**ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH**

**Final Technical Report**

**Title:** Evaluation of Silicosis, Asthma and COPD among Sand and Gravel and Stone Surface Miners

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**Organization:**
Michigan State University
College of Human Medicine
Division of Occupational and Environmental Medicine

**Principal Investigator:**
Kenneth D Rosenman MD

**Contact Information:**
909 Wilson Road
East Lansing, MI 48824
517-353-1846
Fax 517-432-3606
rosenman@msu.edu

**Research Assistant:**
Hailey TenHarmsel MS

**Statistician:**
Ling Wang MS PhD

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## 1.0. Executive Summary

The objective of the study was to evaluate the prevalence of respiratory conditions among workers at sand and gravel mines. We conducted a cross-sectional study of current surface mine workers in Michigan with a focus on asthma, work-related asthma, Chronic Obstructive Pulmonary Disease (COPD) and silicosis. Current workers in the industry were asked to complete a medical questionnaire and those with ≥ 15 years of work in the industry were offered a breathing test and chest x-ray. Analyses were conducted by latency since individuals first began working in the industry and comparing the results to workers in the general Michigan population.

There have been no previous studies that reported the medical results of cohorts of surface sand and gravel miners despite the large number of workers who work in these types of mines; approximately 43% of all miners in the United States are surface sand and gravel or stone miners with 6,150 active surface sand and gravel mines (29,867 miners), and 4,259 surface stone mines (61,644 miners)(NIOSH Statistics: All Mining).

In our study, no radiographs consistent with silicosis were identified. Sand and gravel miners were less likely to smoke cigarettes and to report having COPD although they reported a higher prevalence of current asthma than other workers in Michigan. Analyses by increased years worked at a surface mine generally did not show a relation between an increase in the prevalence of adverse respiratory effects and years worked. However, the prevalence of two adverse respiratory outcomes were increased with years worked: 1) ever having seen a doctor for shortness of breath; and 2) a health professional having ever said they had COPD, emphysema or chronic bronchitis. These adverse respiratory findings and the presence of obstructive changes in a small number of non-smokers, previous case reports of silicosis in workers in the industry, and Mine Safety and Health Administration (MSHA) monitoring results showing elevated silica air levels suggests the potential for adverse respiratory effects in the surface sand and gravel industry either from silica and/or diesel exhaust.

This study was limited by the small number of long-term workers and that only current workers were included. Individuals who became sick and left work or retirees with longer latency periods from first exposure were not included. The study was further limited by the lack of interest of many mine owners and their trade organization to support this project.

Medical screening is generally not provided to surface and gravel miners, so there is no ongoing data generated on health outcomes in surface and gravel miners. Further work that involved retirees and additional long-term current workers in the surface mining industry would be important to determine the true risk of silicosis and other silica-related conditions with a long latency period such as COPD. An additional study that followed a cohort of surface mine workers from time of hire with ongoing evaluation of those who left work at a surface mine coupled with air sampling would be needed to assess the risk of conditions with short latency such as work-related asthma that may cause a worker to leave work in that industry.

## 2.0. Problem Statement and Objective

The risk of silicosis in stone quarry sheds is well documented (Graham et. al., 2001; Wickman and Middendorf, 2002) and there have been some reports from state surveillance systems on the occurrence of silicosis among sand and gravel miners (Valiante and Rosenman, 1989; Reilly et. al., 1993; Maxfield et. al., 1997; Rosenman et. al., 1997).

Individuals exposed to silica during mining operations are at risk not only for silicosis (Leung et. al., 2012) but also for COPD (Omland et. al., 2014). In addition, miners are also potentially at risk of developing work-related asthma (WRA) from exposure to diesel fumes and other workplace allergens and irritants (Tarlo and Lemiere, 2014).

The 2003 American Thoracic Society (ATS) consensus statement estimated for both asthma and COPD that 15% of cases are attributable to work exposures (Balmes et. al., 2003). In 2011, a second ATS consensus statement estimated that 21.5% of adults with asthma have work-aggravated asthma (Henneberger et. al., 2011). The combined estimates from these consensus statements would indicate that 36.5% of all adult asthma is work-related. Data collected in MI and two other states in the Behavioral Risk Factor Surveillance System (BRFSS), a random sample of adults in the general population, found that 54% of adults in MI with asthma reported their work caused or made their asthma worse (Lutzker et. al., 2010). There are an estimated 870,205 adults in MI with asthma and 658,583 with COPD (Tian, 2019). Fifteen to 54% of 870,205 estimated adults with asthma in Michigan translates into 130,531-469,911 cases of WRA and 15% of 658,533 adults with COPD in Michigan translates into 98,780 cases of COPD attributable to work in MI.

Approximately 43% of miners in the United States are either sand and gravel or stone miners. In 2015, there were 6,292 active sand and gravel mines (34,781 miners), and 4,303 stone mines (67,070 miners) in the United States (NIOSH. Statistics: All Mining).

Surface miners in Michigan are required to receive eight hour annual refresher training. The regulations state "§46.1 Scope. The provisions of this part set forth the mandatory requirements for training and retraining miners and other persons at shell dredging, sand, gravel, surface stone, surface clay, colloidal phosphate, and surface limestone mines.
§46.8 Annual refresher training. (a) You must provide each miner with no less than 8 hours of annual refresher training" [64 FR 53130, Sept. 30, 1999, as amended at 67 FR 42382, June 21, 2002].

The owner-operator or an independent contractor can provide this training. MSHA gives grants to states to provide this training. In Michigan, the designee is Matt Portfleet Program Manager, Department of Mining Engineering, Michigan Technological University, Houghton.

Michigan State University (MSU) has been conducting surveillance for work-related asthma and silicosis for over 30 years. In 2011, surveillance was expanded to include all other occupational lung diseases including COPD. The MSU research team has worked closely with both the Michigan Occupational Safety and Health Administration (OSHA) and the Michigan Department of Health and Human Health Services (MDHHS).

## 3.0. Research Approach

### 3.1. Research Task 1: Contacting Michigan Mine workers with Potential Silica Exposure:

In Michigan in 2018, there were 3,834 surface mine workers (includes office workers) at 411 surface mines (MSHA, Mine Data Retrieval System). As of January 6, 2020, there were 3,957 surface mine workers (includes office workers) at 424 mines owned by 243 mine companies (MSHA, Mine Data Retrieval System). As of April 30, 2021, there were 3,546 surface mine workers (includes office workers) at 448 surface mines owned by 241 mine companies (MSHA, Mine Data Retrieval System). In 2020, there were 1,096 workers employed by 111 contractors registered in Michigan at strip, quarry and open pit mines and at mill operation/preparation plants. The data provided by MSHA on contractors does not allow the determination whether these workers employed by contractors worked in Michigan or whether workers employed by contractors registered in other states worked in Michigan. Seven companies were in the MSHA data base both as mine owners and as contractors.

Approach 1: We mailed letters to 164 of the 243 unique mine operator identified January 6, 2020. We had previously reached 79 unique mine operators through Approach 2 described below. The letter to the mine operators stated the scope of our study and that we would contact the company's health and safety coordinator with more information. The Michigan Aggregates Association (MAA) is the major trade association representing surface mine owners in Michigan. We had multiple conversations and written communications with Douglas E Needham, P.E., President of MAA. He indicated the MAA board was not interested in meeting with us; therefore, we proceeded with Approach 1 without input from the MAA board. Of the 164 mine operators, six allowed us to come to their site and provide information to their employees about participating in the study, 10 did not respond to our mailing and did not have a listed working phone number, 19 are now listed as abandoned according to MSHA.gov, and 83 were not interested in allowing us to provide information to their employees. We left multiple messages with the remaining 46 mine operators. Because of COVID-19 and the stay at home order, we did not conduct in-person visits to the mines we were unable to reach by telephone.

Approach 2: Mine workers are required by Mine Safety and Health Administration regulations to receive an 8-hour health and safety refresher training each year. We attended 145 refresher-training sessions that were conducted around the state by the MSHA certified trainers from Michigan Technological University (MTU). We were given a half hour during each training session to discuss respiratory issues and solicit participation from the mine workers in attendance. We also attended five MSHA refresher-training sessions that were conducted by the company itself, which did not utilize MTU trainers. In response to our efforts in Approach 1, we were able to visit six additional companies outside of their regularly scheduled refresher training to discuss respiratory issues and solicit participation with employees. Therefore, we attended a total of 156 training sessions from October 2018 to March 2020. In addition to these 156 trainings, four MSHA trainers with past mining experience were interested in completing the questionnaire as well as one miner who learned of our study from a friend and completed and returned the questionnaire on his own. During the 156 training sessions along with the additional five questionnaires completed without a formal training session, we were able to reach 2,155 surface mine workers. Of the 424 surface mines owned by 243 mine operators in the state, mine workers from 162 mines owned by 79 mine operators and 161 contractors have been contacted through Approach 2. Because of COVID-19, training sessions were suspended. Mine workers from another eight mines owned by six operators were contacted in Approach 1. Table 1 shows the total number of mine workers reached through both approaches.

**Table 1: Number of annual refresher training sessions and number of surface mine workers reached by month, Oct. 2018 – March 2020.**

| Month | Number of Training Sessions | Number of Mine Workers | Number of Mines | Number of Mine operators | Number of Contractors |
|---|---|---|---|---|---|
| October 2018 | 2 | 7 | 0 | 0 | 2 |
| November 2018 | 3 | 44 | 0 | 0 | 2 |
| December 2018 | 6 | 66 | 0 | 0 | 8 |
| January 2019 | 35 | 535 | 17 | 13 | 34 |
| February 2019 | 34 | 599 | 66 | 24 | 44 |
| March 2019 | 35 | 515 | 39 | 22 | 36 |
| April 2019 | 17 | 209 | 16 | 8 | 23 |
| May 2019 | 5 | 61 | 6 | 3 | 6 |
| June 2019 | 0 | 0 | 0 | 0 | 0 |
| July 2019 | 2 | 12 | 6 | 1 | 1 |
| August 2019 | 1 | 7 | 0 | 0 | 1 |
| September 2019 | 1 | 6 | 0 | 0 | 0 |
| January 2020 | 5 | 28 | 7 | 5 | 0 |
| February 2020 | 6 | 22 | 3 | 3 | 4 |
| March 2020 | 4 | 39 | 8 | 6 | 0 |
| N/A | 0 | 5 | 0 | - | - |
| **Total** | **156** | **2,155** | **168** | **85** | **161** |

### 3.2. Research Task 2: Questionnaire

We distributed and collected medical questionnaires and consent forms at the training sessions and computerized the data from the questionnaires using Microsoft Access. The questionnaire used was a combination of a questions we have previously used to assess symptoms in relationship to work on 12,645 workers during 771 follow-up OSHA inspections for work-related asthma cases (Reilly et al., 2020) and questions from the Michigan Behavioral Risk Factor Surveillance System (MiBRFSS) for asthma, COPD and cigarette smoking (Wang and Rosenman, 2018). MiBRFSS is an annual randomized survey of the general population of non-institutionalized adults in Michigan.

