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The presence of asbestos in the natural environment is likely related to mesothelioma in young individuals and women from Southern Nevada

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Abstract

Background—Inhalation of asbestos and other mineral fibers are known causes of malignant mesothelioma (MM) and lung cancers. In a setting of occupational exposure to asbestos, MM occurs 4–8 times more frequently in men than in women, at the median age of 74 years, while an environmental exposure to asbestos causes the same number of MMs in men and women, at younger ages.

Methods—We studied the geology of Nevada to identify mineral fibers in the environment. We compared MM mortality in different Nevada Counties, per sex and age group, for the 1999–2010 period.

Results—We identified the presence of carcinogenic minerals in Nevada, including actinolite asbestos, erionite, winchite, magnesioriebeckite and richterite. We discovered that, compared with the US and other Nevada counties, Clark and Nye counties, in southern Nevada, had a significantly higher proportion of MM that occurred in young individuals (<55 years) and in women.

Conclusions—The elevated percentage of women and individuals younger than 55 years old, combined with a sex ratio of 1:1 in this age group and the presence of naturally occurring asbestos, suggests that environmental exposure to mineral fibers in southern Nevada may be contributing to some of these mesotheliomas. Further research to assess environmental exposures

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should allow the development of strategies to minimize exposure, as the development of rural areas continues in Nevada, and to prevent MM and other asbestos-related diseases.

Keywords

mesothelioma; environmental exposure; asbestos; lung cancer; mineral fibers

Introduction

Malignant mesothelioma (MM) is a rare and highly fatal form of cancer of the pleura or more rarely, peritoneum or pericardium[1], that is caused by the inhalation of asbestos and other mineral fibers. Median survival is 6–12 months from diagnosis[2–3]. In 1997, the International Expert Meeting on Asbestos, Asbestosis and Cancer estimated that about 10,000 MM and 20,000 lung cancer cases are attributable each year to asbestos in Western Europe, North America, Japan and Australia[4]. In the US, there are about 3,200 new MM cases every year with an annual incidence of 5.8 cases per million in states with no commercial asbestos use, and up to 16.5 cases per million in the states where asbestos was used industrially in large amounts[5]. These numbers reflect a significant increase in MM during the past 40 years in men, while rates in women have not significantly increased, as they are rarely occupationally exposed to asbestos[1, 5–6].

The MM M:F sex ratio ranges from 4:1 to 8:1, the highest in countries with asbestos industry[7]. Instead a sex ratio of 1:1 is found when MM are caused by environmental exposure and genetics[8]. In the US, the median age at diagnosis is 74, as most MMs develop because of occupational exposure to asbestos and the mean latency from exposure is 30–50 years[9–10]. During the years 1999–2005, MMs in individuals younger than 55 represented only 6.7%[9]. Because of the long latency from the time of exposure to the development of MM, MMs in individuals younger than 55 are rarely associated with occupational exposure[8]. Instead, these MMs are related to exposure since childhood, such as environmental exposure or secondary exposure to occupationally exposed family members[10]. Thus, MM in young individuals and increased MM rates in women, and particularly a M:F sex ratio <3:1 are indicators of environmental exposures to mineral fibers[10–12].

Asbestos causes also other cancers, in particular more lung cancers than MMs[13]; however, the risk of lung cancer attributable to asbestos is difficult to estimate[14], because of the confounder of cigarette smoking.

Asbestos is a commercial and regulatory term applied to six fibrous silicate minerals historically mined for industrial use[8]. Most research efforts have focused on occupational exposure to asbestos and have demonstrated their carcinogenicity in animals and humans. However, environmental exposure to other non-regulated mineral fibers can also cause MM and other diseases[8, 15]. Documented examples include exposure to erionite in the Cappadocia region of Turkey[16–19], exposure to the amphibole minerals winchite, richterite and magnesio-riebeckite at Libby, Montana USA[20–25], and exposure to antigorite in New Caledonia[8, 15]. All these exposure have been linked to the development of MM in humans. These mineral fibers share some physical and biological properties that are thought to

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contribute to their carcinogenicity, such as a fibrous shape (length/diameter (aspect) ratio >3:1), a high surface area, a width of <0.25μm[26], because ultrathin fibers are more likely to reach the pleura[27] and resistance to biological degradation[28–29].

