An investigation into radiographic findings in Northeastern Minnesota:

Background, supporting data, conclusions and recommendations

September, 1985

Minnesota Department of Health

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I. Introduction and Summary

In January 1985, a physician contacted the Minnesota Department of Health (MDH) to report an apparent excess of pulmonary abnormalities in his Northeastern Minnesota clinic population. One of the abnormalities reported, pleural plaquing, results from exposure to fibrous material, most notably asbestos. The possibility of an excess of asbestos exposure was cause for concern as exposure is associated with an increased incidence of several diseases including asbestosis, lung cancer, and malignant mesothelioma. (Appendix A contains a summary of the diseases associated with asbestos exposure).

An investigation was initiated by MDH in response to this report. All existing data which might help resolve the issue were compiled and analyzed. To assist the MDH in addressing this potential problem, a Range Studies Advisory Committee composed of internationally respected scientists was established. This Committee reviewed available data and made several recommendations.

This report presents the data collected as part of the investigation. The text of the report contains a summary of (1) pertinent background information, (2) the chronology of events in the investigation, (3) the information presented to the Range Studies Advisory Committee and (4) the recommendations made by this Committee and the rationale behind these recommendations. The appendices contain the detailed information, e.g. tables and graphs, summarized in the text.

II. Background Information and Chronology of Events

On January 24, 1985, Ronald P. Seningen, M.D. contacted the MDH and was referred to Alan P. Bender, D.V.M., Ph.D., Chief of the Chronic Disease Epidemiology Section. Dr. Seningen reported an apparent excess of radiographic abnormalities in patients in his practice at the East Range Clinics in Virginia and Aurora. He had noted abnormal areas of thickening of the pleura, the thin membrane which surrounds the lungs.

Pulmonary changes can occur in the parenchyma (lung tissue) or on the pleura. Radiographic examination of the lungs is the primary tool for the assessment of these pulmonary changes. Radiographs are often able to demonstrate pleural and parenchymal changes that are not evident upon physical exam and that do not cause any disability in the patient. Consistent with this, many of the patients found to have pleural changes in this investigation were asymptomatic. The presence of radiographic changes, therefore, is not synonymous with the presence of clinical disease, although the patient with these changes might be more likely to develop disease than a patient without these changes.

As previously noted, exposure to certain asbestiform fibers (e.g. asbestos) is associated with an increased incidence of several diseases including asbestosis, lung cancer and malignant mesothelioma. Asbestosis is one of a group of diseases called the pneumoconioses. The pneumoconioses result from many types of dust exposure and are often characterized by parenchymal fibrosis (replacement of normal lung tissue by scar tissue). The pulmonary changes and clinical presentation of these different diseases can vary. Examples of other pneumoconioses are black lung disease (coal miners pneumoconiosis), and silicosis. In addition, some of the changes associated with a pneumoconiosis are also seen with other non-dust related diseases.

Dr. Seningen, the radiologist who reported the pleural changes, is a B reader, a physician who has received specialized training in the radiographic detection of the pneumoconioses. B reader certification was established in an effort to standardize the radiographic interpretation and documentation of this group of diseases. The National Institute of Occupational Safety and Health (NIOSH) is currently the certifying agency in the United States.

Following the report of abnormal radiographic findings, Dr. Bender and David Parker, M.D., M.P.H., visited Dr. Seningen and reviewed his findings. During this visit, it became apparent that further evaluation of the radiographic findings was indicated in order to validate Dr. Seningen's observations.

Arrangements were made for Thomas Hodous, M.D., a B reader from NIOSH in Morgantown, West Virginia, and pulmonary physician at the University of West Virginia Medical School, to evaluate the x-ray findings in Virginia and to evaluate a sample of radiographs from several other clinics in Grand Rapids, Hibbing, and Duluth. Radiographs from these other three areas were to be used as "controls" to compare the significance of the Virginia findings and to determine if the radiographic changes were present in other clinic populations. While Dr. Hodous reviewed the films a team from the MDH abstracted basic demographic information (e.g., age and sex) from the patient's medical record. Occupational data was abstracted when available. Analysis of Dr. Hodous' review provisionally confirmed Dr. Seningen's findings and surprisingly indicated similar findings at the other clinics.

Further consultation with national experts indicated that two positive B readings for pleural thickening was considered to be evidence for chronic asbestos exposure. Because of the importance of these findings it was decided that additional review of the films was warranted. Dr. Ruth Lilis, a pulmonary specialist and experienced B reader from the Environmental Sciences Laboratory at Mt. Sinai in New York, was contacted and arrangements made for her to read the films in Minnesota. These arrangements were cancelled at the last minute because of Dr. Lilis' health.

On March 2, 1985, a news conference was held at the request of Governor Perpich. Although the findings at this point were preliminary, Governor Perpich wanted to prevent a fragmented and perhaps distorted release of the investigation to the public. At the news conference, the findings to date, including the two X-ray reviews and both cancer incidence and mortality data, were presented and media questions were answered.

Following the news conference, plans were made for additional radiographic reviews. A decision was made to send the films to Dr. Lilis in New York for evaluation. This would allow Dr. Lilis as much time to review the films as necessary and would be less disruptive to the clinics involved. The films were copied, the copies were returned to the clinics and the originals were sent to New York by courier. Following Dr. Lilis' review, the films were transported to NIOSH in Morgantown, West Virginia, to be evaluated by a panel of five expert B readers in a blinded fashion. The x-ray numbers and clinic names were masked to prevent their identification by the reviewers. The films were then added to a set of equivalently masked previously read films from around the country. Each film was read by three of the five panel members.

With the guidance of Dr. Lester Breslow, Chairman, National Academy of Sciences Committee on the Health Risks of Asbestiform Fibers and Dean Emeritus, UCLA School of Public Health, the MDH established the Range Studies Advisory Committee composed of internationally respected scientists. This committee met at the MDH, April 11-12, to review all the data available related to this issue and to make recommendations for further study if warranted. The membership of this committee, along with a more detailed description of events leading up to this meeting, is included in Appendix B.

Three different types of data were presented to the Committee. First, cancer morbidity and mortality data were presented to compare the Iron Range population's cancer experience to that of several other populations. Environmental monitoring data showing airborne fiber levels in the Range communities was also presented. Third, the results of the radiographic reviews were presented. These data, and their implications, are summarized in the following sections.

III. Cancer Morbidity Data

In Minnesota there are several sources of cancer morbidity (incidence) data. From 1969-1976 cancer incidence data was collected in St. Louis, Lake, and Cook Counties as part of the Tri-county Cancer Incidence Study. Data collection for these counties ended in 1976 but continued through 1980 for the city of Duluth. Incidence rates from 1969-1976 for Virginia were available from this study. More recent data is not presently available. Cancer incidence data was collected in Minneapolis-St. Paul from 1969-1971 as part of the Third National Cancer Survey (TNCS). Information on regional and state incidence rates outside of Minnesota was available from a National Cancer Institute program called Surveillance, Epidemiology and End Results (SEER). Morbidity rates from these data, gathered from 10 cancer registries throughout the U.S., can be used as a comparison for Minnesota morbidity rates.

Several different incidence rates were examined. The number of cases of cancer (all sites combined) for Virginia during 1969-76 was comparable to or statistically below the incidence found in 5 comparison populations (Appendix C). The observed number of respiratory cancers, including lung, was comparable to or below the number expected based on the same 5 comparison populations. The incidence of malignant mesothelioma in St. Louis, Cook, or Lake Counties, ascertained from the Minnesota Tri-County data, was comparable to the incidence reported in the SEER data (1973-1980) (Appendix D).

IV. Mortality Data

Mortality information was available from the Minnesota Department of Health, Center for Health Statistics. To compare cancer mortality in St. Louis County and in Virginia to the state as a whole, the observed number of deaths was compared to the number expected if St. Louis County or Virginia had the same mortality rates as the entire state. These two numbers are expressed as a ratio (observed/expected) and referred to as the Standardized Mortality Ratio (SMR). An SMR of 1 indicates that the observed number of deaths is comparable to the expected number, an SMR greater than 1 implies an excess number of deaths among the population of interest (observed) relative to the comparison population, an SMR less than 1 implies there were fewer deaths than expected in the population of interest. An SMR was calculated for all cancer sites and for respiratory cancers alone, for both males and females (Appendix C). The SMR in males, for all cancers, was somewhat elevated in Virginia, however, for respiratory cancers it was not elevated. None of the other ratios examined indicated an increase in cancer deaths in these two areas.

Neither the mortality data nor the morbidity data showed a consistent upward trend in rates which might indicate an increase in cancer occurrence in the Range population at this time. The available incidence rates for respiratory cancer and mesothelioma, are comparable to those expected based on several comparison populations. Although there did appear to be an increase in the all cancer mortality rate for males in Virginia, this increase did not carry over into the more biologically plausible respiratory cancer mortality rate. If ambient dusts (asbestos) were a generalized problem and if sufficient length of exposure has occurred, an increase in cancers of the respiratory system would be expected. The morbidity data also did not reflect this apparent increase. It is very possible that the increase in total cancers is a result of normal random variation in a relatively small population.

V. Environmental Monitoring Data

Over the last 10-15 years environmental monitoring of both the air and water for mineral fibers in Northeastern Minnesota and the Mesabi Range has been done. Much of this was initiated in response to public concern about unsafe fiber levels in the air and water due to mining operations in the area. Only the air monitoring data were presented to the committee because of the relevance of these data to the possible increase in pulmonary changes in persons in the Range area.

Several environmental air sampling programs were conducted in Northeast Minnesota from 1973-1980 (Appendix E). The MDH Community Air Program was conducted from 1978-1980. This program was implemented in an effort to determine mineral fiber levels in community air on the western part of the Mesabi Range. Data from the eastern end of the Iron Range had already been accumulated or was being collected in other programs. The Minnesota Pollution Control Agency's Community Air Sampling Program was begun in 1978 and was conducted to determine fiber levels in locations thought to have potential for the presence of fibrous minerals. This program was coordinated with the MDH Community Air Program to avoid duplication of effort.

Air samples were collected from several cities including Duluth, Hibbing, Virginia, St. Paul, (in residential, commercial and downtown districts), and Minneapolis (in residential and commercial districts). The total fiber levels ranged from 10,529 - 88,377 fibers/m^3, with the highest average number found in the St. Paul commercial district.

The chrysotile and amphibole fiber (types of asbestos) levels, subsets of the total fiber level, were also determined. The chrysotile levels reported are likely higher than those actually present in the air because of problems encountered with filter contamination. For this reason, it is difficult to judge exactly what the air levels were. The areas found to have the highest levels of chrysotile fibers were the commercial districts in St. Paul and Minneapolis where there are several sources of chrysotile fiber exposure, e.g. construction and demolition areas. Areas in the northern part of the state had low chrysotile concentrations. The distribution of amphibole fibers in the state appears to be quite different from that of chrysotile fibers. The cities with mines or ore processing plants nearby (e.g., Silver Bay and Hoyt Lakes) have a slightly higher amphibole fiber count than those further away from such operations. Areas in the western end of the Range such as Virginia and Hibbing had low amphibole fiber concentrations.

Several other air sampling studies have been conducted, including the Copper-Nickel Study and the Mile Post Seven Monitoring Program. These studies, however, were done in the eastern area of the Range and not in the communities involved in the present investigation. A description of these studies and their findings are included in Appendix E.

The results of the community air sampling programs in the state indicate that overall exposure levels on the Range are less than those found in either Minneapolis or St. Paul. None of the measured fiber levels in Virginia, Hibbing or Duluth, communities involved in the radiographic review, were higher than those in other areas. The air monitoring studies conducted in the western end of the Mesabi Range were concluded in 1980, therefore, updated data to confirm these findings were not available.

VI. Radiographic Reviews

The results of the radiographic reviews were also presented to the Committee. Dr. Seningen reviewed the films in his clinic population for evidence of diffuse pleural thickening, and circumscribed pleural thickening, an abnormality associated with exposure to fibrous material. Dr. Seningen reported finding radiographic evidence of pleural thickening in approximately 30% of the patients seen in his practice at the East Range Clinics.

All other B readers evaluated the films for the presence of several different types of abnormalities associated with the pneumoconioses (Appendix F) as well as for diseases that might resemble the pneumoconioses. The pleura were assessed for areas of circumscribed pleural thickening, as done by Dr. Seningen, and for several additional types of fibrous or calcified thickening. Parenchymal changes of interest were either rounded or irregularly shaped small opacities and large opacities.

Dr. Hodous, from NIOSH in Morgantown, West Virginia, was asked to review Dr. Seningen's findings. Dr. Hodous evaluated films at the East Range Clinics and at several clinics in Duluth, Hibbing, and Grand Rapids for a total of 569 films. In all clinics except the East Range Clinic in Virginia, every chest film taken within a specified period of time was reviewed (a sequential sample). At the East Range Clinic less than half the films reviewed were chosen sequentially. The remainder of the films were chosen arbitrarily with a ratio of positive to negative findings, according to Dr. Seningen's evaluation, of 2:1. This was done because the primary purpose of Dr. Hodous' reading was to review Dr. Seningen's positive findings and not necessarily to review a representative sample of the East Range Clinic.

Of the 569 radiographs evaluated, Dr. Hodous found 167 patients (29.3%) with evidence of pleural abnormalities on X-ray, 22 patients (3.9%) with parenchymal abnormalities, and 28 patients (4.9%) with both pleural and parenchymal changes. In all, 38% of the patients were found to have pulmonary changes. (Appendix G). Seventy three-percent (73%) of these patients were male, 27% were female. For the East Range Clinics, Drs. Seningen and Hodous had a 77% concordance.