Of the 2,155 mine workers, 1,207 completed the questionnaire, resulting in a response rate of 56%. These mine workers were from 168 surface mines owned by 85 business entities. There were another 161 business entities that employed contractors. Of the 1,207 mine-related workers who completed the questionnaire, 472 worked for a mine-owning company and 735 worked for a contractor. Of the 948 mine workers that refused to fill out the medical questionnaire, 26 filled out a decline to participate form. Among these 26 workers, two reported ever having asthma and one reported having COPD. They reported no other respiratory problems. Of the 26, only three reported smoking cigarettes, and only two had ≥ 20 years of work in a sand/gravel mine. The other 922 mine workers refused to complete a decline to participate form; although 21 of these 922 mine workers made statements that they believed their information would not be helpful due to their lack of time spent on mine sites or that they have only been into the building on a mine site once or twice in their lifetime.

### 3.3. Research Task 3: Medical Testing

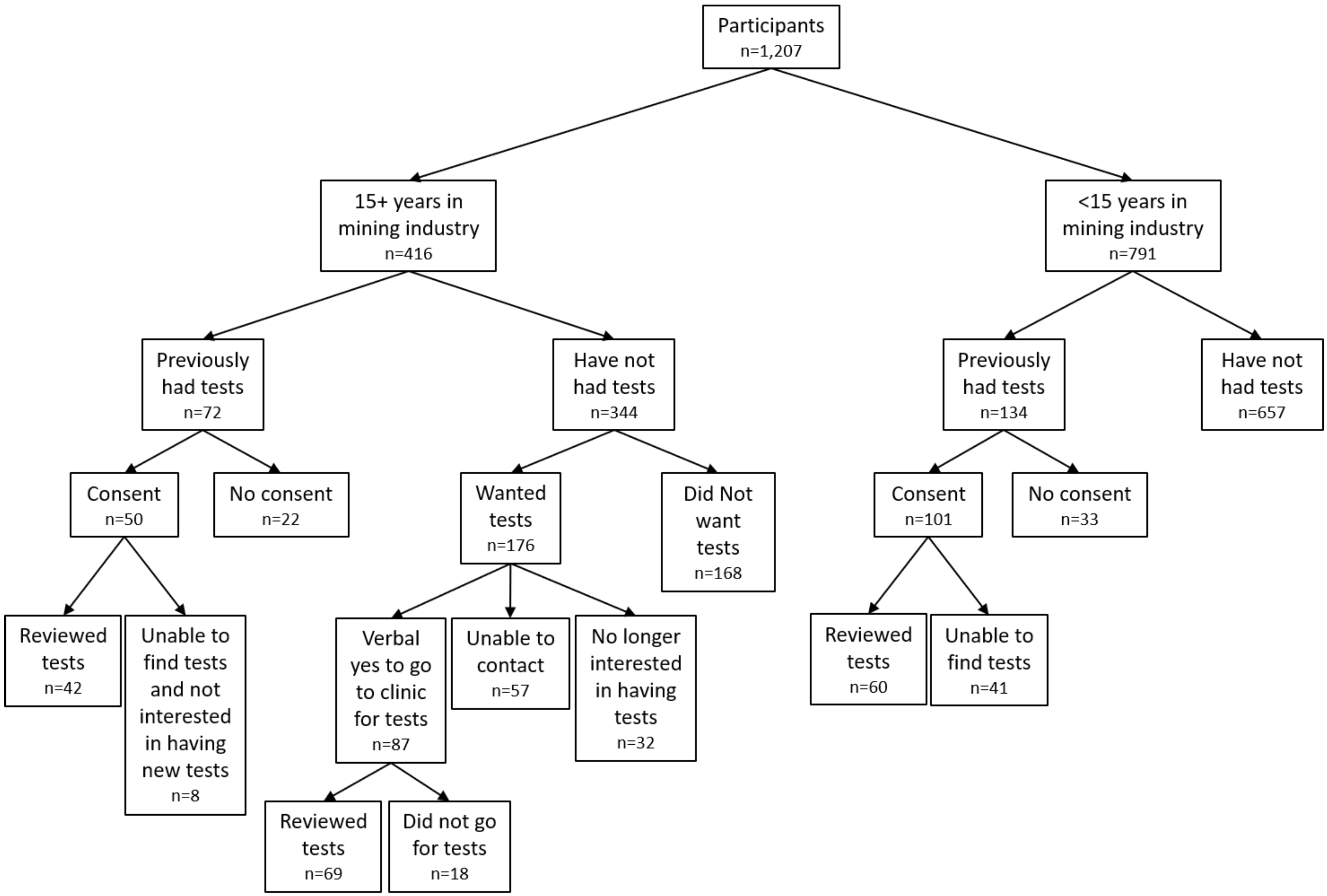
To provide medical testing, we set up billing arrangements with 24 organizations around the state, some of which had multiple clinic and hospital locations. Mine workers, who had worked ≥ 15 years in the mining industry, were eligible to receive a chest radiograph (x-ray) and breathing test (spirometry).  We followed up with the 416 mine workers who completed a questionnaire and worked ≥ 15 years in the mining industry; 72 had either a chest x-ray and/or spirometry within the last three years and 344 had not had a chest x-ray or breathing test in the last three years. We requested permission from the 72 with recent testing to review the chest radiograph and/or breathing test. One hundred seventy-six of the 344, who had not had a recent test, requested the testing. Of the 248 mine workers who either had testing or requested the testing, we reviewed chest radiographs and spirometry tests from 111 mine workers. There were another 60 chest x-rays and spirometry tests reviewed on mine workers who requested a review even though they had worked < 15 years in mining. See Table 2 and Figure 1 that summarizes the medical testing. Because of COVID-19, we suspended contacting individuals about scheduling for testing between the Spring of 2020 and November 2020. Of the 171 participants that we reviewed their chest x-ray and spirometry, for 69 we had ordered the tests and for 102 the mine worker previously had the test. All individuals received a letter from us with the results of their B reading classification and spirometry interpretation.

In November 2020, we mailed all mine workers who had completed a questionnaire with ≥ 15 years in the mining industry who had not wanted to have a chest x-ray/breathing test. Letters went out to 249 mine workers. In response to this letter, another 10 mine workers had medical testing. Some clinics/hospitals required a recent negative COVID-19 result before they did the testing or stopped conducting spirometry at all due to COVID-19.

**Table 2. Mine worker participants chest radiographs and spirometry by number of years in the mining industry.**

| **Participant test status** | **Chest radiograph** | **Spirometry** | **Total number of tests** |
|---|---|---|---|
| Already had test <15 years in mining | 54 | 21 | 75 |
| Already had test 15+ years in mining | 41 (26 had only 1 test, 12 had both, 3 only had CXR but now have both as MSU paid for PFT) | 13 (12 had both, 1 only had PFT but now have both as MSU paid for CXR) | 54 |
| MSU paid for test 15+ years in mining | 70 (59 MSU paid both, 11 MSU paid only CXR) | 62 (59 MSU paid both, 3 MSU paid only PFT) | 132 |
| **Total reviewed** | **165** | **96** | **261** |

**Figure 1. Flow diagram of the status of participants' chest radiographs and spirometry tests.**



### 3.4. Research Task 4: Disease Classification

The disease classification for chest x-rays was based on the B-reader classification system and was conducted by a National Institute for Occupational Safety and Health (NIOSH) certified B reader. A chest x-ray reading of ≥ 1/0 profusion of rounded opacities involving the upper zones was considered silicosis. A chest x-ray reading of ≥ 1/0 profusion of linear opacities involving the lower zones was considered asbestosis (parenchymal changes of interstitial fibrosis). Pleural changes (scarring of the lining of the lung) consistent with pneumoconiosis as per the NIOSH B reader classification guidelines were defined as asbestos-related pleural changes.

Spirometry is the breathing test used to screen for lung disease. Spirometry measures the amount of air exhaled in one second (Forced Expiratory Volume in one second (FEV1)) and the total amount of air exhaled (Forced Vital Capacity (FVC)). For spirometry, the results were considered normal if the FEV1 to FVC ratio was ≥ 90% of predicted and the FVC reading was ≥ 80% of predicted. There were three categories of abnormal spirometry results: Obstructive - If the FEV1 to FVC ratio was < 90% of predicted, the FEV1 reading was < 95% of predicted and the FVC was ≥ 80% of predicted; Restrictive - If the spirometry results had a FEV1 to FVC ratio ≥ 90% of predicted and the FVC reading was < 80% of predicted; and Mixed Obstructive/Restrictive - If the FEV1 to FVC ratio was < 90% of predicted and the FEV1 and the FVC reading were < 80%.

Definite work-related asthma was defined as someone reporting a doctor had told them they had work-related asthma. Possible work-related asthma was defined as reporting being bothered daily or weekly at work by either wheezing, shortness of breath, or chest tightness and/or developing asthma since beginning to work at a mine. If wheezing, shortness of breath or chest tightness were experienced less often than daily or weekly or if the symptoms did not occur at work, the individual was classified as not having possible work-related asthma.