Naturally occurring asbestos (NOA) is a term used to describe fibrous minerals that may or may not meet the regulatory definitions of asbestos but are natural components of rocks and soils[30]. Areas with NOA in soils and sediments are a potential source of exposure for nearby populations especially if these fibers become airborne through natural erosion or human activities producing dust: mines, quarries, roads, and outside activities[8]. Increasing road traffic in rural areas and other dust producing activities are also causing exposure to NOA to a growing number of people[8, 18]. In arid and semi-arid climates, natural wind erosion can be a significant process for dust emissions, which can increase fiber exposures[31]. Such exposures can occur since birth, resulting in MM in young individuals, in both genders[32–33]. NOA presents a significant health risk primarily where the close proximity of NOA occurrences to large populations provides a pathway for human exposure.

Because of both anecdotal reports of MM in young individuals in southern Nevada and the recent finding of naturally occurring asbestos in soil, dust and air near the Las Vegas metropolitan area[34–35], we tested the hypothesis that MM would be increased in that region in a pattern consistent with environmental exposure.

Materials and methods

We studied several health indicators suggestive of a possible environmental exposure to carcinogenic mineral fibers, including: increased proportion of female MMs and a higher percentage of MM in individuals under the age of 55 years.

We analyzed MM mortality data obtained from the CDC in US for the period 1999–2010, by gender, by age group and by county, which included a total of 31,526 MM cases. We also used data from the CDC to study MM incidence and death rates by state and by gender[36]. Because MM is a rare disease, confidence intervals per county and per age groups were calculated assuming that the MM cases followed a Poisson distribution. Because of the small numbers, we grouped the two southern counties of Clark and Nye, defined here as southern Nevada, and compared the proportion of women and of young cases (less than 55 years old) in these two southern counties to those in all other Nevada counties grouped together. Percentages were compared between southern Nevada, all other Nevada counties, and all other US counties, by using the Pearson Chi^2 test with Yates correction, or Fisher's exact test when the expected numbers were less than five, and were considered statistically significant when the p value was <0.05. Incidence and death rates are given with their 95% confidence interval (95% CI).

We compiled and integrated known presence of fibrous minerals in Nevada from published sources[19, 34–35, 37–39]. We used population data by county from the 2010 census (Accessible at: http://www2.census.gov/geo/maps/dc10_thematic/2010_Profile/2010_Profile_Map_Nevada.pdf) in order to better interpret the potential for populations to come in contact with naturally occurring carcinogenic fibrous minerals. The 2010 census

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measured just over 2.7 million people in the state, with 74% living in Clark and Nye counties, southern Nevada (http://censusviewer.com/state/NV). The vast majority of the population in southern Nevada and the largest concentration of people in the entire state, live in the Las Vegas metropolitan area. This includes the cities of Las Vegas, Henderson, North Las Vegas and Boulder City with a population of over 1.9 million. Washoe County in northwestern Nevada has the next highest population, with over 400,000 people. Vast areas of central and northern Nevada have fewer than 1 person per square mile.

Results

Mesothelioma rates in Nevada

For the 2006–2010 period, Nevada has a global MM age-standardized incidence rate of 10 cases per million inhabitants-year (95% confidence interval (CI): 8–12)[36]. This rate is similar to the mean US rate (10 per million; 95% CI: 10–10), and places Nevada in a middle position among the states for MM incidence (minimum: 5 (Hawaii), maximum: 15 (Alaska and Maine) MM cases per million in 2006–2010)[36]. Nevada is not listed among the 15 states having produced asbestos or showing a high occupational exposure[40]; thus a standardized MM incidence of 10 per million in this state is unexpectedly high, compared to the background MM incidence of 5 per million in other U.S. states without known occupational exposure[5, 36].

