Exposures to Commercial Asbestos In Northeastern Minnesota Iron Miners who Developed Mesothelioma

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Minnesota Department of Health
Chronic Disease and Environmental Epidemiology

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background

There is a long history of community concern about a possible link between the mining industry in northeastern Minnesota and the occurrence of cancers and respiratory diseases in that part of the state. In 1973, asbestos-like fibers were found in the Duluth water supply and traced to tailings that had been disposed of in Lake Superior by the Reserve Mining Company. This finding, along with litigation surrounding Reserve's disposal of tailings, prompted studies of the fibers (Langer et al. 1979), the effects of ingestion of the fibers (Hilding et al. 1981), and the morbidity and mortality of iron ore miners (Clark et al. 1980; Higgins et al. 1983; Lawler et al. 1985; Cooper et al. 1988; Cooper et al. 1992), among many other studies. In addition, the Tri-County cancer survey was established by the Minnesota Department of Health (MDH) to monitor cancer rates in northeastern Minnesota (Levy et al., 1976; Sigurdson et al , 1981).

In 1985, health concerns in northeastern Minnesota were again brought to the attention of the MDH. A radiologist in Virginia, Minnesota, reported an excess of lung abnormalities in his patients' X-rays, prompting concern about generalized environmental contamination in the region. Following additional reviews of X-rays at the Mt. Sinai School of Medicine in New York City and the National Institute for Occupational Safety and Health (Parker et al. 1989), a panel of national experts (the Range Studies Advisory Committee) concluded that there was no evidence of a generalized community-wide health problem from environmental exposures. The committee did recommend a follow-up and review of residential and occupational exposures, additional reviews of X-rays, and statewide surveillance for mesothelioma. The committee also supported establishment of statewide cancer surveillance and planning for a study of fibrous properties of minerals on the Iron Range. While statewide cancer surveillance did begin in 1988, MDH was not successful in obtaining public or private funding for the other recommendations.

In the early 1980s, the University of Minnesota School of Public Health, with the support of the Iron Range Resources and Rehabilitation Board (IRRRB) and the cooperation of the seven mining companies then in operation, assembled a database of approximately 72,000 individuals who had ever worked in the mining industry in northeastern Minnesota between the 1930s and

1983. This roster included taconite workers and persons who had worked in certain hematite mine operations.[1] This study also collected information on silica dust exposures in various mining operations and occupations. Unfortunately, the available resources were exhausted before the planned mortality follow-up study could be conducted.

In 1997, the Minnesota Cancer Surveillance System (MCSS) reported that the rate of mesothelioma in men in the seven-county region of northeastern Minnesota was over 70 percent higher than the statewide average for the period 1988-1994 (Minnesota Cancer Surveillance System 1997). This excess has continued or increased through 1999 (see Appendix F). Mesothelioma is a rare form of cancer whose primary and only known cause is asbestos exposure, usually several decades prior to the time of diagnosis. The rate in women was not elevated, pointing to the likelihood of occupational exposures. The mesothelioma findings and the long history of health concerns resulted in the establishment of the Occupational Respiratory Disease Information System (ORDIS) in 1998 by the Minnesota Legislature (Minnesota Statutes 2000, Section 144.6905). As one part of that initiative, MDH, in collaboration with the ORDIS Advisory Work Group, investigated the mesothelioma occurrence. Although ORDIS was repealed in January 2002 during budget reductions, the mesothelioma study was sufficiently complete to allow development of a final report. The findings of this study are presented in this report.

Because of the history of health concerns about mining and the large numbers of people historically employed in iron mining in these counties, the possible relationship between employment in the mining industry and mesothelioma was the primary focus of this study. It was recognized at the outset, however, that at least one other industry unique to northeastern Minnesota significantly contributed to the mesothelioma excess. The former Conwed Corporation plant in Carlton County employed over 5,000 workers between 1958 and 1974 during which time large quantities of commercial asbestos were used in the manufacturing of mineral board and ceiling tile. Union-funded and state-funded screening studies of former workers showed a high prevalence of lung abnormalities typical of asbestos exposure (Minnesota

[1] Hematite is a natural ore containing approximately 60% iron. As hematite supplies began to diminish following World War II, the industry turned to the lower iron content taconite ore (20% iron) which required additional processing. By the 1960s, taconite production exceeded hematite.

Department of Health 1989). Mesotheliomas had been documented among former Conwed workers, and the 1997 cancer report indicated that Carlton County had the highest rate of mesothelioma in the state. However, the excess of mesothelioma was not limited to this county and Conwed was unlikely to be the sole explanation for the elevated rate of mesothelioma (Minnesota Cancer Surveillance System 1999).

Methods for the Current Study

The objectives of the current study were to determine: (1) how many individuals diagnosed with mesothelioma in Minnesota between 1988 and 1996 had any history of working in the iron mining industry; and (2) of these people, how many held jobs that could have involved exposures to commercial asbestos (a major contributor to asbestos-related diseases in many industries during that time period). To accomplish this, a database of all Minnesotans diagnosed with mesothelioma between 1988 and 1996 was compared to the iron miner database. The job histories of the iron miners who developed mesothelioma were then examined to see if their jobs, either inside or outside of the mining industry, could have involved exposure to commercial asbestos. The list of miners who developed mesothelioma was also compared to a list of former employees at the Conwed plant, where exposures to asbestos were clearly possible. Information about other non-mining industry jobs was obtained when available. Potential sources of exposure to commercial asbestos were evaluated through an assessment process that included review panels, job titles, and worker interviews. If no commercial asbestos exposures could be identified, other sources of asbestos exposure would then have to be considered.

Findings

Seventeen individuals (all men) diagnosed with mesothelioma in Minnesota between 1988 and 1996 were found to have worked in the iron mining industry. Since MCSS only collects cancer data for Minnesota residents, it is not known if, or how many, miners may have developed mesothelioma outside of Minnesota. The mesothelioma occurrence among miners found in this study is in sharp contrast to previously published death certificate-based studies of taconite miners that have not found mesotheliomas or excesses of other respiratory diseases. (Prior to 1999, mesotheliomas were usually coded on death certificates as other cancers; they were identified in this study through the Minnesota Cancer Surveillance System.) Since asbestos

exposure is the primary and only known cause of mesothelioma, this finding demonstrates that exposure to asbestos has occurred in the iron mining industry during previous decades.

For two of the 17 miners who developed mesothelioma, a potential source of exposure could not be determined because the jobs they held for significant portions of their job histories are unknown. For the other 15 miners, occupational histories were sufficiently complete to allow evaluation of potential exposures to commercial asbestos. One of the 15 had no apparent occupational exposures to commercial asbestos based on the occupational information that was available. Fourteen of the 15 had potential exposures to commercial asbestos: 11 had job(s) with probable exposure[2] to commercial asbestos and another 3 had job(s) with possible exposure to commercial asbestos.

Potential exposures were found in both mining industry and non-mining industry occupations. Of the 14 men with at least a potential exposure to commercial asbestos, 4 involved mining industry jobs only, 4 were non-mining jobs only, and 6 involved both mining and non-mining jobs. Many of the asbestos-exposed occupations were common to both mining and non-mining industries, such as plumbing, carpentry, boiler operation, and maintenance work. The time between employment in these asbestos-exposed occupations and the diagnosis of mesothelioma in this study is consistent with the 20 or more year latency period that has been observed in other studies of this cancer.

Additional Observations and Conclusions

Several additional observations are important to interpreting these findings. The 17 iron miners who had developed mesothelioma worked at mines across the Iron Range (not only in East Range operations where asbestos-like fibers may occur in the taconite). Also, 5 of the 17 appear to have worked only at hematite mine operations (presumably where they would not have been exposed to taconite dust). Additional information comes from a study of exposures to silica in the taconite industry done in the early 1980s as part of the University of Minnesota study (Sheehy 1986). This study used available monitoring data to identify the level of respirable dust exposure for various job titles and mining operations. Of the 17 iron miners, only one potentially

[2] Definitions and methods of exposure assessment are described in the full report.

held one of the "high dust exposure" jobs for several months 40 years prior to the diagnosis of mesothelioma.

Had none or few of the 17 iron miners with mesothelioma had any potential exposures to commercial asbestos in their work and mostly held mining jobs with the highest taconite dust exposure, exposure to asbestos-like fibers in the taconite dust would have been a plausible explanation. The findings point to a different explanation. It was found that: (a) 14 of the 15 iron miners (for whom a sufficient occupational history was available to make a judgment) had jobs with potential exposures to commercial asbestos, (b) these jobs were held at least 20 years or more prior to diagnosis, and (c) only one miner could be identified as having potentially held any of the highest silica-dust exposure job titles. The explanation most consistent with these findings is that commercial asbestos exposure, rather than taconite dust, is the most likely cause for the occurrence of mesothelioma in men employed in the mining industry. However, at least one miner had no obvious source of exposure to commercial asbestos and other causes cannot be ruled out.

