company's Berkeley Springs plant, in Berkeley Springs, West Virginia.

Current and former workers with one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream (by material processing) of the grinding process represented the population of primary interest. On June 14-17, 1993, a medical evaluation of current workers was conducted. Former workers were tested on June 18, 1993. The medical evaluation included a questionnaire, spirometry, and a single view posterior-anterior (PA) chest x-ray. Chest x-rays were independently classified according to the 1980 International Labour Office (ILO) system by three NIOSH-certified B readers who were unaware of the participant's age, occupation, occupational exposure, smoking history, or any identifying information. For the purposes of this evaluation, silicosis was defined on the basis of a chest x-ray with median small opacity profusion classification of category 1/0 or greater.

Fifty-four (89%) of 61 current workers and 13 (41%) of 32 former workers who met the study criterion participated in the NIOSH medical evaluation. Of these 67, seven (10%) had a chest x-ray consistent with silicosis. The highest median ILO profusion category was 2/2. Two of the seven had a chest x-ray consistent with progressive massive fibrosis (PMF), with "B" size large opacities (based on the median of the three readings).

Nineteen (28%) of the 67 participants who performed spirometry had abnormal patterns; 13 (68%) of the 19 exhibited an obstructive lung pattern, four (21%) exhibited a restrictive pattern, and two exhibited a combined restrictive and obstructive pattern. An abnormal spirometry pattern was present in four of the seven participants with a positive chest x-ray.

U.S. Silica's medical monitoring includes all of the screening tests recommended by the National Industrial Sand Association (NISA) as well as those recommended by NIOSH for workers exposed to ground silica. NISA's current guidelines also recommend multiple readings of all chest x-rays with a small opacity profusion classification of 1/0 or greater and 5-10% of those chest x-rays classified as 0/1 based on a single reading. Since 1990, the company reportedly sent chest x-rays initially classified 1/0 or greater by a single reader for additional classifications. Of the company records we reviewed, company chest x-rays initially classified as negative (0/0 and 0/1) were not routinely sent for additional readings.

Seven (10%) of the 67 survey participants who met the study criterion were found to have chest x-ray findings consistent with silicosis. These results are consistent with patterns of crystalline silica dust exposure at this facility. There were no cases of silicosis among current or former workers with 15 or less years of tenure; however, because of the long latency usually associated with chronic silicosis, this finding is not sufficient to conclude that current crystalline silica dust exposure levels are without adverse effect.

The company medical monitoring practice of obtaining additional B reader classifications of those chest x-rays initially classified 1/0 or greater may produce an estimated prevalence no higher than and possibly lower than that obtained with a single reading, and those workers with a positive chest x-ray whose chest x-rays are initially read as 0/0 or 0/1 will not be identified.

Recommendations are presented in this report and include obtaining at least two readings of all chest x-rays regardless of the initial small opacity profusion classification, increasing the frequency of medical monitoring examinations, and modification of the baseline and routine examinations to include skin testing for tuberculosis (TB).

Keywords: SIC 1446 (Industrial Sand), Silica, Silicosis, Mineral processing, Ground Silica, Silica flour

TABLE OF CONTENTS

INTRODUCTION

In July 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the Mine Safety and Health Administration (MSHA) to estimate the prevalence of silicosis among active and retired miners at U.S. Silica Company's Berkeley Springs plant, in Berkeley Springs, West Virginia. The medical evaluation was part of a joint project between MSHA and NIOSH to study silica exposures and the prevalence of silicosis in workers in a number of ground silica mills. A protocol outlined the responsibilities of each agency (see Appendix I). MSHA selected the nine sites for this study and was responsible for the evaluation of crystalline silica dust exposures as well as dust control methods. NIOSH was responsible for conducting medical evaluations at each site. This is the final report of the NIOSH medical evaluation conducted at U.S. Silica Company's Berkeley Springs facility.

On June 14, 1993, an opening meeting was held with company, union, and miners' representatives to discuss the ensuing evaluation. The medical evaluation of current workers began that afternoon and continued through June 17, 1993. Former workers were tested on June 18, 1993. A second site visit was made October 19 - 20, 1993, to collect additional work history information from participants. All study participants received written notification of their spirometry results in July, 1993. All chest x-rays were promptly reviewed by a pulmonary physician for evidence of acute health problems upon return to NIOSH and prior to the classification process. All study participants received written notification of their chest x-ray results in June, 1994.

In 1993, each company with a site, or sites, selected by MSHA for evaluation, was asked by NIOSH to provide medical and personnel records of current and former employees who had worked at least one year since 1970. Of the nine sites, three were U.S. Silica operations, one of which was the Berkeley Springs facility. In March of 1995, following negotiations and legal proceedings, a settlement was reached concerning NIOSH access to company medical and personnel records. U.S. Silica agreed to extract, copy, and provide the records of former Berkeley Springs workers whom the company determined had met the NIOSH criterion for entry into the study population (i.e., one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream by material processing of the grinding process). U.S. Silica also agreed to extract, copy, and provide certain company medical and personnel records of current Berkeley Springs workers who signed an authorization form. The production of records for all three U.S. Silica sites began in July, 1995 and was completed in November, 1996.

BACKGROUND

U.S. Silica Company, formerly known as Pennsylvania Glass Sand Corporation, has operated a facility at Berkeley Springs since 1904 and began producing ground silica products in 1911. The present processing plant was constructed in 1929-30, with modernization of silica-grinding equipment and increases in capacity occurring in 1946-47, and again in the 1960's and 70's. The General Teamsters and Allied Workers, Local 992, has represented employees at this plant since the early 1950's.

At the Berkeley Springs plant, sandstone is surface-mined and brought to the plant for processing where it is crushed, dried, screened, and milled. Some products are further classified to produce ground silica products ranging in particle size from 5 to 40 microns. The ground silica products that are produced are then bagged in either 50-pound or 2000-pound bulk bags or bulk-loaded into railroad cars or trucks. At the time of our survey in 1993, the plant operated production processes 24 hours a day, 5 days a week, with three 8-hour shifts. Maintenance occurred weekly on Mondays during the first (daylight) shift. No milling or grinding took place while maintenance activities were performed. A total of 116 employees (including clerical and

salaried) worked in the quarry and at the processing plant. The departments that were part of the Berkeley Springs operation were: Mining, Wet Process, Dry Process, Milling, and Maintenance. The main job categories affected by the grinding process were: Miller, Mill Assistant or Helper (duties include clean-up), Bagging or Packaging worker (Bagger, Ground Packer, Utility, or Loader), Mill Tester, Maintenance (e.g.,mechanics and electricians), and Supervisory personnel (e.g., working foreman or general supervisor).

METHODS

Study Objective

The primary objective of the study was to estimate and report the prevalence of silicosis among participating current and former employees in the grinding area and/or downstream (by material processing) of the grinding area, by tenure and job, if feasible. To assess any bias in the prevalence estimate caused by lack of full participation in the medical survey, demographic characteristics and disease status of participants and living non-participants who met the study criterion were compared using information obtained from company records.

Company medical monitoring programs and practices were also examined and evaluated as factors that affect silicosis prevalence and contribute towards its prevention.

Study Population

The study population was defined as all current workers and living former workers who had one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream of the grinding process.

The company provided rosters of current ground silica production and maintenance workers and a roster of former workers from 1970 employed for one year or more. The union provided a roster of all current workers and a roster of former (inactive) workers dating back to January 1991, when the Berkeley plant became a part of the Teamsters Health and Welfare program. Using the union rosters, we mailed letters to workers inviting them to participate in the medical evaluation. Additionally, advertisements were placed in local newspapers to reach those workers who may have moved within the local area or otherwise may have failed to receive a letter. To avoid inadvertent oversight of an eligible worker with prior experience in the grinding area or areas downstream of the grinding process, workers were invited to participate regardless of work area or length of employment. For current workers who chose to participate, eligibility for inclusion in the study population was determined using information from discussions with company representatives, company records, the medical evaluation, and MSHA, and additional information provided by the union. For former workers who chose to participate, eligibility was determined using information from the medical evaluation, company records, company information regarding eligibility when no records were provided (i.e., correspondence), and any additional information provided by the union. We relied chiefly on the company to initially identify eligible non-participating current and former workers and provide their records, which we reviewed.

Data Collection

Posterior-Anterior Chest X-Ray

Chest x-rays were taken on a full size (14 x 17 inch) film. All chest x-rays were read independently by three B readers who, without knowledge of the participant's age, occupation, occupational exposure, smoking history, or any identifying information, classified the films according to the 1980 ILO International Classification of Radiographs of Pneumoconioses.[1] A B reader is a physician who has demonstrated the ability to classify chest x-rays for the pneumoconioses (dust diseases of the lung)

using the ILO Classification System by passing a certification examination administered by NIOSH. The NIOSH-certified B readers used in this project had each classified at least 500 chest x-rays for the 4th round of the NIOSH Coal Workers' X-Ray Surveillance Program. They had also participated in a pilot study which entailed a reading trial of over 400 films of anthracite miners in preparation for a current exposure-response study using National Study for Coal Workers' Pneumoconiosis films. After determining that NIOSH B reader certification was not due to expire any time between June 1993 and December 1994, the readers were contacted and interest and availability to read chest x-rays for the present study were ascertained. The same three B readers were used throughout the entire project.

The ILO classification method is used for epidemiological research, for the surveillance of workers in dusty occupations, and for clinical purposes. The method recognizes two major categories of opacity size: small (≤ 1 centimeter) and large (> 1 centimeter).[2]

The profusion (i.e., number) of small opacities are recorded using a graduated 12-point scale within four major categories (0, 1, 2, 3). A major profusion category of 0 indicates no apparent abnormality, while 3 indicates substantial abnormality. Film classification is achieved by comparing the subject film with the appearance of "standard films" which define small opacity profusion. In classifying small opacity profusion, the final determination of major category is listed first. If a higher or lower major category has also been seriously considered, this category is also listed after a slash mark. If there is no question as to major category, the two listed numbers are identical.[1,2]

Thus, the small opacity profusion scale is as follows:

0			1		
0/-	0/0	0/1	1/0	1/1	1/2

2			3		
2/1	2/2	2/3	3/2	3/3	3/+

Size and shape of the small opacities are also classified, both being differentiated using the letters of the alphabet. Two letters are used to record size [in millimeters (mm)] and shape, the first listed letter indicating the predominant type.[1,2]

Classification of Small Opacity Type

Shape	Size		
	Up to 1.5 mm	1.5 - 3 mm	3-10 mm
Rounded	p	q	r
Irregular	s	t	u

To record the distribution of the small opacities, the lungs are divided into six zones--three on the left and three on the right, for the upper, middle, and lower portions of the lungs.[1,2]

Three categories are used to define large opacities according to size [measured in centimeters (cm)]: A, B, and C.[1] Category A is specified as an opacity >1 cm but <5 cm, or several opacities >1 cm whose combined diameters are <5 cm; Category B is one or more opacities >5 cm whose combined area is less than the equivalent area of the right upper lung zone; Category C is one or more opacities whose combined area is greater than the equivalent area of the right upper lung zone.[1,2]

The technical quality of the chest x-ray (or film quality) is graded and recorded using four scores, 1, 2, 3, or 4. A "1" represents the highest quality, while a "4" represents a chest x-ray considered by a reader as "unacceptable" or "unreadable" for classification purposes.[1,2]

Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five maximal expiratory maneuvers were recorded for each person. All values were corrected to BTPS (body temperature, ambient pressure, saturated with water vapor). The largest forced vital capacity (FVC) and forced expiratory volume in one

second (FEV_1) were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American Thoracic Society's recommendations for spirometry.[5] Predicted values were calculated using the Knudson reference equations.[6] Predicted values for African-Americans were determined by multiplying the value predicted by the Knudson equation by 0.85.[5]

Questionnaire

A modified version of the Medical Research Council (MRC) questionnaire[6] on respiratory symptoms, supplemented with questions concerning demographic information, work history, cigarette smoking habits, physician-diagnosed respiratory illness, frequency and content of company medical evaluations, and participant's knowledge of prior test results, was administered by trained NIOSH personnel.