The analysis of all MM deaths recorded in Nevada for the 1999–2010 period shows a constant mortality rate over these 12 years. In order to respect confidentiality, we cannot show detailed data per subgroup. In all Nevada counties, excluding the southern Nevada counties of Clark and Nye, the MM sex ratio M:F was 6.33:1, as expected when MM occurs prevalently in a setting of occupational exposure (Table 2). In contrast, in southern Nevada (Clark and Nye counties), the MM sex ratio M:F was significantly lower (2.69:1, p=0.0468) (Table 2). The southern Nevada MM sex ratio was also significantly lower compared to the US (4.97:1, p=0.0422) (Table 2). The low sex ratio of MM in the southern Nevada counties cannot be explained by the characteristics of this population: the percentage of women was exactly the same (49.1% in 2000) in Clark and Nye counties and all other Nevada counties.

The percentage of MMs in individuals younger than 55 –a possible indicator of environmental exposure- was significantly higher in the southern Nevada counties (11.28%) than in all other US counties (6.21%, p=0.0249) (Table 2). These young cases were residents of Clark and Nye counties, southern Nevada, where we identified 21 MMs with a M:F sex ratio of 1:1 (11 males and 10 females), the youngest cases being recorded in the age group of 15–19 years. No difference in the population distribution per age groups could explain the increased rate of young MM cases in Clark and Nye counties: compared to the other NV counties, in 2000, the 0–54 years age group in Clark and Nye county represented 79.8% versus 78.6% of the population. Using the 1999–2010 MM mortality cohort from the CDC, we calculated the M:F MM sex ratio and the proportion of young (<55) MM deaths, for seven US states with a known occupational exposure to asbestos[41]. The sex ratios ranged between 4.20 (Pennsylvania) and 8.67 (Alaska), and the proportion of young adults ranged from 2.29% (New Hampshire) to 8.62% (Alaska) (Table 2).

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Naturally Occurring Carcinogenic Fibrous Minerals in Nevada

We compiled all published data about the presence of fibrous mineral, including asbestos minerals and erionite, in Nevada[19, 34–35, 37–39]. In order to evaluate potential environmental exposures to fibrous minerals we have integrated these data and mapped their distribution in relation to populations in Nevada (Figures 1 and 2). The list of carcinogenic mineral fibers detected in Nevada is shown in Table 1.

Attempts to map the distribution of the fibrous actinolite resulted in the identification of 230 samples of asbestos-bearing rock and soil in Clark County (Figure 2). Most of these sites were the result of the analyses performed for planning the construction of the Boulder City Bypass/Interstate 11[38–39].

Fibrous winchite, magnesioriebeckite, actinolite, and richterite were identified across the Colorado River in northwestern Arizona (Figure 3)[35]. These are the same fibrous minerals present in Libby, Montana, where they were related to MM and other asbestos-related diseases. As with the southern Nevada locality, weathering and erosion has distributed the fibrous amphiboles in adjacent alluvial fans, greatly increasing the areal distribution (Figure 2).

Environmental exposure to mineral fibers can happen when human activities and natural processes such as wind or water release fibers in the air. When these processes occur, increasing number of people are exposed. In Nevada carcinogenic fibrous minerals are located in and around residential areas (including the Las Vegas metropolitan area), in areas commonly used for outdoor recreation, such as the Lake Mead National Recreation Area.

Moreover, desert dust storms can carry fibers and cause human exposure. Although dust storms such as those that frequently hit Arizona are less frequent in Nevada, impressive dust clouds resulting from local wind erosion can be observed at any time during the year (Figure 3). Prevailing wind directions and speeds are variable throughout the year, with the highest winds in the spring primarily from the south, southwest, or southeast[40]. These wind directions and arid landscape greatly increase the potential for NOA to be blown from source areas (Figure 2) into the Las Vegas Basin and cause human exposure.

Discussion

Because occupational exposure to asbestos is less frequent in women than in men, MM rates in women, and particularly a low M:F sex-ratio, are sensitive indicators to identify environmental exposures to asbestos and other mineral fibers. This strategy was successfully applied in New Caledonia to identify environmental exposure to antigorite as the cause of a MM epidemic[15, 33]. Compared with the entire US, southern Nevada showed a significantly higher proportion of MM in women. In particular, the two counties of Clark and Nye had a low M:F MM sex ratio of 2.69:1, a result suggestive of non-occupational exposure to carcinogenic mineral fibers; whereas the other NV counties had a M:F sex-ratio of 6.33:1, indicating occupational exposure to asbestos, similarly to seven US states with asbestos industry and workers occupationally exposed to asbestos. The elevated rates of MM in individuals younger than 55 years old, combined with a sex ratio of 1:1 in this age group,

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suggests that an environmental exposure to mineral fibers is occurring in southern Nevada and may be causing some of these MM.