This study shows that potential exposure to commercial asbestos has occurred within specific occupations in the iron mining industry in northeastern Minnesota. Iron miners as a group are at risk of developing mesothelioma and possibly other asbestos-related diseases. Because of the long latency of asbestos-related diseases, these risks will continue into the future even in the absence of ongoing exposures.

Mesothelioma in Northeastern Minnesota: 1988-1996

It was beyond the scope of this study to collect job histories and account for asbestos exposures among all people diagnosed with mesothelioma in northeastern Minnesota. However, data from this study and previous investigations of former Conwed employees offer a likely explanation for the excess of mesothelioma. The 73% excess of mesothelioma during 1988-1996 among men represented 23 additional cases over the expected number (54 actual cases versus 31 expected cases). Most of the mesothelioma cases among iron miners (14 of 17) and Conwed workers (9 of 11) resided in northeast Minnesota at the time of diagnosis, thus contributing to the excess. Accounting for the two miners who also worked at Conwed, these two industries are associated

with 21 mesothelioma cases in northeast Minnesota. Thus, the excess could be largely (if not completely) explained by these two industries that are unique to this region of the state.

Strengths and Limitations of the Study

A descriptive study such as this one has many limitations. The biggest limitation was the use of job title and occupation as indicators of potential exposure to commercial asbestos, rather than actual exposure data (which did not exist). Other limitations include the lack of control subjects (i.e., there was no comparison with miners who did not develop mesothelioma), incomplete work histories, and the lack of information on potential non-occupational asbestos exposures.

This study also has many strengths. The Minnesota Cancer Surveillance System, rather than mortality records, was used to identify all mesothelioma cases in the state. The Iron Miner cohort was used to identify iron miners who developed mesothelioma and to identify their job histories. Exposure assessments were made by panels without knowledge of which job titles were actually held by miners who had developed mesothelioma. And finally, the collaboration between labor and industry in the development of the protocol for this study allowed MDH to interview current and former iron miners about exposures to commercial asbestos in their jobs, in a way that ensured the confidentiality of their responses.

Health Issues Not Addressed by this Study

While these findings establish that miners are at some risk of mesothelioma and that past exposure to commercial asbestos is a likely explanation, this study does not answer many of the questions about the health and safety of iron miners in Minnesota that have been raised over many decades. It is not a comprehensive study of the use of commercial asbestos in the iron mining industry. Furthermore, this study does not address the morbidity and mortality among iron miners from all types of cancer or respiratory diseases, nor does it attempt to address potential health risks from exposures to respirable mineral dusts from taconite ore and its processing. Different study protocols would be required to address these questions.

Mesothelioma and other cancer rates in northeastern Minnesota among both men and women will continue to be monitored and reported by the Minnesota Cancer Surveillance System.

INTRODUCTION

There is a long history of community concern about a possible link between the mining industry in northeastern Minnesota and the occurrence of cancers and respiratory diseases in that part of the state. In 1973, asbestos-like fibers were found in the Duluth water supply and traced to tailings that had been disposed of in Lake Superior by the Reserve Mining Company. This finding, along with litigation surrounding Reserve's disposal of tailings, prompted studies of the fibers (Langer et al., 1979), the effects of ingestion of the fibers (Hilding et al., 1981), and the morbidity and mortality of iron ore miners (Clark et al. 1980; Higgins et al. 1983; Lawler et al. 1985; Cooper et al. 1988; Cooper et al. 1992) among other studies. The Tri-County Cancer Survey was established by the Minnesota Department of Health (MDH) to monitor the occurrence of cancer in northeastern Minnesota. This survey collected data on newly occurring cancers among residents in Cook, Lake, and St. Louis counties during the period 1969 to 1976 (Levy et al. 1976; Sigurdson et al. 1981).

During the 1980s, respiratory health concerns in northeastern Minnesota were brought to the attention of MDH on at least two occasions. In 1985, a radiologist in Virginia, Minnesota, reported an excess of lung abnormalities (associated with asbestos exposure) in his patients' X-rays, prompting concern about generalized environmental contamination in the region. Following additional reviews of X-rays at Mt. Sinai School of Medicine in New York City and the National Institute for Occupational Safety and Health (Parker et al. 1989), a panel of national experts (the Range Studies Advisory Committee) was assembled to review the health and environmental data and make recommendations to the state regarding further actions and studies. The committee concluded that there was no evidence of a generalized community-wide health problem due to environmental exposures. The committee did recommend, however, that several steps be taken to determine the significance of those X-rays in which abnormal findings had been validated. The recommendations included a follow-up and review of residential and occupational exposures, additional reviews of X-rays, and statewide surveillance for mesothelioma. The committee also supported establishment of statewide cancer surveillance and planning for a study of fibrous properties of minerals on the Iron Range. While statewide cancer surveillance

did begin in 1988, MDH was not successful at that time in securing public or private funding for the other recommendations.

In 1986, the United Paperworkers International Union contacted MDH with concerns about asbestos-related diseases among former employees of the Conwed plant in Cloquet, Minnesota. Between 1958 and 1974 this facility used asbestos as a raw material in the manufacture of ceiling tile and mineral board. In 1988, with funding from the state legislature, MDH screened 1,552 former Conwed workers and their spouses for lung disease. Overall, 27.8 percent of the former workers were found to have evidence of lung abnormalities consistent with asbestos exposure. Following the medical screening, an additional 3,000 former workers were traced and notified of their potential exposures to asbestos (Bender et al. 1993).

Concerns about respiratory disease in this region heightened in 1997 when MCSS reported a rate of mesothelioma that was 70 percent higher than the statewide average among men in a seven-county region[3] of northeastern Minnesota for the years 1988 to 1994 (Minnesota Cancer Surveillance System 1997). Mesothelioma is a rare form of cancer whose principal cause is exposure to asbestos. In December 1997, the *St. Paul Pioneer Press* reported 12 years of recurring and unresolved investigations of occupational lung disease in northeastern Minnesota (Morrison 1997). The elevated rate of mesothelioma and other concerns prompted the state legislature in 1998 to establish the Occupational Respiratory Disease Information System (M.S. 2000 Section 144.6905; see Appendix G for full statute).

The two main objectives of the Occupational Respiratory Disease Information System (ORDIS) were: (1) to pilot test—beginning in northeastern Minnesota—a system to track the occurrence of occupational respiratory disease, and (2) to investigate the elevated rate of mesothelioma in northeastern Minnesota. Both objectives were consistent with recommendations made by the Range Studies Advisory Committee 13 years earlier.

[3] The counties included in this region are Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, and St. Louis (see Figure 1.) Data through 1999 continue to confirm this excess (Appendix F).

Recognizing that community support and participation was necessary for accomplishing these objectives, and as required by statute, the Commissioner of Health established the Northeastern Minnesota ORDIS Advisory Work Group to assist and advise MDH. The membership of the Advisory Work Group–and its two technical subcommittees–included local and state public health workers, Mining Safety and Health Administration staff, mining industry management, union leaders, civic leaders, concerned citizens, members of academia, physicians, representatives from the region's Congressional delegation, and others. Eventually, the disease-tracking functions of ORDIS were to have been pilot tested in additional regions of the state to determine the feasibility of such a system on a statewide basis. However, in January 2002, ORDIS activities were terminated and the statute repealed when funding was eliminated as part of a budget reconciliation process.

Because of its established relationship with asbestos, the incidence of mesothelioma is a marker of past asbestos exposure. However, it was not clear what sources of asbestos led to the elevated rate of this cancer among men in northeastern Minnesota. Since diagnosis of mesothelioma generally comes 20 to 40 years or more after initial exposure to asbestos, exposures related to cancers that occurred in the 1980s and early 1990s would have had to have taken place in the 1940s to the 1970s, or earlier. While an increased rate was observed in men, the rate in women was not elevated, pointing to the likelihood of an occupational exposure. Although a large number of employees (over 5,000) worked at the Conwed plant during the years in which asbestos had been used, preliminary evidence indicated that it was unlikely that Conwed was the sole explanation for the elevated rate of mesothelioma (Minnesota Cancer Surveillance System 1999). Because the iron mining industry has been a major employer in this region of the state and because of the history of concern about mineral fibers, concern remained that there may be some mining process (in addition to asbestos-containing commercial products) that resulted in asbestos exposure.