Medical and Personnel Records

Each company was asked to provide medical and personnel records of current and former employees who had worked at least one year since 1970.

Three types of company-held documents were identified from which the presence or absence of silicosis was ascertained – ILO classifications, clinical radiology reports (a chest x-ray report by a radiologist), and miscellaneous documents (e.g., CT scan results, letters from physicians, etc.). The following case definitions for silicosis were established for each type of document:

1. An ILO small opacity profusion classification of 1/0 or greater on the most recent chest x-ray.

2. A clinical radiology report which contained explicit words or phrases indicating the presence of silicosis (e.g., "silicosis" or "pneumoconiosis"), or other descriptions considered consistent with silicosis (see "Results" section).

3. A physician diagnosis of silicosis, or a diagnosis of pneumoconiosis if silicosis was considered in the differential diagnosis.

The case definition used in the analysis depended on the type of records obtained from the company. ILO classifications were considered ideal and the preferred document type for definition, followed by clinical radiology reports, and finally miscellaneous documents. Therefore, if all three types of documents were available for an individual, ILO classifications were used to identify silicosis (case definition 1). If company records only contained clinical radiology reports and miscellaneous documents, case definition 2 was used. Case definition 3 was used when only miscellaneous documents were available.

Medical Monitoring

The 1981 NIOSH recommendations for medical monitoring of workers exposed to ground silica (silica flour),[7] and the recommendations published by the National Industrial Sand Association (NISA) for workers exposed to crystalline silica[8,9] were used as the basis to evaluate company medical monitoring practices.

EVALUATION CRITERIA

Chest X-Ray

A chest x-ray was defined as consistent with silicosis if the median, or middle, classification of small opacity profusion by the three B readers was 1/0 or greater. For cases where only one reader considered a film of unacceptable quality, an additional classification was sought. If the film was considered unacceptable a second time, it was then classified as unreadable (UR). However, if the film was able to be classified, this classification was used to

determine the median, and the results were subsequently used in the data analysis. This procedure was followed so as not to give undue weight to the judgement of a single reader. Progressive massive fibrosis (PMF) was defined as the presence of large opacities of ILO category A, B, or C classified by at least two readers.

The overall shape of the small opacities was based on the predominant shape (i.e., the first listed letter) classified by two or more readers. If only two readers classified shape and the predominant type differed, the shape was considered "mixed."

Spirometry

To identify participants with abnormal spirometry patterns of obstruction and restriction, each examined worker's test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations.[4] Five percent of a normal population will have predicted values that fall below the normal range, or LLN, while 95% will have predicted values above the lower limit.

Using this comparison, obstructive and restrictive patterns were defined as:

Obstruction: Observed ratio of $FEV_1/FVC\%$ below the LLN.
Restriction: Observed FVC below the LLN.

Questionnaire

The following definitions were established for the purpose of questionnaire analysis:

Chronic Cough	a cough on most days for as much as 3 months during the year.
Chronic Phlegm	the production of phlegm on most days for as much as 3 months during the year.
Dyspnea	shortness-of-breath walking with individuals of similar age on level ground.
Chronic Bronchitis	cough and phlegm on most days for as much as 3 months for 2 or more years.

Medical Monitoring

The 1981 NIOSH recommendations for medical examinations of ground silica workers include a medical and occupational history, chest x-ray, and pulmonary function testing (spirometry) for all workers prior to job placement and annually thereafter.[7] The 1977 NISA guidelines recommended obtaining a medical and occupational history, physical examination, and pulmonary function testing every two years. A chest x-ray was also recommended, but frequency was not discussed.[8] The current NISA medical monitoring guidelines, part of NISA's Silicosis Prevention Program which was established in 1993 and published in 1997, recommend a medical and occupational history and physical examination prior to job placement and at least every two years thereafter; pulmonary function testing and a pre-placement skin test for tuberculosis (TB) are optional components of the medical monitoring program. A chest x-ray is also recommended, with frequency determined by worker age, time since first exposure to crystalline silica dust, or as determined by a physician if a worker has any signs or symptoms of silicosis.[9] For a worker who is 35 years of age or less, or over 35 years with 8 years or less since first exposure, NISA guidelines recommend a chest x-ray every 4 years. The frequency increases to every 2 years for workers over 35 years of age with more than 8 years since first exposure.[9] The current guidelines also recommend multiple readings of all chest x-rays with a small opacity profusion classification of 1/0 or greater and 5-10% of those chest x-rays classified as 0/1 based on a single B reading.[9]

Silicosis

Silicosis, a form of pneumoconiosis, is a chronic fibrotic pulmonary disease caused by the inhalation, deposition, and retention of dust containing crystalline silica.[10] Silicosis is usually diagnosed through chest x-ray and occupational history of exposure to silica-containing dust. In nodular silicosis, lung tissue reacts to the presence of crystalline silica dust by forming nodules, which on chest x-ray typically appear discrete, round, and more prominent in the upper zones, although other patterns have been described.[7,11,12,13,14,15] Such radiographic abnormalities are often the first sign of silicosis.

In acute silicosis, the lung is overwhelmed by crystalline silica particles, and a proteinaceous fluid accumulates in the lungs as a reaction to the silica dust.[7,10,16,17] On chest x-ray, the appearance is different from that of nodular silicosis, with very little of the typical nodular scarring.[7,18,19] Consequently, it may often be mis-diagnosed as pulmonary edema or pneumonia.

The following table summarizes the clinical forms of silicosis:

Form	Time to Onset	Intensity of Exposure
NODULAR		
Chronic	10+ years	Low
Accelerated	5-10 years	High
ACUTE	weeks-4 or 5 years	Extremely high

Each form is differentiated by time to onset of clinically apparent disease after initial exposure (induction period), intensity of exposure, and the rate at which the disease progresses.[7,10,12,18] The percentage of crystalline silica in the dust, size of the dust particle, form of crystalline silica, and length of exposure also affect disease onset and progression.[7,19,20] Ground silica (silica flour) consists of essentially pure crystalline silicon dioxide particles (the quartz polymorph), of respirable size (< 10 micrometers).[21,22] Particles of this size may be invisible to the naked eye and are small enough to be deposited in the alveoli. Freshly ground, or fractured, crystalline silica -- which is a typical form of silica in ground silica facilities -- may be more toxic or fibrogenic (i.e., produce more scarring of the lungs), than aged silica.[23,24,25]

A continuum is thought to exist between the chronic and accelerated forms of nodular silicosis. Factors determining the progression of disease are unclear.[14] *Chronic silicosis* (the presence of detectable, discrete, nodules <1cm in diameter on chest x-ray) is the most common form of silicosis and usually becomes evident after 10 years or more of exposure to dust containing crystalline silica.[10,11,26] There may be few, if any, clinical symptoms; the most common symptoms are cough, with or without sputum production and shortness of breath. There may be little or no decrement in pulmonary function. *Accelerated silicosis* is associated with higher exposures to crystalline silica and has a shorter induction period than chronic silicosis. Chest x-ray abnormalities usually appear within 5-10 years.[26] This form of silicosis often progresses after exposure has been discontinued. *Acute silicosis* may develop in a few weeks to 4 or 5 years after initial exposure and is associated with exposures to extremely high concentrations of crystalline silica.[10,11,26] Respiratory impairment is severe with acute silicosis, and the disease is usually fatal within a year of diagnosis.[18,19]

Both chronic and accelerated silicosis can become complicated by the development of infection and/or progressive massive fibrosis (PMF). Infections (e.g., tuberculosis and/or fungal infections) are believed to result from the inability of the overwhelmed lung scavenger cells (macrophages) to kill the organisms that cause these diseases.[27,28] Progressive massive fibrosis (PMF) has at times been called "complicated" silicosis, and is the result of silicotic nodules fusing into large masses. PMF profoundly affects both the structure and function of the lungs.[10,11,12,18]

Recently, the International Agency for Research on Cancer (IARC) reclassified crystalline silica (quartz or cristobalite) from occupational sources as a substance "carcinogenic to humans," and evidence suggests that individuals with silicosis are at increased risk for lung cancer.[29,30] NIOSH currently recommends that crystalline silica be considered a potential occupational carcinogen.[31,32]

RESULTS

The Study Population and Participation

Table 1 outlines the number of current and former workers who were originally identified for study, the number of workers excluded (and the reasons), and the total number of workers that remained to make up the study population. Of a reported 116 current employees, a total of thirty-six current workers were determined to be ineligible (i.e., they did not meet the study criterion) and were excluded from the study population. Eligibility could not be clearly determined by NIOSH for two participating current workers for whom records were provided. The status of 17 current workers was unknown. It is possible these 17 employees were salaried or clerical personnel, since some salaried workers were accounted for on company rosters. A total of 61 current workers were eligible for inclusion in the study population.

Out of 147 former workers identified, 107 were determined to be ineligible, and the records for one worker were missing. Eligibility could not be determined by NIOSH for three non-participating former workers whose names appeared on the union roster but did not appear on the company roster. Finally, four deceased former workers were excluded. A total of 32 former workers were eligible for inclusion in the study population.

Of the 61 current workers eligible for inclusion in the study population, 54 (89 %) participated in the medical survey. Of the 32 eligible former workers, 13 (41 %) participated. Thus, of 93 eligible workers, 67 (72%) participated (Table 2).

Medical Evaluation

The following discussion of results concerns the 67 participants who met the study criterion. All data were collected by NIOSH.