Dr. Lilis evaluated 566 films; 556 of these were the same as Dr. Hodous had reviewed (thirteen of the original 569 films were unavailable for second review). She found 63 patients (11.1%) with pleural changes only, 29 (5.1%) with parenchymal changes only, and 26 patients (4.6%) with both pleural and parenchymal changes. Seven of these patients had parenchymal changes not consistent with dust exposure. Eighty percent (80%) of these patients were male, 20% were female. Forty eight of the men (17%) and four of the women (1.4%) were found to have circumscribed pleural thickening. In all, Dr. Lilis found 19.6% of the patients to have pulmonary changes consistent with previous dust exposure.

The concordance between Dr. Hodous' and Dr. Lilis' readings was not as high as had been seen with Drs. Hodous and Seningen. Of the 192 persons Dr. Hodous considered positive for pleural abnormalities, Dr. Lilis considered only 70 (36.5%) of them to be positive. Dr. Lilis described 13 additional patients as positive that Dr. Hodous had called negative. Of the 50 patients with parenchymal changes described by Dr. Hodous, Dr. Lilis concurred with only 21 of these findings (42.0%) and described 31 additional patients as having these changes.

The NIOSH panel also reviewed the 566 Range films. Before the films were read, they were added to a set of 434 films collected as part of another large NIOSH study. Four hundred (400) of these control films had no evidence of pleural or parenchymal abnormalities; the remaining 34 had pleural abnormalities. These 1000 films, 566 Range films and 434 control films, were then evaluated by the panel of B readers. Each B reader read 600 films; each film was read by 3 B readers. As previously mentioned, all identifiers on the films were obscured to blind the readers as to the source of the films.

The NIOSH panel found 24 patients (4.2%) with pleural abnormalities and 26 patients (4.6%) with parenchymal abnormalities. Overall, this panel found considerably fewer abnormalities than had been found by the previous B readers.

The 434 control films had been added to the Minnesota films to determine if the panel's reading was consistent relative to the numerous previous evaluations of these films. The panel judged virtually 100% of the negative control films as negative, but described only 53% of the positive control films as positive. The panel read as negative 14 of the control films previously found to be positive. Assuming the previous assessment of positivity was correct, this indicates that the NIOSH panel may have described as negative some Minnesota films that actually had evidence of pleural changes.

The degree of variability between readers can be attributed to several different factors. First, the pleural and parenchymal changes of interest were often subtle and difficult to define. Differentiation between normal anatomic shadows and abnormal changes can be difficult. For example, a prominent serratus anterior muscle, or the presence of subcutaneous fat can cause areas of increased density on film similar in appearance to pleural thickening.

Another possible source of variability was in the interpretation of defined abnormalities as either typical or atypical of the pneumoconioses. As previously mentioned, several of the changes of interest are associated with, or can be the result of, a number of different exposures or diseases. Diffuse pleural thickening, for example, is associated with several different exposures including past infection or inflammation, dust exposure, and certain drug therapies. The findings of interest in this study were those that could result from dust exposure. Abnormalities deemed uncharacteristic of dust exposure were noted as such by the readers and consequently were not considered dust related abnormalities in the data analysis.

The variability in interpretation can also be partially attributed to the different conditions under which the readings occurred. The amount of information available to the readers varied greatly. Dr. Seningen had both patient medical histories and previous X-rays at his disposal to aid in diagnosis. Although some general demographic information had been abstracted from the medical record of patients whose radiographs were being reviewed, it was not available to the remainder of the reviewers. There were several types of information not abstracted or not available in the medical record that would have been helpful to these physicians. For example, the patient's height and weight would have helped distinguish between adipose tissue along the chest wall and pleural thickening. The availability of medical histories would have helped determine the possible etiology of certain abnormalities which can result from or are associated with several different exposures. In addition, Drs. Seningen and Hodous were looking specifically for pleural changes when they reviewed the radiographs, as was Dr. Lilis, although she was less aware of the potential problem. The NIOSH panel was unaware of the source of the films. To help insure against a biased reading they were not informed that certain changes were of greater interest than others. Thus, the "mind set" of the B readers also varied greatly.

In summary, the radiographs received three separate evaluations, by Dr. Hodous, Dr. Lilis, and the NIOSH panel members (Dr. Seningen is not included because he only read the films from the two clinics in his practice and read the films for pleural abnormalities). The NIOSH B readers found at least 40-50 patients with pulmonary changes consistent with a pneumoconiosis. There was partial agreement on an additional number of patients.

VII. Range Studies Advisory Committee Recommendations

After reviewing these data, the Committee decided that additional information would be needed before the significance of the radiographic findings could be determined. Specifically they recommended:

1. Obtaining detailed histories of residential and occupational exposures. In addition, smoking histories and demographic characteristics should be used to identify any risk factors which might explain the findings for these individuals;

2. An inspection of selected homes and workplaces, to evaluate them for potential sources of exposure to fibrous materials;

3. A review of other x-ray evaluations of work populations in the range area; and

4. Establishment of a statewide surveillance system for detection and follow-up of mesothelioma cases. Such cases are "sentinel events" which indicate possible public health problems.

The Committee also recommended establishment of a statewide cancer surveillance system, and the initiation of planning for a mineralogic study of the Range area, with special attention to the fibrous growth and physical properties of minerals. The Committee's rationale behind these recommendations is summarized below.

Neither the mortality nor the morbidity data indicate an increase in either all cancers combined, respiratory cancer alone or malignant mesothelioma. The mortality data, which is generally readily available, allowed an examination of rates over time, up to 1981. The most recent morbidity data available for the Northeastern region of Minnesota was 1976 (Duluth data was available through 1980). Data for the Twin Cities area, used as a comparison population, was available only from 1969-1971. Incidence data from the remainder of the state was not available. The cancer morbidity data is therefore, incomplete.

Although mortality data is valuable, incidence or morbidity data has several added advantages. Morbidity data provides information on all persons who develop a disease, not only those that die from a disease. With certain generally fatal cancers the mortality rate approximates the morbidity rate, however, with cancers that can be successfully treated this is not so. It is important from a public health viewpoint to know of all cancer occurrence in order to determine if the rates are increasing. In addition, mortality rates most often rely on death certificate data which can vary greatly in accuracy. Morbidity information can be collected from pathology reports, a more accurate data source.

Based upon these considerations the Range Studies Advisory Committee recommended that a statewide cancer surveillance system be implemented. This system would collect cancer incidence data from the entire state on an ongoing basis. A cancer surveillance system would have the advantage of enabling public health officials to address future concerns over a perceived increase in cancer incidence quickly and effectively. Specific cancer incidence rates could be calculated for any area in the state to determine if there was an excess. If a statewide cancer surveillance system is not feasible, the Committee strongly recommended the establishment of a system to monitor the incidence of certain sentinel events, specifically malignant mesothelioma. If the incidence of malignant mesothelioma was to increase it would indicate exposure to asbestos and would require further investigation.

One difficulty in evaluating the radiographic findings is that it is not known how many pulmonary changes would be expected in a clinic population such as the one in this investigation. Several epidemiologic studies have determined the prevalence of pleural thickening or pleural plaquing in a defined population. The prevalence of pleural thickening in populations not known to be high risk groups ranged from 0.44% to 6.7%. The prevalence of pleural plaquing has been reported at 1.3% and 6.6% in two different studies. These studies have been done in rather specific population groups and therefore it is difficult to extrapolate these results to the clinic populations from the Range communities.

The Committee felt, based on their experience, that the prevalence of pulmonary changes in this sample might not be elevated if the abnormalities were occurring randomly throughout the population. Unfortunately, with the information presently available, it is not possible to determine if this is the case. The Committee expressed concern that these changes might be occurring in one small subset of the population that has had a common exposure. The number of findings, if this were true, may indeed be more than expected.

In order to determine if a single source or type of exposure is associated with these changes, several types of information are needed: demographic data (race, marital status), and residential, occupational, and medical histories. Demographic data are important due to the relationship of such data with disease frequency; certain cancers for example occur more often in specific ethnic groups. Residential history is needed to assess possible environmental exposures, occupational history to assess possible work place exposures. The medical history will serve to rule out other medical causes of the radiographic findings. None of these data are presently available. Therefore, the Committee recommended further study of these patients to determine if there was any commonality of exposure.

The Committee specifically recommended further study of the 566 patients whose X-rays have already been evaluated. These radiographs have already been extensively reviewed by a number of experts. To repeat this process on a new sample would be expensive and, at this time, not warranted. Another advantage to using already available films is that additional radiographs need not be taken.

The Range Studies Advisory Committee also recommended assembling existing evaluations of films from work populations in the Range area. Several studies have addressed the possible adverse health effects associated with hematite and taconite mining operations. The results of these studies are summarized in Appendix H. There are additional industries on the Range which could potentially be a source of dust exposure. Collecting these data would help determine if a common occupational exposure was associated with the pulmonary changes seen. The Committee stressed the need to investigate the possibility of common occupational exposures based upon the results of the radiographic reviews. The vast majority of those patients found to have pulmonary changes were male, increasing the probability of an occupational exposure not experienced by the females in the population. Once again, the use of already existing radiographs would keep the cost of this study at a minimum.

Questions concerning the type and distribution of mineral fibers in Northeastern Minnesota were raised during this investigation. There is continued concern that certain fibers in this area could cause adverse health effects. Several geological studies have been done which described the mineral deposits present. These results, however, have not been confirmed. In addition, these studies did not determine the location and extent of specific fibrous minerals on the Range. To resolve this concern, the Committee recommended that a mineralogical study be conducted to further qualify and quantify these minerals. Specifically, they recommended a study be designed to address the fibrous growth and physical properties of minerals on the Range.

Based on the environmental sampling data presented, the Committee did not feel that a generalized environmental contamination problem was present. They considered it possible however, that common sources of dust exposure existed. To aid in this determination, the Committee recommended a comprehensive evaluation of both the patients' homes and places of employment be conducted. There are many possible sources of fibrous material both in the home and in the work environment. If any source is found which could be contributing significantly to indoor fiber levels then plans can be made to control or eliminate it.

As previously mentioned, the presence of pulmonary abnormalities does not necessarily imply the presence of clinical disease. Furthermore, most of the pleural and parenchymal changes found occur many years after the initial exposure. Nevertheless, awareness of an increased prevalence of these changes, if present, is important from both a medical and a public health perspective. Many of these changes indicate an increased risk of developing clinical disease. These people, therefore, might benefit from health education or medical intervention to prevent and/or treat disease. If a common exposure were involved, even though it may have begun years ago, it would be important to determine if the exposure is still present and, if so, to control or eliminate it.

Appendix A

Asbestos Related Diseases

Asbestos Related Diseases

There are several diseases known to be associated with exposure to asbestos and perhaps other asbestiform fibers. These diseases include lung cancer, mesothelioma, asbestosis, and pleural changes. The risk of developing any one of these diseases depends upon many factors including type of fiber, level of exposure, length of exposure, and characteristics/lifestyles of the exposed individual (e.g. smoking). The following is a summary of the symptoms and course of these diseases and the level of risk specifically associated with asbestos exposure.

Lung cancer: Asbestos is one of many factors associated with an increased risk of developing lung cancer. Exposure to asbestos appears to increase the chance of developing lung cancer at least 5-fold. If an exposed individual is a cigarette smoker this risk is increased at least 50-fold. The risk appears to be dose related i.e., the greater the exposure, the greater the risk of developing lung cancer (Morgan, 1975).

The initial symptoms of lung cancer are variable and may include cough, chest pain and loss of appetite. Quite often lung cancer is first diagnosed upon routine chest X-ray (Harrison, 1980). With disease progression, additional symptoms may develop especially with metastasis. The prognosis varies according to the cell type, the stage of the disease at diagnosis and individual patient characteristics. Treatment may consist of surgical excision, chemotherapy and/or radiation therapy.

Mesothelioma: Mesothelioma may be malignant or benign (non-malignant). In this summary only malignant mesothelioma is discussed. Malignant mesothelioma involves the mesothelial cells of the pleura (the lining surrounding the lungs) or the peritoneum (the membrane lining the abdomen). It is a rare, generally fatal cancer; the incidence in the general population is estimated to be 1:1,000,000 (Becklake, 1976).

Mesothelioma is strongly associated with asbestos exposure. Most persons who develop malignant mesothelioma have a history of asbestos exposure. This association appears even with low levels of exposure for short periods of time (Becklake, 1976). The latency period, time from exposure to disease, is frequently 30-40 years (Goodman, 1983).

Persons with pleural mesothelioma generally present with chest pain and shortness of breath. The initial symptoms associated with peritoneal mesothelioma are abdominal pain and swelling and weight loss (Morgan, 1975). These symptoms usually do not appear until the disease is quite advanced. There is no effective treatment for malignant mesothelioma; the disease is almost invariably fatal with most patients dying within 2 years of diagnosis (NAS, 1984).

Asbestosis: Asbestosis appears to be associated with exposure to many types of asbestiform fibers and is characterized by diffuse interstitial fibrosis, a generalized thickening of the lung tissue (NAS, 1984). The risk of developing the disease is dependent upon the level and duration of the exposure (Morgan, 1975).

Asbestosis is usually diagnosed 10-20 years after the initial exposure (Harrison, 1980). It can vary in severity from asymptomatic to extremely disabling. The disease usually progresses slowly, the initial symptom is shortness of breath which can progress until the patient's respiratory function is severely compromised. In certain cases it may be fatal with death resulting from respiratory or cardiac failure (NAS, 1984). Treatment is symptomatic, the best "treatment" is early removal of the exposure which in certain instances will arrest the progression of the disease (NAS, 1984).

Pleural changes: There are several pleural changes associated with asbestos exposure: circumscribed pleural thickening (plaques), diffuse pleural thickening, calcification and pleural effusion (accumulation of fluid between the pleura and the lung). Persons with these changes are generally asymptomatic although if the changes are extensive some respiratory impairment may result (NAS, 1984). The level and duration of exposure required for disease development is variable. The changes are often first detected radiographically and indicate past asbestos exposure.