### 3.5. Research Task 5: Data Analysis

We created a Microsoft Access database to track the training sessions, number of mine workers, and the responses from the medical questionnaire. Associations between categorical latency levels and outcomes were analyzed using the Cochran-Armitage trend test, which analyzes categorical data (i.e., disease yes or no) versus categorical latency data (i.e. years since first exposed: ≤ 1 year, 2-9 years, 10-19 years and 20+ years). Associations between continuous log-transformed years of latency from first exposure with adverse respiratory outcomes were analyzed using logistic regression. Standardized morbidity ratios (SMR) were calculated controlling for age and cigarette smoking status to compare the observed number of adverse respiratory responses and the number of expected adverse respiratory responses in Michigan workers adjusting for age and gender. SMRs show whether people who work in the surface mining industry had a higher number of observed surface miners of the same age and gender with adverse respiratory effects than expected based on the general population. We used the industry of current workers in BRFSS as the reference population group. P-values less than 0.05 were considered statically significant for all statistical analyses.

### 3.6. Deviations and Corrective Actions

Deviations and corrective actions from all interim reports were addressed. We made multiple attempts to contact all mine sites that did not have a training session through MTU.

## 4.0. Research Findings and Accomplishments

### 4.1. Deliverables, Significant Milestones, and Impact Summary

We submitted preliminary analyses of the questionnaire data as part of our previous interim reports. In a previous report, we updated the preliminary data after we attempted to recontact all mine workers who had responded "unknown" to when a symptom or condition began. This allowed us to reduce the number of participants with unknown responses from 206 to 76 and the number of unknown responses from 274 to 98 (a participant could have had multiple unknown responses).

Deviations and corrective actions from all interim reports were addressed. We made multiple attempts to contact all mine sites that did not have a training session through MTU.

Funds were sufficient to complete the full scope of the project.

### 4.2. Demographics

Among the 1,207 participants, the average age was 44.0 years; 117 (9.8%) ≤ 25, 642 (53.6%) 26-50, 439 (36.6%) > 50. Nine were missing age. Ninety six and a half percent were men, 39 (3.2%) were female, and 3 (0.2%) did not report their sex.

The participants had worked an average of 12.7 years and a median of 9.0 years in a sand/gravel mine; 193 (16.3%) ≤ 1 year, 434 (36.7%) 2-9 years, 249 (21.1%) 10-19 years, 305 (25.8%) ≥ 20 years.

### 4.3. Silicosis and Asbestosis

No individual had radiographic changes of scarring of the lung tissue consistent with silicosis or asbestosis.

### 4.4. Asbestos-Related Pleural Changes

Six individuals had asbestos-related pleural changes. A summary of these six individuals follows:

<u>Bilateral pleural thickening (2)</u>

A 68-year-old male worked at a concrete manufacturer for 52 years since the age of 16. He worked as a truck driver and front end loader the last ten years. He worked in the Michigan Upper Peninsula (UP).

A 70-year-old male truck driver worked at a sand and gravel mine for 20 years in the UP. Prior work included six months in an iron mine in the UP. His pleural thickening was calcified, and he had previously been told about his x-ray findings.

<u>Unilateral pleural thickening (4)</u>

A 35-year-old male truck driver hauled aggregates for less than a year. His previous work history was unknown. He worked in the Thumb area of Michigan.

A 46-year-old male crusher operator worked at a sand and gravel mine for 28 years. He worked in the UP.

A 65-year-old male sales representative worked for 25 years for a sand and gravel mine. Prior to being a sales representative, he had been a batcher for two years at a concrete plant, eight years as a machine operator at an iron and titanium refinery and 12 years at a cement plant. His first 10 years of work prior to being a sales representative was in Quebec. The cement plant was in the northern part of Michigan's Lower Peninsula.

A 55-year-old male heavy equipment operator worked for 16 years for a sand and gravel mine. His previous work history was unknown. He worked in the northern part of Michigan's Lower Peninsula.

### 4.5. Definite Work-Related Asthma

No individual had definite work-related asthma.

### 4.6. Possible Work-Related Asthma

One hundred and seventeen individuals had been told by a health professional they had asthma. Asthma began in 21 individuals after they began working at a mine. Onset of asthma was unknown for eight individuals. Of the 114 individuals with daily or weekly symptoms of wheezing, shortness of breath or chest tightness at work, eight had asthma before starting a mining job, for 10 their asthma began after starting a mining job, for one their asthma began the same year they started a mining job, for one it was unknown when their asthma started and for 94 individuals there was no doctor's diagnosis of asthma. One hundred and twenty-five individuals met our definition of possible work-related asthma, of which 57 were classified as mine workers, maintenance workers or welders, 41 were classified as contractors, 23 were classified as truck drivers, two were environmental contractors, and for two no work history was provided.

### 4.7. Asthma, COPD, Emphysema or Chronic Bronchitis, Saw a doctor for Shortness of Breath

Twenty-two individuals reported they had ever been told by a doctor they had COPD, emphysema or chronic bronchitis. One hundred and twenty-nine individuals had seen a doctor for shortness of breath and 227 had a chronic productive cough. Because some individuals were in more than one category, this represents 303 individuals. Sixty-six of the 117 individuals with asthma overlapped with this group.

The results of asthma, COPD, and respiratory symptoms among individuals who have ever (current and those who quit) smoked cigarettes versus never smoked cigarettes is shown in Table 3. COPD, daily or weekly respiratory symptoms at work and chronic productive cough were significantly increased in those who currently or ever smoked versus those who never smoked cigarettes.

**Table 3. Prevalence of asthma, COPD, saw a doctor for shortness of breath, and self-reported prevalence of respiratory symptoms by cigarette smoking status among 1,207 mine workers in Michigan.**

| Cigarette smoking | Asthma[1] | | COPD, Emphysema, Chronic Bronchitis[2] | | Saw doctor for SOB[3] | | Daily/weekly symptoms at work[4] | | Chronic productive cough[5] | | Possible work-related asthma | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| | # % | # | # % | # | # % | # | # % | # | # % | # | # % | # |
| Ever | 47 (10.1) | 420 | 19 (4.0) | 455 | 53 (10.9) | 434 | 66 (16.4) | 336 | 132 (27.4) | 349 | 71 (14.9) | 406 |
| Never | 62 (10.3) | 541 | 3 (0.5) | 601 | 66 (10.8) | 544 | 45 (8.7) | 471 | 74 (12.3) | 530 | 51 (8.4) | 556 |
| Unknown | 8 (14.0) | 49 | 0 (-) | 54 | 10 (10.4) | 86 | 3 (10.7) | 25 | 21 (22.6) | 72 | 3 (5.8) | 49 |
| Total | 117 (10.4) | 1010 | 22 (1.9) | 1110 | 129 (10.9) | 1064 | 118 (12.5) | 828 | 227 (19.3) | 951 | 125 (11.0) | 1011 |

[1] Chi-square Test 2-sided P = 0.6457, [2] Chi-square Test 2-sided P = 0.0001 (unknowns not included)

[3] Chi-square Test 2-sided P = 0.9910, [4] Chi-square Test 2-sided P = 0.0018

[5] Chi-square Test 2-sided P < 0.0001, [6] Chi-square Test 2-sided P = 0.0015

Outcomes by years since first worked (latency categories: ≤ 1 year, 2-9 years, 10-19 years and 20+ years) at a surface mine were examined (Tables 4-8). The total of responses in each table varies since not all participants answered all questions. Tables 4-8 show the results for all surface mine workers combined, Tables 4a-8a for surface miners, maintenance and welders, Tables 4b-8b for truck drivers and Tables 4c-8c for contactors. The analyses for COPD, daily or weekly respiratory symptoms at work, chronic productive cough and possible work-related asthma were conducted controlling for cigarette smoking status (workers with unknown cigarette smoking status were not included in the analysis). The prevalence of seeing a doctor for shortness of breath statistically increased with latency from first worked in a surface mine (Table 4).

**Table 4. Self-reported prevalence of symptoms by latency since first exposure among 1,207 surface mine workers in Michigan.**

| | **Saw a doctor for shortness of breath?** | | **Bring up mucus most days of the week for 3+ months during 2+ years?**[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 177 | 3 (1.7) | 173 | 18 (10.4) |
| 2 - 9 | 420 | 21 (5.0) | 399 | 39 (9.8) |
| 10 - 19 | 222 | 18 (8.1) | 212 | 27 (12.7) |
| 20 + | 287 | 21 (7.3)[2] | 254 | 23 (9.1)[3] |
| Unknown | 38 | 17 (44.7) | 72 | 52 (72.2) |
| Pre-existing | 49 | 49 (100.0) | 68 | 68 (100.0) |
| Total | 1193* | 129 (10.8) | 1178** | 227 (19.3) |

[1] Smoking status included as covariate; 12 workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.0068, [3]Cochran-Armitage Trend Test 2-sided P = 0.8913
*14 workers did not answer question **29 workers did not answer question

**Table 4a. Self-reported prevalence of symptoms by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Saw a doctor for shortness of breath? | | Bring up mucus most days of the week for 3+ months during 2+ years?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 49 | 1 (2.0) | 52 | 8 (15.4) |
| 2 - 9 | 128 | 10 (7.8) | 120 | 21 (17.5) |
| 10 - 19 | 72 | 7 (9.7) | 64 | 12 (18.8) |
| 20 + | 130 | 12 (9.2)[2] | 113 | 15 (13.3)[3] |
| Unknown | 8 | 8 (100.0) | 25 | 25 (100.0) |
| Pre-existing | 14 | 14 (100.0) | 20 | 20 (100.0) |
| Total | 401* | 52 (13.0) | 394** | 101 (25.6) |

[1]Smoking status included as covariate; 6 workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.1745, [3]Cochran-Armitage Trend Test 2-sided P = 0.6814
*4 workers classified as "miners", "maintenance", or "welders" did not answer question **11 workers classified as "miners", "maintenance", or "welders" did not answer question