Demographics

All 67 participants were white males. Age, tenure, and cigarette smoking status of the participants are presented in Table 3. Current and former workers differed for each characteristic presented. Former workers were older and employed six years longer than current workers. One (8%) of the 13 former workers was employed for 10 years or less, four (31 %) were employed between 11 and 20 years, and eight (62%) were employed for over 20 years. Current workers were employed for a median of 19.5 years; five (9%) of the 54 current workers were employed for 10 years or less, 23 (43%) were employed between 11 and 20 years, and 26 (48%), were employed for over 20 years. A greater proportion of former workers were ex-smokers (69%), and former workers had a higher median number of packyears (one pack-year is equal to smoking an average of one pack of cigarettes per day for a year) than current workers. None of the former workers were current cigarette smokers, versus 22 (41%) of the 54 current workers. An average (mean) of six years had passed since former workers had left employment, and former workers had left the Berkeley Springs plant between one and 18 years prior to the time the NIOSH evaluation was conducted.

Primary Job and Dustiest Job

Overall, 24 (36%) of the 67 participants reported holding their primary job (the job held for the longest period of time) in Maintenance and 14 (21%) reported working as a Bagger or Packer, nine of whom held that job in the Milling department. Nine

(13%) of the participants reported a primary job as a Mill Operator (eight of whom worked in Milling), five (7%) reported working as a Mill Tester, three (4%) worked in clean-up, and three (4%) worked in supervisory positions. The nine remaining participants reported holding a primary job in the quarry, wet processing, or dry processing departments. Sixteen (30%) of the 54 current workers reported their primary job as Maintenance, while eight (62%) of the 13 former workers reported this as their primary job.

Working as a Bagger or Packer in the Milling department was reported with the greatest frequency by current workers as the single dustiest job at the plant. Former workers reported working in Maintenance with the greatest frequency. Maintenance and maintenance activities such as repairing dust collectors and overhauling the separators followed in frequency for current workers.

Other Dusty Jobs

A total of 38 (57%) of the 67 participants reported prior or subsequent employment in occupations or industries other than their current job that might have been associated with exposure to fibrogenic dusts. These included 30 (56%) of the 54 current workers and eight (62%) of the 13 former workers. When the information was examined by employment status and reported tenure in such jobs, 13 (43 %) of the 30 current workers and 4 (50%) of the eight former workers reported such employment for less than five years. Nine (30%) of the 30 current workers and two (25%) of the eight former workers reported working at such jobs for over 10 years. The type of work reported included construction, welding, road work, working in a quarry, and farming, among others.

Chest X-Ray Results

All Participants

Overall, seven (10 %) of the 67 participants had a chest x-ray consistent with silicosis; of these, five (7%) had primarily round small opacities, one had primarily irregular small opacities, and one had "mixed" small opacities. The highest ILO small opacity profusion category among the participants was 2/2. Two of the seven had a chest x-ray consistent with PMF, with "B" size large opacities. All but one of the chest x-rays were taken by NIOSH. Sixty-three (94%) had a median film quality score of 1 (the highest) and two had a median quality score of 2. Two other chest x-rays required an additional classification (one reader marked these films "UR," or "unreadable") and the results were used to determine the median small opacity profusion classification and film quality.

The predominant shape of the small opacities was examined in relation to cigarette smoking status for the seven participants with x-ray evidence of silicosis. Five of the seven were "ever" smokers and two had never smoked. The chest x-rays of three of the five "ever" smokers showed small opacities that were predominantly rounded, one chest x-ray had predominantly irregular small opacities, and one was "mixed" (i.e., the predominant shape differed). The predominant shape of small opacities on the chest x-rays of the two "never" smokers was round.

Of the seven participants with a positive chest x-ray, three reported holding a primary job (the job held for the longest period of time) as a Miller, one reported a primary job as a Bagger/Packer, one was a Mill Tester, one held a supervisory position, and the last worked in Maintenance. Two of the three Millers worked in the Milling department and one worked in Wet Processing. The pattern of primary jobs for those with a positive chest x-ray is different from that of the distribution of primary jobs among participants overall. Three of the seven participants with a positive chest x-ray reported working at another dusty job. One worked for less than 3 years, the second worked between 5 and 10 years, and the third over 20 years.

Current Workers

Table 4 lists the chest x-ray results by reader for all 54 currently working participants. The prevalence

of silicosis among currently working participants was 6% (3/54). None of the 11 participants employed 15 years or less had a positive chest x-ray, while three (7%) of the 43 participants employed over 15 years had a positive chest x-ray. All three were employed for over 20 years and all were between 50 and 59 years of age.

Former Workers

Table 5 lists the chest x-ray results by reader for the 13 participating former workers. Four (31%) former workers had x-ray evidence of silicosis. Neither of the two participants employed 15 years or less had a positive chest x-ray. All four of the former workers with a positive chest x-ray were employed over 15 years and three were employed for over 20 years. One of these four participants was between 50 and 59 years of age and three were over 60 years old.

Chronic Symptoms

A total of 16 (24%) of the 67 participants reported a chronic symptom or health effect, as defined in the "Evaluation Criteria" section of this report. This included eight (15%) of the 54 current workers and eight (62%) of the 13 former workers. Chronic bronchitis was reported by six (9%) of these 67 participants, five of whom were former workers, and 10 (15%) of the 67 reported dyspnea (shortness-of-breath), seven of whom were current workers. Two of the 10 participants who reported dyspnea also reported a condition, or conditions, that could contribute to or cause dyspnea. Four of the 67 participants reported chronic phlegm, and two reported chronic cough. Thirteen (81%) of the 16 participants who reported a symptom were "ever" smokers. Five of the seven participants with a positive chest x-ray reported symptoms, four of whom reported chronic bronchitis. The most frequently reported primary jobs held by symptomatic participants were Maintenance and Bagger or Packer, and their median tenure at Berkeley Springs was 22 years. The median tenure of the 51 asymptomatic participants was 19 years, but the difference in tenure between symptomatic and asymptomatic participants was not statistically significant (p=0.53, Wilcoxon rank-sum). Symptomatic participants had a shorter median tenure in other dusty jobs (4 months) than asymptomatic participants (2 years), but this difference was not statistically significant (p=0.48, Wilcoxon rank-sum) either.

Respiratory Illnesses and Conditions

Physician-diagnosed asthma was reported once, chronic bronchitis was reported by three participants, and emphysema was reported by four participants. Other reported physician-diagnosed lung conditions included were pneumonia and silicosis, among others. A few participants reported unspecified changes on their chest x-ray (e.g., "spots on the lungs"). None of the participants reported a physician diagnosis of tuberculosis (TB). Fifty-two (78%) of the participants reported no physician-diagnosed respiratory illness or condition.

Spirometry

All (100%) of the 67 participants performed spirometry, and 19 (28%) of those had results that fell below the normal range. These included 13 (24%) of the 54 current workers and six (46%) of the 13 former workers. Four of the seven participants with a positive chest x-ray had abnormal spirometry results, one of whom had PMF. Overall, 13 (19%) of the 67 participants exhibited an obstructive lung pattern, four (6%) exhibited a restrictive pattern, and two had a combined obstructive and restrictive pattern. Of the 19 participants with abnormal spirometry, 18 (95%) were 'ever' smokers:10 were current cigarette smokers and eight were ex-smokers; and only one had never smoked cigarettes. Table 6 shows pulmonary function status stratified by cigarette smoking and years of employment. Six of the 19 participants with an abnormal pattern held their primary job in Maintenance, two worked as a Bagger in the Milling department, and three worked as a Bagger in Dry Processing. Two of the 19 held a primary job as Mill Testers, and two were Millers in the Milling department. The four remaining

participants reported working as a Dryer Operator, Crane Operator, Clean-up (in the Mill), and in a Milling supervisory position as primary jobs. The median tenure of the 19 participants with abnormal patterns was 27 years, which was not statistically different from the median tenure (19.5 years) of the 48 participants with normal spirometry results (p=0.28, Wilcoxon rank sum). The median tenure in other dusty jobs for those with abnormal patterns was zero and was not statistically different from those with normal patterns (1.5 years).

When the information for current workers was examined by employment status, nine (17%) of the 54 exhibited an obstructive pattern, three (6%) exhibited a restrictive pattern, and one had a combined restrictive and obstructive pattern. Similarly, four (31%) of the 13 former workers exhibited an obstructive pattern, one exhibited a restrictive spirometry pattern, and one had a combined pattern. The 13 current workers with abnormal patterns had a median tenure of 22 years, and their median tenure in other dusty jobs was two years. The median tenure of the 41 current workers with normal lung function was 19 years, and their median tenure in other dusty jobs was one year. The difference in median tenure was not statistically significant (p=0.83, Wilcoxon rank sum), nor was there a statistical difference in median dusty job tenure. The six former workers with abnormal patterns had a median tenure of 35 years, and their median tenure in other dusty jobs was zero. The median tenure of the seven former workers with normal lung function was 21 years, and their median tenure in other dusty jobs was six years. Only the tenure in other dusty jobs was statistically different (p=0.01, Wilcoxon rank sum).

Company Records

Company records contained information on age, tenure, cigarette smoking history, work in other dusty jobs, and small opacity profusion classification for all 61 (100%) of the eligible current workers. All eligible current workers were male. 'Race' was recorded for 50 (82%) of the 61 eligible current workers; all were white.

The records of former workers were less complete. The table below summarizes the proportion of information available from the records of eligible former workers for each of the variables listed.

Eligible Former Workers N = 32		
Variable	Number of Records with Information	Percent
Race	9	28%
ILO classification	28	88%
Sex	29	91%
Cigarette Smoking History	30	94%
Other Dusty Jobs	31	97%

Of the former workers for whom information on race and sex were available, all (9/9) were white and all (29/29) were male.

Age, tenure, cigarette smoking habit, work in other dusty jobs, and chest x-ray information was examined by employment status for both participants and non-participants (Table 7). The seven non-participating current workers differed little from their participating counterparts with regards to median age and tenure. The non-participants differed slightly in terms of the proportion of workers with an indication of work in another dusty job, or jobs, the proportion of current and ex-cigarette smokers (i.e., "ever" smokers), and the number of individuals with a positive chest x-ray (defined as small opacity profusion of 1/0 or greater) based on a single B reading. None of the seven non-participating current workers had a positive chest x-ray (two were classified 0/1 and five were classified 0/0), while four participants had positive chest x-rays (two were classified 1/0, one was classified 1/1, and one was classified 2/1 with 'B' size large opacities). Of the 50 remaining chest x-rays, 10 were classified 0/1,

and 40 were classified 0/0. The chest x-rays were classified by the same B reader between 1989 and 1993.