In the early 1980s, the University of Minnesota School of Public Health, with the support of the Iron Range Resources and Rehabilitation Board (IRRRB) and the cooperation of the seven mining companies then in operation, assembled a database of approximately 72,000 individuals who had ever worked in the iron mining industry in northeastern Minnesota. This roster

included taconite workers and persons who had worked in certain hematite operations.[4] In addition to demographic information, this database contained the employment histories of these workers. It was assembled with the intent that it would be used to evaluate the causes of death among miners compared to the overall population. The available funds were exhausted, however, before the follow-up and analyses could be completed. With the consent of the University of Minnesota and the IRRRB, MDH obtained this database in 1998 to determine whether or how these data could be used to continue the University study and to address the long-standing health concerns.

In the present study, the iron miner database was used to determine whether individuals diagnosed with mesothelioma in Minnesota had any history of working in the mining industry. The job histories of the iron miners who developed mesothelioma were then examined to determine whether they held jobs that could have involved exposure to commercial asbestos,[5] known to be the primary cause of asbestos-related diseases in many industries. The list of miners who developed mesothelioma was also compared to a list of former employees at the Conwed plant, where exposures to asbestos were clearly possible.

This investigation addresses specific questions regarding the elevated rate of mesothelioma in men in northeastern Minnesota. It is not a comprehensive study of the use of commercial asbestos in the iron mining industry. Nor is it a study of the health effects of exposure to dust from the mining and processing of taconite. Rather, it starts with the major industry of the seven-county region and asks: (1) whether any of the mesothelioma cases diagnosed throughout the state were individuals who had been employed in the iron mining industry, and (2) to what extent any mesotheliomas among miners could be explained by occupational exposures to commercial asbestos used in the mining industry (as with many other industries during that period). That is, the study looks at the jobs held by iron miners who developed mesothelioma, to see if their jobs could have involved exposure to commercial asbestos.

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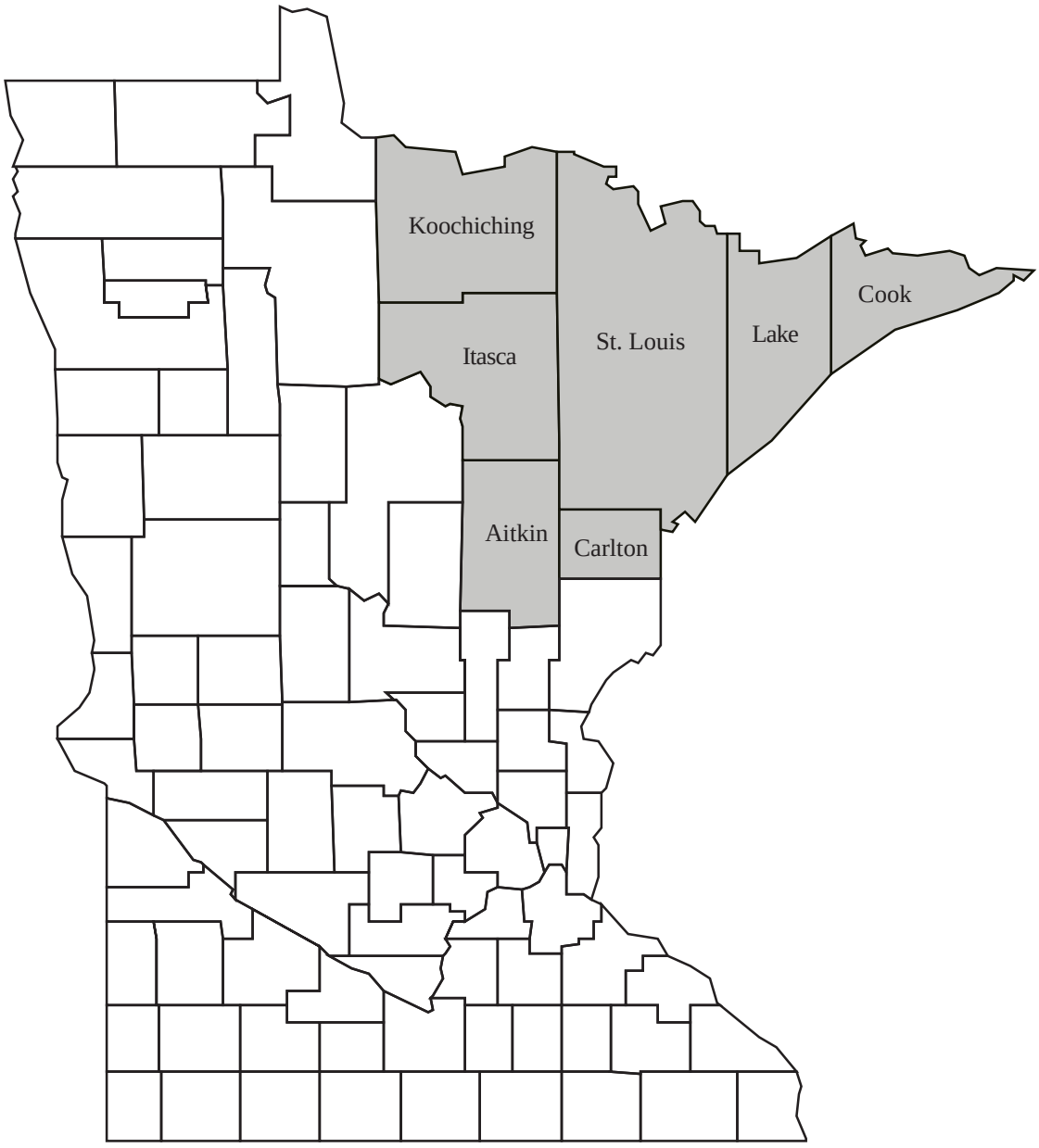
[4] Hematite is a natural ore containing approximately 60% iron. Hematite reserves were largely depleted by the 1970s. Taconite, a lower-grade iron ore containing approximately 20% iron, has been mined commercially in Minnesota since 1955.

[5] In this report, the term "commercial asbestos" will be used to mean commercially-available asbestos and asbestos-containing materials (such as insulation products).

Figure 1. Counties in northeastern Minnesota



MESOTHELIOMA AND ASBESTOS

Risk factors and characteristics of mesothelioma

Mesothelioma is a rare cancer that affects the lining of the chest wall or abdomen. Occupational studies dating back to the 1960s established that the principal cause of mesothelioma is exposure to asbestos. Asbestos is also a cause of lung cancer, but unlike asbestos-related lung cancer, smoking does not increase the risk of mesothelioma by itself or in combination with asbestos exposure (Muscat and Wynder 1991). In some cases, even a short duration of high exposure has been linked to development of this cancer. Typically, asbestos exposure occurs 20-40 years prior to diagnosis of mesothelioma (Hillerdal 1983). Because of this long latency period, it may be very difficult to determine exactly when or where an individual may have been exposed to asbestos.

Besides the long latency period, two other factors complicate studies of mesothelioma. The first is its short survival time. The average life expectancy after diagnosis is less than one year. Thus, in studies of persons diagnosed with this cancer, it is likely that many will die before they can be interviewed, making it difficult to determine their past exposures to asbestos. Second, historical monitoring data (measurements of asbestos levels in the workplace) often are not available. For this reason, many studies use past work histories and job titles as a surrogate for potential exposures.

Asbestos

Asbestos is a commercial term referring to a vaiety of fibrous minerals with unique physical properties, The minerals known as asbestos include chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite Asbestos fibers are strong, thin, and flexible and resistant to fire and corrosion.. The discovery of these physical properties led to the mining and use of asbestos in thousands of commercial products.

Asbestos was used extensively in the United States from the 1930s through the 1960s, mirrored by the increase in mesothelioma rates observed nationwide in the 1970s and 1980s (Price 1997). Asbestos was used in the manufacture of ships during World War II, in commercial buildings

and homes as insulation from 1946 to 1972, and continues to be used in automobile brake linings, cement, and ceiling and floor tiles (Antman 1993). Products that may have contained asbestos include (but are not limited to): construction and building materials (insulation, fireproofing, or soundproofing materials), gaskets, brake linings and clutches, paper or filter products and textiles.

Many industries and occupational groups have been found to have a greater likelihood of asbestos exposure and a correspondingly higher risk of asbestos-related disease. These occupations include asbestos miners and workers, shipyard workers, insulation manufacturers and installers, gas mask manufacturers, brake mechanics, sheet metal workers, paper workers, pipefitters, electricians, boiler operators and construction workers.

