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HETA 93-0793-2645
Unimin Specialty Minerals, Inc. - Elco
Elco, Illinois

Margaret Filios, RN, ScM

PREFACE

The Hazard Evaluations and Technical Assistance Branch of 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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Margaret Filios, RN, ScM, of the Respiratory Disease Hazard Evaluations and Technical Assistance Branch, Division of Respiratory Disease Studies (DRDS). Assistance was provided by Jean Cox-Ganser, Ph.D., Brian Day, MA, Epidemiological Investigations Branch; and Ken Ream, Examination Processing Branch. Desktop publishing by Pamela Hixon and Terry Stewart.

Copies of this report have been sent to employee and management representatives at Unimin Specialty Minerals, Inc.; Laborers International Union of North America, Local 773; Laborers Health & Safety Fund of North America; Mine Safety and Health Administration; Illinois Department of Health; National Industrial Sand Association; Glass, Molders, Pottery, Plastics & Allied Workers International; General Teamsters and Allied Workers; Oil, Chemical and Atomic Workers International. 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:

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Elco, Illinois
July 1997

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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 at specific ground silica operations by conducting a medical evaluation of active and retired miners.

On September 15, 1993, NIOSH conducted a medical survey of current workers at Unimin Specialty Minerals, Inc. - Elco in Elco, Illinois. Former workers were tested September 18-20, 1993, in Tamms, Illinois. The survey included a questionnaire, spirometry, and a single view posterior-anterior (PA) chest x-ray.

The criterion for inclusion in the study population was one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream of the grinding process.

A chest x-ray was defined as consistent with silicosis if the median, or middle, classification of small opacity profusion was 1/0 or greater. A total of 28 current and former workers participated in the NIOSH medical survey and of these, 6 (21%) had a chest x-ray considered consistent with silicosis; the prevalence among currently working participants was 10% (2/20). The highest median International Labour Office (ILO) profusion category was 2/3. Three participants, one current worker and two former workers, had a chest x-ray consistent with progressive massive fibrosis (PMF): two had "A" size large opacities and one had "C" size large opacities classified by at least two Readers. None of the 13 participating current workers employed 10 years or less had a positive chest x-ray. Classification of chest x-rays from the ongoing company medical monitoring program for current workers who met the study criterion, yet chose not to participate in the medical survey, allowed the determination of the prevalence of x-ray evidence of silicosis among all 25 eligible current workers. The prevalence of silicosis among this group was 8% (2/25).

Pulmonary function testing revealed that eight (32%) of the 25 participants who performed spirometry had abnormal patterns. All eight exhibited an obstructive lung pattern.

The prevalence of x-ray defined silicosis among currently working participants who met the study criterion (one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream of the grinding process) was 10% (2/20). In addition, there were four cases of silicosis among the eight former workers who participated in the survey.

The prevalence of silicosis among all eligible current workers was 8% (2/25). There were no cases of silicosis among current workers with 10 or less years of tenure; however, because of the long latency usually associated with chronic nodular silicosis, this finding does not guarantee that current silica dust exposure levels are without adverse effect. Recommendations are presented in this report and include increasing the frequency of medical monitoring examinations.

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

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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 at specific ground silica operations by conducting a medical evaluation of active and retired miners.

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). Briefly, MSHA selected nine sites and was responsible for evaluation of silica dust exposures and dust control methods, while NIOSH was responsible for conducting medical evaluations at each site. The additional evaluation outlined in the Addendum to the protocol will be completed at a later time. This is a final report of the NIOSH medical evaluation conducted at Unimin Specialty Minerals, Inc. - Elco in Elco, Illinois.

On September 8, 1993, NIOSH representatives met with company and union representatives, and several employees, along with an MSHA representative, to discuss logistical and administrative considerations of the survey.

On September 14, 1993, an opening meeting was held with company representatives and a representative from MSHA, to discuss the ensuing evaluation and to address any last minute questions. On September 15, 1993, the medical survey of current workers was conducted. Former workers were tested September 18-20, 1993, in Tamms, Illinois. All study participants received written notification of their spirometry results in September 1993. All chest x-rays were promptly reviewed by a pulmonary physician for acute health problems upon return to NIOSH and prior to the classification process. All study participants and non-participating current workers who had a company chest x-ray classified by the NIOSH B Readers, received written

notification of their chest x-ray results in November 1994.

BACKGROUND

The Elco plant began operation in 1911 as International Minerals and was later re-named Illinois Minerals Company in 1934. In 1983 the plant was sold to Georgia Kaolin. In October 1989, the plant was acquired by a subsidiary of Unimin and subsequently became Unimin Specialty Minerals in 1990. Of the 48 employees retained when Unimin acquired the plant, 28 were still working at Elco at the time of the survey. Eighteen of these employees began working at the plant prior to 1983. At the time of the survey, a total of 42 employees (including clerical and salaried personnel) worked primarily at this plant.