Except for cigarette smoking and the number of individuals with a positive chest x-ray, non-participating former workers differed little from participating former workers. Non-participating former workers had a slightly higher proportion of current smokers than former workers who chose to participate (37% versus 23%), while a larger proportion of participating former workers (23%) had never smoked cigarettes. Based on available ILO classifications, five of the non-participating former workers had a positive chest x-ray versus two participating former workers. Two chest x-rays had a small opacity profusion classification of 1/0, two were classified 1/2, two were classified 2/1 with 'B' size large opacities, and one was classified 2/2 with 'A' size large opacities. Of the 21 remaining chest x-rays, eight had a small opacity profusion classification of 0/1, and 13 were classified 0/0. These chest x-rays were classified between 1979 and 1992 by the same B reader, or one of the reader's associates, who classified all of the chest x-rays of the eligible current workers. The clinical radiology report of the one participating former worker for whom there was no ILO classification was dated 1974 and was negative, and the clinical radiology reports of the three non-participating former workers for whom there were no ILO classifications were from 1972 - 1977 were also negative. All five non-participating former workers with a positive chest x-ray were employed for over 25 years and four were employed for 30 years or more. Two held primary jobs within the Milling department as a Loader/Mill Tester, the other three held primary jobs in Dry Processing, Maintenance, and Mining.

Because the company sent chest x-rays with small opacity profusion classification 1/0 or greater for additional readings beginning in 1990, the classifications from these additional readings were used to develop a single classification, and this data is also presented in Table 7. Three of 11 workers with a positive chest x-ray based on a single B reading had more than one ILO small opacity profusion classification completed. All three were current workers. (The chest x-rays of the seven former workers were all taken prior to 1990). Two of the three workers had a total of three classifications completed, and one worker had one additional classification. For the worker with one additional classification, the second classification was different from the first – there was no agreement between the two readings and the status of this worker was not changed. For those workers where the consensus classification was the median classification, one changed status (i.e., the median small opacity profusion classification was less than 1/0). Thus, the number of individuals with a positive chest x-ray decreased from four to three among participating current workers. Two of the three participants identified in company records as having a positive chest x-ray also had positive NIOSH chest x-rays.

U.S. Silica Company has consistently used standard forms to collect medical and work history information. Except for chest x-ray information, the portions of the forms used from 1979 onward and received by NIOSH were, for the most part, filled out by the individual worker. The work history information found in these forms was often incomplete. Personnel records provided by the company were used in conjunction with these standard forms, and others, to assemble work histories and supplement other missing information whenever possible.

Company Medical Monitoring

Routine medical monitoring has been conducted at the Berkeley Springs facility since the early 1950's. The initial monitoring was offered annually up until the 1970's, when it began to be conducted every two years. The medical monitoring included spirometry, physical examination, and chest x-ray that was read by a contract radiologist. Employee participation in the medical monitoring was optional until 1979, at which time the company (known at that time as Pennsylvania Glass Sand) adopted the 1977 National

Industrial Sand Association (NISA) occupational health program guidelines and recommended medical monitoring. Participation by hourly employees in the monitoring then became mandatory. Medical monitoring consistent with these guidelines (see Evaluation Criteria), including a chest x-ray, was conducted every two years. Office and administrative employees were examined every 4 years. Examinations were completed at a hospital in Berkeley Springs, and all company chest x-rays were sent to the same B reader for classification. Beginning in 1990, chest x-rays with small opacity profusion classification 1/0 or greater were sent for additional readings to other B readers. An annual chest x-ray was obtained if a chest x-ray was classified 1/0 based on a consensus of the additional readings. This was the medical monitoring in place at the time of our survey in 1993. The medical records, except for chest x-rays, were kept at U.S. Silica's corporate offices in locked files separate from personnel records. Chest x-rays were kept by the B reader. No medical records were maintained at the plant itself. A company representative reported that the company medical director forwarded narrative reports of test results in sealed envelopes to the plant manager, who ensured that each employee signed a document indicating that he or she had received their individual medical test results. Employees with abnormal test results were encouraged to see their personal physician or to call the company medical director to discuss their results.

Fifty-three of the 54 participating current workers and all 13 participating former workers reported taking part in either pre-placement or routine medical monitoring offered by the company. All 67 participants reported having had a chest x-ray as part of a past company evaluation. One current worker reported having had a chest x-ray taken by the company, but reported that he had not participated in routine medical monitoring - probably misunderstanding the question. Thirty-nine (72%) of the 54 current workers and four of the former workers were able to recall their company chest x-ray results. Nine current workers either didn't know or didn't recall their company chest x-ray results; one of whom had a positive company chest x-ray. Six current workers and eight former workers reported also having had a recent chest x-ray, for other reasons, in addition to their company chest x-ray. Participants reported that the company medical monitoring was offered every two years.

Subsequent to the NIOSH survey, U.S. Silica implemented NISA's voluntary Silicosis Prevention Program and its medical monitoring guidelines. The monitoring consists of a medical and occupational history, physical examination, chest x-ray, and spirometry prior to job placement as baseline, and every other year. Chest x-rays continue to be sent to, and kept by, the same NIOSH-certified B reader who has classified chest x-rays for the company since 1979. Since November 1994, U.S. Silica has utilized the services of a mobile health testing company to conduct its routine medical monitoring. Pre-placement examinations continue to be conducted at a hospital in Berkeley Springs. Skin testing for tuberculosis (TB) was not one of the screening tests offered in 1993, either as part of the pre-placement examination or the routine medical monitoring. Currently, a TB skin test is obtained if an employee's chest x-ray is classified 1/0. Medical data from the routine medical monitoring are kept by the mobile health testing company in electronic form. Original examination results, except for chest x-rays, continue to be maintained at U.S. Silica's corporate offices in separate locked files with access limited to the medical director, the vice president of administration and his staff, and the legal department. The procedure for notifying individual employees of their test results has remained the same as it was in 1993.

DISCUSSION

Seven (10%) of the 67 current and former workers who participated in the medical evaluation were found to have changes on their chest x-ray consistent with silicosis; two of these seven had PMF. These seven participants had been employed at the U.S. Berkeley Springs facility for 15 years or more, and six were employed for over 20 years. Four of the

participants were between 50-59 years of age, and three were over 60. Five of the seven participants with a positive chest x-ray were current or ex-smokers.

The availability of recent (1989-93) ILO classifications for all 61 eligible current workers from company records permits a comparison of the estimated prevalence of chest x-ray-defined silicosis with the results from the NIOSH medical survey. The company-based readings are not biased by selective participation, since ILO classifications were available for all 61 current workers. Based on company records and classification by a single B reader, four (7%) of the 61 current workers had x-ray evidence of silicosis (defined as small opacity profusion 1/0 or greater). When the additional readings were used to determine a single classification, three (6%) had x-ray evidence of silicosis. Since the company routinely sent only those chest x-rays initially classified 1/0 or greater for additional readings, it is not known if any of the 57 remaining chest x-rays classified 0/0 or 0/1 would have been reclassified as positive (1/0 or greater) had they also been sent for additional readings. Considering just the 54 participants in the NIOSH survey, the prevalence of silicosis in company chest x-rays was 7 % (4/54) based on the single reading and 6% (3/54) based on the additional readings.

A population prevalence estimate based on the results from a sample of volunteer participants may result in an over-estimate, if those who choose to participate are less healthy than those who do not participate. Available data indicate that age and tenure of participants were similar. However, among current workers there is more x-ray evidence of silicosis among participants (see Table 7). Therefore, for all 61 eligible current workers an estimate of silicosis prevalence of 10% may be an over-estimate. Given the high prevalence of chest x-ray abnormality among non-participating former workers (as determined by review of medical records), the NIOSH silicosis prevalence estimate of 10% is probably an under-estimate of prevalence in the study population as a whole.

The study population prevalence of x-ray defined silicosis among the 93 eligible current and former workers could, in theory, range from 11- 28% depending upon the number of cases among non-participating former workers, the source of information (company records or the NIOSH evaluation), the number of cases counted from each source, and consideration of the procedure used to produce a single classification (i.e., multiple readings versus a single reading). An explanation of how these upper and lower boundaries on the estimate were obtained follows.

Using the company records and taking into consideration the results using multiple readings, a total of 10 workers had a positive chest x-ray: three currently working participants, two of the 13 participating former workers, and five of the 19 non-participating former workers. Assuming the remaining 14 non-participating former workers (three of whom did not have an ILO classification but instead had a clinical radiology report) had no radiographically-defined evidence of silicosis, the lower boundary of the prevalence estimate would be 11% (10/93).

To determine the upper boundary of the prevalence estimate, both sources of information were used to count the number of cases. Seven cases out of 67 participants were identified during the NIOSH evaluation and five additional cases out of a total of 26 non-participants with chest x-ray results (7 current workers and 19 former workers) were identified from available company records. Assuming the 14 non-participating former workers had x-ray evidence of silicosis the highest estimate would be 28% (26/93). A more realistic upper boundary may be found by considering the three non-participating former workers who did not have an ILO classification, but who did have a clinical radiology report. Chest x-rays for all three were taken between 1972 to 1977, and all three were negative based on case definition 2 (see 'Methods'). Assuming possible progression and the appearance of clinical changes consistent with silicosis or pneumoconiosis since the time of that chest x-ray, and adding these three to the 12

cases already identified, the upper boundary of the prevalence estimate would then be 16%, or 15/93.

Several factors may have contributed to an underestimation of silicosis in this study. First, cases of silicosis that may have occurred among deceased former workers were not included in this evaluation. Secondly, the low participation rate (41% among eligible former workers), selection bias, and the study design itself, may have had an effect and reduced the likelihood of identifying more cases of silicosis.

Occupational exposures to mineral dust have been associated with airflow limitation and chronic obstructive pulmonary disease.[30,33,34] Published studies suggest that pulmonary impairment and chronic respiratory symptoms are associated with both cigarette smoking and cumulative dust exposure, and may be greater among dust-exposed workers who smoke.[34,35,36] We found, as expected, that abnormal patterns occurred more frequently among "ever" smokers with increasing years of employment. However, these results were also confounded (biased) by competing dust exposure in other dusty jobs. Symptoms appeared related to cigarette smoking but not to length of employment at the plant or at other dusty jobs. Among the 19 participants with abnormal spirometry patterns, four had chronic bronchitis, five reported shortness-of-breath, and eight reported a physician-diagnosed respiratory disease or illness (emphysema, bronchitis, asthma, silicosis, or other abnormality). Pulmonary impairment can exist irrespective of the presence or absence of abnormalities detected on a chest x-ray.[30,34,35,36] Abnormal pulmonary function test results were identified in four of the seven participants with a positive chest x-ray.

Cases of silicosis are not rare among workers currently or formerly employed at facilities that produce ground silica; workers at these facilities are, and have historically, been considered to be at high risk for silicosis. A NIOSH evaluation at a silica mining and milling operation in 1979 found that 7 (27%) of 26 participating current and former workers with one or more years exposure had chest x-ray changes consistent with silicosis.[37] Three cases were identified among 15 current workers, and four cases were identified among 11 former workers. The participation rate among all current workers (i.e., including those with less than 1 year of exposure) was 83% (25/30), and among former workers with one year or more exposure the rate was 35% (11/31).

A similar evaluation at the same time at another silica mining and milling operation found that 17 (44%) of 39 participating current and former workers with one or more years exposure had chest x-ray changes consistent with silicosis; three cases were identified among 15 current workers and 14 cases were identified among 24 former workers.[38] The participation rate among all current workers was 73% (30/41), and among former workers with one year or more exposure the rate was 47% (24/51).