As it exists in nature, asbestos is sometimes found in seams alongside commercially mined minerals such as vermiculite. In certain areas on the eastern end of Minnesota's Iron Range, the taconite contains "asbestos-like fibers" known as cummingtonite-grunerite, a mineral relative of amosite asbestos (Gunderson et al., 1962; Higgins et al., 1983). The extent of exposure to these fibers during mining and processing of taconite and the potential health effects of such exposures have not been well established; however, a risk assessment performed by Nolan and colleagues suggested that the cancer risks due to grunerite asbestos exposure among iron ore miners was relatively small (Nolan et al. 1999). A symposium on the evaluation of the health risks of fibers associated with taconite was held March 30-April 1 in St. Paul, Minnesota.

Past studies of taconite workers from three Minnesota operations have not shown statistically significant elevations in rates of death due to respiratory disease (Higgins et al., 1983; Cooper et al., 1992). However, mortality studies such as these are inadequate to address the risks of mesothelioma since this cancer is often coded as another or unknown type of cancer on death certificates (Lilienfeld and Gunderson 1986).

Methods

The first step in this investigation was to identify the iron miners, if any, who had been diagnosed with mesothelioma. To do this, a list of all mesothelioma cases diagnosed statewide

between 1988 and 1996 was compared to a list of approximately 72,000 persons employed in the iron mining industry before 1983. Second, the job histories of the iron miners who developed mesothelioma were determined. Both mining and non-mining jobs were included. Finally, for each of these jobs, the potential for exposure to commercial asbestos in the job as it existed in the 1940s through the 1970s was determined. These steps are shown in Figure 2 and are described in detail below after the descriptions of the data sources used in this study.

Data Sources

Minnesota Cancer Surveillance System

The Minnesota Cancer Surveillance System (MCSS), the state's cancer registry, is an ongoing program within the Chronic Disease and Environmental Epidemiology section at the Minnesota Department of Health. Since 1988, the MCSS has been collecting diagnostic and demographic information on all new diagnoses of cancer among Minnesota residents. The MCSS continually conducts quality control studies on its data and has been shown to be complete and highly accurate, achieving the highest rating of the North American Association of Central Cancer Registries (Minnesota Cancer Surveillance System 2001). When this study began, MCSS data through 1996 were available. Appendix F provides an update on mesothelioma rates through 1999.

Minnesota Iron Miners cohort

The Minnesota Iron Miners cohort was assembled in the early 1980s as part of the Mineral Resources Health Assessment Program (MRHAP), led by researchers at the University of Minnesota School of Public Health. MRHAP was initiated to study the health of Minnesota iron miners. The cohort consists of approximately 72,000 individuals who worked in the mining industry in northern Minnesota at any time from the 1930s through 1983 when the data was collected. MRHAP researchers worked with the mining companies to obtain personnel records for each of the employees. These records included work histories for mining employment and, for some, job applications and pension records. This cohort had been assembled with the intent that it would be used to study cancer incidence and mortality within the mining industry. Unfortunately, the resources for this study were exhausted before the follow-up and analyses could be completed.

The following mining companies participated in the MRHAP project: Reserve Mining Company, Inland Steel Company, United States Steel Corporation, Jones and Laughlin Corporation, Hanna Mining Company (included National Steel and Butler), Pickands-Mather and Company (Erie Mining Company and Hibbing Taconite Company), and Oglebay Norton (Eveleth Mines). According to MRHAP records, the cohort includes all taconite workers, plus only those hematite workers from operations owned or managed by U.S. Steel, Hanna or Jones and Laughlin. Cleveland-Cliffs was not included due to the 1981 closure of its hematite operation and the subsequent movement of all personnel records to the company's offices in Michigan. Table 1 shows a breakdown of the number of workers included from each mining company.

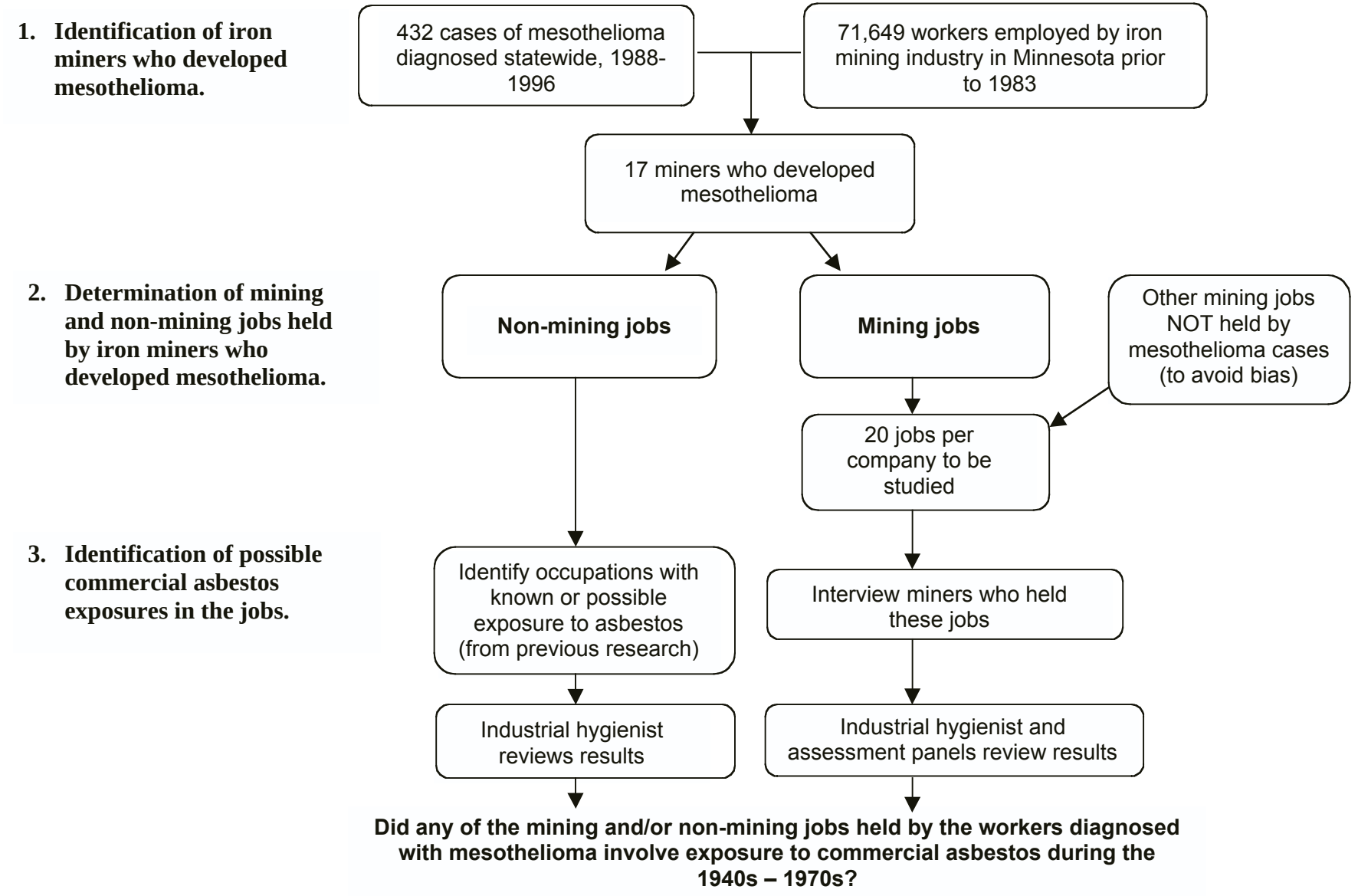
Table 1. Number and percentage of workers in the Minnesota Iron Miners cohort, by company (Mineral Resources Health Assessment Program, University of Minnesota, 1981-1984)

Company	Number of workers in the mining cohort (% of total)	
United States Steel Corporation*	35,935	(45%)
Pickands-Mather and Company (Erie Mining Co./Hibbing Taconite)	13,985	(17%)
Hanna Mining Company*	11,772	(15%)
Reserve Mining Company	10,229	(13%)
Jones and Laughlin Company*	5,822	(7%)
Oglebay Norton (Eveleth)	2,276	(3%)
Inland Steel Company	615	(<1%)
	#80,529	

*Includes hematite or natural ore operations

#The total for each company includes employees who also worked for one of the other mining companies. Because persons who worked for more than one company are counted more than once, the overall total (80,529) is higher than the number of individuals in the cohort (71,649).

Figure 2. Steps in the investigation of mesothelioma among iron mining employees



Conwed cohort

The Conwed cohort consists of approximately 5,000 former employees of the Conwed Corporation (Cloquet) who were employed during the period (1958-1974) in which commercial asbestos was used in the manufacture of ceiling tile and mineral board (Minnesota Department of Health 1989; Williams 1994). In 1988, 1,101 former workers and 451 spouses participated in a medical screening for lung disease. The medical screening consisted of a chest X-ray, lung function testing, a physical examination and an interview about the person's job history, smoking history and medical history. At that time, 27.8 percent of the former workers showed evidence of lung abnormalities consistent with asbestos exposure on their X-rays. In addition, through physician reports and other sources, 9 suspect or certain cases of mesothelioma had been identified as of 1994. Following the screening program, over 3,000 former Conwed employees were traced and notified about their potential exposure (Bender et al. 1993). Subsequent investigation confirmed that 11 former Conwed workers had been diagnosed with mesothelioma in Minnesota between 1988 and 1996.