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Appendix B

MDH Chronology: Radiographic Findings in Northeastern Minnesota

January 24, 1985 - April 12, 1985

CHRONOLOGY

January 24, 1985	Ronald P. Seningen, M.D. is referred to Alan Bender, D.V.M., Ph.D., Chronic Disease Epidemiology. Dr. Seningen reports an apparent excess of pleural abnormalities observed at East Range Clinics, Ltd., Virginia/Aurora, Minnesota.
January 30, 1985	Drs. Bender and Parker visit East Range Clinics, assess radiologic evidence. MDH assumes responsibility for investigating Dr. Seningen,s findings, and plans are drafted for clinic investigations.
January 31, 1985	Drs. Bender and Parker review mortality and morbidity rates for all cancers combined and respiratory cancer alone for both St. Louis County (including and excluding Duluth) and for Virginia. No significant trends are observed in age adjusted rates.
February 1, 1985	National experts are consulted at the National Institute for Occupational Safety and Health, (NIOSH), Centers for Disease Control (CDC), and the University of Michigan. Thomas Hodous, M.D., a B reader, agrees to review Dr. Seningen's radiographs based on a formal request from the Commissioner of Health. Valentine O'Malley, M.D., Deputy Commissioner obtains permission from Dr. Seningen to read all radiographs.
February 2, 1985	Strategy Session is held at Minnesota Department of Health (MDH) including Michael Moen, M.P.H., Director of Disease Prevention and Health Promotion, Drs. Bender and Parker, and Michael Osterholm, Ph.D., Chief of Acute Disease Epidemiology.
February 4, 1985	Study forms are prepared and procedure for abstracting medical records and reviewing radiographs is developed.
February 5-9, 1985	Arrangements are made for reviewing 700 radiographs, and abstracting medical records at seven clinics.
February 13-14, 1985	NIOSH/MDH team reviews medical records and radiographs at the East Range Clinics Ltd. in Virginia and Aurora, the North Star, Itasca, and Grand Rapids Clinics in Grand Rapids, the Duluth Clinic in Duluth and the Adams Clinic in Hibbing. Due to time constraints, only 569 of the original 700 radiographs selected are reviewed.
February 15-23, 1985	Initial analysis and interpretation of data from medical records and CDC/NIOSH roentgenographic interpretation forms. Development of additional contingency plans for further investigations.

February 18, 1985	Dr. Ruth Lilis, a pulmonary specialist and experienced B reader from the Environmental Sciences Laboratory at Mount Sinai Medical School in New York City, agrees to visit Minnesota to review radiographs read by Drs. Hodous and Seningen.
February 20-27, 1985	Continued data analysis
February 28, 1985	Arrangements for having Dr. Lilis come to Minnesota to review radiographs are postponed due to illness.
March 1, 1985	Governor Perpich requests a meeting with Health Department officials about the Range investigation. Dr. Bender, Michael Moen, Director of Disease Prevention and Health Promotion and Commissioner Ashton met with Governor Perpich, Judge Miles Lord and others. The Governor is updated on current MDH efforts and directs the Health Department to hold a press conference on March 2nd, because the media, through sources outside the Health Department, has become aware of the Range investigation and the Governor wishes to prevent fragmentary and inaccurate reporting of this investigation.
March 2, 1985	A press conference is held at the Minnesota Department of Health. Commissioner Ashton provides a formal statement of events and knowledge to date. Dr. Bender responds to media questions.
March 4, 1985	With the guidance of Dr. Lester Breslow, Chairman National Academy of Sciences Committee on the Health Risks of Asbestiform Fibers and Dean Emeritus, UCLA School of Public Health, the MDH established the Range Study Advisory Committee. To facilitate review of radiographs, a decision is made to obtain the original radiographs read by Dr. Hodous, transport these radiographs to the Environmental Sciences Laboratory in New York to be read by Dr. Lilis and then to NIOSH at Morgantown, West Virginia, for additional evaluation.
March 8-11, 1985	556 of the radiographs reviewed by Dr. Hodous and an additional 13 not previously reviewed are collected from participating clinics, copied, and arranged for shipping. Originals are flown with a courier to Dr. Lilis in New York City. Duplicate radiographs are returned to the clinics.
March 12, 1985	MDH staff meets with the Health and Human Services Committee of the Minnesota House of Representatives and the Range Coalition Senators about the current investigation. Discussion includes issues relating to the Environmental Sciences Laboratory, the current investigation by the MDH and possible involvement of the Mayo Clinic.

March 13, 1985 — A public hearing is held with the Range Coalition Senators at which support for the MDH's investigations is affirmed. The MDH stresses the preliminary nature of the available information and cautions against over reaction by the media.

March 14, 1985 — The 569 radiographs are transported by courier to NIOSH in Morgantown, West Virginia. Here they are read by a panel of 5 experienced B readers in a blinded fashion.

March 20, 1985 — The Range Studies Advisory Committee is announced. Members include:

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April 9, 1985	NIOSH completes its radiographic review.
April 11-12, 1985	Range Studies Advisory Committee meets at MDH. The committee is presented with all available data and makes recommendations for further study.

Appendix C

Cancer Morbidity and Mortality Data

CONTENTS

TABLE 1

INCIDENCE OF RESPIRATORY AND LUNG CANCER (1969-1976)
FOR VIRGINIA MINNESOTA, COMPARED TO 5 STANDARD POPULATIONS

	Respiratory			All Cancer		
Standard	Observed(O)	Expected(E)	O/E	Observed(O)	Expected(E)	O/E
All T.N.C.S.	45	60.2	0.75	442	409.4	1.08
Duluth	45	61.7	0.73*	442	496.7	0.89*
All SEER	45	70.5	0.64*	442	453.9	0.97
Iowa SEER	45	62.4	0.72*	442	427.7	1.03
Mpls. T.N.C.S.	45	52.7	0.85	442	436.2	1.01

* $P<0.05$

TABLE 2

COMPARISON OF OBSERVED AND EXPECTED DEATHS FOR RESPIRATORY AND ALL CANCERS:
VIRGINIA MINNESOTA, ST. LOUIS COUNTY (EXCLUDING DULUTH)
1977-1983 TO ALL MINNESOTA DEATHS 1979-1981

CANCER	Virginia MN						St. Louis County (Excluding Duluth)					
	Males			Females			Males			Females		
	Observed(O)	Expected(E)	O/E	Observed(O)	Expected(E)	O/E	Observed(O)	Expected(E)	O/E	Observed(O)	Expected(E)	O/E
RESPIRATORY	34	28.9	1.2	18	11.6	1.6	265	271.6	1.0	89	88.6	1.0
ALL CANCER	120	96.8	1.2*	105	94.8	1.1	876	890.8	1.0	692	693.4	1.0

* P<0.05

TABLE 3

NUMBER OF DEATHS IN
CITY OF VIRGINIA AND
ST. LOUIS COUNTY (EXCLUDING DULUTH):
1977-1983

AGE	Males St. Louis County Excluding Duluth Respiratory Cancer	Females St. Louis County Excluding Duluth Respiratory Cancer	Males St. Louis County Excluding Duluth All Cancer	Females St.Louis County Excluding Duluth All Cancer
0-34	0	1	22	11
35-54	31	14	90	76
55-64	73	27	191	150
65-74	109	27	308	218
75-84	43	15	188	148
85+	9	5	77	89
TOTAL	265	89	876	692

	Males Virginia Respiratory Cancer	Females Virginia Respiratory Cancer	Males Virginia All Cancer	Females Virginia All Cancer
0-34	0	0	2	1
35-54	3	3	10	6
55-64	11	4	30	21
65-74	12	5	34	33
75-84	7	5	32	29
85+	1	1	12	15
TOTAL	34	18	120	105

TABLE 4

PERSON YEARS 1977-1983 FOR VIRGINIA MINNESOTA AND ST. LOUIS COUNTY (EXCLUDING DULUTH)

	Virginia		St. Louis County (Excluding Duluth)	
AGE	Male	Female	Male	Female
0-34	19390	18760	268786	248920
35-54	6832	7420	92484	91952
55-64	4536	5313	45885	47586
65-74	3892	5369	33915	37219
75-84	1323	2884	11431	17619
85+	483	1190	3605	6524
TOTAL	36456	40936	456106	449820

Appendix D

Mesothelioma Cases: Duluth and St. Louis County

CONTENTS

Minnesota Development Regions

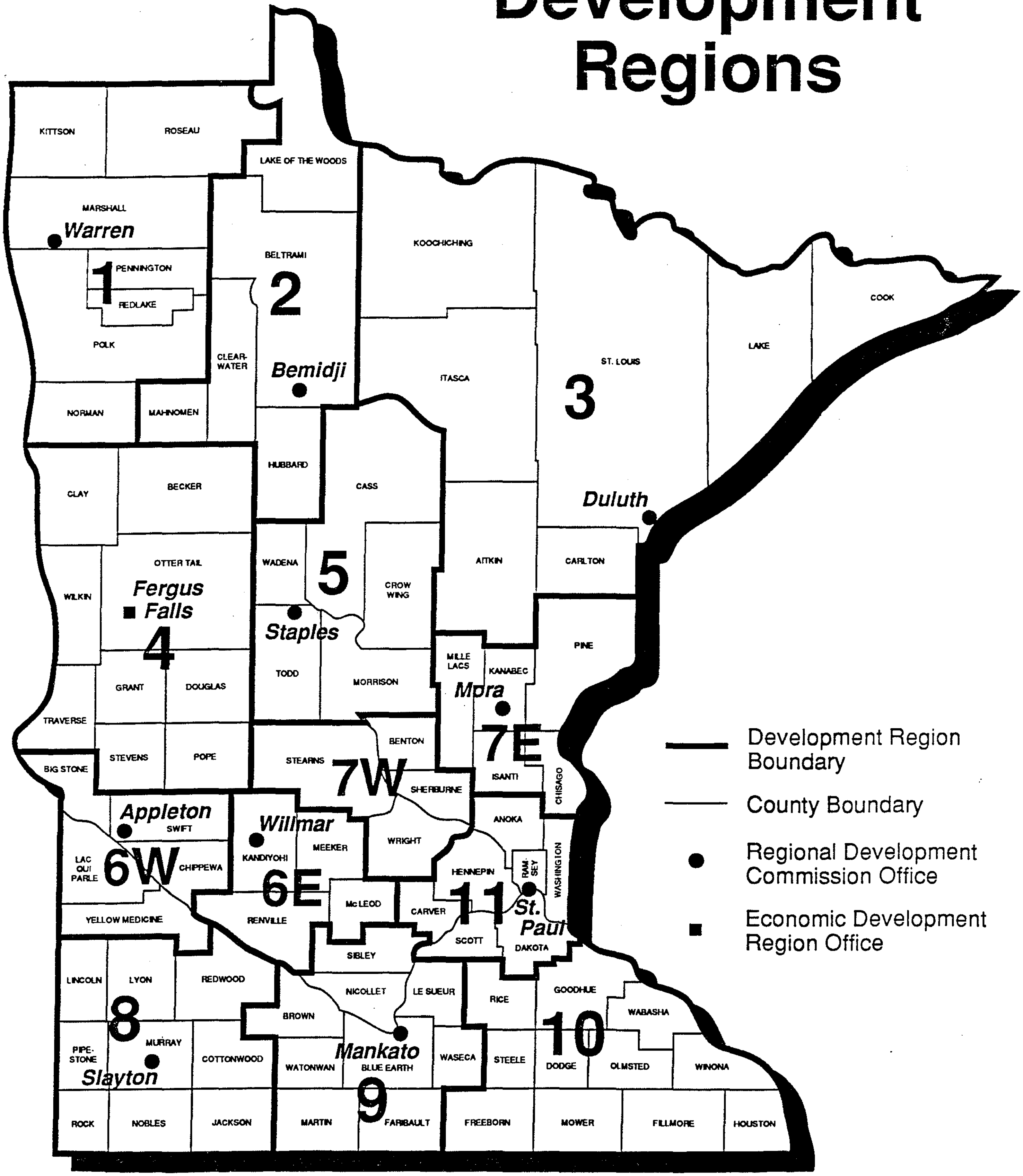


TABLE 1

COMPARISON OF OBSERVED AND EXPECTED* INCIDENCE FOR MESOTHELIOMA:
ST.LOUIS, LAKE, AND COOK COUNTIES (TRI-COUNTY) 1969-1980**

TRI-COUNTY MINNESOTA

MALE			FEMALES			TOTAL		
Observed(O)	Expected(E)	O/E(95% CI)	Observed(O)	Expected(E)	O/E(95% CI)	Observed(O)	Expected(E)	O/E(95% CI)
12***	11.62	1.03(.57,1.94)	7	3.18	2.20(.49,2.49)	19***	14.8	1.28(.64,1.66)

ST.LOUIS COUNTY

MALE			FEMALE			TOTAL		
Observed(O)	Expected(E)	O/E(95% CI)	Observed(O)	Expected(E)	O/E(95% CI)	Observed(O)	Expected(E)	O/E(95% CI)
12***	10.85	1.11(.57,1.94)	7	3	2.33(.49,2.49)	19***	13.85	1.37(.64,1.66)

*Expected values: all SEER incidence data 1973-80.

**The expected rate is calculated for all 3 counties for 8 years (1969-1976) plus Duluth for an additional 4 years (1977-1980).

***One mesothelioma case in a male was not included in the calculation as the male resided in St.Louis County and was diagnosed in 1980 when complete ascertainment for the counties was unavailable.