**Table 4b. Self-reported prevalence of symptoms by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Saw a doctor for shortness of breath? | | Bring up mucus most days of the week for 3+ months during 2+ years?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 36 | 1 (2.8) | 33 | 2 (6.1) |
| 2 - 9 | 52 | 3 (5.8) | 46 | 5 (10.9) |
| 10 - 19 | 28 | 5 (17.9) | 26 | 3 (11.5) |
| 20 + | 39 | 4 (10.3)[2] | 36 | 2 (5.6)[3] |
| Unknown | 4 | 4 (100.0) | 7 | 7 (100.0) |
| Pre-existing | 7 | 7 (100.0) | 15 | 15 (100.0) |
| Total | 166* | 24 (14.5) | 163** | 34 (20.9) |

[1] Smoking status included as covariate; 0 mine "truck drivers" removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.1072, [3]Cochran-Armitage Trend Test 2-sided P = 0.8848
*1 worker classified as a "truck drivers" did not answer question **4 workers classified as "truck drivers" did not answer question

**Table 4c. Self-reported prevalence of symptoms by latency since first exposure among 557 workers classified as "contractors" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Saw a doctor for shortness of breath? | | Bring up mucus most days of the week for 3+ months during 2+ years?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 84 | 1 (1.2) | 78 | 8 (10.3) |
| 2 - 9 | 218 | 7 (3.2) | 211 | 13 (6.2) |
| 10 - 19 | 113 | 6 (5.3) | 111 | 12 (10.8) |
| 20 + | 111 | 5 (4.5)[2] | 98 | 6 (6.1)[3] |
| Unknown | 2 | 2 (100.0) | 17 | 17 (100.0) |
| Pre-existing | 24 | 24 (100.0) | 32 | 32 (100.0) |
| Total | 552* | 45 (8.2) | 547** | 88 (16.1) |

[1] Smoking status included as covariate; 6 mine "contractors" removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.1637, [3]Cochran-Armitage Trend Test 2-sided P = 0.8118

*5 workers classified as "contractors" did not answer question **10 workers classified as "contractors" did not answer question

**Table 5. Self-reported prevalence of diseases by latency since first exposure among 1,207 surface mine workers in Michigan.**

| | Health professional ever said you have asthma? | | Health professional ever said you have COPD, emphysema, or chronic bronchitis?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 162 | 2 (1.2) | 188 | 0 (0.0) |
| 2 - 9 | 371 | 8 (2.2) | 397 | 2 (0.5) |
| 10 - 19 | 204 | 5 (2.5) | 233 | 9 (3.9) |
| 20 + | 277 | 7 (2.5)[2] | 288 | 5 (1.7)[3] |
| Unknown | 26 | 8 (30.8) | 24 | 4 (16.7) |
| Pre-existing | 87 | 87 (100.0) | 2 | 2 (100.0) |
| Total | 1127* | 117 (10.4) | 1132** | 22 (1.9) |

[1]Smoking status included as covariate; 13 workers removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.4047, [3]Cochran-Armitage Trend Test 2-sided P = 0.1529

*80 workers did not answer question **75 workers did not answer question

**Table 5a. Self-reported prevalence of diseases by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional ever said you have asthma? | | Health professional ever said you have COPD, emphysema, or chronic bronchitis?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 41 | 1 (2.4) | 51 | 0 (0.0) |
| 2 - 9 | 106 | 4 (3.8) | 119 | 2 (1.7) |
| 10 - 19 | 66 | 3 (4.5) | 72 | 3 (4.2) |
| 20 + | 123 | 4 (3.3)[2] | 130 | 3 (2.3)[3] |
| Unknown | 3 | 3 (100.0) | 2 | 2 (100.0) |
| Pre-existing | 35 | 35 (100.0) | 1 | 1 (100.0) |
| Total | 374* | 50 (13.4) | 375** | 11 (2.9) |

[1]Smoking status included as covariate; 7 workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.9292, [3]Cochran-Armitage Trend Test 2-sided P = 0.7936 *31 workers classified as "miners",
"maintenance", or "welders" did not answer question **30 workers classified as "miners", "maintenance", or "welders" did not answer question

**Table 5b. Self-reported prevalence of diseases by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional ever said you have asthma? | | Health professional ever said you have COPD, emphysema, or chronic bronchitis?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 36 | 1 (2.8) | 41 | 0 (0.0) |
| 2 - 9 | 50 | 1 (2.0) | 50 | 0 (0.0) |
| 10 - 19 | 22 | 0 (0.0) | 32 | 3 (9.4) |
| 20 + | 39 | 1 (2.6)[2] | 38 | 1 (2.6)[3] |
| Unknown | 2 | 2 (100.0) | 0 | 0 (N/A) |
| Pre-existing | 8 | 8 (100.0) | 0 | 0 (N/A) |
| Total | 157* | 13 (8.3) | 161** | 4 (2.5) |

[1] Smoking status included as covariate; 0 mine "truck drivers" removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.9969, [3]Cochran-Armitage Trend Test 2-sided P = 0.2259
*10 workers classified as "truck drivers" did not answer question **6 workers classified as "truck drivers" did not answer question

**Table 5c. Self-reported prevalence of diseases by latency since first exposure among 557 workers classified as "contractors" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional ever said you have asthma? | | Health professional ever said you have COPD, emphysema, or chronic bronchitis?[1] | |
|---|---|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 77 | 0 (0.0) | 85 | 0 (0.0) |
| 2 - 9 | 193 | 2 (1.0) | 205 | 0 (0.0) |
| 10 - 19 | 107 | 2 (1.9) | 118 | 3 (2.5) |
| 20 + | 108 | 2 (1.9)[2] | 113 | 0 (0.0)[3] |
| Unknown | 0 | 0 (N/A) | 1 | 1 (100.0) |
| Pre-existing | 38 | 38 (100.0) | 1 | 1 (100.0) |
| Total | 523* | 44 (8.4) | 523** | 5 (1.0) |

[1] Smoking status included as covariate; 3 mine "contractors" removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.5373, [3]Cochran-Armitage Trend Test 2-sided P = N/A

*34 workers classified as "contractors" did not answer question **34 workers classified as "contractors" did not answer question

**Table 6. Results of chest radiographs (CXR) consistent with pneumoconiosis and abnormal (i.e., obstruction, restriction, or mixed obstruction and restriction) spirometry tests by latency since first exposure among surface mine workers in Michigan.**

| | Chest radiograph | | Spirometry | |
|---|---|---|---|---|
| **Latency in years** | **Number of tests** | **Abnormal n (%)** | **Number of tests** | **Abnormal n (%)** |
| ≤ 1 | 9 | 1 (11.1) | 7 | 2 (28.6) |
| 2 - 9 | 29 | 1 (3.4) | 14 | 4 (28.6) |
| 10 - 19 | 34 | 1 (2.9) | 17 | 6 (35.3) |
| 20 + | 78 | 3 (3.8)[1] | 52 | 13 (25.0)[2] |
| Unknown | 2 | 0 (0.0) | 1 | 0 (0.0) |
| Pre-existing | 13 | 0 (0.0) | 5 | 1 (20.0) |
| Total | 165 | 6 (3.6) | 96 | 26 (27.1) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.5882, [2]Cochran-Armitage Trend Test 2-sided P = 0.6909

**Table 6a. Results of chest radiographs (CXR) consistent with pneumoconiosis and abnormal (i.e., obstruction, restriction, or mixed obstruction and restriction) spirometry tests by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions.**

| | Chest radiograph | | Spirometry | |
|---|---|---|---|---|
| **Latency in years** | **Number of tests** | **Abnormal n (%)** | **Number of tests** | **Abnormal n (%)** |
| ≤ 1 | 5 | 1 (20.0) | 3 | 2 (66.7) |
| 2 - 9 | 6 | 0 (0.0) | 3 | 2 (66.7) |
| 10 - 19 | 13 | 0 (0.0) | 6 | 2 (33.3) |
| 20 + | 43 | 2 (4.7)[1] | 31 | 8 (25.8)[2] |
| Unknown | 0 | 0 (N/A) | 0 | 0 (N/A) |
| Pre-existing | 3 | 0 (0.0) | 2 | 1 (50.0) |
| Total | 70 | 3 (4.3) | 45 | 15 (33.3) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.4432, [2]Cochran-Armitage Trend Test 2-sided P = 0.0616

**Table 6b. Results of chest radiographs (CXR) consistent with pneumoconiosis and abnormal (i.e., obstruction, restriction, or mixed obstruction and restriction) spirometry tests by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions.**

| | Chest radiograph | | Spirometry | |
|---|---|---|---|---|
| **Latency in years** | **Number of tests** | **Abnormal n (%)** | **Number of tests** | **Abnormal n (%)** |
| ≤ 1 | 0 | 0 (0.0) | 1 | 0 (0.0) |
| 2 - 9 | 8 | 1 (12.5) | 4 | 1 (25.0) |
| 10 - 19 | 3 | 0 (0.0) | 2 | 1 (50.0) |
| 20 + | 7 | 0 (0.0)[1] | 6 | 1 (16.7)[2] |
| Unknown | 0 | 0 (N/A) | 0 | 0 (N/A) |
| Pre-existing | 4 | 0 (0.0) | 0 | 0 (N/A) |
| Total | 22 | 1 (4.5) | 13 | 3 (23.1) |

[1]Cochran-Armitage Trend Test 2-sided P = N/A, [2]Cochran-Armitage Trend Test 2-sided P = 1.0000

**Table 6c. Results of chest radiograph (CXR) consistent with pneumoconiosis and abnormal (i.e., obstruction, restriction, or mixed obstruction and restriction) spirometry tests by latency since first exposure among 557 workers classified as "contractors" based on job descriptions.**

| | Chest radiograph | | Spirometry | |
|---|---|---|---|---|
| **Latency in years** | **Number of tests** | **Abnormal n (%)** | **Number of tests** | **Abnormal n (%)** |
| ≤ 1 | 4 | 0 (0.0) | 2 | 0 (0.0) |
| 2 - 9 | 15 | 0 (0.0) | 6 | 1 (16.7) |
| 10 - 19 | 16 | 1 (6.3) | 8 | 2 (25.0) |
| 20 + | 27 | 1 (3.7)[1] | 14 | 4 (28.6)[2] |
| Unknown | 0 | 0 (N/A) | 0 | 0 (N/A) |
| Pre-existing | 6 | 0 (0.0) | 2 | 0 (0.0) |
| Total | 68 | 2 (2.9) | 32 | 7 (21.9) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.5165, [2]Cochran-Armitage Trend Test 2-sided P = 0.3512