Identification of iron miners who developed mesothelioma

MCSS records for all Minnesota residents diagnosed with mesothelioma between 1988 and 1996 were linked to the Minnesota Iron Miner cohort database, to see how many had ever been employed in the mining industry.[6] The records were matched on first, middle and last name, date of birth, and social security number. Any MCSS mesothelioma records that matched to persons in the iron miner database were then manually checked against the Conwed database to see how many also had worked at that facility.

The computerized matches were performed using a probabilistic record linkage program developed by the Minnesota Department of Health (Punyko et al. 1995). This program can be used to identify which individuals from an external database (like the mining cohort) match individuals listed in MCSS.

[6] Because former iron miners could have moved out of the seven counties of northeastern Minnesota, the iron miner database was linked to MCSS records for all Minnesota residents, not just those from northeastern Minnesota.

Determination of mining employment histories for those who developed mesothelioma

Mining jobs held by workers who developed mesothelioma were identified using the Minnesota Iron Miner cohort records. Because of the long latency period for mesothelioma (20 to 40 or more years from exposure to diagnosis), the focus was on the jobs held in the 1940s through the 1970s—the time period during which people who developed mesothelioma between 1988 and 1996 most likely would have been exposed to asbestos.

Determination of possible commercial asbestos exposures in mining occupations

The protocol for determining exposures to commercial asbestos in the mining occupations was established by the Mesothelioma Technical Subcommittee of the ORDIS Advisory Work Group, in conjunction with MDH staff and MDH's consulting Certified Industrial Hygienist[7]. Members of the subcommittee included retired iron miners, mining company industrial hygienists, safety representatives from the United Steelworkers of America (USWA) locals, and a public utility industrial hygienist. (See Acknowledgements.)

The Mesothelioma Technical Subcommittee determined that the best way to gather information about exposures to commercial asbestos in different jobs was to interview persons who held these jobs in the time period of interest (1940s to 1970s). The subcommittee provided technical assistance to MDH staff in the development of a questionnaire that was used to ask workers about potential exposures to commercial asbestos in the different mining jobs. Questions asked about materials handled and tasks that may have involved direct or indirect exposures to asbestos (Fletcher et al., 1993), referring to the work environment as it existed in the 1940s through the 1970s. (See Appendix A for copy of questionnaire.)

MDH assembled a list of 20 job titles for each of the mining companies, to be evaluated for possible exposures to commercial asbestos. Each list consisted of those jobs held by workers from that company, if any, who had been diagnosed with mesothelioma, plus other mining job titles added to make up a total of 20 jobs per company. These extra job titles were included so

[7] Charles McJilton, Ph.D., CIH, while a professor of industrial hygiene at the University of Minnesota School of Public Health, directed the industrial hygiene assessment for the MRHAP study. The assessment included walk-through surveys of all participating mines for the purpose of identifying exposures to total dust, silica and welding fumes. In addition, historical monitoring data were collected to create a profile of past exposures to silica dust and other exposures in different jobs (Sheehy et al., 1986; Sheehy et al., 1987).

that the interviewees and those assessing the jobs could not assume that the job they were reporting on, or evaluating, had been held by a worker who developed mesothelioma.

Potential interviewees were identified by their company and/or their union as persons who either through their employment in the position, or as a supervisor or coworker, had knowledge of a job being studied. The mining companies and associated union offices each submitted separate lists of worker names to MDH. For those companies that were no longer in existence (i.e., Jones & Laughlin), other company and union contacts supplied names of potential interviewees. For those companies currently not unionized (i.e., Northshore, formerly Reserve Mining Company), other USWA locals provided names. MDH staff consolidated the lists and contacted workers by mail to invite them to participate in the interviews. Workers who agreed to participate were mailed a questionnaire. Approximately two weeks later, an MDH interviewer called to go through the questions and collect their answers.

Interviews of current and former miners

From the fall of 2000 through the spring of 2001, MDH staff interviewed iron miners (both current workers and retirees) to find out whether their jobs may have involved exposure to commercial asbestos. More than 350 telephone interviews were conducted covering 122 different job titles. Ninety-six percent of the respondents had experience in the job they reported on, while the remaining 4 percent were coworkers and/or supervisors. An attempt was made to interview at least three persons per job title.

Review of interviews to determine possible asbestos exposures in mining jobs

The interviews were then summarized by MDH's consulting certified industrial hygienist who examined the interview responses and used them to assign an initial rating of the likelihood (low vs. high) and intensity (low vs. high) of exposure to commercial asbestos for each job.

An assessment panel for each company was convened to make the final exposure determinations for the 20 jobs from each company. Each panel consisted of knowledgeable union and

management representatives, plus a non-mining industrial hygienist or safety engineer.[8] The panels used the summaries, the interview responses (with identifying information removed), available job descriptions from the relevant time period, and their own knowledge of the mining environment to estimate the potential for exposure to commercial asbestos in each of the jobs. The panels considered regular (everyday) and shutdown[9] responsibilities separately, and rated the jobs as exposed (high likelihood/high intensity; high likelihood/low intensity; low likelihood/high intensity or low likelihood/low intensity), not exposed, or unknown exposure. See Appendix B for a copy of the assessment form used by the panels. When no interviews were available (i.e., no interviewees could be found), the panels made determinations using other information (e.g., job descriptions and their own knowledge). If no determination could be made, the potential for exposure was marked unknown.

Determination of non-mining employment histories and possible asbestos exposures

An effort was made to identify non-mining jobs held by the miners who developed mesothelioma since these jobs could also have involved exposure to commercial asbestos. MDH staff used employment applications included in the iron miner records, workers compensation claim records, and newspaper death notices. The extent of available information about non-mining industry jobs varied by individual. Other studies of asbestos-exposed occupations were then reviewed to determine which of the non-mining jobs, if any, could have involved exposure to commercial asbestos. Any Conwed job was considered as having potential asbestos exposure. A final review of these jobs was provided by MDH's consulting industrial hygienist.

[8] Because Jones & Laughlin closed in the 1980s, no union or management representatives were available. Exposure determinations were based solely on a review of available interviews by MDH's consulting industrial hygienist. We were unable to secure a management representative for the Erie Mining Company panel due to the closure of LTV Mining Company (Erie's successor) in 2001.

[9] Shutdowns are scheduled periods (often weeks) when regular processing at a mining operation stops so that equipment can be retooled or maintained. Workers may change jobs or even move to a different facility to perform shutdown duties (usually maintenance work). Thus, shutdown responsibilities and the related work environment generally differ from the usual work for an individual.

RESULTS

Description of iron miners diagnosed with mesothelioma

Of the 340 male Minnesota residents diagnosed with mesothelioma between 1988 and 1996, 17 were found to have worked in the iron mining industry (i.e., were included in the Minnesota Iron Miner Cohort). Two of the 17 also worked at Conwed. None of the 92 female Minnesotans diagnosed with mesothelioma between 1988 and 1996 were found in the iron miner cohort. No information is available on individuals who may have been diagnosed with mesothelioma while residing out of state or before 1988 or after 1996.

The age at diagnosis for the 17 males ranged from 55 to 82. Fifteen (88%) were diagnosed with pleural mesothelioma (mesothelioma that developed in the chest cavity) while two (12%) were diagnosed with peritoneal mesothelioma (developed in the abdomen).

Three of the 17 miners (18%) were diagnosed while residing outside of the seven-county region of northeastern Minnesota. It is not unexpected that some individuals would have moved out of northeastern Minnesota in the years following their employment in the mining industry

Occupational histories of the iron miners diagnosed with mesothelioma

The number of different iron mining jobs held by each of the 17 men varied, as did the length of their employment in the industry, ranging from 2 months to 40 years. They worked for mining operations across the Iron Range, with only 4 of the 17 known to have changed jobs between mining companies. In addition, 5 of the 17 worked exclusively in hematite operations; there was no evidence that they had ever worked for a taconite operation.

With the addition of known non-mining jobs, the extent of the employment history documented for these individuals ranges from 5 to 60 years. The years of their employment range from the 1930s through the 1980s. Complete job histories for the relevant exposure period for 10 of the 17 cases were available for analysis (Table 2).

