Erionite in Road Gravel Associated With Interstitial and Pleural Changes—An Occupational Hazard in Western United States

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Objective: To determine the rate of chest radiographic abnormalities among residents of North Dakota potentially exposed to road gravel containing the fibrous mineral erionite. **Methods:** Participants (n = 34) completed a questionnaire, chest radiograph, and high resolution computed tomography scan to assess the rate of interstitial and pleural changes consistent with fibrous mineral exposure. **Results:** Interstitial, pleural, or both changes typically associated with asbestos exposure were observed by high resolution computed tomography in seven (21%) individuals. The primary exposure pathway for six of these was from gravel pits, road maintenance, or both. Three participants (8.8%) demonstrated bilateral localized pleural changes with calcification; two of these also had accompanying interstitial changes. All three reported extensive work in gravel pits, road maintenance, or both. **Conclusions:** These results indicate that occupational exposure to erionite contained within road gravel in the United States represents a potential health hazard. **Clinical Significance:** This study identifies chest radiographic changes among residents of North Dakota occupationally exposed to road gravel containing erionite. Public health officials and physicians in affected areas should be aware of the potential health effects of erionite exposure. Precautionary measures should be taken to limit occupational exposure to gravel containing erionite.

Erionite, a naturally occurring fibrous mineral, is categorized as a Group 1 carcinogen by the International Agency for Research on Cancer[1] and has been demonstrated in animal studies to have greater carcinogenic potential than crocidolite asbestos fibers.[2–4] The toxicity and carcinogenic potential of erionite is associated with its in vivo durability, respirable size, and hexagonal structure with a surface area approximately 20 times larger than crocidolite asbestos.[5–7]

In contrast to commercial asbestos where exposure occurs primarily in occupational settings, exposure to erionite throughout the world is reportedly infrequent and principally through environmental pathways. Epidemiologic data on the toxicity of erionite arise from the study of three villages located in the Cappadocian region of Central Anatolia in Turkey where erionite was excavated from local volcanic tuffs to create storage areas and for use in construction material.[8] In these villages malignant mesothelioma and other outcomes associated with asbestos exposure, including localized and diffuse pleural thickening and interstitial fibrosis, are significantly increased compared with unexposed villages.[6,8,9] Fibrous zeolite deposits are also common in the Intermountain West region of the United States including areas of Nevada, California, Arizona, Colorado, Idaho, New Mexico, North Dakota, South Dakota, Utah, and Wyoming.[10,11] Exposure to erionite in North America, however, is thought to be rare though a case of extensive parenchymal and pleural fibrosis was noted in a road construction worker and resident of Utah in an area rich in zeolite deposits.[12] A lung biopsy confirmed the presence of fibrous and nonfibrous particles with a composition consistent with erionite.[12] Following the discovery of erionite in samples of road dust near Battle Mountain, Nevada, a review of chest radiographs (n = 275) from a local community hospital found the rate of pleural plaques to be 1.8% with no pleural calcifications identified.[12] Recently, concern has been raised about a potential emerging mesothelioma epidemic in Mexico secondary to fibrous erionite exposure.[11] Two cases of mesothelioma in individuals born in Mexico had confirmed high lung burdens of fibrous erionite.[13]

In North Dakota, gravel deposits that contain erionite are located in or near the Arikaree, Brule, and Chadron geologic formations corresponding to the Chalky Buttes, Little Badlands, and Killdeer Mountain areas in Slope, Stark, and Dunn counties (Fig. 1). Over the past few decades, gravel pits have been excavated in areas where naturally occurring deposits of erionite are found and the gravel used to surface local roads, parking lots, and other areas. Ambient and activity-based air sampling and indoor dust sampling conducted by the US Geological Survey and the US Environmental Protection Agency has confirmed the presence of erionite in gravel in some of these areas.[14]

In response to a request from the North Dakota Department of Health (NDDoH) the US Environmental Protection Agency, in collaboration with the Agency for Toxic Substances and Disease Registry and the University of Cincinnati College of Medicine (UCCM), initiated an investigation of the possible health effects of erionite exposure in Dunn and surrounding counties in western North Dakota. The objective of this study was to determine if erionite in road gravel poses a potential health hazard among residents of North Dakota with the highest potential exposure by identifying early chest radiographic changes historically associated with asbestos exposure.