In 1980, a NIOSH evaluation at a plant in New Jersey found six (13%) radiographically-defined cases of silicosis among 47 participating current and former workers.[39] Five out of the six cases identified during this evaluation were current workers. The participation rate for all current workers was 87% (26/30), and among former workers with one year or more employment since January 1, 1972 the rate was 70% (21/30).

These previous investigations utilized similar procedures and the standard pneumoconiosis classification of the time, the 1971 ILO-U/C.[40] More recently, Johnson and Busnardo[41] described a case of silicosis in a maintenance mechanic employed from 1976 - 1981 at a plant that manufactures ground silica. By way of comparison, a 1985 study involving the classification (ILO-U/C 1971) of chest x-rays of 1422 blue-collar workers not exposed to dust or other respiratory hazards found only three (0.21%) chest x-rays with a median small opacity profusion of 1/0 or greater.[42] This study found only one chest x-ray with irregular small opacity profusion of 1/0, and no chest x-rays with rounded small opacity profusion of 1/0 or greater among over 700 males.

In the present evaluation, the predominant shape of small opacities on five of the seven positive chest x-rays was rounded, one chest x-ray showed predominantly irregular small opacities, and one chest x-ray had "mixed" opacities. The distribution of opacities was predominantly in the upper zones or in all lung zones for all seven chest x-rays. Silicosis is usually manifested as rounded opacities on chest x-ray, but it can present as predominantly irregular opacities and/or "mixed" opacities especially when the affected individual has been exposed to other dusts in addition to silica.[12,13,26] Although five of the seven participants with positive chest x-rays were "ever" smokers, cigarette smoking alone does not explain all the observed chest x-ray abnormalities. Smoking cannot explain the small rounded opacities seen in three of the participants who were smokers, because there is no evidence that smoking can cause small rounded opacities.[43] Although some have suggested that smoking may cause small irregular opacities, studies of large groups of workers exposed to silica have failed to show a significant effect of smoking on the presence of small irregular opacities classified according to the ILO system.[43] In summary, the irregular pattern and 'mixed' pattern noted on two of the chest x-rays in our survey are consistent with silicosis. However, other possibilities, such as exposure to another type of dust in addition to crystalline silica prior to, during, or after employment at Berkeley Springs, or a respiratory illness that is not work-related, cannot be ruled out.

MSHA's current standard for respirable dust containing crystalline silica came into effect July 1974. As reported in the MSHA environmental study, MSHA has documented past episodes of non-compliance with its respirable crystalline silica dust standard at the Berkeley Springs plant. During the period 1988 to February 1993, 9% (8/87) of personal samples collected by MSHA inspectors in the mill area or affected downstream operations were citable under the MSHA standard for respirable crystalline silica.[44] All seven participants with a positive chest x-ray began working at Berkeley Springs between seven to 29 years before MSHA's current silica dust standard came into effect in July 1974. All seven of these participants were employed for 15 years or more. Three of the seven participants with a positive chest x-ray reported previous work at other dusty jobs. Two of these three participants with other dusty jobs had prior or subsequent employment of a length (≥ 5 years) that may have made a major contribution to signs of silicosis on their chest x-ray, although the degree to which these participants' other dust exposure contributed to the abnormalities seen on their chest x-rays cannot be determined. The development of chest x-ray abnormalities is known to be related to both duration of exposure and to intensity of exposure, together known as cumulative exposure. A relationship between exposure to increasing levels of crystalline silica dust and the prevalence of chest x-ray evidence of silicosis is accepted, although the precise relationship is unknown.[30,45]

Routine medical monitoring has been available to employees of the Berkeley Springs facility since the early 1950's. It is currently conducted every two years and includes all of the screening tests recommended by NISA as well as those recommended by NIOSH based on the 1981 recommendations for workers exposed to ground silica. Chest x-rays are classified by a NIOSH-certified B reader and have been sent to the same reader since 1979. A company representative reported that since 1990, chest x-rays classified 1/0 or greater have been sent for additional classifications. Company chest x-rays initially classified as negative (0/0 and 0/1) by a single reader were not routinely sent for additional readings. The inconsistency of chest x-ray classification among B readers is well documented,[2,46,47,48] and use of a single reader has consequences, intended or not, for the individual worker as well as groups of workers. For example, had "Reader 3" been the only reader for this NIOSH evaluation, one of the seven workers identified as having silicosis based on a median of three readings would have initially been considered to have a negative (0/0) chest x-ray, and the prevalence of silicosis among participants would have been 9% (6/67) (see Tables 4 and 5). Alternately, had "Reader 2" been the only reader, an additional 28 participants would have been

considered to have silicosis and the prevalence among all participants would have been 52% (35/67). Obtaining multiple readings on all chest x-rays is one way of minimizing reader variability and reduces both 'false positive' (i.e., a chest x-ray wrongly classified as positive) and 'false negative' (i.e, a chest x-ray wrongly classified as negative) results. Obtaining multiple readings for the screening of chest x-rays for pneumoconiosis is standard practice for NIOSH studies[47] and the federally mandated Coal Workers' X-ray Surveillance Program (CWXSP),[50] although NIOSH has not formally recommended multiple readings for the medical monitoring of workers exposed to silica.[7,12,13,20,29]

The frequency of the medical monitoring at Berkeley Springs differs from the frequency recommended by NIOSH for ground silica workers, and screening for TB was not reported to be part of the baseline examination or the periodic medical monitoring. Pre-placement and annual medical examinations are recommended by NIOSH for all workers who manufacture, use, or handle ground silica or materials containing ground silica.[7]

CONCLUSIONS

1. Seven (10%) of the 67 survey participants had a chest x-ray consistent with silicosis. Available data on age, tenure, and disease status from company records suggest that 10% may be an underestimate as applied to the study population as a whole. Although most (36%) of the 67 participants reported working in Maintenance, cases of silicosis occurred more frequently among those who reported Miller as their primary job.

2. It is reasonable to conclude that the abnormalities seen on these chest x-rays are attributable to past crystalline silica dust exposure at the Berkeley Springs facility, although time worked at other dusty jobs may have contributed to the abnormalities observed in at least two cases. This conclusion is supported by MSHA documentation of prior episodes of non-compliance with its respirable silica dust standard. There were no cases of silicosis among current and former workers with 15 or less years of tenure; however, because of the long latency usually associated with chronic silicosis, this finding is not sufficient to conclude that current crystalline silica dust exposure levels are without adverse effect.

3. The company medical monitoring practice of obtaining additional B reader classifications only for those chest x-rays initially classified 1/0 or greater will produce an estimated prevalence no higher than, and possibly lower than, that obtained with a single reading. This practice fails to identify positive chest x-rays among workers whose chest x-rays are initially read as 0/0 or 0/1.

RECOMMENDATIONS

The following recommendations are based on findings of the medical evaluation conducted by NIOSH at U.S. Silica, Berkeley Springs, MSHA regulations, and NIOSH policy. Recommendations regarding primary prevention through engineering controls have been provided by MSHA in a separate report.

1. The medical examination and screening tests should be available to all workers who work in or downstream of the grinding mill prior to job placement and annually thereafter.[7] However, medical monitoring should not be used as a substitute for environmental controls to reduce worker exposure to crystalline silica.

2. Any employee with chest x-ray evidence of silicosis or pneumoconiosis or those employees with pulmonary function impairment and/or symptoms of respiratory distress (for example, shortness of breath), should be referred for a more thorough medical evaluation. The evaluation should be conducted by a physician qualified to advise the employee and the company whether continued work-related exposure to crystalline silica dust at the Berkeley Springs plant would be

associated with an increased risk of impairment of respiratory health.

3. The current practice of obtaining additional B reading only for those x-rays with a positive first reading creates a negative bias in the evaluation of workers for silicosis. To avoid this bias, ideally, all chest x-rays should be sent for a second B reading regardless of the initial classification, and for a third B reading if there is disagreement between the first two readings.

4. Skin testing for tuberculosis (TB) should be conducted prior to job placement and annually thereafter,[12,13,26,51,52] with appropriate follow-up for definitive diagnosis and medical treatment, as indicated. The association of TB with silicosis and silica exposure is well-known.[30,53,54] Skin testing procedures should be in accordance with CDC guidelines.[55,56]

5. Each employee should receive a written copy of their medical examination results in full detail, whether or not the results are abnormal, in addition to a summary narrative. Results should be provided directly to the employee by the medical facility or contractor responsible for the examination, and employees should have the opportunity to review the results with a health care professional at the time they receive them.

6. Medical records should continue to be maintained separately from personnel records in a confidential manner. The access to medical records should be limited to health care personnel, such as the medical director.

7. All cases of silicosis should be reported to MSHA by the company, as required. MSHA requires operators to report any miner with small opacity profusion of 1/0 or greater on chest x-ray, or a diagnosis of silicosis, or an award of compensation. Examining physicians, health care providers, contractors, and/or radiologists are encouraged to report cases or any occupational disease to the West Virginia Bureau of Public Health.[57,58] To enhance the uniformity of reporting, NIOSH has developed reporting guidelines and a surveillance case definition for silicosis (Appendix II). This definition and guidelines are recommended for surveillance of work-related silicosis by state health departments and regulatory agencies receiving reports of cases from physicians and other health care providers.[12,13,26]

REFERENCES

1. International Labour Office [1980]. Guidelines for the use of ILO international classification of radiographs of pneumoconioses. Revised Ed. 1980. Geneva, Switzerland: International Labour Office, (International Labour Office Occupational Safety and Health Series No. 22, Rev 80).

2. Morgan RH [1986]. Radiology. In: Merchant JA, Boehlecke BA, Taylor G, Pickett-Harner M (eds). Occupational Respiratory Diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health DHHS (NIOSH) Publication No. 86-102.

3. American Thoracic Society [1987]. Standardization of spirometry - 1987 update. Am Rev Respir Dis 136:1258-1298.

4. Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B [1983]. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis 127:725-734.

5. Lanese RR, Keller MD, Foley MF, Underwood, EH [1978]. Differences in pulmonary function tests among whites, blacks, and american indians in a textile company. J Occup Med 20:39-44.

6. Medical Research Council's Committee on the Etiology of Chronic Bronchitis [1960]. Standardized questionnaire on respiratory symptoms. Br Med J 2:1665.

7. NIOSH [1981]. Current Intelligence Bulletin 36: silica flour: Silicosis (crystalline silica). Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-137.

8. National Industrial Sand Association [1977]. Occupational health program for exposure to free crystalline silica. Prepared by Clayton Environmental Consultants.

9. National Industrial Sand Association [1997]. Occupational health program for exposure to crystalline silica in the industrial sand industry. 1st ed. National Industrial Sand Association, Inc.

10. Ziskind M, Jones RN, Weill H [1976]. Silicosis. Am Rev Respir Dis 113:643-665.

11. Peters JM. [1986]. Silicosis. In: Merchant JA, Boehlecke BA, Taylor G, Pickett-Hamer M (eds.). Occupational Respiratory Diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-102.