Women and children can be exposed to fibrous minerals as a result of their husband's or father's occupational exposure when bringing these fibers home on their clothes. However, in southern Nevada there are no major asbestos industries, thus this seems an unlikely hypothesis. Instead, the presence of asbestos and other fibers in the environment of Clark and Nye Counties, where a lower M:F sex ratio and an increased proportion of MM are seen in young individuals, suggests that some of these MMs are caused by environmental exposure.

Some of the known sources of carcinogenic fibrous minerals in Nevada occur in unpopulated areas in north and central portions of the state, others near the Las Vegas metropolitan area (Figure 1). In Washoe county, which is the second highest populated Nevada county, there are no known areas containing asbestos in the environment and one single locality containing erionite. We did not find any epidemiological indication of environmental exposure to carcinogenic mineral fibers in Washoe County. Instead, in southern Nevada, the Las Vegas metropolitan area has 1.9 million people either in direct contact with NOA or residing in areas that for part of the year are downwind from NOA sources (Figures 1, 2). Portions of the Las Vegas metropolitan area have the regulated asbestos mineral actinolite present in rock, soil, and air[34, 38–40]. Additionally, fibrous winchite, magnesioriebeckite, actinolite, and richterite are present in a large area just across the Colorado River in northwestern Arizona[34] (Figure 2). At this time, erionite is known to occur in southern Nevada only near the small community of Beatty, and at the Nevada National Security Site (NNSS, formerly the Nevada Test Site) (Figure 1).

The rock and soils that contain the amphibole NOA make up a very large area in southern Nevada and northwestern Arizona that include urban areas (e.g. Boulder City) and rural areas where people routinely enjoy outdoor activities including horseback riding, running, hiking, bicycling, and off-road vehicle (ORV) recreation. It has been estimated that in Nevada over 15% of the population engages in ORV recreation every year[31]. Airborne dust is a common phenomenon in this region due to the aridity[42]. When desert pavements are disturbed by activities such as horseback riding and especially ORV recreation, large quantities of dust containing fibers are released into the air by wind erosion[31, 34].

One common area for ORV recreation in Nevada is the Eldorado Dry Lake, which lies south of Henderson and west of Boulder City (Figure 2). The dry lake bed is a known source of fibrous amphiboles[34]. This dry lake bed produces significant dust during windy days and/or as the result of ORV and other recreational activities. In order to protect the population from environmental exposure to mineral fibers, similar ORV recreation areas have been restricted in California[43]. All of these recreational activities can cause fibers to become airborne and to attach to clothing, equipment, and cars where they are then potentially brought into homes where secondary exposures to other family members can occur.

Airborne asbestos fibers have been measured in Clark County[33, 38]. Dust samples were collected along dirt roads as drivers drove past in Boulder City and in the McCullough

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Range, and ambient dust was collected in the backyard of a Boulder City resident. In all samples, fibrous amphiboles were present[34]. Ambient air measurements were taken at 4 locations near Railroad Pass (between Boulder City and Henderson) over a 3-month period (May 8-Aug 9, 2014) and detected asbestos fibers in the air[38].

We considered factors that could have led to false positive results. First, Nevada is a destination for retirement and people could have been exposed elsewhere and developed MM in Nevada. However, by focusing on MM rates in young individuals, we decreased the risk that the results were influenced by asbestos workers who may have retired in Nevada. Secondly, another possible source of exposure to asbestos may occur in old buildings. Several old hotels and casinos were demolished in Las Vegas during the past 20 years, raising some concern about possible exposure to asbestos for the residents during the demolition. However, because MM have a 30–50 years mean latency from exposure, it is unlikely that the MM rates we detected in Nevada were influenced by this factor. Thirdly, there is no significant asbestos trade in NV. Thus, indirect exposure through family members involved in asbestos trades seems an unlikely explanation for the higher MM rates in women and young individuals. Lung content analyses to investigate for the presence, type and amounts of carcinogenic mineral fibers in the lungs of MM cases are needed to further prove causality. Future research should try to address whether the relative increase in MM incidence that we observed in women and young adults is related to specific types of mineral fibers among the several fiber types we detected in Southern Nevada (Table 1). We need also to investigate whether individual traits, such as genetics, are responsible for MM development in some of these individuals or whether MM is simply due to exposure since childhood. Precise information about women and young individuals who developed MM, including their residential history and activities that may increase their exposure to dust and fibers, will allow to study whether the overall amount of environmental exposure (measured in years of exposure and in activities that may increase exposure, such as ORV use) and/or its discontinuation influence the incidence or latency of MM in these cohorts.