At the Elco operation, microcrystalline quartz is surface mined and brought to the plant for processing where it is crushed, dried, milled, and bagged or bulk loaded into intermediate containers. The plant operates production processes 24 hours a day, seven days a week, with three 8-hour shifts and one 12-hour swing shift. The departments that are part of the Elco operation are: Mining, Crushing, Milling, Loading and Bagging, Maintenance, Clean-up, and Administrative or Supervisory personnel. The job categories affected by the grinding process at the plant are Crusher Operator, Mill Operator, Fine Grind Operator, Bagger, Maintenance, Clean-up Man, and Supervisory personnel (e.g., shift 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 of the grinding area at each operation, by tenure and job, if feasible.

Although not a primary objective, it was of interest to assess the direction and magnitude of possible bias in the prevalence estimate obtained from the medical evaluation as it applied to the study population as a whole. To do so, demographic characteristics and disease status of participants and living non-participants who met the study criterion were compared using company records.

Study Population

The criterion for inclusion in the study population was one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream of the grinding process. Company records were used to determine employees' eligibility for inclusion in the study. Tenure data from company records were considered more accurate than information obtained by questionnaire during the medical survey, which is subject to errors from recall. Jobs within and downstream of the grinding circuit were ascertained using information from both the medical survey and company records and verified with MSHA.

To avoid inadvertent oversight of eligible current workers with prior experience in these areas, all current workers were invited to participate regardless of work area or length of employment. Using rosters provided by the company, letters were mailed inviting current and former workers to participate in the medical survey. 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. No further follow-up was made to eligible workers who chose not to participate in the medical survey.

Several employees had prior tenure at a second Unimin plant in close proximity to the Elco plant, and/or may have had a position that required spending time at both plants. In these cases, individuals were considered an employee at the plant designated by Unimin and where, in most cases, they spent the majority of their time. Medical test results for these people are reported only once, for the site where these individuals were assigned.

Tenure at Elco alone was calculated, as well as combined tenure from both sites. Current and former workers who met the study criterion are the focus of this report.

Data Collection

Posterior-Anterior Chest X-Ray

Chest x-rays from company medical screening completed earlier in 1993 were provided by Unimin for all current employees, and were utilized for current workers who chose not to participate in the NIOSH medical survey. Participants in the NIOSH survey could elect to have NIOSH classify their 1993 company chest x-ray or have a chest x-ray taken by NIOSH.

NIOSH 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⁾

The NIOSH-certified pneumoconiosis 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 (CWXSP). 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 (NSCWP) 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 and large.⁽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			2			3		
0/-	0/0	0/1	1/0	1/1	1/2	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
Round	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 score, or 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 (FEV₁) 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.⁽³⁾ Predicted values were calculated using the Knudson reference equations.⁽⁴⁾ 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, or subsequent to the opening of a plant.

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.

OR

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

OR

3. A physician diagnosis of silicosis, or a diagnosis of pneumoconiosis if silicosis was considered as part of 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 contained both clinical radiology reports and miscellaneous documents, case definition 2 was used. Case definition 3 was used when only miscellaneous documents were available.

For those employees who worked at both Unimin plants, tenure, chest x-ray results, and cigarette smoking status were adjusted to reflect the period of time these employees spent at each respective plant. Participants who were currently employed at one plant and were also a former employee at the second plant were considered a "participant" at the plant where they were currently working and a "non-participant" at the plant where they formerly worked. This procedure was followed since participation as a former worker could not be assumed.

The 1981 NIOSH recommendations for medical monitoring of workers exposed to ground silica (silica flour),⁽⁷⁾ and recommendations published by the National Industrial Sand Association (NISA) for

workers exposed to crystalline silica⁽⁸⁾ 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 was 1/0 or greater. For cases where only one Reader considered a film of unacceptable quality, an additional classification was sought if the participant met the criterion for inclusion in the study population. 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

Each examined worker's test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations

to identify participants with abnormal spirometry patterns of obstruction and restriction.⁽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 are defined as:

Obstruction: Observed ratio of FEV₁/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.

Chronic 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⁾ NIOSH guidelines recommend a medical and occupational history, physical exam, and pulmonary function testing every two years. A chest x-ray is also recommended, although frequency is not discussed.⁽⁸⁾

Silicosis

Silicosis, a form of pneumoconiosis, is a chronic fibrotic pulmonary disease caused by the inhalation, deposition, and retention of dust containing crystalline silica.⁽⁹⁾ Silicosis is

usually diagnosed through chest x-ray and occupational history of exposure to silica-containing dust. Lung tissue reacts to the presence of silica dust in the lung by forming nodules, which on chest x-ray typically appear discrete, round, and more prominent in the upper lobes, although other patterns have been described.^(7,10,11,12) Such radiographic abnormalities are often the first sign of silicosis. The following summarizes the clinical forms of the disease:

<u>FORM</u>	<u>TIME TO ONSET</u>	<u>INTENSITY OF EXPOSURE</u>
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.^(7,9,11,13) 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.^(7,14,15) Ground silica (silica flour) consists of essentially pure crystalline silicon dioxide (quartz) particles, of respirable size (< 10 micrometers).^(16,17) 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.^(18,19)

A continuum is thought to exist between the chronic and accelerated forms of nodular silicosis. Factors determining the progression of disease are unclear.⁽¹²⁾ 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.^(9,10,20) 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. Radiographic abnormalities usually appear within 5-10 years.⁽²⁰⁾ 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.^(9,10,20) 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.^(7,9,21,22) On chest x-ray, the appearance is different from that of nodular silicosis, with very little of the typical nodular scarring.^(7,13,15) Consequently, it may often be mis-diagnosed as pulmonary edema, pneumonia, or tuberculosis. Respiratory impairment is severe with acute silicosis, and the disease is usually fatal within a year of diagnosis.^(13,15)

Both chronic and accelerated silicosis can become complicated by the development of infection and/or progressive massive fibrosis (PMF). Infections (i.e., 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.^(23,24) 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.^(9,10,11,13)

Evidence suggests that crystalline silica is a potential occupational carcinogen,⁽²⁵⁻²⁷⁾ and NIOSH currently recommends that crystalline silica be treated as a potential occupational carcinogen.^(28,29)

RESULTS

Participation

Of 42 current employees, 25 were eligible for entry into the study population; 20 (80%) participated in the medical survey. Of the estimated 85 living former workers (from available lists provided by the company), 70 were eligible for entry into the study population and eight (11%) participated in the medical survey. The estimated total number of workers

in the study population was 95: 28 were participants and 67 were non-participants (Table 1). The company acknowledged that records for many former workers were unavailable from the earlier owners. Records were missing for seven participating former workers, although there was an indication that five had worked at the plant (e.g., the participants' name appeared on a list of former workers or may have occurred on lists of tuberculosis skin test results). In the two instances where there were no records and no indication of employment, the participants were included based upon information obtained during the medical survey.

Medical Survey

Participants

The following discussion of results concerns the 28 participants who met the study criterion. Although the primary objective was to estimate the prevalence of silicosis among participating current and former employees, reporting summary statistics, or numbers (such as a median), from the former workers may be misleading, given the low participation rate and because disease was not equally divided between current and former workers in this survey. The results from participating current workers will be presented separately, using summary statistics, and the results obtained from the former workers who participated will be presented, primarily, using a narrative format.

DEMOGRAPHICS

All participants

All of the participants were men, and the majority (93%) were white.

Current Workers

Among the 20 current workers, the median age was 38 years, and ages ranged between 27 and 57 years. Current workers were employed for a median of nine years. The number of years worked ranged between 2 and 19 years. Only one current worker had prior employment (< 6 months) at the nearby Unimin plant, and therefore his tenure was not included in the analysis. Fifteen (75%) of 20 current workers were “ever” smokers (that is, current smokers and ex-smokers combined), and their median number of pack-years (a pack-year is equal to smoking an average of one pack per day for a year) was 17.

Former Workers

Of the eight former workers, four were less than 35 years old, three were between 40 and 50 years, and one was over 60 years. None of the eight were employed for 20 years or more or prior to 1970: four were employed for less than five years, three were employed between five and 10 years, and one was employed for over 10 years. Six (75%) of the eight former workers were “ever” smokers. The number of pack-years ranged between 21 and 66. Five years or less had passed since five of the former workers had left employment at the Elco plant, over 10 years had passed for one of these participants, and two had left work over 15 years ago.

CHEST X-RAY RESULTS

All participants

Overall, 21% (6/28) of the participants had a chest x-ray considered consistent with silicosis; the prevalence among currently working participants was 10% (2/20). The highest median ILO profusion category among the participants was 2/3. Of the six participants with a positive chest x-ray, two held their primary job

as a Crusher Operator, two worked in Maintenance, one was a Bagger, and one held a supervisory position.

A total of 21 chest x-rays were taken by NIOSH, and seven participants chose to have their company chest x-ray used for classification. Of the 21 NIOSH films, 20 had a median quality score of 1 (the highest) and one had a median score of 2. One NIOSH chest x-ray required an additional classification (the first Reader marked the film “UR,” or “unreadable”) and the resulting median classification and film quality score remained 0/0 and 1. All seven company chest x-rays had a median film quality score of 1.

The predominant shape of the small opacities was examined in relation to cigarette smoking status for the six participants with x-ray evidence of silicosis. Five of the six participants were “ever” smokers and one participant had never smoked. The films from four of the five “ever” smokers showed small opacities that were predominantly rounded and one film had predominantly irregular opacities. The predominant shape of small opacities on the film of the “never” smoker was rounded.