**Table 7. Prevalence of being bothered daily or weekly at work by wheezing, chest tightness, or shortness of breath by latency since first exposure among surface mine workers in Michigan.**

| | Daily or weekly breathing symptoms at work?[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 140 | 9 (6.4) |
| 2 - 9 | 342 | 24 (7.0) |
| 10 - 19 | 185 | 13 (7.0) |
| 20 + | 217 | 20 (9.2)[2] |
| Unknown | 35 | 21 (60.0) |
| Pre-existing | 27 | 27 (100.0) |
| Total | 946* | 114 (12.1) |

[1] Smoking status included as covariate; 12 mine workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.3050
*261 workers did not answer question

**Table 7a. Prevalence of being bothered daily or weekly at work by wheezing, chest tightness, or shortness of breath by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions.**

| | Daily or weekly breathing symptoms at work?[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 38 | 5 (13.2) |
| 2 - 9 | 101 | 13 (12.9) |
| 10 - 19 | 58 | 6 (10.3) |
| 20 + | 106 | 15 (14.2)[2] |
| Unknown | 6 | 6 (100.0) |
| Pre-existing | 8 | 8 (100.0) |
| Total | 317* | 53 (16.7) |

[1]Smoking status included as covariate; 7 mine workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.8774
*88 workers classified as "miners", "maintenance", or "welders" did not answer question

**Table 7b. Prevalence of being bothered daily or weekly at work by wheezing, chest tightness, or shortness of breath by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions.**

| | Daily or weekly breathing symptoms at work?[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 28 | 1 (3.6) |
| 2 - 9 | 39 | 4 (10.3) |
| 10 - 19 | 22 | 3 (13.6) |
| 20 + | 27 | 3 (11.1)[2] |
| Unknown | 2 | 2 (100.0) |
| Pre-existing | 9 | 9 (100.0) |
| Total | 127* | 22 (17.3) |

[1] Smoking status included as covariate; 0 mine "truck drivers" removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.5724
*40 workers classified as "truck drivers" did not answer question

**Table 7c. Prevalence of being bothered daily or weekly at work by wheezing, chest tightness, or shortness of breath by latency since first exposure among 557 workers classified as "contractors" based on job descriptions.**

| | Daily or weekly breathing symptoms at work?[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 6 | 2 (3.1) |
| 2 - 9 | 184 | 7 (4.3) |
| 10 - 19 | 94 | 4 (4.3) |
| 20 + | 79 | 3 (3.8)[2] |
| Unknown | 11 | 11 (100.0) |
| Pre-existing | 10 | 10 (100.0) |
| Total | 443* | 39 (8.8) |

[1] Smoking status included as covariate; 5 mine "contractors" removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.8045*114 workers classified as "contractors" did not answer question

**Table 8. Prevalence of possible work-related asthma by latency since first exposure.**

| | Possible work-related asthma[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 175 | 10 (5.7) |
| 2 - 9 | 408 | 30 (7.4) |
| 10 - 19 | 211 | 15 (7.1) |
| 20 + | 274 | 22 (8.0)[2] |
| Unknown | 41 | 21 (51.2) |
| Pre-existing | 27 | 27 (100.0) |
| Total | 1136* | 125 (11.0) |

[1] Smoking status included as covariate; 13 workers removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.4343

*71 workers did not answer questions

**Table 8a. Prevalence of possible work-related asthma by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions.**

| | Possible work-related asthma[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 50 | 5 (10.0) |
| 2 - 9 | 120 | 15 (12.5) |
| 10 - 19 | 68 | 7 (10.3) |
| 20 + | 125 | 16 (12.8)[2] |
| Unknown | 6 | 6 (100.0) |
| Pre-existing | 8 | 8 (100.0) |
| Total | 377* | 57 (15.1) |

[1] Smoking status included as covariate; 7 workers removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.7507
*28 workers classified as "miners", "maintenance", or "welders" did not answer questions

**Table 8b. Prevalence of possible work-related asthma by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions.**

| | Possible work-related asthma[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 37 | 2 (5.4) |
| 2 - 9 | 52 | 5 (9.6) |
| 10 - 19 | 24 | 3 (12.5) |
| 20 + | 36 | 2 (5.6)[2] |
| Unknown | 2 | 2 (100.0) |
| Pre-existing | 9 | 9 (100.0) |
| Total | 160* | 23 (14.4) |

[1] Smoking status included as covariate; 0 mine "truck drivers" removed from analysis due to unknown smoking status
[2]Cochran-Armitage Trend Test 2-sided P = 0.9460
*7 workers classified as "truck drivers" did not answer questions

**Table 8c. Prevalence of possible work-related asthma by latency since first exposure among 557 workers classified as "contractors" based on job descriptions.**

| | Possible work-related asthma[1] | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 77 | 2 (2.6) |
| 2 - 9 | 212 | 9 (4.2) |
| 10 - 19 | 109 | 5 (4.6) |
| 20 + | 106 | 4 (3.8)[2] |
| Unknown | 11 | 11 (100.0) |
| Pre-existing | 10 | 10 (100.0) |
| Total | 525* | 41 (7.8) |

[1] Smoking status included as covariate; 6 mine "contractors" removed from analysis due to unknown smoking status

[2]Cochran-Armitage Trend Test 2-sided P = 0.7466

*32 workers classified as "contractors" did not answer questions

The analysis of the categorical data presented as odds ratios is shown in Table 9 and showed the same statistical increased likelihood to see a doctor for shortness of breath with time since first worked in a surface mine as the categorical data (Table 4).

**Table 9. Odds ratios from pairwise comparisons of symptoms between latency categories.**

| **Saw a doctor for shortness of breath? latency** | **Saw a doctor for shortness of breath? latency** | **Odds Ratio** | **95% Confidence Interval** | | **p-value** |
|---|---|---|---|---|---|
| 2 - 9 | <=1 | 3.053 | 0.589 | 15.830 | 0.4418 |
| 10 - 19 | <=1 | 5.118 | 0.966 | 27.120 | 0.0588 |
| 10 - 19 | 2 - 9 | 1.676 | 0.697 | 4.031 | 0.7214 |
| 20+ | <=1 | 4.579 | 0.881 | 23.808 | 0.0894 |
| 20+ | 2 - 9 | 0.667 | 0.288 | 1.545 | 1.0000 |
| 20+ | 10 - 19 | 1.118 | 0.463 | 2.701 | 1.0000 |
| **Bring up mucus most days of the week for 3+ months during 2+ years? latency** | **Bring up mucus most days of the week for 3+ months during 2+ years? latency** | **Odds Ratio** | **95% Confidence Interval** | | **p-value** |
| 2 - 9 | <=1 | 1.158 | 0.481 | 2.788 | 1.0000 |
| 10 - 19 | <=1 | 1.820 | 0.719 | 4.607 | 0.5346 |
| 10 - 19 | 2 - 9 | 1.571 | 0.760 | 3.244 | 0.6030 |
| 20+ | <=1 | 1.014 | 0.384 | 2.676 | 1.0000 |
| 20+ | 2 - 9 | 1.142 | 0.525 | 2.485 | 1.0000 |
| 20+ | 10 - 19 | 1.794 | 0.781 | 4.124 | 0.3830 |

| Health professional ever said you have asthma? latency[1] | Health professional ever said you have asthma? latency | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|
| 2 - 9 | <=1 | 1.763 | 0.216 | 14.407 | 1.0000 |
| 10 - 19 | <=1 | 2.010 | 0.217 | 18.599 | 1.0000 |
| 10 - 19 | 2 - 9 | 1.140 | 0.249 | 5.223 | 1.0000 |
| 20+ | <=1 | 2.074 | 0.246 | 17.480 | 1.0000 |
| 20+ | 2 - 9 | 0.850 | 0.213 | 3.385 | 1.0000 |
| 20+ | 10 - 19 | 0.969 | 0.203 | 4.632 | 1.0000 |

[1] "Do not know" responses were not included

| Health professional ever said you have COPD, emphysema, or chronic bronchitis? latency[1] | Health professional ever said you have COPD, emphysema, or chronic bronchitis? latency | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|
| 10 - 19 | 2 - 9 | 8.856 | 1.336 | 58.701 | 0.0173 |
| 20+ | 2 - 9 | 0.264 | 0.035 | 1.986 | 0.3420 |
| 20+ | 10 - 19 | 2.336 | 0.596 | 9.158 | 0.4116 |

[1] "Do not know" responses were not included

| Daily or weekly breathing symptoms at work? latency | Daily or weekly breathing symptoms at work? latency | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|
| 2 - 9 | <=1 | 1.192 | 0.408 | 3.488 | 1.0000 |
| 10 - 19 | <=1 | 1.229 | 0.373 | 4.046 | 1.0000 |
| 10 - 19 | 2 - 9 | 1.031 | 0.400 | 2.656 | 1.0000 |
| 20+ | <=1 | 1.563 | 0.511 | 4.785 | 1.0000 |
| 20+ | 2 - 9 | 0.763 | 0.326 | 1.784 | 1.0000 |
| 20+ | 10 - 19 | 0.786 | 0.291 | 2.124 | 1.0000 |

| Chest radiograph latency | Chest radiograph latency | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|
| 2 - 9 | <=1 | 0.286 | 0.006 | 13.808 | 1.0000 |
| 10 - 19 | <=1 | 0.242 | 0.005 | 11.659 | 1.0000 |
| 10 - 19 | 2 - 9 | 0.848 | 0.019 | 37.631 | 1.0000 |
| 20+ | <=1 | 0.320 | 0.013 | 7.854 | 1.0000 |
| 20+ | 2 - 9 | 0.893 | 0.040 | 19.858 | 1.0000 |
| 20+ | 10 - 19 | 0.758 | 0.034 | 16.747 | 1.0000 |

| Spirometry latency | Spirometry latency | Odds Ratio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|
| 2 - 9 | <=1 | 1.000 | 0.067 | 14.931 | 1.0000 |
| 10 - 19 | <=1 | 1.364 | 0.103 | 18.028 | 1.0000 |
| 10 - 19 | 2 - 9 | 1.364 | 0.174 | 10.662 | 1.0000 |
| 20+ | <=1 | 0.833 | 0.078 | 8.857 | 1.0000 |
| 20+ | 2 - 9 | 1.200 | 0.203 | 7.079 | 1.0000 |
| 20+ | 10 - 19 | 1.637 | 0.336 | 7.971 | 1.0000 |

Analysis using latency as continuous data is presented in Table 10. Since latency is right skewed, log transformed latency was used in the analysis. It showed the same significant increased likelihood to see a doctor for shortness of breath with time since first worked in a surface mine as the categorical data (Table 4) but also found significant higher odds ratios of having COPD, emphysema and chronic bronchitis as log latency increases, which was not seen with the categorical analysis.