In summary, in Clark and Nye counties, southern Nevada, the significantly higher proportion of MM under the age of 55 and the high proportion of MM in women suggest a non-occupational exposure to mineral fibers from early age. Known sources of carcinogenic fibrous minerals in southern Nevada region include the regulated actinolite asbestos, as well as winchite, magnesioriebeckite, and richterite, which are largely the same minerals responsible for the disease epidemic in Libby Montana. Erionite is also present, but currently it has been identified in only two localities, both of which are farther away from large populations as compared to the fibrous amphibole localities (Figure 1). This arid region commonly experiences dust storms and is popular for ORV and other recreational activities that increase human exposures to mineral dusts. The results herein suggest that further research is needed, including epidemiological, geological, mineralogical and health-based personal exposure studies in order to characterize the residential and occupational history of the MM cases we studied, to highlight the highest risk areas within Clark and Nye counties, to identify the type of fibrous minerals and their precise distribution throughout Nevada, and to identify the activities responsible for the release of fibers in the air, which may be the cause of some of the MMs in this region. A precise knowledge of where these carcinogenic fibers occur, what causes their release in the air and the history of possible environmental exposure of the MM cases we detected, will provide essential information to prevent future exposure in the population as the major development of rural areas continues in Nevada. The design of new highways and human settlements, for example, should keep this information into consideration to decrease the risk of MM and other asbestos-related diseases caused by asbestos and other mineral fibers present in the environment.

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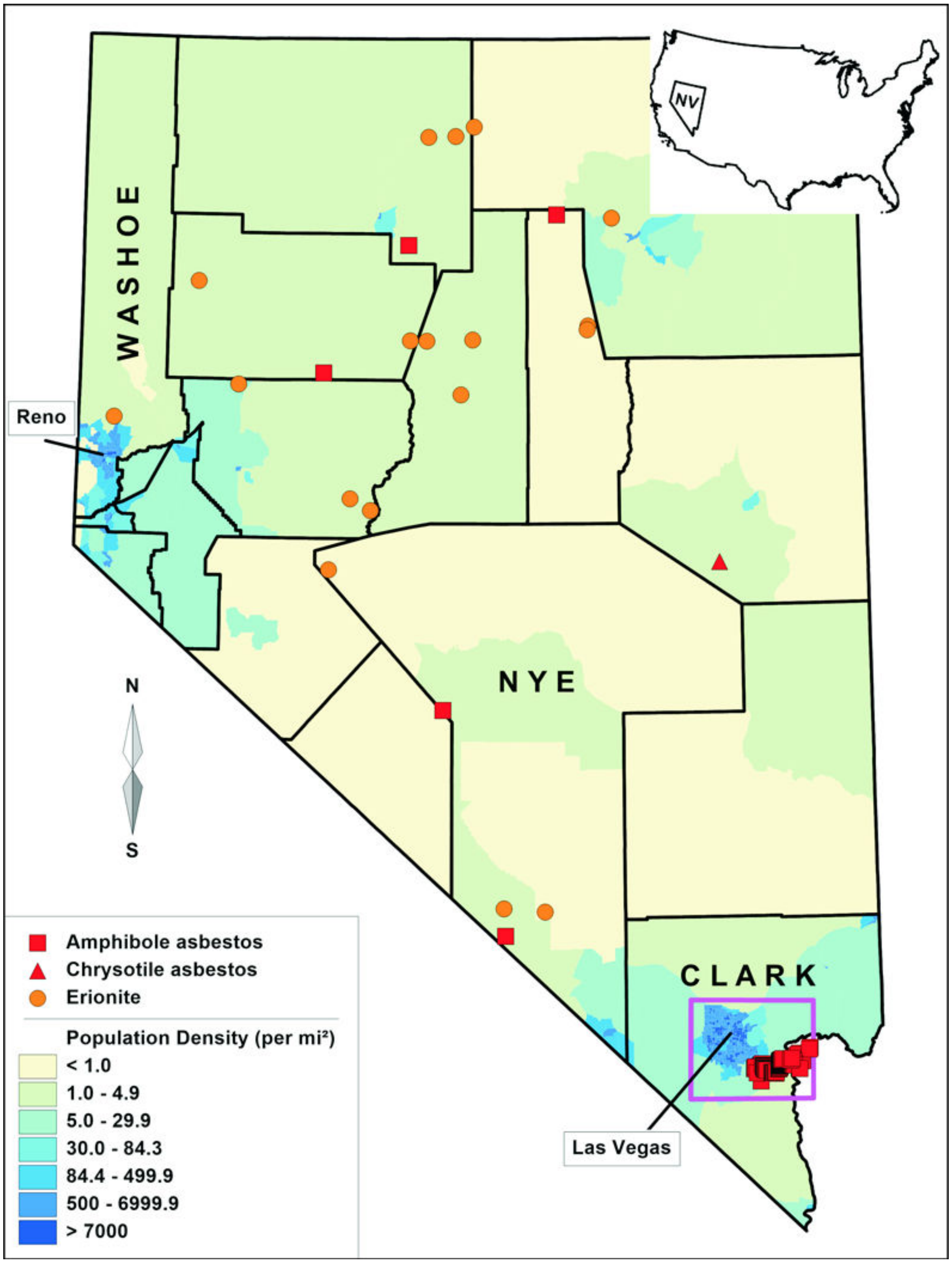