12. CDC (Centers for Disease Control) [1990]. Silicosis: clusters in sandblasters-Texas, and occupational surveillance for silicosis. MMWR 39 (25):433-437.

13. NIOSH [1996]. NIOSH Alert: request for assistance in preventing silicosis and deaths in construction workers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96-112.

14. Weill H, Jones RN, Parkes WR [1994]. Silicosis and related diseases. In: WR Parkes, eds. Occupational Lung Disorders. 3rd ed. Oxford: Butterworth-Heinemann, Ltd., pp. 285-339.

15. Fraser RG, Paré JAP, Paré PD, Fraser RS, Genereux GP [1990]. Pleuropulmonary disease caused by inhalation of inorganic dust (pneumoconiosis). In: Diagnosis of diseases of the chest. 3rd ed. Vol.3. Philadelphia: W.B. Saunders Company, pp. 2289-2300.

16. Silicosis and Silicate Disease Committee [1988]. Diseases associated with exposure to silica and nonfibrous silicate minerals. Archives of Pathology and Laboratory Medicine 112:673-720.

17. Beuchner HA, Ansari A [1969]. Acute silico-proteinosis. Disease of the Chest 55:274-285.

18. Sheppard D, Hughson WG, Shellito J [1990]. Occupational lung diseases. In: J. LaDou, ed. Occupational Medicine. Norwalk, CN: Appleton & Lange, pp. 221-236.

19. Wegman DH, Christiani DC [1995]. Respiratory disorders. In: BS Levy & DH Wegman, eds. Occupational Health: Recognizing and Preventing Work-Related Disease. 3rd ed. Boston: Little, Brown and Company, pp. 427-454.

20. NIOSH [1974]. NIOSH criteria for a recommended standard: occupational exposure to crystalline silica. Washington, DC: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 75-120.

21. NIOSH [1984]. Health hazard control technology assessment of the silica flour milling industry. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-110.

22. Hinds, WC [1982]. Respiratory deposition. In: Hinds, WC, Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles. New York: Wiley-Interscience Publishers, p. 219.

23. Vallyathan V, Xianglin S, Dalal, NS, Irr W, Castranova V [1988]. Generation of free radicals from freshly fractured silica dust: potential role in acute silica induced lung injury. Am Rev Respir Dis 138:1213-1219.

24. Vallyathan V, Kang JH, Van Dyke K, Dalal, NS, Castranova V [1991]. Response of alveolar macrophages to in vitro exposure to freshly fractured versus aged silica dust: the ability of prosil 28, an organosilane material, to coat silica and reduce its biological reactivity. J Tox Environ Health 33:303-315.

25. Vallyathan V, Castranova V, Pack D, Leonard S, Shumaker J, Hubbs AF, Shoemaker DA, Ramsey DM, Pretty JR, McLaurin JL, Khan A, Teass A [1995]. Freshly fractured quartz inhalation leads to enhanced lung injury and inflammation. Am Rev Respir Crit Care Med 152:1003-1009.

26. NIOSH [1992]. NIOSH Alert: request for assistance in preventing silicosis and deaths in rock drillers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-107.

27. Allison AC, Hart PD [1968]. Potentiation by silica of the growth of *mycobacterium tuberculosis* in macrophage cultures. Brit J Exper Pathology 49:465-476.

28. Ng TP, Chan, SL [1991]. Factors associated with massive fibrosis in silicosis. Thorax 46 (4):229-232.

29. International Agency for Research on Cancer (IARC) [1997]. IARC monographs on the evaluation of carcinogenic risks to humans: silica, some silicates, coal dust and para-Aramid fibrils. Vol 68. Lyon, France: World Health Organization.

30. American Thoracic Society [1997]. Adverse effects of crystalline silica exposure. Am J Respir Critical Care Med 155:761-768.

31. NIOSH [1988]. NIOSH testimony to the U.S. Department of Labor: statement of the National Institute for Occupational Safety and Health. Presented at the public hearing on OSHA PELs/Crystalline Silica, July 1988. NIOSH policy statements. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health.

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

33. Becklake MR [1985]. Chronic airflow limitation: its relationship to work in dusty occupations. Chest 88:608-617.

34. Oxman AD, Muir DC, Shannon HS, Stock SR, Hnizdo E, Lange HJ [1993]. Occupational dust exposure and chronic obstructive pulmonary disease: a systematic overview of the evidence. Am Rev Respir Dis 148:38-48.

35. Hnizdo E, Baskind E, Sluis-Cremer GK [1990]. Combined effect of silica dust exposure and tobacco smoking on the prevalence of respiratory impairments among gold miners. Scand J Work Environ Health 16:411-422.

36. Wiles FJ, Baskind E, Hessel PA, Bezuidenhout B, Hnizdo E [1992]. Lung function in silicosis. Intl Arch Occup Environ Health 63:387-391.

37. NIOSH [1979]. Health hazard evaluation and technical assistance report: Tammsco, Inc., Tamms, Illinois. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 79-104-107.

38. NIOSH [1979]. Health hazard evaluation and technical assistance report: Illinois Minerals Company, Elco, Illinois. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 79-103-108.

39. NIOSH [1980]. Health hazard evaluation and technical assistance report: Unisil Corporation, Millville, New Jersey. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 80-103-04M.

40. Jacobsen G, Lainhart WS, eds. [1972]. ILO U/C 1971 International classification of radiographs of the pneumoconioses. Med Radiogr Photogr 48(3):65-110.

41. Johnson WM, Busnardo, MS [1993]. Silicosis following employment in the manufacture of silica flour and industrial sand. J Occup Med 35(7):716-719.

42. Castellan RM, Sanderson WT, Petersen MR [1985]. Prevalence of radiographic appearance of pneumoconiosis in an unexposed blue collar population. Am Rev Respir Dis 131:684-686.

43. Blanc PD, Gamsu G [1989]. Cigarette smoking and pneumoconiosis: structuring the debate (editorial). Am J Ind Med 16:1-4.

44. MSHA (Mine Safety and Health Administration) [1999]. Ground Silica Mill Study. U.S. Silica Company, Berkeley plant. February/March, 1993. MSHA, Arlington, Virginia.

45. Hughes JM [1995]. Radiographic evidence of silicosis in relation to silica exposure. Appl Occup Environ Hyg 10(12):1064-1069.

46. Attfield MD, Althouse R, Reger RB [1986]. An investigation of inter-reader variability among x-ray readers employed in the underground coal miner surveillance program. Ann Am Conf Gov Ind Hyg 14: 401-409.

47. Ducatman AM [1991]. Variability in interpretation of radiographs for asbestosis abnormalities: problems and solutions. Annals of the New York Academy of Sciences. 643:108-120.

48. Attfield MD, Wagner GR [1992]. A report on a workshop on the National Institute for Occupational Safety and Health B reader certification program. J of Occ Med 34(9): 875-879.

49. Attfield MD, Castellan RM [1992]. Epidemiolgical data on US coal miners' pneumoconiosis, 1960 to 1988. Am J Public Health 82:964-970.

50. Code of Federal Regulations [1978]. 42 CFR 37 - Specifications for medical examinations of underground coal miners. Washington, DC: U.S. Government Printing Office, Federal Register.

51. American Thoracic Society and Centers for Disease Control [1994]. Treatment of tuberculosis and tuberculosis infection in adults and children. Am J Respir Crit Care Med 149:1359 -1374.

52. CDC (Centers for Disease Control and Prevention) [1995]. Screening for tuberculosis and tuberculosis infection in high-risk populations; recommendations of the advisory council for the elimination of tuberculosis. MMWR 44 (No. RR-11): 19-34.

53. Snider, DE Jr. [1978]. The relationship between tuberculosis and silicosis. Am Rev Respir Dis 118: 455-460.

54. Chen GX, Burnett CA, Cameron LL, Alterman T, Lalich NR, Tanaka S, Althouse R [1997]. Tuberculosis mortality and silica exposure: a case-control study based on a national mortality database for the years 1983-1992. Int J Occup Environ Health 3:163-170.

55. American Thoracic Society/CDC [1990]. Diagnostic standards and classification of tuberculosis. Am Rev Respir Dis 142:725-35.

56. CDC [1994]. Guidelines for preventing the transmission of *mycobacterium tuberculosis* in health-care facilities. MMWR 43 (No. RR-13).

57. Freund E, Seligman PJ, Chorba TL, Safford SK, Drachman JG, Hull HF [1989]. Mandatory reporting of occupational diseases by clinicians. J Am Med Assoc 262 (21): 3041-3044.

58. CDC [1990]. Mandatory reporting of occupational diseases by clinicians. MMWR 39 (No. RR-9):19-28.

TABLE 1
Determination of the Study Population
U.S. Silica - Berkeley Springs
HETA 91-0375

	CURRENT WORKERS		FORMER WORKERS		Total
	Participants	Non-participants	Participants	Non-participants	
Number of Workers Originally Identified	78	38	38	109	263
Reason for Exclusion from Study Population					
- Not eligible based on job and/or tenure	22	2	23	4	51
- Company determined worker not eligible	—	12	2	78	92
- Missing records	—	—	—	1	1
- NIOSH unable to verify eligibility	2	—	—	3	5
- Deceased	—	—	—	4	4
- Status Unknown (salaried/clerical employees)	—	17	—	—	17
Number of Workers Remaining for Study	54	7	13	19	93

TABLE 2
Study Population and Participation Rate By Employment Status
U.S. Silica - Berkeley Springs
HETA 91-0375

Employment Status	N	Total # Eligible	Number of Participants	Number of Non-Participants	Participation Rate (%)
Current Worker	116	61	54	7	89
Former Worker	147	32	13	19	41
TOTAL	263	93	67	26	72

TABLE 3
Characteristics of 67 Participants by Employment Status
U.S. Silica - Berkeley Springs
HETA 91-0375

	EMPLOYMENT STATUS								
CHARACTERISTIC	54 CURRENT WORKERS			13 FORMER WORKERS			TOTAL		
Age (yrs) [median]	44			64			49		
Range (yrs)	29 - 64			36 - 70			29 - 70		
Tenure (yrs) [median]	19.5			25			21		
Range (yrs)	1 - 41			9 - 45			1 - 45		
Cigarette Smoking Status	Number	%	Pack-years [median]	Number	%	Pack-years [median]	Number	%	Pack-years [median]
Never smoker	11	20%	—	4	31%	—	15	22%	—
Current smoker	22	41%	27	0	—	—	22	33%	27
Ex-smoker	21	39%	16	9	69%	28	30	45%	16
Pack - Years (median), Ever smokers			22			28			23

Ever Smokers =Current and Ex smokers combined

TABLE 4
Chest X-ray Results by Reader for 54 Participating Current Workers
U.S. Silica - Berkeley Springs
HETA 91-0375