**Table 10. Odds ratios of outcomes and symptoms by increasing log latency since first exposure**

| Outcome | Odds Radio | 95% Confidence Interval | | p-value |
|---|---|---|---|---|
| Saw a doctor for shortness of breath | 1.376 | 1.097 | 1.728 | 0.0059 |
| Bring up mucus most days of the week for 3+ months during 2+ years[1] | 1.043 | 0.882 | 1.234 | 0.6218 |
| Health professional ever said you have asthma[2] | 1.206 | 0.843 | 1.727 | 0.3049 |
| Health professional ever said you have COPD, emphysema, or chronic bronchitis[3] | 2.103 | 1.226 | 3.608 | 0.0070 |
| Daily or weekly symptoms at work[4] | 1.124 | 0.913 | 1.384 | 0.2701 |
| Chest radiograph abnormal | 0.871 | 0.445 | 1.707 | 0.6882 |
| Spirometry abnormal | 0.931 | 0.632 | 1.372 | 0.7169 |

[1]Smoking status included as covariate; 78 workers removed from analysis due to unknown smoking status
[2]"Do not know" responses were not included
[3]Smoking status included as covariate; 51 workers removed from analysis due to unknown smoking status
[4]Smoking status included as covariate; 25 workers removed from analysis due to unknown smoking status

Tables 11 -15 show standardized morbidity ratios (SMRs) for surface mine workers compared to workers in all occupations from the Michigan BRFSS data. It found that the prevalence of COPD, ever had asthma and ever smoked cigarettes was decreased as compared to non-mine workers in Michigan. However, Table 14 shows that surface mine workers had a higher prevalence of current asthma than non-mine workers in Michigan. Tables 14a -c show that the prevalence of current asthma controlling for cigarette status did not increase with latency for all sand and gravel miners combined nor among miners, maintenance and welders, truck drivers or contactors.

**Table 11. Standardized morbidity ratio (SMR) for surface mine workers with COPD compared to workers in all occupations (BRFSS) with COPD[1].**

| Age | Observed Events | Expected Events | SMR | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|---|
| 18 - 24 | 0 | 2.3374 | 0.0000 | . | . | |
| 25 - 34 | 0 | 9.1504 | 0.0000 | . | . | |
| 35 - 44 | 0 | 11.3606 | 0.0000 | . | . | |
| 45 - 54 | 6 | 23.2263 | 0.2583 | 0.0516 | 0.4650 | |
| 55 - 64 | 11 | 30.5659 | 0.3599 | 0.1472 | 0.5725 | |
| 65 - 74 | 5 | 8.1920 | 0.6104 | 0.0754 | 1.1453 | |
| 75+ | 0 | 0.5737 | 0.0000 | . | . | |
| Total | 22 | 85.4063 | 0.2576 | 0.1500 | 0.3652 | <0.0001 |

[1] "Do not know" responses were not included

**Table 12. Standardized morbidity ratio (SMR) for surface mine workers who have ever had asthma compared to workers in all occupations (BRFSS) who have ever had asthma[1].**

| Age | Observed Events | Expected Events | SMR | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|---|
| 18 - 24 | 16 | 18.2589 | 0.8763 | 0.4469 | 1.3057 | |
| 25 - 34 | 32 | 44.0879 | 0.7258 | 0.4743 | 0.9773 | |
| 35 - 44 | 22 | 37.6126 | 0.5849 | 0.3405 | 0.8293 | |
| 45 - 54 | 23 | 38.8767 | 0.5916 | 0.3498 | 0.8334 | |
| 55 - 64 | 17 | 35.7383 | 0.4757 | 0.2496 | 0.7018 | |
| 65 - 74 | 4 | 8.5384 | 0.4685 | 0.0094 | 0.9276 | |
| 75+ | 0 | 0.3976 | 0.0000 | . | . | |
| Total | 114 | 183.511 | 0.6212 | 0.5072 | 0.7353 | <0.0001 |

[1] "Do not know" responses were not included

**Table 13. Standardized morbidity ratio (SMR) for surface mine workers who still had asthma compared to workers in all occupations (BRFSS) who still have asthma[1].**

| Age | Observed Events | Expected Events | SMR | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|---|
| 18 - 24 | 6 | 1.38342 | 4.3371 | 0.8668 | 7.8074 | |
| 25 - 34 | 12 | 2.81903 | 4.2568 | 1.8483 | 6.6652 | |
| 35 - 44 | 8 | 1.91052 | 4.1873 | 1.2857 | 7.0890 | |
| 45 - 54 | 9 | 2.33567 | 3.8533 | 1.3359 | 6.3707 | |
| 55 - 64 | 9 | 1.48784 | 6.0490 | 2.0971 | 10.0010 | |
| 65 - 74 | 3 | 0.30527 | 9.8273 | 0.0000 | 20.9477 | |
| Total | 47 | 10.2417 | 4.5891 | 3.2771 | 5.9010 | <0.0001 |

[1] "Do not know" responses were not included

**Table 14. Self-reported prevalence of current asthma by latency since first exposure among 1,207 surface mine workers in Michigan.**

| | Health professional said you currently have asthma? | |
|---|---|---|
| Latency in years | Number of respondents | Yes n (%) |
| ≤ 1 | 4 | 2 (66.7) |
| 2 - 9 | 8 | 3 (37.5) |
| 10 - 19 | 5 | 3 (50.0) |
| 20 + | 7 | 2 (40.0)[1] |
| Unknown | 7 | 6 (85.7) |
| Pre-existing | 63 | 34 (54.0) |
| Total | 94* | 50 (54.4) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.6765

*1,113 workers did not answer question or did not know if they currently had asthma

**Table 14a. Self-reported prevalence of current asthma by latency since first exposure among 405 workers classified as "miners", "maintenance", or "welders" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional said you currently have asthma? | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 2 | 1 (50.0) |
| 2 - 9 | 1 | 1 (100.0) |
| 10 - 19 | 2 | 2 (100.0) |
| 20 + | 4 | 2 (50.0)[1] |
| Unknown | 3 | 2 (66.7) |
| Pre-existing | 28 | 12 (42.9) |
| Total | 40* | 20 (50.0) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.3123
*365 workers classified as "miners", "maintenance", or "welders" did not answer question or did not know if they currently had asthma

**Table 14b. Self-reported prevalence of current asthma by latency since first exposure among 167 workers classified as "truck drivers" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional said you currently have asthma? | |
|---|---|---|
| **Latency in years** | **Number of respondents** | **Yes n (%)** |
| ≤ 1 | 2 | 1 (50.0) |
| 2 - 9 | 2 | 0 (0.0) |
| 10 - 19 | 1 | 1 (100.0) |
| 20 + | 2 | 0 (0.0)[1] |
| Unknown | 1 | 1 (100.0) |
| Pre-existing | 5 | 4 (80.0) |
| Total | 13* | 7 (53.8) |

[1]Cochran-Armitage Trend Test 2-sided P = 0.3074
*154 workers classified as "truck drivers" did not answer question or did not know if they currently had asthma

**Table 14c. Self-reported prevalence of current asthma by latency since first exposure among 557 workers classified as "contractors" based on job descriptions from 1,207 surface mine workers in Michigan.**

| | Health professional said you currently have asthma? | |
|---|---|---|
| Latency in years | Number of respondents | Yes n (%) |
| ≤ 1 | 0 | 0 (N/A) |
| 2 - 9 | 4 | 1 (25.0) |
| 10 - 19 | 2 | 0 (0.0) |
| 20 + | 1 | 0 (0.0)[1] |
| Unknown | 0 | 0 (N/A) |
| Pre-existing | 25 | 14 (56.0) |
| Total | 32* | 15 (46.9) |

[1]Cochran-Armitage Trend Test 2-sided P = N/A

*525 workers classified as "contractors" did not answer question or did not know if they currently had asthma

**Table 15. Standardized morbidity ratio (SMR) for surface mine workers who have ever smoked compared to workers in all occupations (BRFSS) who have ever smoked[1].**

| Age | Observed Events | Expected Events | SMR | 95% Confidence Interval | | p-value |
|---|---|---|---|---|---|---|
| 18 - 24 | 28 | 22.194 | 1.2616 | 0.7943 | 1.7289 | |
| 25 - 34 | 114 | 118.855 | 0.9591 | 0.7831 | 1.1352 | |
| 35 - 44 | 114 | 116.981 | 0.9745 | 0.7956 | 1.1534 | |
| 45 - 54 | 96 | 126.929 | 0.7563 | 0.6050 | 0.9076 | |
| 55 - 64 | 105 | 128.198 | 0.8190 | 0.6624 | 0.9757 | |
| 65 - 74 | 29 | 35.035 | 0.8277 | 0.5265 | 1.1290 | |
| 75+ | 0 | 1.577 | 0.0000 | . | . | |
| Total | 486 | 549.768 | 0.8840 | 0.8054 | 0.9626 | 0.0038 |

[1] "Do not know" responses were not included

## 4.8. Spirometry

Twenty six of the 96 (27.1%) individuals with spirometry results had abnormal results (Table 6); 12 had obstructive changes (eight cigarette smokers, four who had never smoked), 10 had restrictive changes (six cigarette smokers, four who had never smoked) and four had mixed obstructive-restrictive (three cigarette smokers, one who had never smoked). There was no trend in increasing percent abnormal with increasing latency of work in a sand/gravel mine. Spirometry results by cigarette smoking status is shown in Table 16. Of the 12 individuals with obstructive changes, two reported COPD and two reported asthma. Among the ten with restrictive changes three reported asthma and among the four with mixed obstructive-restrictive changes two reported asthma and one both asthma and COPD. Fourteen of the 26 individuals with abnormal spirometry were obese, seven were overweight, three were normal weight and for two their body mass index (BMI) was unknown. Eight of 12 with obstructive changes were obese or overweight (including two with morbid obesity), three were normal weight and one unknown. Nine of 10 of those with restrictive changes on spirometry were obese or overweight (including three with morbid obesity), and one was unknown. All four with mixed changes were obese or overweight (including one with morbid obesity).