Figure 1.

Map of fibrous mineral sources in Nevada. Locations for asbestos taken from Van Gosen[42]. Erionite localities compiled from Van Gosen et al.[24]. Asbestos localities in Clark County from Buck et al.[39], Tetra Tech[43], Kleinfelder[44], and Metcalf and Buck[40]. Census data taken from 2010 census (https://www.census.gov/geo/maps-data/data/tiger-data.html)

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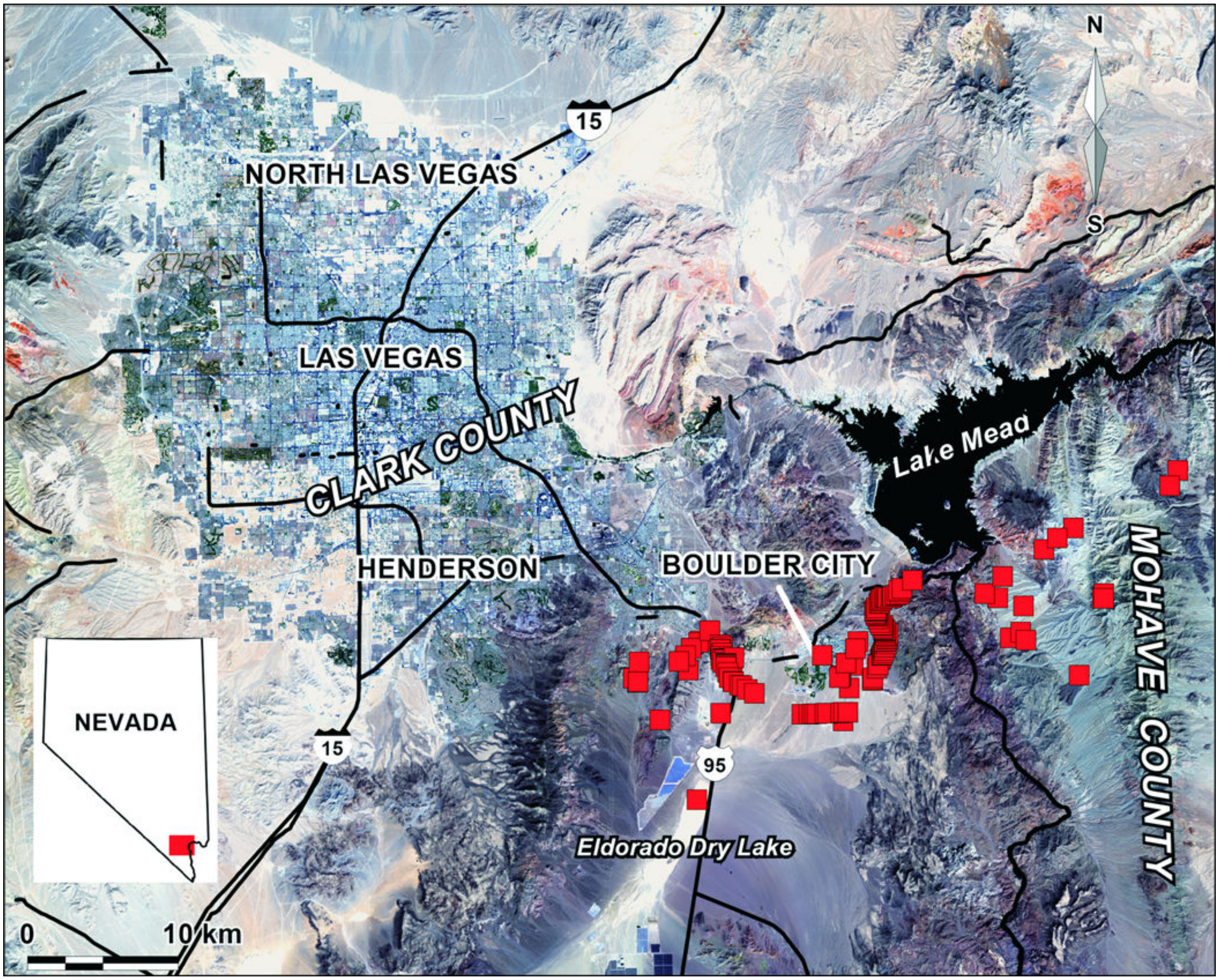