Current Workers

Table 2 lists the chest x-ray results by Reader for all 20 participating current workers. Two (10%) of the 20 had a chest x-ray consistent with silicosis, one of whom had PMF. Table 3 presents the distribution of chest x-ray results by tenure based on questionnaire response for the current workers. None of the 13 participating current workers employed 10 years or less had a positive chest x-ray, and of the seven participants employed over 10 years, two (29%) had a positive chest x-ray.

Seven (35%) of the 20 participating current workers reported holding their primary job (the job held for the longest period of time) as a Bagger, four (20%) as Maintenance, three (15%) as a Crusher Operator, two worked as a Fine Grind or Mill Operator, and two worked in supervisory or administrative positions. One participant reported a primary job as Clean-up Man, and one worked as a Lab Tech. Bagging was reported with the greatest frequency as the single dustiest job at the plant among current workers.

Former Workers

Table 4 lists the chest x-ray results by Reader for former workers. Four former workers had a chest x-ray considered consistent with silicosis; two had PMF. Both of the individuals with PMF had “A” size large opacities as classified by at least two Readers.

Among the four participating former workers employed for less than five years, two had x-ray evidence of silicosis, one of whom had PMF. Of the three former workers employed between five and 10 years, one had a positive chest x-ray. The former worker employed over 10 years had PMF. Two of the four participants with a positive chest x-ray were between 40 and 49 years old, and two were 50 years of age or older.

Two of the eight participating former workers reported holding their primary job (the job held for the longest period of time) as a Bagger, two as a Crusher Operator, and two as Maintenance. One former worker held his primary job in a supervisory position, and one as a Boiler Operator. Bagging was reported by former workers as the single dustiest job.

OTHER DUSTY JOBS

All Participants

Three of the six participants with a positive chest x-ray reported previous work in occupations or industries other than a ground silica operation, either prior to or after employment at the Elco plant, that might have been associated with exposure to fibrogenic dusts. One reported working in construction and over 5 years of intermittent work as a welder. The second participant reported working in construction and mining for over 5 years. The third reported less than three months at another dusty job. Two of the three individuals with PMF reported never working at any other dusty job.

CHRONIC SYMPTOMS

Current Workers

As defined in the “Methods” section of this report, one of 20 participating current workers reported symptoms of chronic cough, and one reported chronic phlegm. One was a current cigarette smoker and one had never smoked.

Former Workers

Among the eight participating former workers, five reported symptoms of chronic dyspnea (shortness-of-breath). Chronic bronchitis and chronic cough were each reported by two former workers. When these results were examined by cigarette smoking status, the symptoms appeared to be related to smoking. All of the former workers who reported a chronic symptom were “ever” smokers.

RESPIRATORY ILLNESSES AND CONDITIONS

Current Workers

Physician-diagnosed emphysema, asthma, and tuberculosis were each reported once. Other physician-diagnosed lung conditions that were reported were “Pigeons disease” (a type of allergic pneumonitis caused by exposure to bird droppings), and silicosis. Seventeen participating current workers reported no physician-diagnosed respiratory illness or condition.

Former Workers

Among the eight former workers, one reported physician-diagnosed chronic bronchitis and one reported an unspecified chronic lung problem. Six former workers reported no respiratory illness or condition.

SPIROMETRY

All Participants

Eighty-nine percent (25/28) of the participants performed spirometry and 32% (8/25) of those had results below the normal range, in all cases an obstructive lung pattern. Four of the eight were current workers and four were former workers. Of the eight participants with abnormal patterns, seven (88%) were “ever” smokers. Table 5 shows pulmonary function status stratified by cigarette smoking and years of employment. One current worker with a positive chest x-ray had abnormal pulmonary function test results, and all four former workers with a positive chest x-ray had abnormal pulmonary function test results as well.

Non-participants

The availability of company chest x-rays for all current employees permitted the classification of films of the five current employees who met the study criterion yet chose not to participate in the medical survey. Each of the NIOSH B Readers classified small opacity profusion for all five non-participants as 0/0, and all five chest x-rays had a median film quality score of 1.

COMPANY RECORDS

The work history and medical surveillance records provided by Unimin of current employees and of those employees who were retained when Unimin acquired the plant appeared to be regularly updated and complete. Information was collected in a standard manner using the forms found in NISA’s guidelines. The records of former workers employed prior to Unimin ownership were not as complete and many were not available. Table 7 presents a breakdown of the number and proportion of records that were available, and number and proportion of records that were missing, by employment status. Records containing information on age, tenure, smoking history, and small opacity profusion classification were available for all 25 eligible current workers, but only 23% (16) of the 70 eligible former workers. When examined by participation status, records were available for 79% (22/28) of the participants but only 28% (19/67) of the non-participants overall (i.e., both current and former workers).

Of the 25 eligible current workers, participants and non-participants were the same median age (38 years) and had proportionally the same distribution among the three cigarette smoking categories (Table 6). The five non-participants differed from participants in length of employment and the number of individuals with a positive chest x-ray (defined as small opacity profusion 1/0 or greater). Non-participants were employed for a median of 12 years versus nine years, and all five had an ILO small opacity profusion classification of 0/0, versus one participant with a positive chest x-ray (small opacity profusion 3/3), as determined by the same, single B Reader.