READER 1			READER 2			READER 3			MEDIAN	
rofusion	Size/Shape	Zone(s)*	Profusion	Size/Shape	Zone(s)	Profusion	Size/Shape	Zone(s)	Profusion	Film Quality
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	sp	2,5,6	0/0			0/0	1
0/0			1/1	qp	All	0/0			0/0	1
0/1	qs	1,2	1/1	ps	All	0/0			0/1	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/1	st	2,4,5	1/0	pq	All	1/0	tu	1,2,4,5	1/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
1/0	qt	1,2,4,5	1/2	qp	1,2,4,5	1/1, A	rq	1,2,4,5	1/1	1
0/0			1/0	ps	1,2,4,5,6	0/0			0/0	1
0/0			1/0	ss	2,3,5,6	0/0			0/0	1
0/0			1/0	st	2,5,6	0/0			0/0	1
0/0			1/0	ps	All	0/0			0/0	1
0/0			1/0	pt	2,3,5,6	0/0			0/0	1
1/1, A	rq	All	1/2, B	qp	1,2,3,4,5	2/1, B	rq	1,2,4,5	1/2, B	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/1	st	2,3,5,6	0/0			0/0	1

1, 2, and 3 correspond to the right upper, middle, and lower zones, respectively; while 4, 5, and 6 correspond to the left upper, middle, and lower zones

TABLE 4 (continued)
Chest X-ray Results by Reader for 54 Participating Current Workers
U.S. Silica - Berkeley Springs
HETA 91-0375

READER 1			READER 2			READER 3			MEDIAN	
Profusion	Size/Shape	Zone(s)*	Profusion	Size/Shape	Zone(s)	Profusion	Size/Shape	Zone(s)	Profusion	Film Quality
0/0			0/0			0/0			0/0	1
0/0			1/1	st	All	0/0			0/0	1
0/0			1/1	sp	All	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	pq	All	0/0			0/0	2
0/0			1/1	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	st	All	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/1	st	All	0/0			0/0	1
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			1/0	ss	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			0/0			0/0			0/0	1

* 1, 2, and 3 correspond to the right upper, middle, and lower zones, respectively; while 4, 5, and 6 correspond to the left upper, middle, and lower zones.

TABLE 5
Chest X-ray Results by Reader for 13 Participating Former Workers
U.S. Silica - Berkeley Springs
HETA 91-0375

READER 1			READER 2			READER 3			MEDIAN	
ofusion	Size/Shape	Zone(s)*	Profusion	Size/Shape	Zone(s)	Profusion	Size/Shape	Zone(s)	Profusion	Film Quality
2/1, B	rq	All	1/2, B	qp	All	2/2, B	rq	1,2,4,5	2/1, B	2
0/0			1/1	st	2,3,5,6	0/0			0/0	1
0/0			1/2	st	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	1
UR			1/2	sp	All	0/0			0/1**	2
1/0	qr	All	2/2	qt	All	2/2, A	rq	All	2/2	1
0/0			1/1	pp	All	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/1	st	All	0/0			0/0	1
0/0			0/0			0/0			0/0	1
0/0			1/0	ss	2,3,5,6	0/0			0/0	1
1/0	qs	1,2,4,5	1/0	st	All	0/0			1/0	1
UR			1/2	pq	All	2/2	qq	1,4	2/1***	1

* 1, 2, and 3 correspond to the right upper, middle, and lower zones, respectively; while 4, 5, and 6 correspond to the left upper, middle, and lower zones.
** The additional small opacity profusion classification was 0/1 with a film quality score = 2 . The median column incorporates this additional reading.
*** The additional small opacity profusion classification was 2/1 with a film quality score = 1. The median column incorporates this additional reading.

TABLE 6
Lung Function Impairment by Years of Employment
and Cigarette Smoking Status for 67 Participants
U.S. Silica - Berkeley Springs
HETA 91-0375

Years of Employment	Never Smokers N = 15			Ever Smokers N = 27			TOTAL		
	N	Impaired		N	Impaired		N	Impaired	
		n	%		n	%		n	%
0 - 5	0	0	—	3	1*	33	3	1	33
6 - 10	1	0	—	2	0	—	3	0	—
11 - 15	2	0	—	5	2*	40	7	2	29
16 - 20	5	0	—	15	5*	33	20	5	25
21 and up	7	1	14	27	10*	37	34	11	32
TOTAL	15	1	7	52	18	35	67	19	28

* Each of these cells includes a participant with ≥ 10 years employment at a prior or subsequent dusty job.

TABLE 7
Age, Length of Employment, Experience in Other Dusty Jobs, Cigarette Smoking, and Small Opacity Profusion from Company Records by Employment Status and Participation
U.S. Silica - Berkeley Springs
HETA 91-0375

	CURRENT WORKERS				FORMER WORKERS			
	Participants N=54		Non-participants N=7		Participants N=13		Non-participants N=19	
ıe (yrs) [median]	44		41		64		64	
Range (yrs)	29-64		31-60		36-70		32-76	
ıure (yrs) [median]	20		20		23		20	
Range (yrs)	1-40		1-34		8-45		4-34	
ıer Dusty Job (s)	Number	%	Number	%	Number	%	Number	%
Yes	39	72	4	57	8	62	12	63
No	15	28	3	43	5	38	6	32
Unknown	—	—	—	—	—	—	1	5
arette Smoking	Number	%	Number	%@	Number	%	Number	%
Current smoker	25	46	3	43	3	23	7	37
Ex - smoker	20	37	2	29	6	46	9	47
Never smoker	9	17	2	29	3	23	2	11
Unknown	—	—	—	—	1	8	1	5
all Opacity ıfusion ≥ 1/0* ıgle B reading)	Number	%	Number	%	Number[a]	%	Number[a]	%
	4	7	0	—	2[b]	17	5[b]	31
all Opacity ıfusion ≥ 1/0 ing additional B dings)	3*	6	—	—	—	—	—	—

rcentages do not add to 100 due to rounding.
determined by the classification closest in time prior to the NIOSH survey by a single B reader.
) Classification missing for 1 participating and 3 non-participating former workers; all four had a clinical radiology report on file.
l chest x-rays taken prior to 1990.
ıe chest x-ray had a second reading but did not reach consensus; a second chest x-ray had a single reading (2/1,B) and is included.

APPENDIX I

PROTOCOL
MSHA/NIOSH GROUND SILICA MILL STUDY

This protocol describes a joint Mine Safety and Health Administration (MSHA) and National Institute for Occupational Safety and Health (NIOSH) project to study silica exposure and the prevalence of silicosis in workers in ground silica mills. MSHA selected the mill portions of nine ground silica operations, based on one or more of the following criteria: (1) one or more outstanding violations of MSHA's respirable silica standard and a history of overexposure to respirable silica; (2) size of the mills, both large and small, based on number of employees; (3) use of advanced control technology; and (4) a representative number of ground silica mills from each Metal and Nonmetal Mine Safety and Health District. Nine mills were chosen for the study rather than all sixteen because of the two year time frame (fiscal years 1993 - 1995) planned to complete the study. A list of the sixteen mills is provided in Attachment 1 and a list of the nine selected mills is given in Attachment 2. Noncompliance with MSHA's respirable silica standard is indicated on the attachments.

In late 1991, when the selection was made, six of the sixteen mills were selected using criteria number one. U.S. Silica Company's Berkeley Mill and Columbia Mill, and the Nicks Silica Company Mill had no outstanding respirable silica violations. The Berkeley Mill uses many advanced controls and is the largest mill. The Columbia Mill, a large mill and Nicks Silica Company, a small mill in MSHA's Southeastern District, were selected using criteria number two and four. There are ground silica mills in four of the six Metal and Nonmetal Mine Safety and Health Districts and each of these four Districts are represented in the study. Three mills were selected from the South Central District and North Central District, two mills were selected from the Southeastern District, and one mill was selected from the Northeastern District.

MSHA will evaluate silica dust exposures in the 9 selected ground silica mills. NIOSH will estimate the prevalence of silicosis in active and former workers in the same 9 mills. At the completion of the study, MSHA will issue a report on findings of each mill and a summary of all mills.

I. BACKGROUND

Ground silica particles are hazardous due to their respirable size and high concentration of crystalline silica, a known cause of nonmalignant respiratory disease (silicosis) and possible cause of lung cancer. A NIOSH feasibility study of the adequacy of company records for a proposed NIOSH study of silicosis was released in 1990. Examination of four industrial sand facilities' B Reader reports found 27% of workers with > 20 years work experience had small opacities on x-ray.[1] The feasibility study was of industrial sand mills of which ground silica was a subset.

II. PROTOCOL OBJECTIVES & METHODS

The following protocol describes the joint MSHA/NIOSH study and identifies responsibilities for each part of the project.

1. NIOSH and MSHA will inform management and employee representatives about the project prior to initiation.

   (a) Entrance and close-out meetings will be held with local management and employees or employee representatives at each site.

   (b) All current and former employees will receive invitations from NIOSH to participate in the medical portion of the study.

2. NIOSH will radiographically examine current and former employees at the 9 selected ground silica mills for evidence of silicosis.

   (a) Posterior-anterior radiographs will be taken, randomly mixed, and independently classified for pneumoconiosis according to the 1980 ILO system by two NIOSH certified B Readers. If the two readings do not agree on small opacity profusion, a third reading will be obtained and the median reading will be used to define an abnormality. A chest x-ray showing opacities of profusion category $\geq$ 1/0 in a ground silica mill worker will be categorized as consistent with silicosis. The B Readers will not be informed of any exposure history and the films will be masked of identifying information. The same three B Readers will be used throughout the entire project.

   (b) Participants with a recent chest x-ray (within 1 year of the current NIOSH survey) may provide the chest x-ray to NIOSH to be read, rather than have a new chest x-ray taken during this evaluation.

   (c) All participants will receive written notification of their chest x-ray results. Persons found to have abnormal chest x-rays will be encouraged to consult their personal physician.

3. NIOSH will administer a questionnaire which elicits occupational history, demographic information, respiratory symptoms, and smoking history.

4. NIOSH will obtain pertinent records held by the companies.

   (a) NIOSH will copy pertinent medical and personnel records.

   (b) Review company medical records for diagnoses suggestive of silicosis.

   (c) Collect personnel records showing detailed work histories for current and former workers.

5. NIOSH will evaluate the pulmonary function status of the participants through spirometry testing.

   (a) Spirometry will conform to the American Thoracic Society's criteria for screening spirometry.

   (b) All participants will receive written notification of their spirometry results. Persons found to have abnormal results will be encouraged to consult their personal physician.

6. MSHA will determine exposure levels of employees at the 9 ground silica mills.

   (a) Obtain and compare records of past respirable silica dust sampling performed by MSHA and the ground silica mill operators.

   (b) Sample all job classifications in the mill portion of the nine selected ground silica mills.

   (c) Cite, under MSHA regulations, any overexposure to respirable silica dust determined from MSHA samples.