MATERIALS AND METHODS

Study Population

Current or former residents of western North Dakota with the highest potential exposure to road gravel containing erionite were eligible to participate in this study. Participants were identified via local newspaper releases and outreach efforts. Two news releases were provided to local media with information regarding the study and contact information for interested residents. Information regarding the study was distributed by mail to residents of the study area and to local companies with workers likely exposed to road gravel (eg, gravel pit companies, county road equipment maintenance facilities, and delivery companies). In addition, study information and flyers were posted in local businesses, post offices, schools, county maintenance offices, and medical clinics in the study area (Fig. 1). Outreach efforts also included the distribution of study information in person to school superintendents, postal carriers, delivery truck drivers, churches, county offices, and local police departments. A follow-up recruitment effort was initiated by requesting subjects who had already completed the eligibility questionnaire to provide study information to interested family members, coworkers, and other

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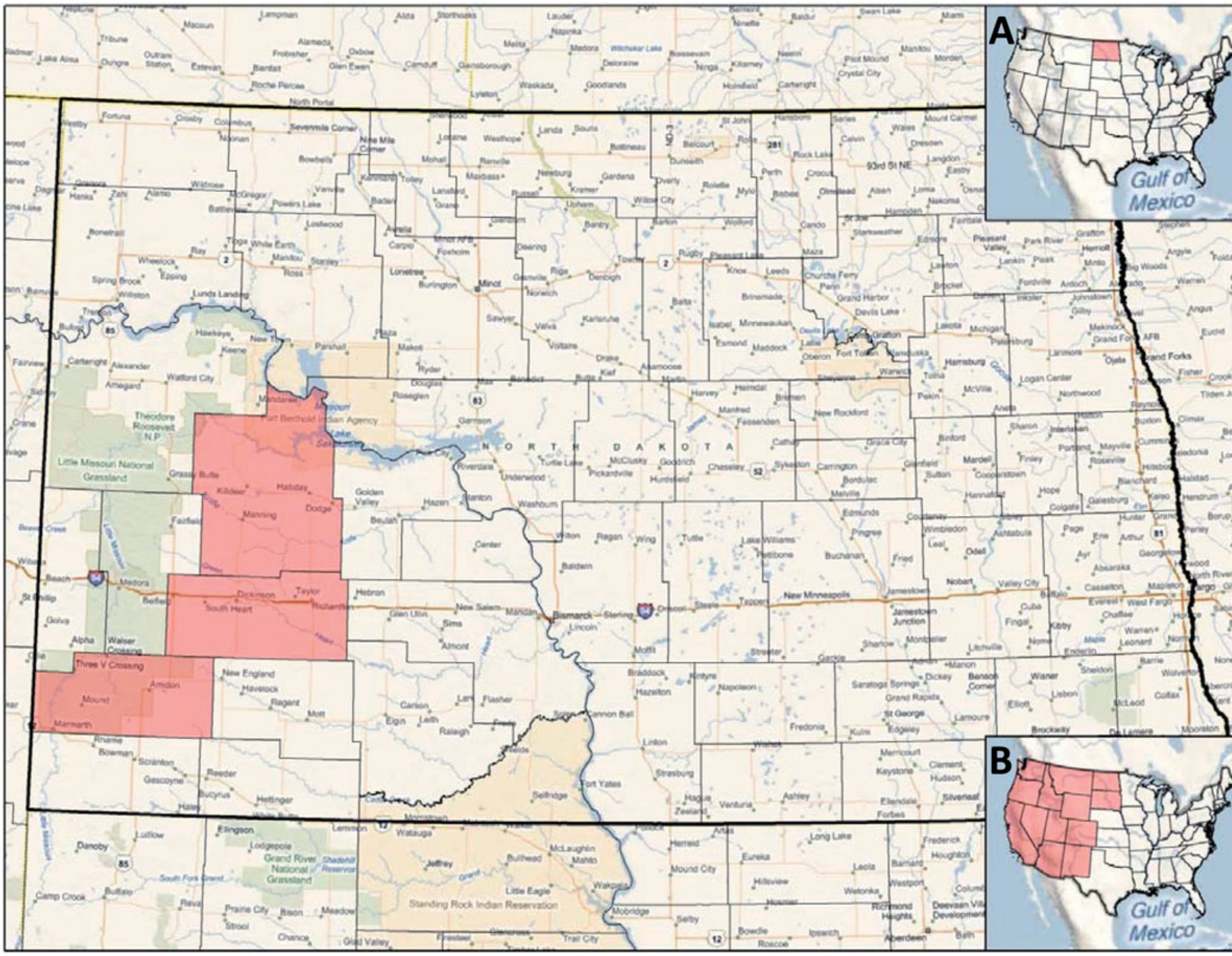