Records were available for two participating and 14 non-participating former workers. Two of these 14 non-participating former workers were also currently working at the other Unimin plant. Tenure, chest x-ray results, and cigarette smoking status for these two individuals were adjusted to reflect the period of time spent at Elco. The record of one participating former worker contained only a work history. Information regarding age, sex, smoking history, tenure, and small opacity profusion was available for the second participating former worker and 13 of the 14 non-participants. Age was not obtained for one non-participant, and one non-participants' record did not contain an ILO classification but did contain a clinical radiology report.

All of the 14 non-participating former workers for whom records were available were men. Seven (50%) were current smokers, four (29%) were ex-smokers, and three (21%) had never smoked. Their median age was 36 years and median length of employment at Elco was nine years. Information on prior work history was found in the record of one non-participant and

indicated work in a job with a potential for dust exposure. One (8%) of the 13 non-participants with an ILO classification had a positive chest x-ray (small opacity profusion 2/2), and one had a small opacity classification of 0/1. Both of these individuals worked in Maintenance their entire tenure. Eleven chest x-rays were classified 0/0. All of the chest x-rays were classified between 1990 and 1991 by the same B Reader except one, which was classified in 1982 by a different B Reader. The clinical radiology report for the remaining non-participant was negative.

COMPANY MEDICAL MONITORING

Routine medical monitoring has been conducted at the Elco facility since 1981. At that time, hourly workers began participating in annual screening which included pulmonary function testing, chest x-ray, skin testing for tuberculosis, and an occupational history. In 1986, salaried employees were included in the medical monitoring. Chest x-rays have been classified using the ILO system since monitoring was initiated. However, prior to Unimin ownership, not all of the classifications were completed by a NIOSH-certified B Reader. Currently, medical monitoring is conducted every other year by a mobile health testing service. If an employee is found to have any change or abnormality on their chest x-ray, the employee is referred to a physician for follow-up and/or for further testing. The company may then attempt to move the employee to a less dusty area in the plant.

The plant keeps a copy of the examination results, and medical records are isolated from personnel records in separate files. Original examination results are kept at the corporate

Safety and Health office in Virginia. The plant manager, safety and health supervisor, and corporate safety and health office have access to these records. A company representative stated that employees have been notified of examination results in writing throughout the years. Since Unimin ownership, employees are required to sign a document stating that they have received their examination results.

Twenty-six of the 28 participants reported taking part in the company medical monitoring. Seventeen participants were able to recall their chest x-ray results as it related to the company monitoring. Five participants (four current workers and one former worker) either didn't know or didn't remember their results. The process of how employees were notified of results was not consistently reported among those current workers who gave us this anecdotal information; a few workers reported receiving only verbal notification of their results prior to 1993, while others reported presently receiving written notification which contained little detail other than whether their results were "normal" or "abnormal."

DISCUSSION

Six (21%) of 28 current and former workers who participated in the medical survey had changes on their chest x-ray consistent with silicosis; three had PMF. The majority of workers with chest x-ray abnormalities were former workers and current or ex-smokers.

A population prevalence estimate based on 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. The large proportion (72%) of missing information for non-participants is a potential source of serious bias and the observed estimate, if taken from

available records, would be questionable. The study population prevalence of x-ray defined silicosis among the 95 participants and non-participants could range from 5-72% depending upon the number of cases among the non-participants. An explanation of how these upper and lower boundaries on the estimate were obtained follows. None of the five non-participating current workers had x-ray evidence of silicosis, either as determined by NIOSH or based on company records, and at least one of the non-participating former workers had a positive chest x-ray. Assuming the remaining 61 non-participating former workers had no radiographically-defined evidence of silicosis, and excluding both participants with exposure to fibrogenic dusts at other jobs, yields the most conservative estimate, 5% (5/95). Conversely, assuming all 62 non-participating former workers had x-ray evidence of silicosis, and including all 6 participant cases, yields the highest estimate, 72% (68/95). The "true" study population prevalence lies somewhere in between these two estimates.

The availability of chest x-rays and records for all 25 of the eligible current workers permits a determination of the prevalence among current workers that is unbiased by selective participation. The prevalence of x-ray evidence of silicosis among current workers who met the study criterion was 8% (2/25) with inclusion of the NIOSH results for the five non-participants. Using only company records, one (4%) of the 25 eligible current workers had x-ray evidence of silicosis (defined as small opacity profusion 1/0 or greater). The difference in prevalence (which is due entirely to one participant's results) may be a function of (a) the difference in methodology (i.e., use of the median classification from three B readings versus classification by a single B Reader), or (b) progression of disease since the time of the company chest x-ray.