7. MSHA Technical Support will evaluate the effectiveness of dust controls in the selected mills.

   (a) Observe and measure the performance of dust controls. Evaluate maintenance, housekeeping and work practices and how they effect dust control.

8. MSHA will evaluate respiratory protection programs at the 9 ground silica mills.

   (a) Evaluate respiratory programs to determine if they meet the minimum requirements of ANSI Z88.2-1969, Practices For Respiratory Protection, as mandated by Title 30 CFR, Part 56.5005, when respirators are required. The minimum requirements are listed in Attachment 3.

9. NIOSH and MSHA will report results of their surveys as follows:

   (a) NIOSH reports will summarize findings of medical surveys, including the prevalence of silicosis among participants overall, by mill, job, and tenure if feasible.

   (b) MSHA will issue reports combining findings of NIOSH and MSHA for each of the 9 mills selected as well as a summary report.

   (c) Each agency will review and comment on all reports prior to release.

(d) Individual mill reports and summary report will be provided to the industry associations, national unions representing workers in the ground silica industry, participating mill management and employee representatives, and other interested parties.

III. STUDY POPULATION

All current (estimated 332) and former workers (estimated number unknown) of the 9 mills to be studied will be invited to participate. No further follow up will be made to eligible individuals who do not participate.

ADDENDUM: FURTHER STUDIES OF TWO SOUTHERN ILLINOIS GROUND SILICA MILLS PREVIOUSLY STUDIED BY NIOSH IN 1979 (11-01982 AND 11-02051)

I. BACKGROUND

In 1979, NIOSH was requested to provide Technical Assistance to MSHA at two ground silica mills.[2,3] Through medical and environmental surveys, NIOSH determined that a significant health hazard existed at these mills due to overexposure to respirable quartz. Forty-four percent of workers with greater than a year experience in one mill were found to have x-ray evidence of silicosis. Twenty-seven percent of the workers with similar work histories in the other mills were also found to have x-ray evidence of silicosis. Of 65 current and former workers with $\geq$1 year exposure studied in the two mills, 7 cases of progressive massive fibrosis were discovered by NIOSH.

In response to these findings, NIOSH in 1981 issued Current Intelligence Bulletin 36, "Silica Flour: Silicosis (Crystalline Silica)", describing a significant respiratory hazard in silica flour mills from respirable quartz.[4]

II. OBJECTIVES AND METHODS

1. NIOSH will estimate the incidence of new cases of silicosis among workers at the two mills.

    (a) The x-rays of current and former employees of the two mills will be compared with those previously taken in 1979 to identify any new cases of silicosis developing since 1979.

2. NIOSH will compare the prevalence estimates of silicosis found in the 1979 Technical Assistance surveys of two southern Illinois ground silica mills to the current estimates of prevalence for those two mills.

    (a) Methods 2 (a) and (b) discussed in the study protocol.

(b) Reclassify the x-rays taken by NIOSH in 1979 at these two mills according to the 1980 ILO classification system. (The films taken in 1979 were classified used the 1971 ILO classification system). The B Readers will not be made aware when more than one film on an individual is to be classified. The films will be randomly mixed and classified independently. The same three B Readers will be used throughout the entire project.

3. NIOSH will evaluate the change in spirometry results among the workers previously examined in 1979.

(a) Compare an individual worker's 1979 spirometry results to those obtained in this study.

4. NIOSH will review the implementation of recommendations made in the 1979 NIOSH Technical Assistance survey reports (HETA Nos. 79-103-108 and 79-104-107). The following recommendations were made: engineering and work practice improvements to reduce free silica exposures below the NIOSH REL; periodic environmental monitoring of silica exposures by the operator; respiratory protection while the effectiveness of the engineering controls are evaluated; all workers exposed to silica dust not examined in the NIOSH study should undergo comprehensive medical examinations; workers with radiographic evidence of silicosis should be given the opportunity to transfer to jobs without silica exposure; current workers with pulmonary function impairment be evaluated by a qualified physician and advised whether to continue in a dusty trade; medical examinations should be performed at first exposure to silica dust and at yearly intervals; bagged silica flour should be correctly labeled and contain appropriate health warnings.

(a) Review company industrial hygiene records.
(b) Review company respiratory protection program.
(c) Review employee medical and personnel records.
(d) Review product bag labels.

III. REFERENCES

1. Amandus H [1990]. A feasibility study of the adequacy of company records for a proposed NIOSH study of silicosis in industrial sand workers. Final report to Director, NIOSH. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Respiratory Disease Studies, DHHS (NIOSH).

2. NIOSH [1979]. Hazard evaluation and technical assistance report: Tammsco, Incorporated: Tamms, Illinois. Morgantown, WV: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 79-104-107.

APPENDIX I (con't)

3. NIOSH [1979]. Hazard evaluation and technical assistance report: Illinois Minerals Company: Elco, Illinois. Morgantown, WV: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 79-103108.

4. NIOSH [1981]. Current Intelligence Bulletin 36: silica flour; silicosis (crystalline silica). Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 81-137.

APPENDIX I (con't)

ATTACHMENT 1

GROUND SILICA MILLS - 1991

	Northeastern District		Employees
46-02805	U.S. Silica Co.	Berkeley Plant	102
	Southeastern District		
38-00027	Spartan Minerals Co.	Pacolet Mill	21
38-00138	U.S. Silica Co.	Columbia Plant	50
38-00299	Unimin Corp.	Unimin-Lugoff	19
40-02937	Nicks Silica Co.	Nicks Silica Co.	13
	North Central District		
11-01013	U.S. Silica Co.	Ottawa Plant	94
11-01580	Unimin Corp.	Troy Grove Plant	18
11-01981	Unimin Specialty Min.	Plant (NC)	30
11-02051	Unimin Specialty Min.	Plant/Mill (NC)	22
33-01354	Central Silica Co.	Glass Rock Quarry (NC)	34
33-01355	Central Silica Co.	Millwood Sand Div.	25
	South Central District		
03-00299	Malvern Minerals	Malvern Minerals Sandstone (NC)	19
23-00504	American Tripoli, Inc.	American Tripoli, Inc. (NC)	12
23-00544	U.S. Silica Co.	Pacific Plant	30
34-00377	U.S. Silica Co.	Mill Creek Plant (NC)	50
41-01059	Unimin (Texas) Corp.	Unimin (Texas)	20

NC - Noncompliance

APPENDIX I (con't)

ATTACHMENT 2

GROUND SILICA MILLS - 1991

	Northeastern District		Employees
46-02805	U.S. Silica Co.	Berkeley Plant	102
	Southeastern District		
38-00138	U.S. Silica Co.	Columbia Plant	50
40-02937	Nicks Silica Co.	Nicks Silica Co.	13
	North Central District		
11-01981	Unimin Specialty Min.	Plant (NC)	30
11-02051	Unimin Specialty Min.	Plant/Mill (NC)	22
33-01354	Central Silica Co.	Glass Rock Quarry (NC)	34
	South Central District		
03-00299	Malvern Minerals	Malvern Minerals Sandstone (NC)	19
23-00504	American Tripoli, Inc.	American Tripoli, Inc. (NC)	12
34-00377	U.S. Silica Co.	Mill Creek Plant (NC)	50

NC - Noncompliance

APPENDIX I (con't)

ATTACHMENT 3

Minimum Requirements of ANSI Z88.2-1969

(1) The operator must establish a written standard operating procedure governing the selection and use of the respirator.

(2) The operator must select the respirators on the basis of the hazards to which the worker is exposed. The respirator must be MSHA/NIOSH approved for the specific hazards.

(3) The respirator user shall be instructed and trained in the proper use of respirators and their limitations. The minimum training shall include the following (as quoted from ANSI Z88.2-1969):

a. Instruction in the nature of the hazard, whether acute, chronic, or both, and a complete appraisal of what may happen if the respirator is not used.

b. Explanation of why more positive control is not immediately feasible. This shall include recognition that every reasonable effort is being made to reduce or eliminate the need for respirators.

c. A discussion of why this is the proper type of respirator for the particular purpose.

d. A discussion of the respirator's capabilities and limitations.

e. Instruction and training in actual use of the respirator (especially a respirator for emergency use) and close and frequent supervision to ensure that it continues to be properly used.

f. Classroom and field training to recognize and cope with emergency situations.

g. Other special training as needed for special use.

Training shall provide the employees an opportunity to handle the respirator, have it fitted properly, test its facepiece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere.

(4) Fit testing

All respirator wearers must be fit tested before using negative pressure respirators. ANSI Z88.2-1969 does not require fit testing of positive pressure respirators. Use a validated protocol for fit testing.

(5) The operator must keep records to show that the proper respirator was issued to the respirator wearer. This is usually accomplished by recording the fit test results for each wearer, along with the date that the wearer received the respirator.

(6) Respirators shall be cleaned and disinfected. Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced to maintain MSHA/NIOSH approval. ANSI states that cleaning and maintenance shall be done "as frequently as necessary to ensure proper protection is provided to the wearer."

(7) Emergency-use respirators must be thoroughly inspected at least once per month and after each use. Keep a record of the inspection dates and findings.

(8) Respirators shall be stored in a convenient, clean and sanitary location. The respirators must be stored in a manner that protects them against contamination, temperature extremes, and other potentially damaging conditions.

(9) A single individual must administer the respiratory protection program. This individual shall regularly evaluate the effectiveness of the program. Monitoring will be conducted regularly to ensure that the selected respirators continue to provide appropriate protection to the wearer.

APPENDIX I (con't)

ATTACHMENT 4

PART II 2 (a) OBJECTIVES AND METHODS

Posterior-anterior radiographs will be taken, randomly mixed, and independently classified for pneumoconiosis according to the 1980 ILO system by three NIOSH certified B Readers. The median reading will be used to report an abnormality. A chest x-ray showing opacities of profusion category ≥ 1/0 in a ground silica mill worker will be categorized as consistent with silicosis. The B Readers will not be informed of any exposure history. The films will be masked of identifying information. The same B Readers will be used throughout the entire project.

APPENDIX II [12]

SURVEILLANCE GUIDELINES: SILICOSIS

Reporting Guidelines

State health departments and regulatory agencies should encourage physicians (including radiologists, pathologists, and other health care providers) to report all diagnosed or suspected cases of silicosis. These reports should include persons with

– a physician's provisional or working diagnosis or silicosis, OR

– a chest radiograph interpreted as consistent with silicosis, OR

– pathologic findings consistent with silicosis

To set priorities for workplace investigations, State health departments and regulatory agencies should collect appropriate clinical, epidemiologic, and workplace information about persons reported to have silicosis.

Surveillance Case Definition

A. 1. History of occupational exposure to airborne silica dust

AND

2. Chest radiograph or other imaging technique interpreted as consistent with silicosis

OR

B. Pathologic findings characteristic of silicosis

For Information on Other Occupational Safety and Health Concerns

Call NIOSH at:
1-800-35-NIOSH (356-4674)
or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html

National Institute for Occupational Safety and Health
NIOSH

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