Table 2. Completeness of occupational histories obtained for iron mining employees who developed mesothelioma

Completeness of occupational histories obtained	No.
Complete (entire work history)	7
Complete for 20-40 year period prior to diagnosis	3
Missing up to 5 years in 20-40 year period prior to diagnosis	4
Complete, but specific years for some occupations are unknown	1
Job title for significant time period is unknown (employer known)	1
Incomplete (have work history only up to age 26)	1

Table 3 lists the mining occupations held by the 17 iron miners who developed mesothelioma between 1988 and 1996. The mining jobs (and non-mining jobs) are not shown for each individual separately since this may have allowed identification of individual study subjects—a violation of state data privacy statutes. Because of the long latency period for mesothelioma, only those jobs held 20 or more years prior to diagnosis are included. Also listed are estimates of the likelihood that a particular occupation involved exposure to commercial asbestos. The estimates for the mining occupations came from the exposure assessment panels described previously. For jobs in which no panel estimate was available, (i.e., the Jones & Laughlin jobs), estimates from MDH's consulting industrial hygienist were used. If there were no interviews completed for a particular job and no panel estimate, the likelihood was marked unknown. All mining occupations were located at taconite operations unless otherwise specified. From one to six of the job titles were held by any one individual.

For the purposes of readability, the panel exposure estimates in Table 3 are expressed in terms of "probable" and "possible" likelihood of exposure. Probable was used when the panel exposure estimate was one of the following: high likelihood/high intensity; high likelihood/low intensity or low likelihood/high intensity. Possible is used when panel exposure estimate was low likelihood/low intensity. (Refer to page 20 and Appendix B for details about the assessment panel exposure estimates.) Similar or identical job titles may have different exposure assessments due to several possible factors: the jobs may have been at different companies or at different time periods. Also, different assessment panels participated for different companies.

All of the non-mining occupations held by these individuals are listed together in Table 4. The exposure estimates for the non-mining occupations come from studies found in the occupational health literature, which are noted in the table, plus review by the consulting industrial hygienist.

Table 3. Mining occupations held 20 or more years prior to diagnosis for iron mining employees who developed mesothelioma and corresponding likelihood of exposure to commercial asbestos

Mining Occupations+	Likelihood of Exposure	Length of Employment	Comments
Assistant foreman-mechanical	Probable	1-10 yrs.	
Auto mechanic helper*	Probable	1-10 yrs.	
Carpenter foreman	Probable	>10 yrs.	
General laborer*	Probable	1-10 yrs.	
Labor-agglomerating	Probable	>10 yrs.	
Locomotive fireman*	Probable	< 1 yr.	
Locomotive fireman*	Probable	< 1 yr.	
Maintenance mechanic	Probable	1-10 yrs.	
Maintenance mechanic	Probable	< 1 yr.	
Maintenance mechanic general*	Probable	1-10 yrs.	
Plumber	Probable	1-10 yrs.	
Shovel oiler	Probable	>10 yrs.	
Warehouseman	Probable	>10 yrs.	Cut asbestos sheets.
Drill helper*	Possible	1-10 yrs.	
Drill operator	Possible	>10 yrs.	Exposures possible during shutdowns, not regular activities.
Engineering technician-concentrator	Possible	1-10 yrs.	Asbestos was removed from concentrator area (pipe covering and fittings) in 1990s, per abatement records
Furnace operator	Possible	>10 yrs.	
Locomotive brakeman*	Possible	< 1 yr.	Very low generation of fibers, per panel
Mechanic Helper (shops)*	Possible	< 1 yr.	
Shovel oiler*	Possible	< 1 yr.	
Shovel operator	Possible	>10 yrs.	
Tractor operator	Possible	>10 yrs.	
Truck driver*	Possible	1-10 yrs.	Exposures possible during shutdowns, not regular activities.
Truck driver*	Possible	>10 yrs.	

*Job in a hematite mine operation

+Similar or identical job titles may have different exposure estimates because they may have been at different mining operations and/or at different time periods.

Table 3. Mining occupations held 20 or more years prior to diagnosis for iron mining employees who developed mesothelioma and corresponding likelihood of exposure to commercial asbestos (continued)

Mining Occupations+	Likelihood of Exposure	Length of Employment	Comments
Assistant engineer	Unknown	1-10 yrs.	
Blaster helper*	Unknown	< 1 yr.	Pit position
Drill helper*	Unknown	< 1 yr.	Could have been exposures during shutdowns, but unknown if this is relevant to this hematite operation.
Drill helper*	Unknown	< 1 yr.	
Dumpman*	Unknown	< 1 yr.	
General laborer*	Unknown	< 1 yr.	Unknown if pit or plant laborer.
General laborer*	Unknown	< 1 yr.	Unknown if pit or plant laborer.
General laborer*	Unknown	< 1 yr.	Unknown if pit or plant laborer.
General laborer*	Unknown	< 1 yr.	
Oiler, ore shipping	Unknown	1-10 yrs.	
Scraper operator*	Unknown	< 1 yr.	
Driller*	No	1-10 yrs.	
Driller exploration*	No	1-10 yrs.	
Dumpman*	No	< 1 yr.	
General laborer-Shops (Auto)*	No	< 1 yr.	
Instrument man, surveying	No	1-10 yrs.	Contract worker
Laborer (shops)*	No	< 1 yr.	
Locomotive trainman – switching	No	>10 yrs.	Worked with diesel engine trains (not steam engines which may have involved exposures to commercial asbestos).
Rail track layer*	No	< 1 yr.	
Sampler*	No	< 1 yr.	
Scrammer*	No	< 1 yr.	Underground mine position
Switchman*	No	< 1 yr.	
Track laborer	No	1-10 yrs.	
Track laborer*	No	< 1 yr.	
Trackman*	No	1-10 yrs.	
Trackman*	No	< 1 yr.	
Truck driver*	No	< 1 yr.	
Truck driver*	No	< 1 yr.	

*Job in a hematite mine operation

+Similar or identical job titles may have different exposure estimates because they may have been at different mining operations and/or at different time periods.

Table 4. Non-mining occupations held by iron mining employees who developed mesothelioma and corresponding likelihood of exposure to commercial asbestos

Non-Mining Occupation	Likelihood of exposure	Comments
Boiler operator, US Navy	Probable	(McDonald et al., 1980; Selikoff et al. 1990; Muscat et al., 1991; Peto et al. 1995; Teschke et al. 1997)
Conwed	Probable	(Minnesota Department of Health 1989)
Engineer, steamship company	Probable	
Fireman's helper, public utility	Probable	City used steam heat; (McDonald et al., 1980; Selikoff et al. 1990; Muscat et al., 1991; Peto et al. 1995; Teschke et al. 1997)
Plumber	Probable	(Englund 1995; Peto et al. 1995; Teschke et al. 1997)
Private construction	Probable	(Huncharek 1992)
Sheet metal worker, construction industry	Probable	(Michaels and Zoloth 1988)
Steam fireman, public utility	Probable	(McDonald et al., 1980; Selikoff et al. 1990; Muscat and Wynder 1991; Peto et al. 1995; Teschke et al. 1997)
Carpenter	Possible	
Construction engineer	Possible	(Huncharek 1992)
Construction, surveying	Possible	(Huncharek 1992)
Contractor, construction company	Possible	Work included plastering. (Huncharek 1992)
Machine repair	Possible	
Maintenance department, school district	Possible	(Anderson et al. 1991)
Manufacturer of construction materials - concrete	Possible	(Albin et al. 1990)
Railroad engineer, maintenance & construction	Possible	(Schenker et al. 1986; Mancuso 1991)
Conveyor belt repairman	Unknown	
Driver, US Army	Unknown	
Instrument man, engineering company	Unknown	
Military service	Unknown	
Railroad engineer and surveyor	Unknown	Tenure included steam era; (Schenker et al. 1986; Mancuso 1991)
Sampler, laboratory	Unknown	
Track maintenance, labor & construction	Unknown	Tenure included steam era; (Schenker et al. 1986; Mancuso 1991)

Table 4. Non-mining occupations held by iron mining employees who developed mesothelioma and corresponding likelihood of exposure to commercial asbestos (continued)

Non-Mining Occupation	Likelihood of exposure	Comments
US Army	Unknown	
Aviation cadet & air navigator, US Naval Reserve	No	
Bulldozer operator	No	
Bus driver	No	
City engineer/building inspector	No	
Crusher house attendant	No	It is not clear whether this job, held in 1949, was at an iron mining operation.
Deck hand	No	
Ensign, Coast Guard	No	
Farmer/farm worker	No	
Industrial sales representative	No	
Instrument man & inspector, Highway department	No	
Laborer, match manufacturing industry	No	
National Guard	No	
Shovel oiler & operator	No	
Yard work, manufacturing company	No	

Eleven of the 17 miners with mesothelioma were employed in occupations in which a probable source of exposure to commercial asbestos could be identified. Another three of the 17 had possible sources of exposure to commercial asbestos. For these 14 individuals, the time between the period of employment in these "high risk" occupations and the diagnosis of mesothelioma is consistent with the latency period (greater than 20 years) that has been observed in other studies of this cancer. As shown in Table 3, some of these "high risk" occupations are common to many industries, such as plumbing, carpentry, boiler operation, and maintenance work.