TABLE 2

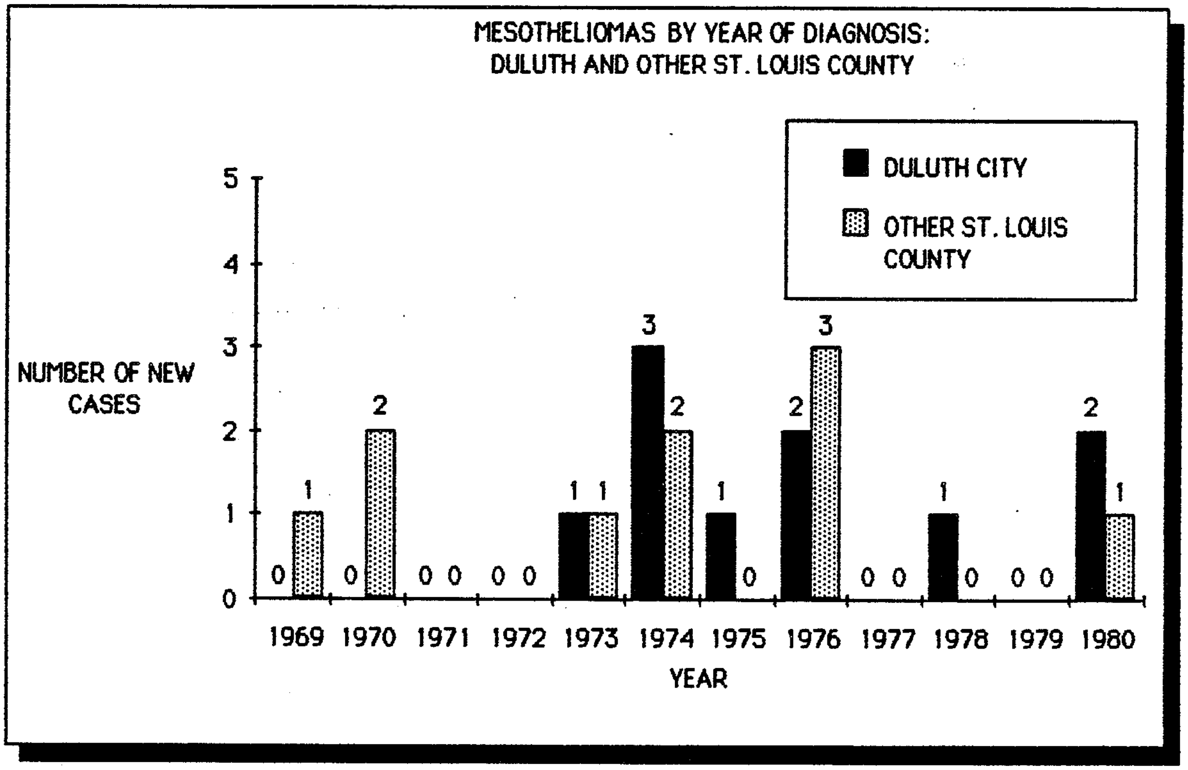
SEER* MESOTHELIOMA INCIDENCE 1973-1980
PER 1970 STANDARD MILLION

GENDER	SITE		
	TOTAL**	PLEURA	PERITONEAL
MALES	10.3/M	8.9/M	1.1/M
FEMALES	2.7/M	1.8/M	0.8/M

*Surveillance, Epidemiology, End Results statistics for all SEER areas combined.

**Total includes pleura, peritoneal and unknown site.

FIGURE 1



NOTE: CASE ASCERTAINMENT FOR OTHER ST. LOUIS COUNTY IS INCOMPLETE FOR YEARS 1977-1980

FIGURE 2

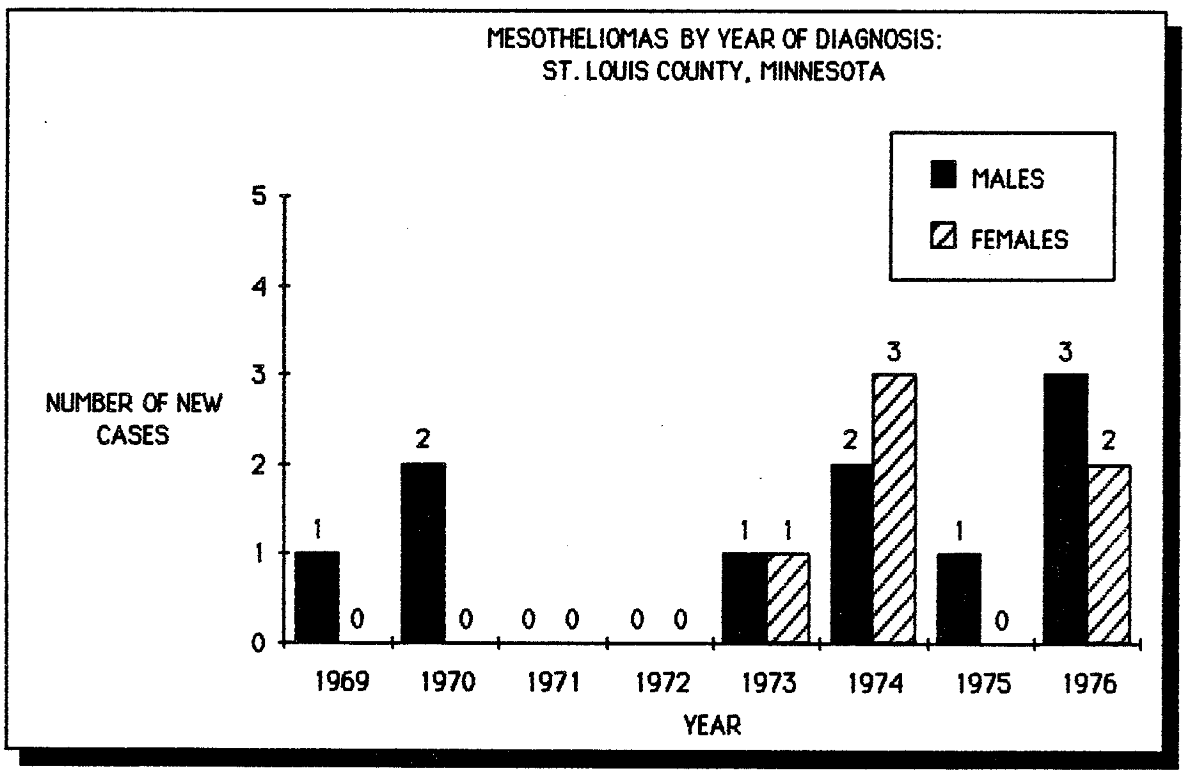
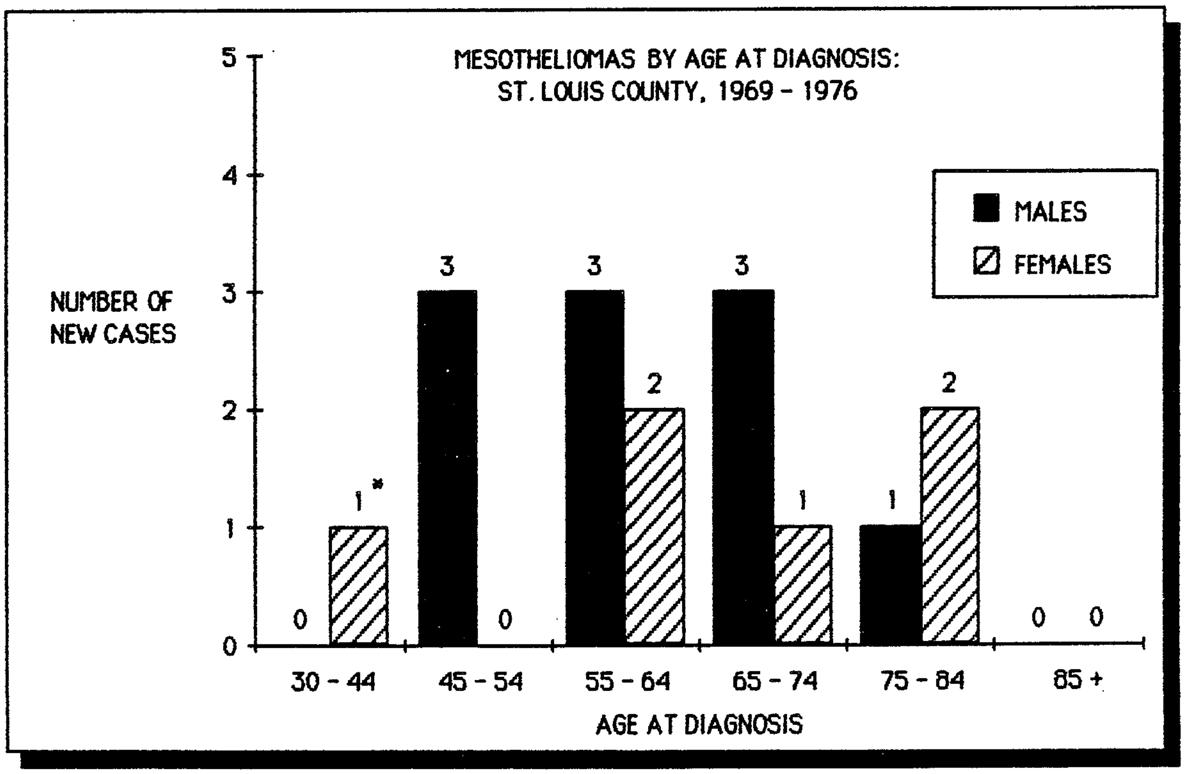

MESOTHELIOMAS BY YEAR OF DIAGNOSIS:
ST. LOUIS COUNTY, MINNESOTA
MALES
FEMALES
NUMBER OF NEW CASES
0
1
2
3
4
5
1
0
2
0
0
0
0
0
1
1
2
3
1
0
3
2
1969
1970
1971
1972
1973
1974
1975
1976
YEAR

FIGURE 3



* Slides read as leiomyosarcoma of the cecum at Mayo Clinic shortly before death. An autopsy elsewhere read as malignant mesothelioma of peritoneum.

Appendix E

Summary of Previous Air Monitoring Data

CONTENTS

TABLES

Tables

FIGURES

Figures

COMMUNITY AIR SAMPLING IN NORTHEASTERN MINNESOTA

INTRODUCTION

The Minnesota Department of Health (MDH) has studied and evaluated the concentrations of fibers in the state since it first became aware of the potential hazard in 1973. At that time there was no agreement from one laboratory to another on the concentration of fibers in the air or water in northern Minnesota. As a result the department began its own sampling and analysis programs.

In this narrative, we discuss the different sampling and analysis programs which pertain to an evaluation of possible radiographic anomalies in northern Minnesota. This discussion is limited to a description of the air sampling and analysis work, but several studies have measured the fiber concentration in surface, underground and community water supplies. A complete list of the different studies is provided in Appendix A. Tables of the fiber concentrations for three major air sampling programs in Minnesota are provided in Appendix C. These include the MDH community air program, the MPCA community air program and the Reserve Mining Milepost 7 tailings basin monitoring program. All fiber concentrations are reported in fibers per cubic meter. To convert to fibers per milliliter divide the reported value by 1,000,000.

Because there was no accepted method for the analysis, early work at MDH concentrated on method development and evaluation. The method released by the EPA in 1976 as the 'Preliminary Interim Method for Determining Asbestos in Water' was ultimately adopted. The details of that method (with MDH enhancements) is provided in appendix B. Some of the assumptions related to that method and therefore to the analyses of community air will be discussed briefly.

The current transmission electron microscope (TEM) methods do not distinguish an asbestiform amphibole fiber from an amphibole fiber which is not asbestiform. Amphibole minerals can occur in many different habits, ranging from blocky through prismatic and needle-like to asbestiform. In general, except by looking at the length to width ratio, it is extremely difficult to tell the habit of an individual fiber in the TEM. In our method, any particle which has parallel sides and a length to width ratio of three or more is a fiber. The incidence of truly asbestiform amphibole material in the Iron Formation is probably quite low. Most of the amphibole fibers which were counted in the community air samples had aspect ratios (length/width) of between three and six.

The current EPA methods are also extremely weak in identifying amphibole minerals when other similar minerals are present. Northern Minnesota contains an assemblage of minerals that can be very difficult to sort out in a TEM without using special techniques. As a result, MDH has enhanced the EPA method to allow amphibole minerals to be reliably identified in northern Minnesota. These minerals can be separated by using energy dispersive spectroscoy and zone axis electron diffraction patterns on every fiber.

<u>Minnesota Department of Health Community Air Program</u>
(St. Paul, Minneapolis, Hibbing, Virginia and Duluth)

This program was initiated primarily to obtain background data on mineral fiber levels in community air on the western end of the Mesabi Iron Range. On the main or western end of the Mesabi Range the silicate minerals are chiefly sheet silicates: minnesotaite, stilpnomelane and greenalite. Amphiboles are not found in the western portion of the iron formation. In the eastern (metamorphosed) section of the range the silicates are chiefly chain silicates, including the amphiboles cummingtonite-grunerite, actinolite and hornblende. The eastern end of the iron formation underwent metamorphic alteration as the intrusive Duluth Gabbro Complex to the south and east was formed (Figure 1). The amphibole minerals, because of their relationship to commercial amphibole asbestos, had been of primary concern in the Reserve Mining case; however, there were some references in the literature to fibrous grains of stilpnomelane and minnesotaite from the Main Mesabi (Gruner, 1946 and French, 1968). It was with this background that the program was initiated. We hoped to determine the distributions of non-amphibole fibers and any amphibole fibers that might be found in the air from minor sources, such as the Giant's Range granite or glacial tills.

In addition, sampling in St. Paul, Minneapolis and Duluth was conducted to provide fiber level data that could be compared to data from Silver Bay air and Duluth water. This was necessary to provide background fiber exposure information for the ongoing Duluth, Lake County and St. Louis County cancer mortality studies.