Generally, testing of active workers or recently active workers can result in an under-estimation of a prevalence due to a "healthy worker survivor effect." This effect, or bias, is a pattern typically found in working populations where healthy people are employed and remain employed while individuals

who are less healthy tend not to be employed in the first place and those who become ill tend to leave employment over time. Cases of silicosis that may have occurred among deceased former workers were not included in this evaluation. The number of cases among participating former workers is not unexpected, since silicosis can appear even after exposure has ceased. Additionally, the current workforce is fairly young, and 60% (25/42) have worked less than 10 years at the Elco plant. One would not expect to see chronic nodular silicosis develop in less than 10 years from the time of first exposure. This factor, coupled with the low participation rate among eligible former workers (11%), the large proportion of missing company records (77%), and the study design itself, may have reduced the likelihood of identifying and/or reporting more cases of silicosis.

Pulmonary function testing revealed that eight (32%) of the 25 participants who performed spirometry had abnormal patterns. Abnormal pulmonary function test results were identified among five of the six participants with a positive chest x-ray, three of whom had progressive massive fibrosis. As might be expected, the majority (88%) of participants with abnormal patterns were current or ex-smokers. The prevalence of all chronic symptoms was higher among former workers and smokers. Pulmonary function data was examined by years of employment and cigarette smoking status. The cells of the table (Table 5) contained very small numbers, and did not yield any clear association of exposure as measured by years of employment and lung function. This could be due to the small sample size. Occupational exposures to mineral dust have been associated with airflow limitation and chronic obstructive pulmonary disease.^(30,31) Literature suggests that pulmonary impairment, which may be greater among dust-exposed workers who also smoke, is associated with both cigarette smoking and cumulative dust exposure, irrespective of the presence of radiographically detectable disease.^(31,32,33)

A NIOSH evaluation at this same plant in 1979 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.⁽³⁴⁾ The participation rate among all current workers (i.e., including those with less than 1 year of exposure) was 73% (30/41), and among former workers with one year or more exposure was 47% (24/51).

A similar evaluation at the same time at another silica mining and milling operation in the area 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.⁽³⁵⁾ Three cases were identified among 15 current workers and four cases were identified among 11 former workers. The participation rate among all current workers was 83% (25/30), and among former workers with one year or more exposure was 35% (11/31).

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.⁽³⁶⁾ 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 1 January 1972 was 70% (21/30).

These previous investigations utilized similar procedures and the standard pneumoconiosis classification of the time, the 1971 ILO-U/C.⁽³⁷⁾ In contrast to the present study and to the studies referred to above, a 1985 study involving the classification (ILO-U/C 1971) of 1422 chest x-rays of non-exposed blue-collar workers found only 3 (0.21%) chest x-rays with a median small opacity profusion of 1/0 or greater.⁽³⁸⁾ The 1985 study also 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. More recently, Johnson and Busnardo⁽³⁹⁾ described a case of silicosis in a maintenance mechanic employed from 1976 - 1981 at a plant that manufactures ground silica.

In the present evaluation, the predominant shape of small opacities on five of the six positive chest x-rays was rounded. Although five of the six participants with a positive chest x-ray were current or ex-smokers, cigarette smoking alone does not explain the observed chest x-ray abnormalities. There is little evidence in the literature to suggest that smoking without occupational dust exposure results in pneumoconiosis-like opacities; and the opacities that have been observed have been predominantly irregular, not rounded.⁽⁴⁰⁾

Of the six participants identified in the present evaluation as having a chest x-ray consistent with silicosis, three reported beginning work at the Elco plant before MSHA's current silica dust standard came into effect (July 1974), and three began working after 1974. All six of these participants reported beginning their employment after 1970 and prior to 1983 when the plant was operated as Illinois Minerals Company. Three participants started working between 1970 and 1974; two of these three were former workers with < 5 years of tenure, one of whom also reported working at another dusty job. Two of the six participants with a positive chest x-ray began working after 1974, and one began working after 1980. Of these three participants employed after 1974, one reported prior employment at another dusty job.

Routine medical monitoring has been in place since 1981. Currently, comprehensive medical monitoring, which incorporates all of the elements recommended by NIOSH, takes place every other year. Chest x-rays are classified by a NIOSH-certified B Reader and have been classified by the same Reader since 1990. The company makes an effort to follow up on any abnormal results found during the monitoring and transfer affected employees to less dusty areas. However, the frequency of the medical monitoring differs from the frequency recommended by NIOSH for ground silica workers. Preplacement 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

The prevalence of x-ray defined silicosis among currently working participants who met the study criterion (one year or greater cumulative tenure since 1970 in the grinding area of the mill or in areas downstream of the grinding process) was 10% (2/20). In addition, there were four cases of silicosis among the eight former workers who participated in the survey. Two cases were identified among former workers with < 5 years of tenure who were employed during the early 1970's. At least one of these cases most likely represents disease that occurred as a result of earlier working conditions at this plant when exposures were shown to be excessive.⁽³⁴⁾ Examination of the limited pulmonary function data did not yield any clear association of exposure as measured by years of employment and lung function.