FIGURE 1. Counties in Western North Dakota with potential erionite contamination (Insert A-North Dakota; Insert B-Western States with known deposits of erionite).

individuals who may be exposed to gravel dust. All study information and eligibility questionnaires were posted on the NDDoH Web site for potential participants to return by mail.

Prospective subjects completed an eligibility survey designed to identify participants hypothesized, a priori, to have the highest potential for exposure to gravel containing erionite based upon occupational and environmental history, duration of potential exposure, and time since initial exposure. Occupations initially identified included working in gravel pits, working in road maintenance, or an occupation requiring frequent driving on gravel roads in the study area (eg, mail carrier, school bus driver, law enforcement officer). Eligibility questionnaires were returned by mail and reviewed to assess respondents most likely to have the highest potential exposure based upon the following criteria: (1) job history and task, (2) latency-—longest time period since initial potential exposure, (3) duration—longest duration of potential exposure, and (4) absence of reported exposure to nonerionite fibers (ie, asbestos).

Data Collection and Exposure Assessment

All eligible participants were informed of the study purpose, procedures, risks, and benefits and given the opportunity to ask questions either by phone, mail, or email. The study protocol, procedures, recruitment materials, and informed consent documents were approved by the University of Cincinnati Medical institutional review board and the NDDoH institutional review board and North Dakota Healing Arts Screening Program for radiographic procedures. All subjects signed an informed consent document prior to study participation.

Trained interviewers from the UCCM administered an occupational and environmental questionnaire by phone to obtain information regarding potential past exposure to road gravel containing erionite, asbestos, or both. Participants were queried if they had ever had a full or part-time job in a gravel pit, as a road maintenance worker, as a school bus driver, mail carrier, delivery truck driver, or in any other job where they may have been exposed to gravel or gravel dust. For each reported occupation the subject was asked the start and end date of employment (month/year), job tasks, and their frequency of driving on gravel roads in the study area. Co-exposure to asbestos or asbestos-like fibers was assessed by report of having worked in job tasks associated with asbestos exposure, such as a pipe fitter, plumber, brake repair person, insulator, dry wall finisher, carpenter, roofer, electrician, welder, and/or vermiculite worker. Road maintenance workers were asked to report the frequency of working in the road equipment maintenance facility changing brake pads or clutch pads. In addition, a pulmonary medical questionnaire was administered that queried participants regarding demographic characteristics, smoking status, pulmonary symptoms, and medical conditions that could impact their pulmonary health status. Participants with no to minimal potential erionite exposure were excluded from follow-up radiographic evaluation.

Radiographic Evaluation

Posterior-anterior chest radiographs and high resolution computed tomography (HRCT) scans were conducted at a single facility in the local area. The consistency and quality of each chest radiograph was evaluated by the radiology facility and poor quality films were immediately repeated. In addition to standard film screen chest radiographs, subjects completed a HRCT scan at the same visit with supine and prone images without intravascular infusion of contrast material. Scans were completed in both positions to differentiate subtle subpleural irregular opacities related to normal vascular hydrostatic pressure from permanent interstitial fibrotic changes. High resolution computed tomography scans were conducted as these are more sensitive and specific when compared with chest radiographs for the identification of pleural and interstitial changes associated with asbestos-like fiber exposure.[15,16] A customary clinical radiologic interpretation of the chest radiographs and HRCT scan was provided by the radiologist on site. All customary interpretations indicating a need for immediate medical attention were followed-up by letter and phone to the subject to provide counseling and directing the participant to an appropriate source of medical care. High resolution computed tomography scans were transferred directly to compact disc from the scanner in DICOM (digital imaging and communications in medicine) compatible format and transferred along with chest radiographs to the UCCM.