Sampling was conducted between July 26, 1978 and August 8, 1980. Membrane filter samplers were used with 102 mm diameter cellulose acetate filters of 0.8 um pore size. Sampling was conducted over 18 day periods with a one hour on, five hour off duty cycle. Total sample volumes averaged 150 to 200 cubic meters. A total of 166 samples were taken, of which 46 were counted by TEM for fiber concentrations.

Amphibole fiber concentrations for both Hibbing and Virginia averaged 1507 fibers per cubic meter. Chrysotile concentrations are accounted for in the blank analyses (see

Appendix C for fiber concentrations). The amphibole fiber concentrations are two orders of magnitude lower than Silver Bay air prior to air pollution controls at the Reserve benificiation plant and are about the same as the amphibole fiber concentrations in downtown St. Paul as measured in both the MPCA program and this study (see Appendix).

Very few stilpnomelane and minnesotaite fibers were found in the Hibbing and Virginia air samples. Most of these mineral particles were non-fibrous i.e. length:width aspect ratio < 3:1. Because so few stilpnomelane and minnesotaite fibers were found they were not reported as separate categories in the analyses, but can be found along with other unidentified mineral fibers under the categories of non-amphibole and ambigious in the data tables. Our observations in the TEM led us to the conclusion that neither of these minerals was truly fibrous, but formed > 3:1 aspect ratio particles as a result of ore processing.

The question posed by Gruner and French on the occurence of widely distributed fibers of stilpnomelane and minnesotaite in rock samples from the western end of the range remains unanswered. We do know however, that exposures of Iron Range communities to these minerals in fibrous form has not occurred to any signifigant degree.

The downtown location in Duluth had an average amphibole concentration of 4760 fibers/cubic meter, similar to Babbitt in the MPCA program. The chrysotile concentration averaged 16,334 fibers/cubic meter, similar to downtown St. Paul (Table 1). The Duluth High School samples average 902 fibers/cubic meter for amphibole, the lowest measured levels in northeastern Minnesota. The chrysotile concentrations were again due to background contamination.

St. Paul residential amphibole concentrations average 581 fibers/cubic meter. Chrysotile fiber levels appear to be due mostly to background contamination (Appendix). The downtown St. Paul location had an average amphibole concentration of 1929 fibers/cubic meter. The chrysotile concentration was 13,706 fibers/cubic meter, including some fibers that were actually in the air (not part of filter or laboratory contamination). The chrysotile concentration compares favorably to the downtown St. Paul average concentration (22,000 fibers/cubic meter) found in the MPCA study.

The Minneapolis commercial district average amphibole concentration was 902 fibers/cubic meter, similar to Duluth High School. The average chrysotile concentration was 23,934 fibers/cubic meter, very similar to the downtown St. Paul concentration in the MPCA program.

The residential Minneapolis amphibole fiber average was 1407 fibers/cubic meter, quite similar to downtown St. Paul. Chrysotile concentrations were accounted for by background contamination.

Silver Bay

The Department of Health started monitoring from the roofs of the three Silver Bay schools in September of 1973 in order to determine the exposure of the residents of Silver Bay to amphibole fibers generated by the processing of taconite ore at the Reserve Mining Company benificiation plant in Silver Bay.

The samplers used in this program were high volume particulate samplers (8 x 10" filter format) using 1.2 um effective pore size, cellulose ester filters. The large format was chosen because it was not known at the time whether smaller formats at relatively high flows would result in uneven particle distributions on the filters.

The samplers were run 2 hours on, 2 hours off for a total of 70 hours. Total sample volumes averaged 2900 cubic meters. Twelve samples collected in 1974 and 1975 were analyzed by several different laboratories using TEM. This was the first time that good inter-laboratory aggreement was obtained on a set of air samples from Silver Bay. The mean amphibole fiber concentration by TEM for these 12 samples between three laboratories with best agreement ranged from 230,000 - 307,000 fibers/cubic meter (see Tables 1 and 2).

More than 700 samples were collected during the life of the program. X-ray diffraction analyses for amphibole mass was run on the first 326 samples (collected Sept. 20, 1976 - January 9, 1976).

The amphibole mass ranged from <.28 ug/cubic meters to 15.80 ug/cubic meters. Cook (1978) correlated these mass analyses with TEM fiber counts for 12 samples in 1974-75 and found a very high correlation coefficient (r=0.94) at the 99% confidence limit. Using the derived linear regression correlation equation, Cook determined the following average fiber concentrations in fibers/cubic meter:

Sampling Site	9/20/73-12/2/74	12/2/74-1/9/76
Campton	132,000	165,000
McDonald	102,000	91,000
Kelly	145,000	174,000

Samples collected during the summer of 1976 under contract for EPA by University of Minnesota, Duluth, were analyzed to determine what the effects of plant shut-down at Reserve Mining Company would be on amphibole fiber concentrations. At Kelley High School the shut-down resulted in about an eight-fold reduction (311,000 reduced to 40,000 Fibers/cubic meter).

In order to determine the effect of the Reserve taconite benificiation plant on amphibole fiber concentrations in Silver Bay community air, the MDH selected ten samples from the period proceeding a planned plant shut-down and during the shut-down (Table 3a).

In addition, three composite samples were analyzed for each quarter of 1977. There were 10 to 13 individual samples in each composite sample (Table 3b). The composites were obtained by placing small pieces from several filters together in an ashing dish. The composite analyses were conducted in an attempt to approximate average exposures from a large number of samples. In Table 3b the mean fiber concentrations for individual samples and composites are compared. The effect of the plant shut-downs is evident in both sets of samples with mean concentrations dropping from 47,000 fibers/cubic meter before shut-downs to about 5,000 fibers/cubic meter during the shut-downs (Table 3c).

The Minnesota Department of Health program was discontinued in April, 1980, after the Milepost Seven Tailings Basin Monitoring Program had begun.

Copper-Nickel Study

As part of the Regional Copper-Nickel Study by the Minnesota Environmental Quality Board, the Minnesota Department of Health analyzed air, water, and process ore samples for mineral fibers (Ashbrook, 1978). The sampling was done to determine background levels prior to initiation of any copper-nickel mining or processing.

The air samples were taken between February 6 and October 14, 1977. Sampling sites at six locations in areas with proximity to potential copper-nickel mining were selected at Fernberg Road (Ely), the Environmental Learning Center (Isabella), Bearhead Lake State Park (northwest of Babbitt), Toimi, Erie Mining Company Office (Hoyt Lakes) and Babbitt.

Samples were collected on 102 mm diameter membrane samplers using 0.8 um pore size cellulose acetate filters. The samplers were run continuously for a 24 hour sampling period, filtering between 150 and 200 um of air. Average total fiber levels (minus chrysotile) ranged from about 7,500 to 35,000 fibers/cubic meter. The chrysotile, based on the examinaton of blank data, was due to chrysotile in the filter matrix.

Average amphibole fiber levels ranged from 5,730 fibers/cubic meters at Fernberg Road to 92,300 fibers/cubic meter at Bearhead Lake State Park. The highest single amphibole fiber level occurred at the Erie Mining Office in Hoyt Lakes. Amphibole fiber levels appeared to be highest when the wind was coming from the direction of the eastern end of the Biwabik iron formation (Mesabi Range).

Median amphibole fiber levels were one to two orders of magnitude below those in Silver Bay in 1974-75 (Table 4). Non-amphibole fibers and fibers of ambiguous mineralology (exclusive of chrysotile) were about 10 times higher in the 1974-75 Silver Bay study as in the Copper-Nickel Study.

Minnesota Pollution Control Agency Community Air Sampling

From October 5, 1978 to July 26, 1980 the Minnesota Pollution Control Agency collected samples of community air for fiber analysis by the Minnesota Department of Health. These samples were taken in St. Paul, St. Cloud, Cloquet, Hoyt Lakes and Babbitt. In addition, similar samples from a different MPCA program and a Reserve Mining Company program (during the summers of 1974 and 1976 at the towns of Babbitt, Mountain Iron, Isabella, Cloquet and St. Paul) had been previously analyzed by MDH. Table 5 and Table 6 provide these data.

The purpose of the MPCA programs was to determine fiber levels in locations that were thought to have potential for the presence of fibrous minerals. The program was coordinated with the Minnesota Department of Health Community Air Program in order to eliminate duplication of effort and provide wider coverage of potential problem areas.

The sampling was conducted with the same type of equipment, flow rates and filters used in the MDH Community Program, however, the sampling periods were different. The samplers were run continuously for three days, then collected. Ninety-eight samples were selected for analysis of fibers by TEM. All samples collected were analyzed by x-ray diffraction to determine mass of amphibole present. In most cases, x-ray diffraction analyses were below detection limits of 0.50 ug/cubic meter.

The amphibole fiber concentrations for St. Paul, St. Cloud, Cloquet and Babbitt were similar, averaging about 3,000-4,500 fibers/cubic meter. Hoyt Lakes averaged about 9,000 amphibole fibers/cubic meter (Appendix C). Chrysotile fiber concentrations could be accounted for in all but the St. Paul samples by the blank analyses. The commercial area sample from St. Paul averaged 55,000 chrysotile fibers/cubic meter, while the downtown sample averaged 22,000 fibers/cubic meter (Appendix). The commercial area sample was taken near a highway that had the highest total suspended particulate concentrations in the state.

Mile Post Seven Monitoring Program

As a result of the state's federal court case against Reserve Mining, the company was required to cease discharge of their taconite tailings to Lake Superior and provide for on-land disposal. A tailings basin at Mile Post Seven (on the Reserve Railroad, west of Silver Bay) was built.

As part of its operating permit the company was required to monitor for mineral fibers in the air at four locations around the basin and at two of the schools in Silver Bay. The samples were analyzed at the Minnesota Department of Health.

Sampling began in September, 1978 and has continued to date. The program was reduced in scope at the end of the first operating permit in 1983. A sufficient data base had been accumulated and it was apparent that pollution controls had reduced fiber levels in Silver Bay. It was also apparent that there was no significant problem with wind blown fibers around the tailings basin.

Membrane samplers were used with 102 mm diameter cellulose ester filters (0.8 um pore size). The samplers were run continuously for three days and the total sample volumes were about 500 cubic meters. X-ray diffraction analysis was run on the first 2900 samples, but discontinued when it was found that most amphibole mass concentrations were below detection limits. Over 3500 samples have been collected to date; 503 have been analyzed by TEM for mineral fibers.

The average amphibole fiber concentration for the two Silver Bay Schools monitored in the Mile Post Seven Monitoring Program (1979-1984) was 9093 fibers/cubic meter. This is twice the average amphibole concentration for the three sites around the tailings basin (4675 fibers/cubic meter). (Appendix C) Average chrysotile concentrations for both the schools and the basin were nearly the same (3131 and 2264 fibers/cubic meter, respectively). The chrysotile concentrations can be attributed to filter and laboratory contamination. The average amphibole concentration of the school sites as measured in the Milepost Seven Program shows a 25 fold drop from the 1974-76 Silver Bay school monitoring by the Minnesta Department of Health (mean amphibole fiber concentration, 235,000 fibers/cubic meter).

SUMMARY

An examination of the mineral fiber information in the state of Minnesota indicates the differences between different areas of the state. Those cities which have mines or ore processing plants nearby and where the ore contains amphibole minerals, tend to have slightly higher amphibole concentrations than those further away from such operations. Silver Bay, Hoyt Lakes and Babbitt rank one, two and three in amphibole concentration (see Table 7) and they are all situated near mining or processing operations on the east end of the Iron Range. As expected, cities located on the western end of the range had low amphibole fiber concentrations. The analysis of tailings samples and knowledge of the mineralogy of the iron formation would lead one to expect few amphibole fibers from this part of the range.

The highest chrysotile fiber concentrations were found in commercial districts in St. Paul and Minneapolis. Cities in the northern part of the state had low chrysotile concentrations. Most of the chrysotile fibers found on these samples is due to contamination of the filters and contamination during sample preparation and it is difficult to judge what the actual chrysotile fiber concentration is from these samples. It does seem significant, however, that relative chrysotile concentrations are higher in the large cities where several sources (construction, demolition, brake linings) are located.

The results of all the monitoring for mineral fibers in the state seem to indicate that overall exposure levels are extremely low relative to occupational health standards. The current OSHA standard for asbestos is 2 fibers/ml for an eight hour average. (There are proposals to lower it to 0.5 or 0.2 fibers/ml.) For comparison with the numbers on our tables this would be 2,000,000 fibers per cubic meter. Thus, even Silver Bay, in 1975 (when the average ambient air concentration was estimated to be 235,000 fibers per cubic meter) was considerably below the OSHA standard. Silver Bay now has levels comparable to other cities on the Iron Range.

The fiber analyses of samples from Silver Bay were done using a transmission electron microscope instead of the phase contrast light microscope specified by the OSHA standard. Many of the fibers which were counted on samples from Silver Bay and other Minnesota Cities are either too thin to be visible in the light microscope or they are shorter than the 5 um minimum length which is part of the OSHA standard. As a result, the reported fiber concentrations for the Minnesota cities are really higher than they would be using a standard OSHA fiber count. In other words, a light microscope OSHA count would yield a lower fiber concentration.