The prevalence of silicosis among all eligible current workers was 8% (2/25). There were no cases of silicosis among current workers with 10 or less years of tenure; however, because of the long latency usually associated with chronic nodular silicosis, this finding does not guarantee that current silica dust exposure levels are without adverse effect. Continuation of the medical monitoring program may facilitate early detection of clinically apparent disease. The data gathered from the program can be highly beneficial to workers in general if it is used to provide feedback about the efficacy of environmental controls and in turn reduce worker exposure to crystalline silica.

RECOMMENDATIONS

1. 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 or health care providers, and/or radiologists are encouraged to report cases of silicosis to the Illinois State Health Department using the reporting guidelines and surveillance case

definition developed by NIOSH (Appendix II).⁽¹¹⁾

2. The present company medical monitoring program should continue, with examinations conducted annually. Each employee should receive a copy of their company medical examination results in full detail, and ideally, the results should be reviewed with a health care professional at the time the employee receives their individual results.

3. Both personnel and medical records should continue to be maintained separately and in a confidential manner, with access to medical records limited to health care personnel. These records should be kept for at least 30 years following an employee's termination of employment.

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 [1995]. Standardization of Spirometry - 1994 Update. Am J Respir Critical Care Med 152:1107-1136.
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. Ziskind M, Jones RN, Weill H [1976]. Silicosis. Am Rev Respir Dis 113:643-665.
10. Peters JM. [1986]. Silicosis. 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.
11. CDC (Centers for Disease Control) [1990]. Silicosis: Clusters in Sandblasters-Texas, and Occupational Surveillance for Silicosis. MMWR 39 (25):433-437.
12. 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.
13. Sheppard D, Hughson WG, Shellito J [1990]. Occupational Lung Diseases. In: J. LaDou, ed. Occupational Medicine. Norwalk, CN: Appleton &

Lange, pp. 221-236

14. 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.

15. 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.

16. 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.

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

18. 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.

19. Vallyathan V, Kang JH, Van Dyke K, Dalal, NS, Castranova V [1991]. Response of alveolar macrophages to invitro 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.

20. 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.

21. 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.

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

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

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

25. Amandus HE, Castellan RM, Shy C, Heineman EF, Blair A [1992]. Reevaluation of silicosis and lung cancer in North Carolina dusty trades workers. Am J Ind Med 22:147-153.

26. DHHS [1994]. Seventh Annual Report on Carcinogens, Summary 1994. Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institute of Environmental Health Sciences, pp 359-366.

27. IARC [1987]. IARC monographs on the evaluation of carcinogenic risk to man: silica. Vol. 42. Lyon, France: World Health Organization, International Agency for Research on Cancer.

28. 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.

29. 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.
30. Becklake MR [1985]. Chronic airflow limitation: its relationship to work in dusty occupations. *Chest* 88:608-617.
31. 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.
32. 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.
33. Wiles FJ, Baskind E, Hessel PA, Bezuidenhout B, Hnizdo E [1992]. Lung function in silicosis. *Intl Arch Occup Environ Health* 63:387-391.
34. 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.
35. 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.
36. 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.
37. Jacobsen G, Lainhart WS, eds. [1972]. ILO U/C 1971 International classification of radiographs of the pneumoconioses. *Med Radiogr Photogr* 48(3):65-110.
38. 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.
39. Johnson WM, Busnardo MS [1993]. Silicosis following employment in the manufacture of silica flour and industrial sand. *J Occup Med* 35(7):716-719.
40. Blanc PD, Gamsu G [1989]. Cigarette Smoking and Pneumoconiosis: Structuring the debate (editorial). *Am J Ind Med* 16:1-4.

TABLE 1
 Study Population and Participation Rate By Employment Status
 Unimin Specialty Minerals, Inc. -Elco
 HETA 93-0793

Employment Status	N	Total # Eligible	Number of Participants	Number of Non-Participants	Participation Rate (%)
Current Worker	42	25	20	5	80
Former Worker	85	70	8	62	11
TOTAL	127	95	28	67	29

TABLE 2
 Chest X-Ray Results by Reader for 20 Participating Current Workers
 Unimin Specialty Minerals, Inc. - Elco
 HETA 93-0793

READER A			READER B			READER C			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			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
1/0	qs	1,2,4,5	1/0	pp	All	0/0			1/0	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
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			1/0	pp	All	0/0			0/0	1
0/0			1/1	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			0/0			0/0			0/0	1
2/3, B	ts	All	2/3, C	qr	All	3/2, C	qq	1,4	2/3,C	1
0/0			0/0			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

*1,2, 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 3
 Distribution of Chest X-Ray Results by Tenure
 For 20 Participating Current Workers
 Unimin Specialty Minerals, Inc. - Elco
 HETA 93-0793