Chest radiographs were evaluated independently by three board certified chest radiologists and "B" readers at the UCCM. The radiologists were blinded with regard to the study objectives including the exposure of interest, subject's age, gender, and smoking history. All chest radiograph interpretations were conducted according to the 2000 International Labour Office Classification of radiographs of pneumoconiosis. High resolution computed tomography scans were evaluated for the presence or absence of unilateral/bilateral discrete or diffuse pleural thickening with or without calcification and irregular interstitial changes consistent with asbestos exposure. A subject was classified as having pleural changes if two of three B-readers identified: (1) diffuse pleural thickening (thickening of the pleural membrane that includes blunting of the costophrenic angle with or without calcification), and (2) localized pleural thickening, that is, pleural plaques, with or without calcification along the chest wall, diaphragm, and/or pericardium, not otherwise classified as diffuse pleural thickening, or both. Interstitial abnormalities were defined by the presence of round or irregular parenchymal opacities profusion category 1/0 or greater based on the chest radiographs (International Labour Office, 2000) and the presence or absence of parenchymal findings consistent with asbestosis on the HRCT scans. All participants received a medical summary letter with their individual results and appropriate health counseling where indicated.

Statistical Analysis

The observed rate of interstitial and pleural changes was compared with published background rates using the exact Binomial test assuming a one-tailed hypothesis test. The background rate of pleural changes observed on chest radiograph was assumed to be 3.9% based upon the rate of any pleural changes consistent with pneumoconiosis observed by chest radiograph in the National Health and Nutrition Examination Survey II among male and female adults aged 35 to 74 years.[17] The rate of interstitial changes observed on chest radiograph was compared with a background rate of 1.6% of small opacities, profusion category 1/0 or greater as reported by Meyer et al and calculated as a pooled rate for six North American populations of males and females aged 15 to 84 years.[18] The rate of interstitial changes observed on HRCT was compared with a background rate of 1.5% as observed in a HRCT/CT study of male transportation workers over the age of 49 employed in France.[19] The average cumulative asbestos fiber exposure in this comparison population was 1.7 ± 2.3 fibers per mL-years and the average latency period was 34.2 years.[19] The rate of pleural abnormalities, and specifically, bilateral localized pleural changes consistent with asbestos exposure was reported in this same study to be 10.8% and 3.4%, respectively. As the observed pleural changes in this study were bilateral, the background rate for comparison was assumed to be 3.4%.

RESULTS

Study Participants and Exposure

In total, 41 individuals completed the eligibility questionnaire and all were invited to participate in the study. Of these, 93% ($n = 38$) completed the informed consent process and were contacted to complete the occupational and environmental questionnaire and pulmonary medical questionnaire. Two of these subjects withdrew, however. Of the 36 remaining participants who completed the study questionnaire, one was not eligible due to minimal exposure to road gravel and one did not complete the radiographic evaluation. Two participants had recent CT scans (one conventional, one HRCT) for unrelated medical reasons and these were used. For one subject an accompanying chest radiograph was obtained. Thus, the final study cohort consisted of 34 participants. Of the final study population, 76.5% ($n = 26$) were male and the average age was 61 years (range: 40 to 80 years). Multiple exposure pathways were reported for 47% ($n = 16$) of the participants. These were subsequently ranked by potential exposure to road gravel containing erionite. The most frequently reported primary exposure pathway at 44.1% ($n = 15$) was having worked in gravel pits, road maintenance or both (Table 1). Occupations with frequent driving or participants who reported their primary source of exposure to be frequent driving comprised 20.6% ($n = 7$) followed by ranching/farming at 17.6% ($n = 6$), and "other" exposure pathways at 17.6% ($n = 6$). The average time from initial exposure and average duration of exposure via the primary exposure pathways was 34 years (range: 3 to 67 years) and 22 years (range: 0.8 to 63 years), respectively (Table 1).