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Air Monitoring Sites (Fibers) And Selected Geological Features

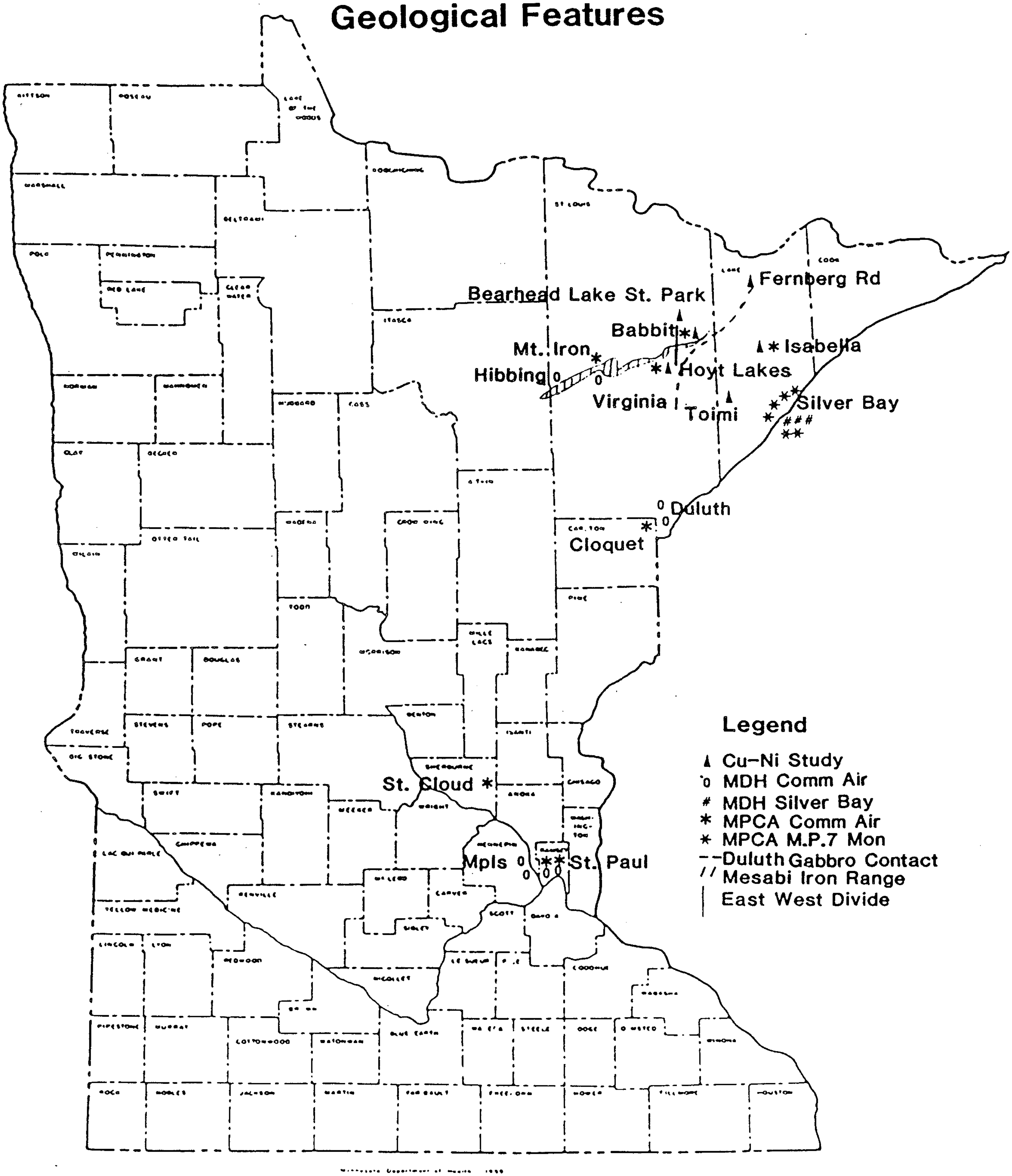


Figure 1.

TABLE 1.

Minnesota Department of Health Samples
Taken at Schools in Silver Bay*

Sample Number	Amphibole Fibers/Cubic Meter						
	Mt. Sinai	EPA-WOL	M.D. Health	IITRI	ADL	Manchester	Kramer
7144A	335,000	262,000	390,000	5,900	5,500	99,000	410,000
7144B	164,000	235,000	177,000	2,700	5,400	110,000	205,000
7144C	323,000	178,000	174,000	3,000	6,600	91,000	265,000
9040	384,000	513,000	450,000	3,900	12,800	100,000	58,200
9041	502,000	448,000	351,000	2,500	6,100	160,000	590,000
9042	583,000	516,000	569,000	800	6,200	291,000	48,000
9061	53,000	33,000	67,000	1,000	1,600	74,000	760,000
9062	358,000	71,000	112,000	5,800	12,400	215,000	310,000
9063	240,000	76,000	120,000	600	3,800	20,000	525,000
4221	252,000	158,000	138,000	4,400	10,400	50,000	105,000
4222	100,000	99,000	96,000	1,400	8,000	70,000	240,000
4223	394,000	230,000	221,000	3,200	20,600	84,000	92,000
Average	307,000	230,000	239,000	2,900	8,300	114,000	300,733

*Samples were collected in December, 1974 and March, May and August, 1975 at each of three schools.

Table 2

AIR SAMPLING PROGRAM AT SILVER BAY, MINNESOTA

		MINNESOTA DEPARTMENT OF HEALTH					NERL Lab. Duluth	Mount Sinai
Sample Number	School	Total Fibers per m^3	Ambiguous Fibers per m^3	Non-amphibole (Not Classified) per m^3	Chrysotile Fibers per m^3	Amphibole Fibers per m^3	Amphibole Fibers per m^3	Amphibole Fibers per m^3
4221	Campton	335,000	104,000	92,000	0	138,000	158,000	252,000
4222	McDonald	143,000	19,000	25,000	1,000	96,000	99,000	100,000
4223	Kelly	472,000	106,000	145,000	0	221,000	230,000	394,000
9061	Campton	135,000	26,000	35,000	3,000	67,000	33,000	53,000
9062	McDonald	234,000	45,000	50,000	25,000	112,000	71,000	358,000
9063	Kelly	213,000	43,000	38,000	11,000	120,000	76,000	240,000
9040	Campton	848,000	238,000	148,000	5,000	450,000	513,000	384,000
9041	McDonald	719,000	196,000	172,000	0	351,000	448,000	502,000
9042	Kelly	1,048,000	239,000	239,000	0	569,000	516,000	583,000
7144a	Campton	614,000	109,000	88,000	26,000	390,000	262,000	335,000
7144b	McDonald	238,000	24,000	30,000	5,000	177,000	235,000	164,000
7144c	Kelly	250,000	36,000	29,000	12,000	174,000	178,000	323,000

Table 3a.

SILVER BAY AIR - KELLY SCHOOL
(Fibers/Cubic Meter)

Sample Number	Dates	Amphibole	Chrysotile	Non-Amphibole Non-Chrysotile	Ambiguous	Total	Total w/o Chrysotile
635 a (1)	5/3/77-5/10/77	34085	4445	10374	13338	62242	57797
635 a (2)	6/1/77-6/8/77	57111	2284	15991	18276	93662	91378
635 a (3)*	7/7/77-7/14/77	4103	2611	7834	2984	17532	14921
50004 a*	8/10/77-8/18/77	15500	7030	6330	5620	34480	27450
50001 a*	8/30/77-9/6/77	1510	3030	605	1820	6965	3935
50011 a*	10/5/77-10/14/77	2030	2490	2940	1580	9040	6550
50009 a*	10/26/77-11/2/77	8060	13900	5860	3670	31490	17590
50038 *	11/22/77-11/29/77	2450	3060	2040	1220	8770	5710
50026	12/19/77-12/29/77	3560	937	1120	3000	8617	7680
50074	1/23/78-1/30/78	1040	623	935	831	3429	2806

*During Shutdown Period of Reserve Mining Company

(Shutdown 6/26/77-7/30/77, Started Up 7/31/77, Shutdown by Strike 8/1/77-12/7/77)

Table 3b.

SILVER BAY AIR COMPOSITES, 1977
(Fibers/Cubic Meter)

Site	Quarter	Amphibole	Chrysotile	Non-Amhpibole Non-Chrysotile	Ambiguous	Total	Total w/o Chrysotile
Kelly	1st	14800	2770	6460	11100	35130	32360
McDonald	1st	6360	2650	4770	8480	22260	19610
Campton	1st	20800	3610	8120	9030	41560	37950
Kelly	2nd	49252	0.0	26678	24626	100556	100556
McDonald	2nd	34557	1819	9094	14550	60020	58201
Campton	2nd	27488	4581	13744	21761	67574	62993
Kelly	3rd	2335	180	4311	1077	7903	7723
McDonald	3rd	1928	1516	1516	1240	6200	4684
Campton	3rd	5835	1750	4085	1750	13420	11670
Kelly	4th	5663	2831	4450	2831	15775	12944
McDonald	4th	2896	14480	1448	2413	21237	6757
Campton	4th	2831	2511	4090	4090	13522	11011

Table 3c.

COMPARISON OF THE MEANS OF KELLY SCHOOL SAMPLES AND COMPOSITES FOR THE SAME TIME PERIOD IN 1977

(values in fibers/m^3)

DATE	MEAN*	COMPOSITE
2nd Quarter	46,000 (2)	49,000
3rd Quarter	7,037 (3)	2,355
4th Quarter	4,025 (4)	5,663

*The number in parentheses is the number of samples used to compute the mean

Table 4. Comparison of fiber levels* found in air.

Location	Amphibole	Chrysotile	Non-amphibole non chrysotile	Ambiguous	Total	Total without Chrysotile	Comments	Source
Babbitt	4,750	9,400	8,550	9,400	25,300	18,100	Median values found in Cu-Ni sampling program	
Bearhead Lake State Park	3,640	2,380	7,350	2,120	17,200	16,300		
Environmental Learning Center	2,700	5,640	26,500	4,600	42,500	34,600		Table 1
Erie Mining Office	14,200	6,780	4,360	10,400	36,000	35,000		
Fernberg Rd.	1,520	7,670	9,120	1,820	20,400	12,500		
Toimi	3,590	3,580	6,800	2,390	25,700	19,700		
Silver Bay:								
Compton School	264,000	4,000	90,000	207,000	475,000	--	Median values of four samples	Table 5
Kelly School	198,000	6,000	92,000	75,000	361,000	--		
McDonald School	145,000	3,000	40,000	35,000	236,000	--		

* Fibers/m^3

Table 5. Minnesota Pollution Control Agency samples collected at Babbitt during 1974.

Location	Sample #	Date	Concentration of Amphibole Fibers (fibers per cubic meter	Estimated Wind Dir.	Wind Speed	Comments
Babbitt	409	7-16-74	37,000	S	≃ 7.6MPH	Rain .02"
Babbitt	372	6-28-74	49,000	S	≃13.8MPH	
Babbitt	313	6-4-74	17,000	S	≃12.7MPH	Rain .17"
Babbitt	355	6-16-74	<600	NNW	≃13.6MPH	
Babbitt	*		7,900			

(*) Composite of sample nos. 294, 288, 272, 266, 259, 235, 223, 206, 322, 324, 313, 355, 369, 372, 386, 409, 412.

Table 6. Reserve Mining Company samples collected August 11-24, 1976.

Location	Sample #	Concentration of Amphibole Fibers (Fibers per cubic meter)
Mt. Iron	041	8,500
Mt. Iron	644 (192)	2,000
Isabella	151 (669)	2,400
Cloquet	932 (633)	4,800
Isabella	218 (265)	<1,000
St. Paul (Dayton Bluff)	854	1,200

Table 7

AVERAGE AIR FIBER CONCENTRATIONS (FIBERS/CUBIC METER) IN MINNESOTA CITIES, RANKED FROM HIGHEST TO LOWEST FOR EACH FIBER TYPE.

CITY	AMPHIBOLE CONC.	CITY	CHRYSOTILE CONC.	CITY	TOTAL CONC.
SILVER BAY (1979-1984)	9093	ST. PAUL (COMMERCIAL)	55607	ST. PAUL (COMMERCIAL)	88337
HOYT LAKES	8966	MPLS. (COMMERCIAL)	23934	ST. PAUL (DOWNTOWN)	39197
BABBITT	4795	ST. PAUL (DOWNTOWN)	17853	MPLS. (COMMERCIAL)	38051
DULUTH (DOWNTOWN)	4760	HIBBING	17584	DULUTH (DOWNTOWN)	36212
ST. CLOUD	4518	DULUTH (DOWNTOWN)	16334	ST. CLOUD	30690
ST. PAUL (COMMERCIAL)	4198	ST. CLOUD	11471	CLOQUET	28592
CLOQUET	4021	CLOQUET	8607	HIBBING	27061
ST. PAUL (DOWNTOWN)	2426	ST. PAUL (RESIDENTIAL)	8232	HOYT LAKES	25302
HIBBING	1522	HOYT LAKES	6267	VIRGINIA	19243
VIRGINIA	1507	DULUTH (CENTRAL HIGH.)	5536	SILVER BAY (1979-1984)	18819
MPLS. (RESIDENTIAL)	1407	VIRGINIA	5113	MPLS. (RESIDENTIAL)	17280
MPLS. (COMMERCIAL)	902	BABBITT	4006	ST. PAUL (RESIDENTIAL)	16510
DULUTH (CENTRAL HIGH.)	867	SILVER BAY (1979-1984)	3131	BABBITT	14645
ST. PAUL (RESIDENTIAL)	551	MPLS. (RESIDENTIAL)	2695	DULUTH (CENTRAL HIGH.)	10520

Appendix A

List of Various Programs for Fiber Analyses Involving MDH

1. Minnesota Department of Health, Community Air Monitoring Program in Virginia, Hibbing, Duluth, St. Paul and Minneapolis (1978-79).

2. Minnesota Department of Health, Silver Bay Air Monitoring Program at three schools in Silver Bay (1973-80).

3. Minnesota Pollution Control Agency, Community Air Monitoring Program in Babbit, Hoyt Lakes, Cloquet, St. Cloud, St. Paul, Mountain Iron, Isabella (1979-80).