Table 5. Summary of estimated exposures to commercial asbestos 20 or more years prior to diagnosis for iron mining employees who developed mesothelioma

Likelihood of exposure to commercial asbestos	Total No.	Non-Mining# only	Mining* only	Both Mining and Non-Mining+
Probable	11	3	4	4
Possible	3	1	0	2
None Identified	1	-	-	-
Unknown due to incomplete job histories	2	-	-	-

#Exposure in non-mining occupation(s) held by worker
*Exposure in mining occupation(s) held by worker
+Exposure in both mining and non-mining occupations held by worker

There was only one subject for whom no source of exposure to commercial asbestos was identified; the entire work history was available for him, but none of the jobs, mining or non-mining, appeared to have involved exposure to commercial asbestos.

The source of exposure could not be determined for the two subjects with incomplete job histories. For one subject, the job titles were missing for a significant portion of the individual's employment with a mining company. For the other subject, only jobs held up to age 26 could be identified; information about his subsequent employment comes from his death certificate, which indicates that his "usual occupation" was with a manufacturing company.

The estimated exposures for the 17 are summarized in Table 5. To make the table more readable, the 2 individuals who had a mining job that involved possible exposure and a non-mining job that involved probable exposure were counted as “non-mining—probable”. The reverse would also have been true (probable mining exposure and possible non-mining exposure counted as “mining—probable”); however, none of the subjects fit this category. Of the 14 who held occupations in which exposure to commercial asbestos was possible or probable, mining occupations were the only identified source for 4; non-mining occupations were the only identified source for 4; and both mining and non-mining occupations were identified for 6.

DISCUSSION

This study was a collaborative effort between the Minnesota Department of Health and the ORDIS Advisory Work Group. The Mesothelioma Technical Subcommittee of the Advisory Work Group worked with MDH to develop the study protocol, questionnaire and exposure assessment forms, and served on exposure assessment panels. Members also provided names of the union and mining company contacts who, in turn, provided names of miners for the interviews. The information gained from this effort, along with other information identified by MDH, were then analyzed and interpreted by MDH staff in developing the overall conclusions.

Commercial Asbestos Exposures Among Iron Miners who Developed Mesothelioma

This study identified 17 miners who were diagnosed with mesothelioma. While the mesothelioma risk among miners is not solely attributable to exposures within the mining workplace, this finding is in sharp contrast to previously published death certificate-based studies of taconite miners that have not found mesotheliomas or excesses of other respiratory diseases. (Mesotheliomas are often coded on death certificates as other cancers; the mesotheliomas were identified in this study through the Minnesota Cancer Surveillance System.) This finding, along with the results of the exposure assessment, demonstrates that exposure to asbestos has occurred in the iron mining industry during previous decades. Because of the long latency of asbestos-related diseases, these risks will continue into the future even in the absence of ongoing exposures. (See Appendix C for more information on asbestos and the workplace.)

For 2 of the 17 miners who had developed mesothelioma, a potential source of exposure could not be determined because the jobs they held for significant portions of their job histories are unknown. For the other 15 miners, occupational histories were sufficiently complete to allow evaluation of potential exposures to commercial asbestos. One of the 15 had no apparent occupational exposures to commercial asbestos based on the occupational information that was available. Fourteen of the 15 had potential sources of exposure to commercial asbestos: 11 had a *probable* source of exposure to commercial asbestos and another 3 had a *possible* source of exposure to commercial asbestos.

Potential exposures were found in both mining industry and non-mining industry occupations. Of the 14 with at least a potential exposure, 4 involved mining jobs only, 4 were non-mining jobs only, and 6 involved both mining and non-mining jobs. Many of the asbestos-exposed occupations were common to both mining and non-mining industries, such as plumbing, carpentry, boiler operation, and maintenance work. The time between employment in these asbestos-exposed occupations and the diagnosis of mesothelioma is consistent with the 20 or more year latency period that has been observed in other studies of this cancer.

Additional Observations and Conclusions

Several additional observations are useful in interpreting these findings. The 17 iron miners who developed mesothelioma worked at mines across the Iron Range (i.e., not only at East Range operations where asbestos-like fibers may occur in the taconite). Also, 5 of the 17 appear to have worked only at hematite operations (presumably where they would not have been exposed to taconite dust). Added information comes from a study of exposures to silica in the taconite industry done in the early 1980s (Sheehy 1986). (This study was part of the MRHAP effort and took place at the same time as the development of the iron miner database.) In the mines he studied, Sheehy reported that the job titles with the highest exposures to respirable dust (at specific operations) were: pellet plant welder, fine crusher oiler, coarse crusher laborer, and coarse crusher maintenance mechanic. The job titles with the next three highest exposures (at specific operations) were: pellet laborer, roll feed attendant, filter attendant. If respirable dust is considered an indicator for exposure to "asbestos-like fibers" in the taconite dust, and if the fibers act like other forms of asbestos, then one might expect to see these job titles in the histories of those who developed mesothelioma. Of the 17 iron miners, only one potentially[10] held one of these “high dust exposure” jobs (in the crusher department) for several months some 40 years prior to the diagnosis of mesothelioma.

Had none or few of the 17 iron miners with mesothelioma had any potential exposures to commercial asbestos in their work and mostly held mining jobs with the highest taconite dust exposure, exposure to asbestos-like fibers in the taconite dust would have been a plausible

[10] It is uncertain whether this job was at an iron-mining company since it was not listed in his mining employment history.

explanation for their mesothelioma. The findings point to a different explanation. It was found that: (a) 14 of the 15 iron miners (for whom a sufficient occupational history was available to make a judgment) had jobs with potential exposures to commercial asbestos, (b) these jobs were held at least 20 years or more prior to diagnosis, and (c) only one miner could be identified as having potentially held any of the highest silica-dust exposure job titles. The explanation most consistent with these findings is that commercial asbestos exposure, rather than taconite dust, is the most likely cause for the occurrence of mesothelioma in men employed in the mining industry. However, at least one miner had no obvious source of exposure to commercial asbestos and other causes cannot be ruled out.

Mesothelioma in Northeastern Minnesota

The mesothelioma study was designed to determine how many iron miners had developed mesothelioma (anywhere in the state) and to what extent potential exposures to commercial asbestos could be identified from their job histories. The study was not designed to account for all cases of mesothelioma in northeastern Minnesota and identify potential sources of asbestos exposure. That would have required contacting all families of mesothelioma cases (and perhaps other individuals) in northeastern Minnesota to obtain work histories. However, this study and previous investigations of former Conwed Corporation employees provide a likely explanation for the 73% excess of mesothelioma among men in northeastern Minnesota. There were 54 cases of mesothelioma diagnosed among men residing in northeastern Minnesota during the period 1988 through 1996, representing an excess of 23 cases over the expected number of 31. Among miners, 14 of the 17 mesothelioma cases were among miners residing in northeastern Minnesota; among former Conwed workers, 9 of 11 mesotheliomas were among workers residing in northeastern Minnesota. Removing the two cases among miners who had also worked at Conwed, these two industries are associated with 21 cases. Consequently, the excess of mesothelioma could be largely (if not completely) explained by these two industries that are unique to this region of the state. (See Appendix F for the most recent update on mesothelioma in northeastern Minnesota.)

Limitations and Strengths of this Study

This study has several limitations as well as several strengths. The major limitation of this study was the assessment of previous commercial asbestos exposure. This assessment was based on job titles and occupational histories – not actual monitoring data – and utilized existing records. Study protocols did not allow MDH staff to contact next of kin to gain more information about the work histories and potential exposures of the 17 individuals diagnosed with mesothelioma who worked in the mining industry. Complete work histories were not found for 2 of the 17. For one case, documentation only up to age 26 was available. The occupation and industry listed on the death certificate provide more clues as to what an individual was doing before he died/retired (and provide confirmation of occupation for those with complete work histories). However, the individual's "usual occupation/industry" is not necessarily the job held more than 20 years before diagnosis of cancer.

Complete information may or may not have been found regarding an individual's work outside of the mining industry. This depended on whether the prior work history was included in their employment records, or was available through other sources (e.g., death notices). In addition, nothing was known about any non-occupational asbestos exposures (e.g., hobbies, home environment, spouse's or parental occupational exposures).