Chest Radiographs

As shown in Table 1, the observed rate of interstitial changes consistent with pneumoconiosis was 3.0% ($n = 1$) among the 33 available chest x-rays and was not significantly increased when compared to the assumed population rate of 1.6% ($P = 0.41$). The chest radiograph in one individual (participant 31) demonstrated right middle lobe-only interstitial changes (Table 2). The HRCT demonstrated diffuse bilateral predominantly mid and upper lung zone findings more typical of nonasbestos-related changes. No pleural changes were noted. The primary exposure pathway was road maintenance (duration: 30 years, latency: 33 years) and the secondary exposure pathway was frequent driving (Table 2). Activities with potential confounding exposure included intermittent welding and working in the road equipment maintenance facility. No other medical condition potentially impacting the lung was reported by this participant who never smoked.

The rate of localized pleural changes observed on chest radiograph was 3.0% ($n = 1$) and was not increased above the background rate of 3.9%. One individual (participant 12) demonstrated extensive bilateral localized pleural changes with calcification (Table 2). Similar findings without interstitial changes were noted on the HRCT. The primary exposure pathway associated with this participant was work in road maintenance (duration: 38 years, latency: 39 years). In

TABLE 1. Summary of Chest Radiographic Changes by Exposure Pathway

				Radiograph		HRCT	
Exposure Pathway	N	Average Duration, (SD), yrs	Average Latency (SD), yrs	Interstitial Changes (Pathway Prevalence)	Pleural Changes (Pathway Prevalence)	Interstitial Changes (Pathway Prevalence)	Pleural Changes (Pathway Prevalence)
Gravel pits/road maintenance	15	20 (17)	31 (15)	1 (6.7%)	1 (6.7%)	5 (33.3%)	3 (20.0%)
Frequent driving*	7	13 (8)	32 (15)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Rancher/farmer	6	35 (18)	40 (15)	0 (0.0%)	0 (0.0%)	1 (16.7%)	0 (0.0%)
Other†	6	24 (20)	40 (18)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	34‡	22 (17)	34 (15)	1 (3.0%)	1 (3.0%)	6 (17.6%)	3 (8.8%)

*Includes mail carriers, delivery truck drivers, and other occupations where frequent driving was reported.
†Includes oil field workers, residents, and other occupations.
‡Includes one subject with HRCT only and one subject with conventional computed tomographic scan and chest radiograph.
HRCT, high resolution computed tomography.

addition, confounding asbestos exposure occurred during service as a boiler technician in the US Navy.

High Resolution Computed Tomography

The rate of interstitial changes observed on HRCT was 17.6% (n = 6) and was significantly increased ($P < 0.01$) compared with a rate of 1.5% based on HRCT scans in male transportation workers with low cumulative asbestos fiber exposure.[19] Of these, gravel pit, road maintenance, or both were the primary exposure pathway for five with one individual's exposure pathway (participant 25) being a rancher and farmer (Table 2). Five of the six individuals with interstitial changes were identified on HRCT only with participant 31 having been identified on both chest radiograph and HRCT. Four of the six (participants 25, 31, 33, 35) had interstitial changes alone; of these, two reported being a current or former smoker (participants 25 and 35) at 41 and 40 pack-years, respectively, and one (participant 33) had an occupational history of working in the coal mining industry for 23 years and only 3 years from initial potential exposure to road dust. Two of the six individuals (participants 14 and 24) had both bilateral localized pleural changes with calcification and interstitial changes. Removal of participant 33 due to minimal time period from initial exposure to road gravel and participant 31 due to atypical distribution of interstitial changes (Table 2) results in a rate of interstitial changes of 12.5% (n = 4, $P < 0.01$).

Two individuals (participants 14 and 24) had both mild bilateral localized pleural changes with calcification and minimal unilateral and bilateral lower lobe interstitial changes based on HRCT. Both were ex-smokers at 3 and 7 pack-years, respectively, and the primary exposure pathways were gravel pits, road maintenance, or both. Neither of these participants reported any potential past asbestos exposure. As mentioned previously, one participant with a history of previous asbestos exposure and work in road maintenance (participant 12) had extensive localized pleural changes with calcification on both chest radiograph and HRCT. The total of three (8.8%) participants with bilateral localized pleural changes based on HRCT scans results in an elevated but not significant ($P = 0.11$) increase when compared with a rate of bilateral localized pleural changes of 3.4% among low exposed urban transportation workers based on CT scans.[19] The primary exposure pathway was gravel pits, road maintenance, or both for these three participants with an average duration and latency of 19 years and 29 years, respectively. Removal of participant 12 due to previous asbestos exposure results in an observed 6.1% rate (n = 2) of localized pleural changes.