MAJOR PROFUSION CATEGORY	TENURE (years)				TOTAL	
	1-5	6-10	11-15	16-20	n	(%)
0	4	9	5	--	18	(90)
1	--	--	--	1	1	(5)
2	--	--	1*	--	1	(5)
3	--	--	--	--	--	(--)
Total	4	9	6	1	20	(100)

*Progressive Massive Fibrosis (PMF)

TABLE 4
 Chest X-Ray Results by Reader for 8 Participating Former Workers
 Unimin Specialty Minerals, Inc. - Elco
 HETA 93-0793

READER A			READER B			READER C			MEDIAN	
Profusion	Size/Shape	Zone(s)*	Profusion	Size/Shape	Zone(s)	Profusion	Size/Shape	Zone(s)	Profusion	Film Quality
1/0	pq	1,2,4,5	½	pp	All	1/1	pp	1,4	1/1	1
1/0	st	2,3,5,6	½	st	2,3,5,6	0/0			1/0	1
½, A	qr	All	2/1, A	rq	All	2/1, A	rr	1,4	2/1, A	1
2/2, A	rq	All	2/3, A	qr	1,2,4,5,6	2/1, B	qq	1,4	2/2, A	1
UR			0/0			0/0			0/0	1**
0/0			0/0			0/0			0/0	1
0/0			1/1	ss	2,3,5,6	0/0			0/0	1
0/0			0/0			0/0			0/0	2

*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 0/0, with a film quality score = 3 (see text).

TABLE 5
Lung Function Impairment by Years of Employment
and Cigarette Smoking Status for 28 Participants*
Unimin Specialty Minerals, Inc. - Elco
HETA 93-0793

Years of Employment	NON-SMOKERS			SMOKERS			TOTAL		
	n	Impaired n (%)		n	Impaired n (%)		N	Impaired n (%)	
1-5	1	0	--	6	2	(33)	7	2	(29)
6-10	2	1	(50)	9	2	(22)	11	3	(27)
11-15	2	0	--	4	3	(75)	6	3	(50)
16-20	1	0	--	0	0	--	1	0	--
Total	6	1	(17)	19	7	(37)	25	8	(32)

*3 participants did not perform spirometry

TABLE 6
Number and Proportion of Company Records Available and Missing
for the Study Population by Employment Status
Unimin Specialty Minerals, Inc. - Elco
HETA 93-0793

Employment Status	N	Number and Proportion with Records Available	Number and Proportion with Records Missing
Eligible Current Workers	25	25 (100%)	0 (0%)
Eligible Former Workers	70	16 (23%)	54 (77%)

TABLE 7
 Characteristics of 25 Eligible Current Workers from Company Records
 By Participation
 Unimin Specialty Minerals, Inc. - Elco
 HETA 93-0793

CHARACTERISTIC	PARTICIPANTS N = 20		NON-PARTICIPANTS N = 5		TOTAL N = 25	
Age (yrs) [median]	38		38		38	
Range (yrs)	27-57		33-51		27-57	
Tenure (yrs) [median]	9		12		10	
Range (yrs)	1-16		1-17		1-17	
<u>Cigarette Smoking</u>	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>
Current Smoker	4	20	1	20	5	20
Ex - Smoker	12	60	3	60	15	60
Never Smoker	4	20	1	20	5	20
Small Opacity Profusion ≥ 1/0*	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>	<u>Number</u>	<u>%</u>
	1	5	0	-	1	4

*As determined by the classification closest in time prior to the NIOSH survey by a single B Reader

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.

APPENDIX I (con't)

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

APPENDIX I (con't)

(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.

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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 ≥ 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⁾

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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

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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.
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

	<u>Northeastern District</u>		<u>Employees</u>
46-02805	U.S. Silica Co.	Berkeley Plant	102
	<u>Southeastern District</u>		
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
	<u>North Central District</u>		
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
	<u>South Central District</u>		
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

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ATTACHMENT 2

GROUND SILICA MILLS - 1991

	<u>Northeastern District</u>		<u>Employees</u>
46-02805	U.S. Silica Co.	Berkeley Plant	102
	<u>Southeastern District</u>		
38-00138	U.S. Silica Co.	Columbia Plant	50
40-02937	Nicks Silica Co.	Nicks Silica Co.	13
	<u>North Central District</u>		
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
	<u>South Central District</u>		
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

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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.

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- (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.

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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 $\geq 1/0$ in a ground silica mill worker will be categorized as consistent with silicosis. The B Readers will not be informed of any exposure history. The films will be masked of identifying information. The same B Readers will be used throughout the entire project.

APPENDIX II ⁽¹¹⁾

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 of silicosis, OR
- a chest x-ray 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.

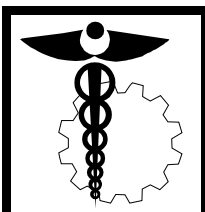
Surveillance Case Definition

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

AND

2. Chest x-ray or other imaging technique interpreted as consistent with silicosis

OR
- B. Pathologic findings characteristic of silicosis



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