4. Minnesota Pollution Control Agency, Milepost Seven Monitoring Program for fibers in air, surface waters and ground water (1978-85).

5. Minnesota Environmental Quality Council, Copper Nickel Study for fibers in air surface water, process ore samples and road dust (1977).

6. Minnesota Department of Health- Minnesota Pollution Control Agency, Study of mineral fibers in the tailings of Minnesota taconite plants (1980).

7. Minnesota Department of Health, study of mineral fibers in the water distribution system of Duluth (1976).

8. Minnesota Department of Health, study of the occurence of amphibole fibers in the Giant's Range granite (1978).

9. Minnesota Pollution Control Agency, Reserve Mining Co. Peletizer Stack Sampling Program for Mineral Fibers (1976-79).

10. Minnesota Department of Health, Statewide Water Suppy Monitoring Program for Mineral Fibers (1976-1985).

11. Minnesota Department of Health, North Shore of Lake Superior Community Water Supply Monitoring Program for Mineral Fibers (1976-1985).

12. Minnesota Department of Health, Program for Mineral Fiber Monitoring in Abondon Mining Pits (potential water supplies). (1977-85).

13. Minnesota Department of Health, mineral fiber monitoring in Lake Vermillion and Colby Lake (Hoyt Lakes) [1976-78].

14. ASTM Methods Committee, Lake Superior water analyses for mineral fibers (1977-79).

15. U.S. Army Corps of Engineers, Program for Analysis of Mineral Fibers in Sediments of Lutsen Harbor (1979).

16. Minnesota Department of Health, analysis of building materials from Virginia, Minnesota courthouse for asbestos (1984).

17. U.S.E.P.A.- Minnesota Department of Health, study titled: "An investigation of the structural and chemical features of PMP-1," an asbestiform actinolite (1982)

18. Minnesota Department of Health, studies of the occurence and identification of fibrous sepiolite, laumontite, thomsonite, enstatite, anthophyllite, minnesotaite, stilpnomelane and talc (1977-85).

19. Minnesota Department of Health, developed the use of 16 common zone axis in the identification of monoclinic amphibole fibers (1975-78).

METHODS SUMMARY

The air samples for transmission electron microscope (TEM) analysis were collected on a type MF cellulose acetate filter material (0.8 - 1.2 um pore sizes) manufactured by Millipore Corporation. Air was drawn through the filters by a sampling device which created a vacuum behind the filter, collecting fibers and particles from the sampled air on the outer side of the filter. Sample filters were prepared for TEM fiber counting using the following protocol:

1. A portion of each filter was cut out with a scalpel and placed sample side down in a small glass dish. The filter and dish were loaded into a low temperature plasma asher. The plasma asher used highly reactive ionized oxygen to oxidize the filter material and other organics at a low temperature (approximately 100^{o}C), leaving behind any mineral fibers or other noncombustible particles. The glass dishes were covered with a petri dish top immediately upon removal from the asher to prevent contamination or sample loss.

2. The filter ash remaining was suspended in filtered distilled water using ultrasonication. This suspension was filtered onto a 47 mm diameter 0.1 um pore size polycarbonate filter (Nuclepore Corporation) using a vacuum filtration apparatus.

3. The polycarbonate filter was removed from the filtration apparatus and placed in a 50 mm covered plastic petri dish with double-backed tape arranged around the edges. The double-backed tape was used to prevent the filter from clinging to the dish cover or flapping about during coating and handling.

4. The filter was coated first with carbon and then with gold (4 mm of gold wire evaporated from a tungsten wire about eight centimeters above the sample) in an Edwards model 306 vacuum evaporator. Carbon coating of the filters was done to provide a support film for the fibers in the microscope and gold coating was done to provide an internal standard for the interpretation of diffraction patterns obtained from the mineral fibers.

5. Several 3 mm square sections (cut from the coated filter with a scalpel) were mounted coated side down on 200 mesh copper TEM grids. The grids were placed on the wire screen of a modified Jaffe-Wick washer (Figure 2).

6. A drop of chloroform was added to each filter square and the Jaffe-Wick washer was filled with enough chloroform to saturate the filter paper (wick) and bring the level to about one-half the height of the screen. The petri dish was covered and the filters were allowed to dissolve for sixteen hours. After dissolution only the carbon/gold film containing the fibers to be counted remained.

7. The grids were removed from the washer with a tweezers, allowed to air dry while held in the tweezers, and stored in a clean covered grid box prior to examination in the electron microscope.

Figure 2

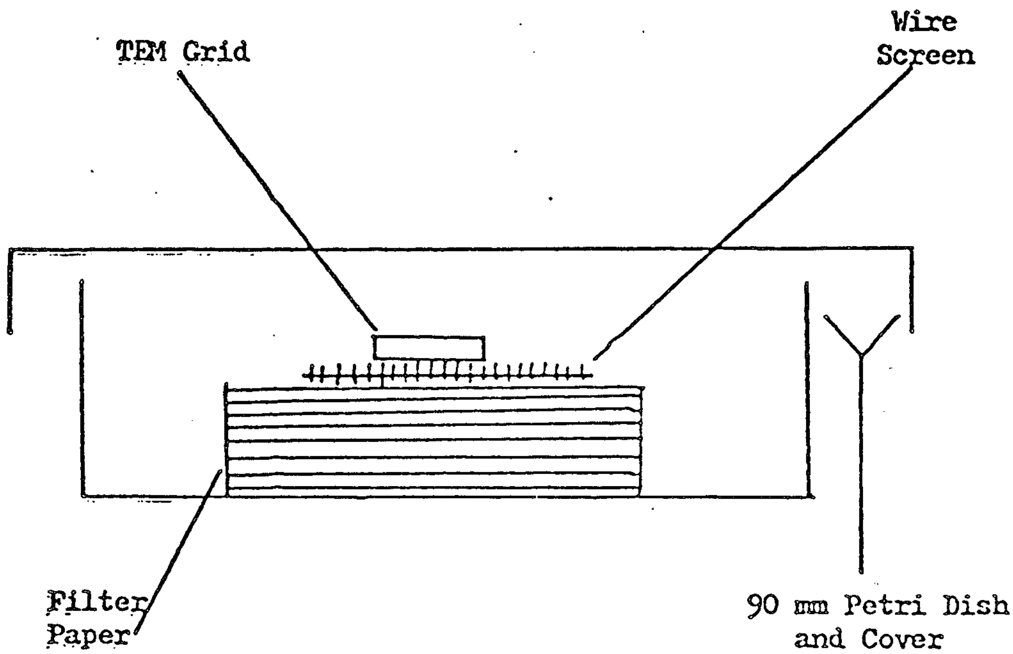


Diagram of a modified Jaffe-Wick washer.

Blank controls were untreated cellulose acetate filters prepared at the same time and in the same way as the sample filters. Blank filters were prepared in order to detect, identify, and count any contaminating mineral fibers that might be present in the filters.

The counting of the copper grids containing the prepared air samples was done in transmission electron microscopes equipped for energy dispersive x-ray analysis. Grid openings to be counted were randomly selected and each selected opening was completely scanned at a 2,100 X instrument magnification aided by a 10 X binocular viewing scope (21,000 X total magnification). For each sample a minimum of 40 total fibers of at least a three to one aspect ratio were counted. At 40 fibers the count was considered complete since the statistical confidence intervals were acceptable (with an upper 95% confidence limit of 36% and a lower limit of 28%). Since entire grid square areas were used to arrive at a mean fiber per unit area figure, it was necessary to count the remainder of the fibers on the last grid opening after 40 fibers had been counted. On lightly loaded samples the count was stopped after 20 grid squares were counted (whether or not 40 fibers had been tallied) in order to limit the amount of time spent on each sample.

Each fiber was measured for length and width at the time of counting by means of an etched cross on the TEM screen. Other elements of the counting procedure are summarized as follows:

1. Fiber morphology was examined and possible mineral fibers were identified. Particles with an aspect ratio of less than three to one were rejected.

2. An attempt was made to obtain a selected area electron diffraction (SAED) pattern for each fiber. Each pattern was obtained by tilting the fiber on a bi-directional tilting stage until a line of regular reflections began to appear. The fiber was then tilted a few more degrees to bring in a complete zone axis pattern on the TEM screen. Patterns were roughly classified and photographed for later evaluation.

3. An energy dispersive x-ray spectrum was obtained by focusing the microscope's electron beam on the fiber. The spectrum obtained provided information about the elemental composition of the mineral particle.

Preliminary data and fiber classifications obtained during the fiber counting procedure on the microscope were analyzed in detail after counting. All of the information available for each fiber was used to determine the most reasonable identification and ultimately each fiber was placed in one of four broad categories. The categories were:

AMPHIBOLE

CHRYSOTILE

AMBIGUOUS

NON-AMPHIBOLE/NON-CHRYSOTILE

SAED pattern photographs were examined in detail and compared with a reference manual containing over 16 common amphibole patterns. Patterns that did not match the common amphibole patterns or the characteristic chrysotile pattern were measured (spacings of the spots and angle of spot allignment) and indexed before classification. Some of the sixteen common amphibole patterns are illustrated in Figure 3. Figure 4 is a stereographic projection of the most easily accessible grunerite (an amphibole) zone axes.

Energy dispersive x-ray analysis (EDXRA) data was processed by a computer program which classified the fibers on the basis of the element to silica ratios. Final placement in one of the four broad classifications was based on all of the data available for each individual fiber and on observed relationships between SAED patterns and EDXRA classifications.

After fiber counting and classification, concentrations of fibers in each category and total fiber concentrations were determined. The fiber average per grid opening was used as the basis for determining the number of fibers per square millimeter on the original (cellulose acetate) filter. This fiber per square millimeter figure was used to calculate the number of fibers per cubic meter of air. The air sample fiber concentrations were calculated using the following formula:

$$\frac{\text{FIBERS/GRID SQUARE}}{\text{GRID SQUARE AREA}} \times \frac{\text{AREA OF 47 MM DIAMETER FILTER}}{\text{AREA OF SAMPLE ASHED}} \times$$

$$\frac{\text{AREA OF SAMPLE FILTER}}{\text{CUBIC FT OF AIR SAMPLED}} \times \text{CUBIC FT/M}^3 = \text{FIBERS/M}^3$$

Confidence intervals were reported as upper and lower percentage values of the calculated concentrations. Table 8 was used to facilitate the determination of confidence intervals for the randomly distributed fibers found on the filters.

Chrysotile fibers were found in many of the air sample preparations. These small asbestos fibers were not, for the most part, components of the the sampled air. Chrysotile fibers were a component of the Nuclepore and Millipore filters used for sample collection and were a contaminant added to the sample in the ashing process. An increase in chrysotile fiber numbers has been demonstrated in each successive stage of the ashed sample preparation process. Effective blank levels were determined from periodically updated mean amphibole and median chrysotile blank values. Fiber contamination in sample preparation is limited to chrysotile fibers. Similar contamination problems have not been demonstrated for other fiber types, although a very low level of amphibole contaminination is found in the filter materials received from the manufacturers.

The fiber analysis method outlined above is comparable to the EPA provisional method for asbestos analysis. The use of EDXRA and SAED, as well the reporting of effective blank levels, are enhancements to the EPA method. EDXRA and SAED improve the classification of fibers, especially in samples where many non-amphibole/non-chrysotile particles are present. The reporting of effective blank levels makes valid interpretation of the fiber concentrations possible.

Figure 3. Some common amphibole zone axis patterns.

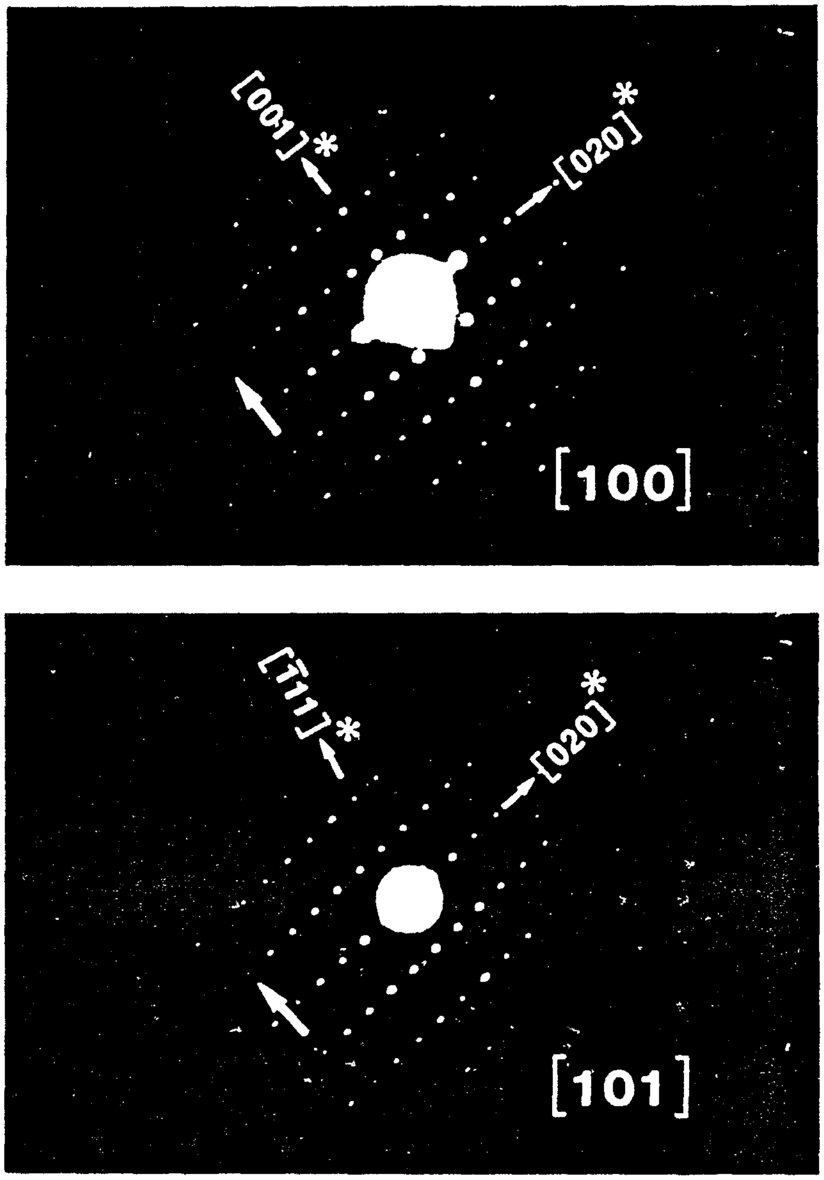
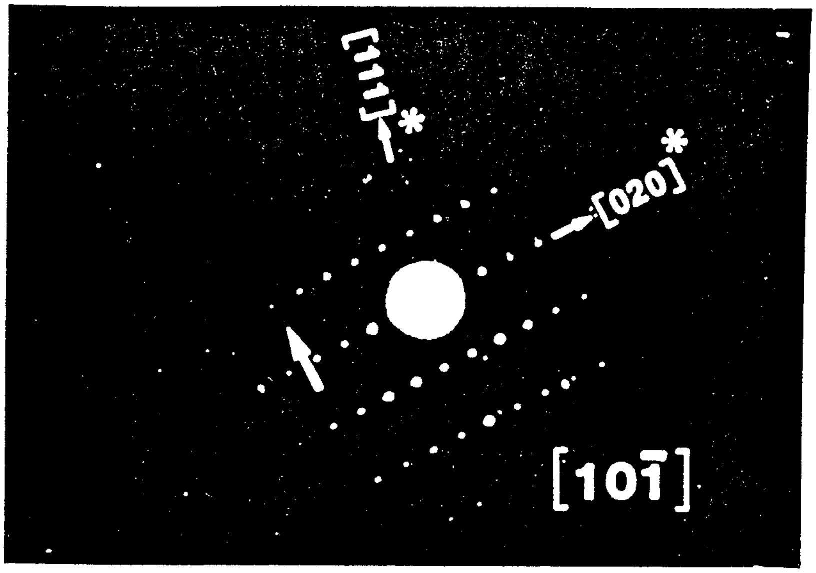