DISCUSSION

This study has identified within the United States the presence of interstitial and bilateral localized pleural changes with calcification in two workers with prolonged occupational exposure to road gravel that contains fibrous erionite. The HRCT changes in these two sentinel cases are minimal but are consistent with erionite exposure involving the parietal pleura and lung parenchyma.

The rate of interstitial and pleural changes on chest radiograph in background populations can range from 0.21% to 1.9% and 0.0% to 6.8%, respectively, depending upon the case definition, occupational history, age, gender, and geographic location of the population.[19–21] In this study, the rate of interstitial and pleural changes observed by chest radiograph was not significantly increased. The use of HRCT, a more sensitive and specific radiographic technique with the potential to depict subtle pleural and interstitial changes[22] not yet evident on standard chest radiographs resulted in a significantly increased rate of interstitial changes (17.6%) and an increased, though not significantly, rate of localized bilateral pleural changes with calcification (8.8%). However, the lack of corresponding pleural changes in four of six individuals with interstitial changes in combination with prolonged smoking history in two, atypical interstitial pattern in one, and short latency from initial potential erionite exposure in one makes it unlikely the minimal interstitial changes in these four are related to fibrous erionite exposure.[23]

Environmental exposure to erionite has been studied in three villages located in the Cappadocian region of Turkey where the fiber is present in volcanic tuffs used for building materials.[6] Resident exposure to erionite within the ambient air in these villages occurs 24 hours per day through normal activities of daily living.[6] Among residents of these erionite-exposed villages the rate of calcified pleural changes using standard chest radiographs was significantly higher (9.3%) than residents of Turkish villages with environmental asbestos exposure (5.4%) and residents of villages unexposed to either erionite or environmental asbestos (<1%).[6] Within our study, the rate of bilateral localized pleural changes with calcification on chest radiograph and HRCT was 3.0% and 8.8%, respectively. Exposure to erionite in the Turkish villages has also been associated with diffuse interstitial fibrosis, bronchial carcinoma,[6] and malignant mesothelioma.[24]

Gravel samples collected from North Dakota were compared with samples obtained from central Turkey for fiber concentration, fiber length, width, and aspect ratio. The samples were also analyzed to determine mineral chemistry using electron probe microanalysis and scanning electron microscopy with energy dispersive x-ray analysis. Mineral structure was determined using x-ray diffraction.

TABLE 2. Co-exposures, Smoking History, and Health History Among Subjects With Chart Radiographic Changes

Participant	Primary Exposure Pathway	Duration (yrs)*	Latency (yrs)*	Ever Smoke	Current Smoke	Pack-years	Other Exposure	Other Pulmonary Conditions/ Symptoms	Radiograph (Number of B-readers identifying abnormality/3)		HRCT (Number of B-readers identifying abnormality/3)	
									Interstitial Changes	Pleural Changes	Interstitial Changes	Pleural Changes
12	Road maintenance	38	39	Yes	Yes	44	Road maintenance shop, boiler technician in US Navy with intermittent asbestos exposure (~20 times total, 3–4 hr each)	Pneumonia/ pleurisy, acute benign pericarditis, shortness of breath walking up slight hill	None	Bilateral chest wall and di-aphragmatic plaques with calcification (3/3)	None	Bilateral chest wall and diaphragmatic plaques with calcification (3/3)
14	1. Road maintenance 2. Rancher/ farmer	5	19	Yes	No	3	None reported	Shortness of breath walking up slight hill	None	None	Right lower lobe interstitial changes (2/3)	Bilateral chest wall plaques with calcification (3/3)
24	Gravel pits/road maintenance	14	30	Yes	No	7	None reported	Chest tightness when walking	None	None	Bilateral lower lobe interstitial changes (2/3)	Bilateral chest wall plaque with unilateral chest wall calcification (3/3)
25	Rancher/farmer	33	49	Yes	Yes	41	None reported	Phlegm, emphysema, hoarse/difficulty swallowing, shortness of breath walking up slight hill	None	None	Bilateral lower lobe interstitial changes (2/3)	None
31	1. Road maintenance 2. Delivery truck driver	30	33	No	No		Road maintenance shop, intermittent welding (~5 × / month) as part of road maintenance occupation	Short ness of breath	Right middle lobe opacities r/u, profusion 1/1 (2/3)	None	Diffuse bilateral predominately mid and upper zone fibrous with mild honeycomb more typical of nonasbestos related changes (3/3)	None
33	Road maintenance	3	3	No	No		Coal mine heavy equipment operator (23 yrs duration, 34 yrs latency)	None	None	None	Bilateral lower lobe interstitial changes (2/3)	None
35	1. Road maintenance 2. Rancher/ farmer	32	39	Yes	No	40	None reported	Phlegm, pneumonia as a child, emphysema	None	None	Bilateral lower lobe and right middle lobe interstitial changes (2/3)	None