Quantitative exposure data on which to base the assignment of probable asbestos exposure were not available. Even with qualitative exposure estimates, assumptions were made that a particular job title in a particular year at a particular mine conferred a particular probability of exposure. In addition, nothing was known about possible use of personal protective equipment.

The Mesothelioma Technical Subcommittee deliberated over the difficult issue of what constitutes a biologically significant or meaningful exposure to commercial asbestos. This was necessary to develop criteria for use by the assessment panels, to make sure that they were making consistent decisions on the likelihood and intensity of exposure to asbestos in different jobs. The subcommittee chose to focus on identifiable sources of exposure, as opposed to the plant environment as a whole. They also decided to consider regular tasks and shutdown tasks separately since they could potentially have involved quite different exposures. For the final

determinations in Table 3, low likelihood/low intensity exposures were classified as possible exposures and all other categories (i.e., low likelihood/high intensity, high likelihood/low intensity and high likelihood/high intensity) were classified as probable exposures.

This study was a detailed evaluation of individuals known to MDH investigators. Such a study, often referred to as a case study, has attendant limitations. The possibility that those known to investigators differ from those (if any) not included in the study findings and the inability to compare findings to other non-affected workers are inherent limitations of case studies.

There may be individuals with mesothelioma who worked in the mining industry but were not included in the present investigation because they were not included in the mining cohort. The mining cohort is not an all-inclusive list of mining industry employees. This cohort includes only persons employed by the seven taconite and hematite mining companies that participated in the MRHAP study. Not all mines in northeastern Minnesota were included (e.g., underground mines). Not all occupations within a mine were included (e.g., certain salaried occupations). However, a search of the death certificates for all 432 Minnesota mesothelioma cases from the years 1988 to 1996 reveals only two more with an occupation and industry listed that are potentially related to iron mining: “shop foreman/steel industry” and “truck driver/mining industry”. Notwithstanding the limitations of usual occupation and industry information from death certificates, this shows that the number of iron miners missed is likely to be small.

On the other hand, there may be iron miners in the iron miner database who developed mesothelioma, but were not included in the state's cancer registry. Statewide cancer data were available for this study for the years 1988 (the first year of MCSS) through 1996 (the most recent year at the start of this study). People diagnosed before or after that nine-year period would not have been included. In addition, MCSS collects information on cancer incidence only for Minnesota residents; miners who resided out of state at the time of diagnosis would not have been included in the MCSS data.

Finally, this study did not include “control” subjects to which the mesothelioma subjects could be compared in terms of job histories and other factors. However, as previously noted, randomly

selected job titles were added to the list of jobs held by mesothelioma cases for each company, and the assessment panels did not know whether any specific job title had been held by an individual diagnosed with mesothelioma.

Despite these limitations, this study has several strengths. First, a major strength is this study's use of cancer registry data, rather than mortality records, to identify all mesothelioma cases in the state. MCSS data comes from the pathology reports and clinical records confirming that a cancer has been diagnosed. Quality control studies confirm the completeness and accuracy of these data. In contrast, death certificate based studies will likely miss many, if not most, cases of mesothelioma that are often coded to other causes of death (such as lung cancer). It was found, for example, that only one of the 17 mesotheliomas among miners and only one of the 11 mesotheliomas among Conwed workers would have been detected by the usual cause-of-death codes from death certificates (despite the fact that most of the death certificates had some mention of mesothelioma on the death certificate itself).

A second strength is the study's use of the previously established Minnesota Iron Miner Cohort. Because of study legislative restrictions, MDH staff could not contact those diagnosed with mesothelioma or their next of kin. Without the mining cohort information it would have been much more difficult and much less accurate to determine whether persons diagnosed with mesothelioma had ever worked in the mining industry. Computerized comparisons between cancer registry data and the 72,000-record mining cohort allowed for the identification of the 17 miners who had developed mesothelioma. Mining cohort data also provided most of the information about the job titles and dates of employment for the study subjects.

Finally, the involvement of the Commissioner's Advisory Work Group provided MDH with information that was vital to the satisfactory completion of this study. With the collaboration between labor and industry in the development of the protocol for this study, MDH was able to interview current and former iron miners about exposures to commercial asbestos in their jobs, in a way that ensured the confidentiality of their responses. In addition, the use of assessment panels consisting of mining company, labor and other industrial hygiene/safety professionals

brought the most knowledgeable people together to make the best assessments with the available information.

HEALTH ISSUES NOT ADDRESSED BY THIS STUDY

As noted previously in this report, there is a long history of health issues and concerns related to the iron mining industry. Many previous studies and investigations—epidemiological and otherwise—have been conducted to address specific issues. For example, the establishment of a regional cancer surveillance system in northeastern Minnesota in the 1970s (a decade before statewide cancer surveillance) was designed to address concerns about digestive system cancers in association with fibers in the Duluth water supply. While each epidemiological study will have varying degrees of success in answering specific questions (depending on resources, available data, design, etc.), a single epidemiological study is necessarily very limited in its conclusions and often raises or leaves open many related health issues.

The excess of mesothelioma among men in northeastern Minnesota was a significant public health finding leading, in part, to legislative support for ORDIS. Consequently, one of the objectives of ORDIS was to investigate the mesothelioma excess and its possible link to the iron mining industry. (The development of methods to track occupational respiratory diseases was the major and long-term objective of ORDIS.) The present study was designed to answer two specific questions about mesothelioma: (a) to what extent, if any, have mesotheliomas occurred among former employees in the iron mining industry, and (b) to what extent were exposures to commercial asbestos associated with miners who had subsequently developed mesothelioma. The existence of statewide cancer data and the roster of 72,000 former iron miners enabled identification of 17 miners who had developed mesothelioma in Minnesota during a nine-year period. For the 15 miners who developed mesothelioma and for whom sufficient occupational histories were available from existing records, 14 had an identifiable source of exposure to commercial asbestos.

While these findings establish that miners are at some risk of mesothelioma and that past exposure to commercial asbestos is a likely explanation, this study does not address other significant health questions. In particular, this study does not address the morbidity and mortality among iron miners from all types of cancer or respiratory diseases, nor does it attempt to address potential health risks from exposures to respirable mineral dusts from taconite ore and

its processing (silica, taconite, cummingtonite-grunerite, etc.). As described below, different study protocols would be required to address these questions.

To determine if iron miners are at increased risk of death from various types of cancer, respiratory diseases (asbestosis, silicosis, etc.) or other causes, a **follow-up mortality study** would be required. Using the Minnesota Iron Miner Cohort, for example, a complete enumeration of all deaths among this cohort would be determined, including the causes of death. This would include all deaths whether they occurred in Minnesota or elsewhere. Death rates among miners would be compared to rates in the overall population and could be examined for various years, locations, length of employment, and other factors. If death rates were found to be significantly higher among miners for specific causes (e.g. asbestosis), detailed work histories and exposure assessments of these cases could be compared to miners who died of other causes. Previous mortality studies of taconite workers from three of the mines have not shown excesses of cancer deaths (Higgins et al. 1983; Cooper et al. 1988; Cooper et al. 1992). However, the numbers of workers in these studies with an adequate length of follow-up may not have been adequate for diseases with long latency. One study of gold miners with at least 5 years of exposure to cummingtonite-grunerite has shown excess risk of mortality due to respiratory cancer and non-malignant respiratory disease (Gillam et al. 1976); while another study of workers at the same mine with more than 20 years of experience did not find these excesses (McDonald et al. 1978).

Mortality studies will miss non-fatal conditions and diseases, which may represent a substantial burden of disease. Even some fatal diseases, such as mesothelioma, may be coded with insufficient specificity. Mortality studies typically do not have information on smoking, job histories outside of the industry under study, and other important factors that need to be accounted for in interpreting study findings. For dust-related respiratory diseases, **medical screening studies** are likely to reveal a more complete and more timely picture of respiratory morbidity. For example, a medical screening study in 1988 for asbestos-related diseases in 1,552 former Conwed workers and spouses consisted of a breathing test, a chest X-ray, a physical exam, and an interview which included questions about the worker's medical history, smoking history and job history. This screening revealed that approximately one in four workers (but not

spouses) had lung abnormalities consistent with asbestos exposure. These outcomes are much more prevalent among asbestos-exposed populations than fatalities from asbestosis or cancer. A previously published morbidity study of taconite workers found limited evidence of respiratory morbidity, although this study included relatively few subjects (Clark et al. 1980).

ONGOING MONITORING OF CANCER RATES BY MCSS

The MCSS will continue to monitor mesothelioma and other cancer rates among men and women in northeastern Minnesota as additional data become available. These data will be reported to local public health officials, industry and union officials, community leaders, and any other interested parties.

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