**Table 16. Spirometry outcome by cigarette smoking status.**

| | Spirometry Outcome | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Normal | | | Obstructive | | Restrictive | | Mixed Obs/Res | | Total Abnormal | | | |
| Latency | Cigarettes | | | Cigarettes | | Cigarettes | | Cigarettes | | Cigarettes | | | |
| (years) | Yes | No | ALL | Yes | No | Yes | No | Yes | No | Yes | No | ALL |
| ≤ 1 | 4 | 1 | 5 | 2 (100.0) | 0 (-) | 0 (-) | 0 (-) | 0 (-) | 0 (-) | 2 (100.0) | 0 (-) | 2 |
| 2-9 | 6 | 4 | 10 | 2 (100.0) | 0 (-) | 0 (-) | 0 (-) | 1 (50.0) | 1 (50.0) | 3 (75.0) | 1 (25.0) | 4 |
| 10-19 | 6 | 5 | 11 | 2 (100.0) | 0 (-) | 0 (-) | 2 (100.0) | 2 (100.0) | 0 (-) | 4 (66.7) | 2 (33.3) | 6 |
| ≥ 20 | 16 | 22 | 39[3] | 2 (33.3) | 4 (66.7) | 5 (71.4) | 2 (28.6) | 0 (-) | 0 (-) | 7 (53.8) | 6 (46.2) | 13 |
| Total | 33[1] | 36[2] | 70[1,2,3] | 8 (66.7) | 4 (33.3) | 6[4] (60.0) | 4 (40.0) | 3 (75.0) | 1 (25.0) | 17[4] (65.4) | 9 (34.6) | 26 |

[1] One individual who reported having smoked cigarettes had spirometry completed before first surface mine work.

[2] One individual who reported never having smoked cigarettes did not report year of first surface mine work and three others had spirometry completed before first surface mine work.

[3] One individual responded "Do not know" to having ever smoked cigarettes with ≥ 20 years since first surface mine work to spirometry completed.

[4] One individual who reported having smoked cigarettes had spirometry completed before first surface mine work.

### 4.9. Discussion

The risk of silicosis in stone quarry sheds (Graham et. al., 2001; Wickman and Middendorf, 2002) and in the milling/bagging of silica (NIOSH, 1981) has been documented. There have been case reports from state surveillance systems on the occurrence of silicosis among surface sand and gravel miners (Valiante and Rosenman, 1989; Maxfield et. al., 1997; Reilly et. al., 2020). However, no previous studies were identified of medical results of cohorts of surface sand and gravel miners despite the large number of workers who work in these types of mines. Approximately 43% of all miners in the United States are surface sand and gravel or stone miners. In 2021, there were 6,150 active surface sand and gravel mines (29,867 miners), and 4,259 surface stone mines (61,644 miners) in the United States (NIOSH Statistics: All Mining).

There is clearly the potential for silica exposure in surface sand and gravel mines. Three hundred and thirty six of the 429 surface mine locations in Michigan had at least one silica measurement above the NIOSH Recommended Exposure Limit (REL) of 0.05 mg/m$^3$. There were 1,280 silica samples > NIOSH REL at the 336 mine locations from 1/3/2001 through 5/5/2021.

No cases of silicosis were identified in this study of Michigan surface sand and gravel miners. There were no quarry shed workers in our study. We do not have data about how many facilities mill silica in Michigan.

Individuals exposed to silica are also at increased risk of developing COPD (Omland et al., 2014). COPD has also been associated with increased exposure to diesel exhaust among miners (Ferguson et al., 2020). As compared to the working population in Michigan (Wang and Rosenman, 2018), the surface sand and gravel mine workers reported less COPD (Table 11). Consistent with this finding, surface sand and gravel mine workers had a lower prevalence of ever smoking cigarettes compared to the working population in Michigan (Wang and Rosenman, 2018) (Table 15). Although, there was no association in the prevalence of COPD with time since first worked in a surface sand or gravel mine among all mine workers when categorically analyzed (Table 5), there was a positive association between COPD and latency of work when log transformed latency was used in analysis (Table 10). No significant association between COPD and latency was found by the occupation categories of miners, maintenance workers and welders (Table 5a) truck drivers (Table 5b) or contactors (Table 5c). These occupation categories were used as surrogates of potential exposure to silica with miners, maintenance workers and welders considered to have the highest potential for exposure, truck drivers less and contactors the lowest.

Individuals who work in surface sand and gravel mines may be at increased risk of new onset work-related asthma from exposure to diesel fumes or aggravation of pre-existing asthma from exposure to silica or other irritants (Tarlo and Lemiere, 2014). As part of our study, we used the questions on respiratory disease and cigarettes from the annual randomized survey of the general population of non-institutionalized adults in Michigan (MIBRFSS). We have previously analyzed this data to report on respiratory disease and cigarette smoking by industry (Wang and Rosenman, 2018). The data we used from MIBRFSS was the ideal reference population to compare responses we obtained from Michigan surface miners. As compared to the working population in Michigan (Wang and Rosenman, 2018), surface sand and gravel workers reported ever having asthma less frequently (Table 12). However, the mine workers had a higher prevalence of current asthma across all ages compared to the working population in Michigan (Table 13). Neither currently nor ever having asthma was associated with time since first working in a sand or gravel mine among all mine workers (Tables 5 and 12) or by the occupation categories of miners, maintenance workers and welders (Tables 5a and 14a) truck drivers (Tables 5b and 14b) or contactors (Tables 5c and 14c).

For over 30 years, our research team has worked with Michigan OSHA to inspect companies where workers develop asthma from exposures at their job. Part of the inspection protocol involves interviewing the co-workers of the index cases identified, to determine whether any co-workers have developed new-onset asthma from work or have symptoms consistent with work-related asthma. We compared this data to the mining data. The percentage of miners with possible work-related asthma is similar to the 12% of co-workers reported in facilities, generally factories, inspected by MI OSHSA during follow up inspections of index cases of work-related asthma (Reilly et. al., 2020). The prevalence of possible work-related asthma did not increase with increased latency since first worked in a sand or gravel mine among all mine workers (Table 8).

Although specific diagnoses were not increased with increased latency since first worked, reporting having seen a doctor for shortness of breath after controlling for cigarette smoking did increase with time since first worked in a sand or gravel mine among all mine workers (Table 4).

There was no association between abnormal spirometry and latency since first worked (Table 6). Fourteen of the 26 individuals with abnormal results had decreased Forced Vital Capacity (FVC) on spirometry, a potential indication of restrictive disease (i.e., silicosis). However, for thirteen of the 14 where BMI was known (one unknown) all were either overweight (six) or obese (seven). Excess weight is a common cause for a decreased FVC in the absence of lung disease. Lung volumes measured by plethysmography would be needed to determine if these individuals truly had restrictive disease. Such testing was beyond the scope of this project. Obesity and being overweight was also common (eight of 12) in those with a decreased Forced Expiratory Volume in one second (FEV1), the measure of obstruction. As expected, obstructive changes were more common in individuals with a history of cigarette smoking. The number of individuals with abnormal obstructive changes on their spirometry was too small to assess the potential interaction of silica exposure and cigarettes. However, it should be noted there were five individuals (four with obstruction and one with mixed changes) who reported no history of cigarette smoking.

Three of the six workers with pleural changes (scarring of the lining of the lung) consistent with asbestos exposure worked in the UP, a fourth worked in the Quebec asbestos mining region before moving to Michigan. Asbestos is a known contaminant of the iron and soil overload that has been mined in the UP. Marquette County in the UP has the highest rate of mesothelioma in Michigan (Rosenman et. al., 2020). Complete work histories were not known for the two individuals with pleural changes from the northern Lower Peninsula. Potentially asbestos may be a component of sand/gravel mined in the UP and the cause of the small number of radiological changes consistent with asbestos exposure. No worker had changes consistent with interstitial fibrosis of the lung parenchyma (asbestosis). Asbestosis typically requires that an individual had more exposure to asbestos than the exposure that can cause asbestos-related pleural changes.

A major limitation of this project is that only current workers were included. Individuals who became sick and left work or retirees with longer latency periods from first exposure were not included. The tendency for sick individuals to leave work or find another job that causes less symptoms is called the Healthy Worker Effect and will reduce the prevalence of symptoms and disease as compared to a longitudinal study that followed up all workers in an industry even after they left work (Senthilselvan et al., 2020). The healthy worker effect is presumed to explain the lack of an increased prevalence of possible work-related asthma with increased latency since first worked because individuals with symptoms at work would be more likely to leave work over time. The exclusion of retirees reduces the likelihood of identifying conditions with long latencies such as silicosis, which is less common in those with duration or latency less than 20 years. Only 78 of the individuals in this cohort, who had radiographs reviewed for silicosis, had latency periods greater than 20 years. However, there were no individuals with silicosis identified even among these long latency workers, although three of the long latency workers had pleural changes consistent with asbestos exposure. We used latency in the analyses as our marker of exposure, which in our cohort was very similar to duration of work at a mine, since only active workers were included in the study. Another major limitation was the limited number of participants. We were able to reach only a limited number of surface mine workers, although the count of surface mine workers in Michigan from MSHA included office workers who were presumed to have little silica/diesel fume exposure. Our inability to contact miners was due to the lack of interest of many mine owners and their trade organization to support this project. Of the 2,155 individuals reached 1,207 (56%) completed the questionnaire. Nine hundred twenty-two of the 948 individuals who declined to participate did not indicate why they did not want to participate. For medical testing, we were able to review records of 42 of 72 (58.3%) who previously had chest radiography/spirometry. One hundred seventy six of the 344 (51.2%) eligible to have medical testing agreed to have the testing but only 67 of 344

(19.5%) followed through to schedule and show up to the hospital/clinic for the medical testing (Figure 1).