Figure 2.

Southern Clark County, NV and western Mohave County, AZ. Occurrences of fibrous minerals are shown as red squares. Occurrences compiled from Buck et al.[39], Tetra Tech[43], Kleinfelder[44], 2014 and Metcalf and Buck[40].

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Figure 3.
Typical dust storm entering Henderson-Las Vegas from the south. McCullough Mountains are obscured by dust (October 19, 2009). Inset figure showing SEM image of fibrous amphiboles from Black Hill, close to Henderson.

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Table 1

Mineral fibers that have been linked to cancer in humans

Mineral Name	Commercial name	Mineral group	Present in southern NV
Riebeckite*	Crocidolite	Amphibole	
Anthophyllite*		Amphibole	
Grunerite-Cummingtonite*	Amosite	Amphibole	
Tremolite*		Amphibole	Y
Actinolite*		Amphibole	Y
Chrysotile*		Serpentine	
Erionite		Zeolite	Y
Winchite		Amphibole	Y
Richterite		Amphibole	Y
Magnesio-riebeckite		Amphibole	Y
Antigorite		Serpentine	

*Identifies the six mineral fibers that comprise the "asbestos" family. These are the only type of fibers whose use is strictly regulated in the US, Europe and several other countries.

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Table 2

Sex ratios and proportion of individuals (<55 years) among MM deaths in Clark and Nye counties compared to other Nevada counties and to the overall US during the time period 1999–2010. In addition, the same information is provided for US States with known asbestos industry and professional exposure[41], for the same time period

MM cohort	Proportion of MM deaths < 55 years old		All MM deaths M:F sex ratio	
		p value		*p value*
Clark + Nye counties (N=133)	11.28%	-	2.69	-
All other counties, NV (#)	9.09%	0.8075	6.33	0.0468*
All other US (N=31,408)	6.21%	0.0249*	4.97	0.0422*
State of Alaska (#)	8.62%		8.67	
State of New Hampshire (#)	2.29%		6.00	
State of North Carolina (N=707)	6.93%		5.43	
State of Pennsylvania (N=2102)	4.52%		4.20	
State of South Carolina (N=374)	6.95%		5.03	
State of Virginia (N=915)	6.56%		4.94	
State of Wyoming (#)	3.80%		7.78	

#Numbers cannot be shown by subgroups for confidentiality reason, because some are <10.

*p<0.05 – statistically significant