*Calculated for occupation/exposure with highest rank of a priori likelihood of exposure to road gravel containing erionite.
HRCT, high resolution computed tomography.

The results of these analyses confirmed the presence of erionite in gravel utilized in western North Dakota and that the erionite fibers from North Dakota were similar in morphology, mineral chemistry, and mineral structure to the fibers obtained from central Turkey.[14] Fiber concentrations in North Dakota following activity-based sampling transportation scenarios (eg, driving cars and school buses on gravel roads) ranged from 0.0107 to 0.0391 f/cc (phase contrast microscopy equivalent) with an average of 0.0249 f/cc. Stationary air samplers located near the road measured concentrations ranging from 0 to 0.0012 f/cc with an average of 0.0008 f/cc. These activity-based and stationary sampling results may under-represent levels to which road maintenance workers are exposed particularly during gravel pit and road grading activities. In another study of worker exposure to gravel-containing naturally occurring asbestos in gravel in Alaska, road grader operators were found to have the highest exposure. Of 564 breathing zone time-weighted average samples obtained, 3% indicated fiber exposure at or near the Occupational Safety and Health Administration permissible exposure limit of 0.1 f/cc using the National Institute of Occupational Safety and Health 7400 phase contrast microscopy procedure.[25] Additional analysis on select samples indicated approximately 40% of the fibers were tremolite or actinolite asbestos using transmission electron microscopy analysis.

There are potential limitations to this study including the limited sample size and lack of quantitative airborne erionite exposure characterization of the participants. The purpose of this study was to recruit a population with the highest potential for exposure to road gravel containing erionite. Through extensive recruitment efforts in this sparsely populated area of North Dakota, we were able to elicit participation of 15 individuals (44%) with a high potential for prolonged exposure to gravel. Other potentially exposed residents of the area were subsequently enrolled to increase sample size and variability of occupations. In contrast to many occupational studies, the lack of personal sampling data is a study limitation. Nevertheless, this study provides evidence of a likely association in two individuals between working in road maintenance, gravel pits, or both with potential erionite exposure and mild bilateral localized pleural changes with calcification and corresponding minimal lower lobe interstitial changes based on HRCT.

Another potential limitation is the lack of background rates of HRCT scan findings consistent with asbestos related pleural changes either in North Dakota or the US population in general. Our findings of bilateral pleural changes, however, in two participants (6.1%) with past potential erionite exposure is similar to that found in the French urban transportation workers (3.4%) based on HRCT/CT scans and who had relatively low cumulative asbestos exposure. The average age and time from initial potential mineral fiber exposure between the French transportation workers and our participants was similar. In addition, HRCT is a more specific methodology to detect pleuroparenchymal changes consistent with asbestos exposure.[26] Thus, it is unlikely that there has been an over-estimation of the HRCT scan findings.

In summary, these study results suggest occupational exposure to road gravel containing erionite, particularly for workers employed in road maintenance or gravel pits, can result in pleural and possible interstitial changes historically associated with commercial asbestos exposure. On the basis of the known health impact from exposure to erionite in Turkey and more recently Mexico, precautionary measures should be considered to limit occupational exposure to gravel containing erionite particularly in road maintenance and gravel pit workers. A North Dakota State registry should also be considered as a partnership between local health care providers and the NDDoH to monitor the rate of radiographic changes potentially associated with erionite exposure in specific geographical locations within North Dakota. In those workers involved with road maintenance and gravel pit work with gravel containing erionite, an environmental monitoring and pulmonary medical surveillance program should also be considered.

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