## 5.0. Publication Record and Dissemination Efforts

During the training sessions and outreach to mines we disseminated information on silicosis and respiratory disease (See appendix 1). We plan to submit a paper on the results of our study in a peer reviewed medical publication.

## 6.0. Conclusions and Impact Assessment

Although this study was limited by the small number of long-term workers, no radiographs consistent with silicosis were identified. While the absence of cases of silicosis in this cohort is reassuring, the occurrence of case reports of silicosis of individuals who worked in surface sand and gravel miners and MSHA monitoring results showing elevated silica air levels indicate there is some risk of silicosis in this industry. Sand and gravel miners were less likely to smoke cigarettes and to report having COPD although they reported more current asthma than other production workers in Michigan. Analyses by increased years worked at a surface mine generally did not show a relation between adverse respiratory effects and years worked. However, two adverse respiratory outcomes were associated with years worked: 1) ever having seen a doctor for shortness of breath; and 2) a health professional ever said they had COPD, emphysema or chronic bronchitis. In comparison to the Michigan working population, surface miners reported having more current asthma. These three adverse respiratory findings and the presence of obstructive changes in a small number of non-smokers suggests the potential for adverse respiratory effects in the surface sand and gravel industry either from silica and/or diesel exhaust.

## 7.0. Recommendations for Future Work

Further work that involves retirees and additional long-term current workers in the surface mining industry would be important to determine the true risk of silicosis and other silica-related conditions with a long latency period such as COPD. An additional study that followed a cohort of surface mine workers from time of hire with ongoing evaluation of those who left work at a surface mine coupled with air sampling would be useful to assess the risk of conditions with short latency such as work-related asthma that cause a worker to leave work.

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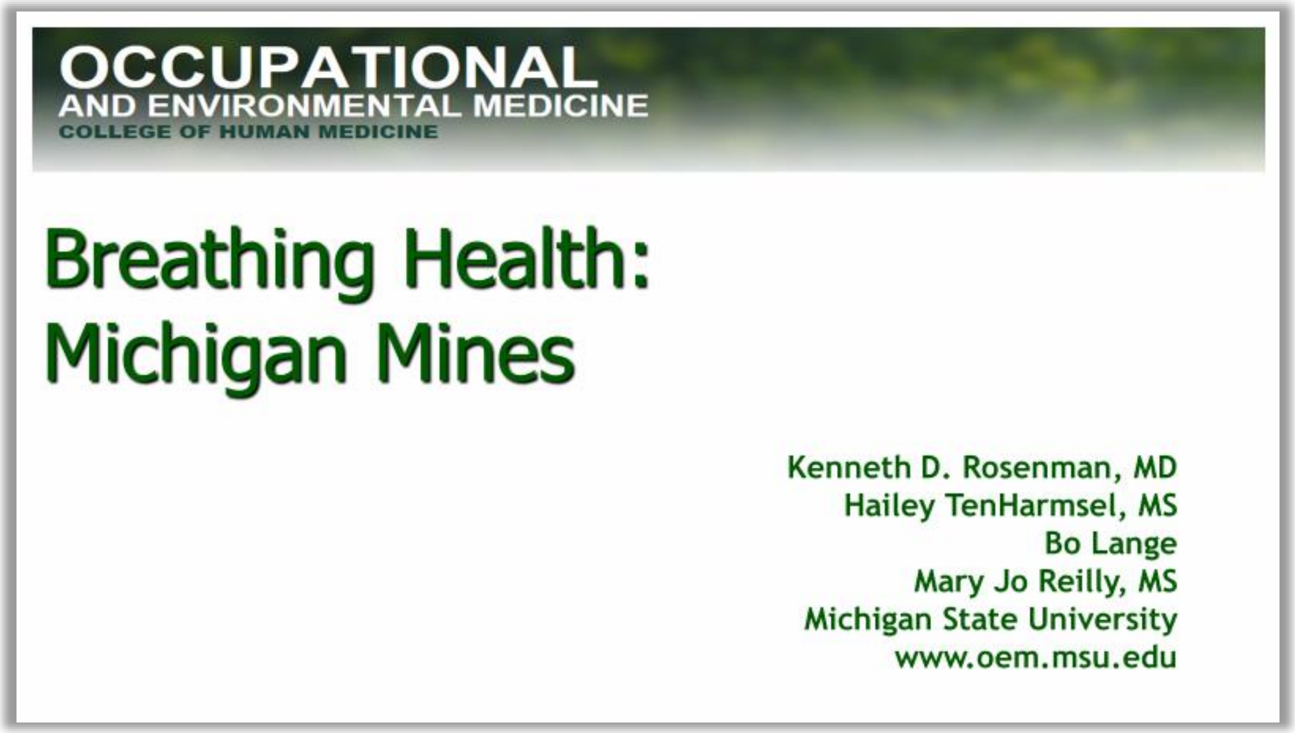
**9.0 Appendix – Training Material**

Power Point Presentation with Resources Handout Shown on Last Slide



OCCUPATIONAL
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## Objectives

- Describe health effects of exposures in mining
  - Breathing health of people who work in mining in Michigan
    - Medical Questionnaire
    - Chest x-ray
    - Breathing test

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## Support from Alpha Foundation

Alpha Foundation

- Alpha Foundation
  - Established after Upper Big Branch Mine disaster
  - Improve mine health and safety through funding research and development projects
  - Request for silica and asthma research
- Characterize breathing health of people who work in mines and compare to workers in other industries

OCCUPATIONAL
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## Exposures in Mining That Can Affect the Lungs

- Silica
  - Most common component of earth's crust
    - Beach sand, gravel, quartz, silica sand
    - Small particles can get into the lungs without being seen
- Diesel Fumes
  - Machinery associated with mining operations
- Welding Fumes

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## Health Effects of Mining Exposures

- Silicosis – Silica
  - Scarring of the lungs, nodules
  - Develops 20-30 years after exposure
- COPD (Emphysema) – Chronic Obstructive Pulmonary Disease – Silica & diesel fumes
  - Destroys lung tissue
  - Combination of silica/diesel fumes and cigarettes increases risk

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## Health Effects of Mining Exposures

- Work-Related Asthma – Silica & diesel & welding fumes
  - 37% of adult asthma
  - New Onset – never had asthma, develops from work exposures
  - Work-Aggravated – already have asthma, work exposures increase symptoms, medicines, and medical care
- Lung Cancer – Silica & diesel fumes
  - Combination of silica/diesel fumes and cigarettes increases risk
- Tuberculosis – Silica
  - Silica exposure increases susceptibility

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## Other Diseases Associated with Silica Exposure

- Rheumatoid Arthritis
  - Connective tissue disease, affects the joints
- Scleroderma
  - Scarring/tightening of the skin & all other organs
- Kidney Disease (Chronic Renal Failure)
  - Dialysis

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## Silicosis

- Decreased air space due to scarring
- Symptoms
  - Shortness of breath
  - Wheezing
- May require oxygen
- Remove from exposure

**Dr. Rosenman is NIOSH-certified to read chest x-rays for dust diseases.**

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## COPD (Emphysema) – Chronic Obstructive Pulmonary Disease

- Damaged lung tissue
- Too much air in lungs, can't get to blood
- Cigarette smoking increases risk
- Symptoms
  - Shortness of breath
  - Wheezing
- May require oxygen
- Remove from exposure

## Rheumatoid Arthritis

- Damaged connective tissue
- More common in women
  - Without silica exposure
- Men – caused by silica exposure

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## Scleroderma

- Scarring/tightening of the skin
- Irreversible
- More common in women
  - Without silica exposure
- Men – caused by silica exposure

# THANK YOU FOR YOUR HELP!


www.oem.msu.edu

rosenman@msu.edu 517-353-1846

yondohai@msu.edu 517-353-8593

reilly@msu.edu 517-353-4979


RESOURCE SHEET

Workers in mines and sand and gravel operations are at risk of developing the chronic lung diseases silicosis, work-related asthma and chronic obstructive pulmonary disease (COPD). Exposures to silica in sand, gravel and mining dust, and diesel fumes from vehicles used during mining operations can both cause and aggravate these conditions.

Listed below are links to resources on these lung conditions and the effect of work exposures.

**To learn more about silicosis:**
American Lung Association – Learn About Silicosis
http://bit.ly/2pzifiW

Work Safely with Silica
http://bit.ly/2QUhCaz

MSHA's Occupational Illness and Injury Prevention Program Health Ideas and Tips for Sand and Gravel Mines
http://bit.ly/2OOOLaD

**To learn more about work-related asthma:**
NIOSH - http://bit.ly/2fcbkO4

OSHA - http://bit.ly/2xLpxrr

American Lung Association – Guide to Controlling Asthma at Work
http://bit.ly/2xCJopF

**To learn more about COPD:**
http://bit.ly/2xC1tEq

http://bit.ly/2OShf4M

http://bit.ly/2Od2Cvw

If you have questions, please feel free to call or email me or Mary Jo Reilly (reilly@msu.edu).


**DEPARTMENT OF MEDICINE**

**Occupational & Environmental Medicine**

Kenneth D. Rosenman M.D.
Professor of Medicine

Michigan State University
909 Fee Road
117 West Fee Hall
East Lansing, MI
48824-1315

517 353-1846
Fax 517 432-3606

rosenman@msu.edu