Figure 3, continued.



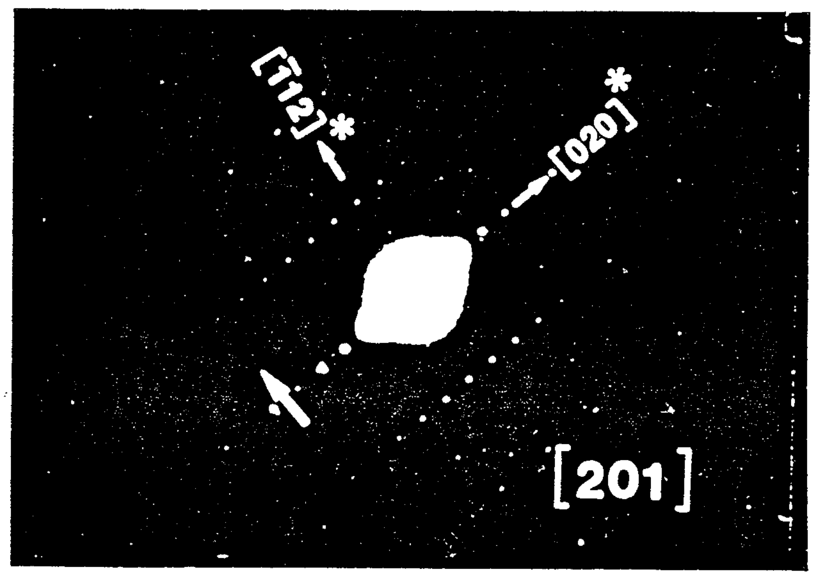
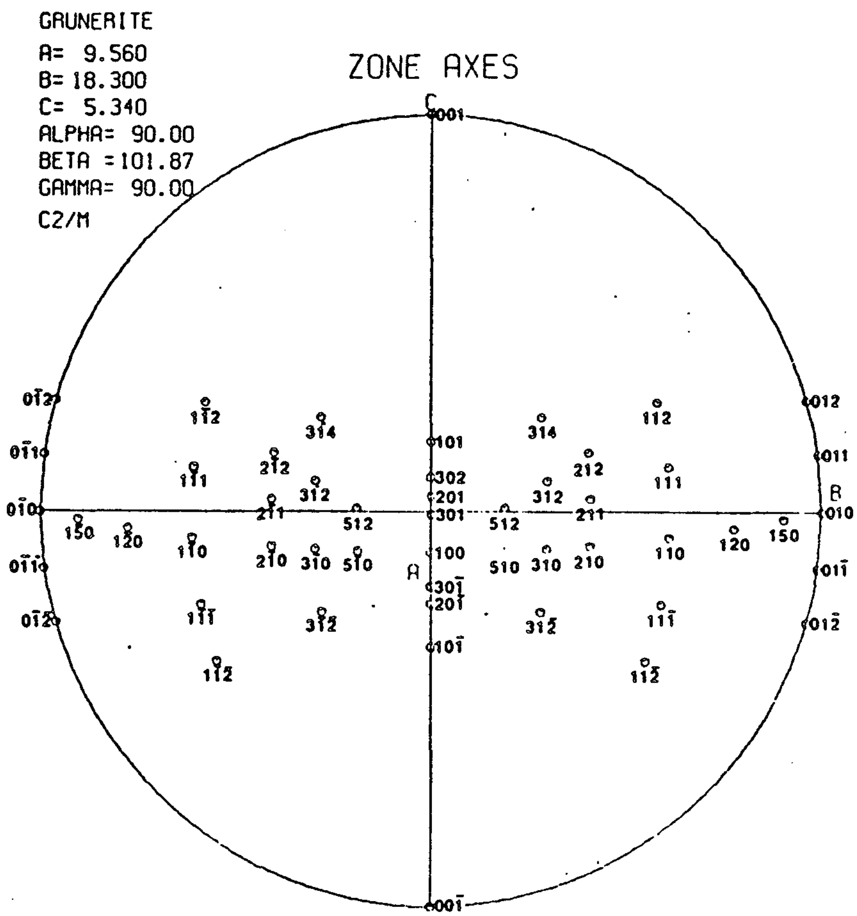


Figure 4. Stereographic projection of easily accessible zone axes in grunerite.



No. Fibers Counted	% of Mean		No. Fibers Counted	% of Mean		No. Fibers Counted	% of Mean		No. Fibers Counted	% of Mean	
	Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
1	97.5	269	26	34.7	46.5	51	25.5	31.5	76	21.2	25.2
2	87.9	261	27	34.1	45.5	52	25.3	31.1	77	21.1	25.0
3	79.4	192	28	33.5	44.5	53	25.1	30.8	78	21.0	24.8
4	72.8	156	29	33.0	43.6	54	24.9	30.5	79	20.8	24.6
5	67.6	133	30	32.5	42.8	55	24.7	30.2	80	20.7	24.5
6	63.3	118	31	32.1	41.9	56	24.5	29.9	81	20.6	24.3
7	59.9	106	32	31.6	41.2	57	24.3	29.6	82	20.5	24.1
8	56.8	97.0	33	31.2	40.4	58	24.1	29.3	83	20.3	24.0
9	54.2	89.6	34	30.8	39.7	59	23.9	29.0	84	20.2	23.8
10	52.0	83.9	35	30.3	39.1	60	23.7	28.7	85	20.1	23.6
11	50.1	78.9	36	30.0	38.4	61	23.5	28.5	86	20.0	23.5
12	48.3	74.7	37	29.6	37.8	62	23.3	28.2	87	19.9	23.4
13	46.8	71.0	38	29.2	37.3	63	23.2	27.9	88	19.8	23.2
14	45.4	67.8	39	28.9	36.7	64	23.0	27.7	89	19.7	23.1
15	44.0	64.9	40	28.5	36.2	65	22.8	27.5	90	19.6	22.9
16	42.8	62.4	41	28.2	35.7	66	22.7	27.2	91	19.5	22.8
17	41.6	60.1	42	27.9	35.2	67	22.5	27.0	92	19.4	22.6
18	40.7	58.1	43	27.6	34.7	68	22.3	26.8	93	19.3	22.5
19	39.8	56.2	44	27.3	34.2	69	22.2	26.6	94	19.2	22.4
20	38.9	54.4	45	27.0	33.8	70	22.0	26.3	95	19.1	22.2
21	38.1	52.9	46	26.8	33.4	71	21.9	26.1	96	19.0	22.1
22	37.3	51.4	47	26.5	33.0	72	21.8	25.9	97	18.9	22.0
23	36.6	50.0	48	26.3	32.6	73	21.6	25.7	98	18.8	21.9
24	35.9	48.4	49	26.0	32.2	74	21.5	25.5	99	18.7	21.7
25	35.3	47.6	50	25.8	31.8	75	21.3	25.3	100	18.6	21.6

Table 8. 95% confidence intervals of the sample mean.

LOCATION: SILVER BAY SCHOOL
SITE NUMBER: 201

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109004	09/06/79	252.	11844.	16884.
109006	09/24/79	17975.	5752.	31636.
109007	10/12/79	3796.	6716.	14016.
109005	10/30/79	2268.	5103.	11718.
109048	11/17/79	10327.	1796.	21103.
109028	12/05/79	3420.	3648.	9576.
109031	12/23/79	707.	3030.	5656.
109036	01/10/80	3927.	< 187.	8415.
109042	01/28/80	2604.	930.	7998.
109297	02/15/80	3210.	2140.	10058.
109330	03/04/80	16800.	6000.	42000.
109359	03/22/80	8279.	5844.	19967.
109359R	03/22/80	3880.	1552.	8924.
109384	04/09/80	3136.	3920.	25088.
109413	04/27/80	14674.	6072.	27324.
109474	06/02/80	12905.	2670.	21805.
109474A	06/02/80	13512.	3941.	20831.
109474B	06/02/80	17298.	3906.	23994.
109578	06/20/80	14337.	1062.	22833.
109511	07/08/80	30420.	2340.	50310.
109505	07/26/80	26250.	1050.	44100.
109619	08/13/80	8029.	1036.	11396.
109636	08/28/80	2516.	1184.	6068.
109652	09/18/80	1645.	7755.	10810.
109658	10/06/80	26214.	10023.	50886.
109663	10/24/80	3100.	1736.	6572.
109669	11/11/80	2130.	1562.	6106.
109680	12/17/80	1903.	519.	7439.
109874	01/04/81	6225.	8715.	26145.
109916	01/22/81	2603.	685.	5206.
109951	02/09/81	7640.	2674.	17190.
109000	02/27/81	1512.	1848.	4200.
109036	03/17/81	3276.	3822.	12285.
109072	04/04/81	18360.	5100.	47940.
109111	04/22/81	770.	1430.	4620.
109111R	04/22/81	1248.	8424.	12792.
109142	05/07/81	10905.	3635.	29080.
109178	05/25/81	8970.	598.	12558.
109214	06/12/81	16240.	580.	24940.
109250	07/03/81	160480.	8160.	225760.
109277	07/21/81	5558.	4764.	17071.
109306	08/08/81	9264.	1544.	16212.
109340	08/26/81	686.	857.	3428.
109376	09/13/81	20768.	3776.	41536.
109407	10/01/81	1046.	523.	2764.
109439	10/19/81	2600.	2800.	8600.
109525	11/06/81	4810.	1924.	17797.
109551	11/24/81	2847.	6351.	12483.
109470	12/12/81	2938.	2712.	9492.

BASIN NEAR SILVER BAY

LOCATION: SILVER BAY SCHOOL
SITE NUMBER: 201

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109499	12/30/81	11634.	4986.	23268.
109573	01/17/82	11109.	966.	19803.
109596	02/01/82	3025.	121.	5082.
109616	02/19/82	4176.	< 144.	5760.
109646	03/12/82	3641.	10261.	17212.
109675	03/30/82	1872.	936.	4797.
109675R	03/30/82	4512.	1504.	8084.
109704	04/17/82	949.	949.	2288.
109735	05/05/82	1148.	1312.	6560.
109762	05/23/82	6821.	< 359.	15078.
109782	06/10/82	2500.	750.	4875.
109792	06/28/82	2100.	1500.	6450.
109792R	06/28/82	4845.	4522.	12597.
109796	07/16/82	1932.	1771.	6118.
109801	08/03/82	4690.	1340.	13065.
109807	09/08/82	2300.	1380.	9200.
109828	09/26/82	1386.	2079.	9933.
109834	10/14/82	500.	723.	1668.
109840	11/01/82	4212.	2106.	9126.
109846	11/19/82	605.	2178.	5687.
109852	12/07/82	848.	848.	3323.
109858	12/25/82	1552.	1455.	4171.
109864	01/12/83	1049.	1923.	4020.
109870	01/30/83	896.	384.	2176.
109876	02/17/83	3247.	4393.	9550.
109882	03/07/83	844.	422.	2050.
109895	04/30/83	2565.	1890.	5400.
109928	09/21/83	1128.	602.	3083.
109978	11/15/83	355.	1300.	2364.
109930	12/05/83	467.	2148.	3829.
AVERAGE CONCENTRATION		7989.	2905.	16737.
HIGH CONCENTRATION		160480.	11844.	225760.
LOW CONCENTRATION		252.	121.	1668.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
2. FIBER CONCENTRATIONS INCLUDE CONTAMINATION FROM FILTERS AND THE LABORATORY. MOST OF THE REPORTED CHRYSOTILE CONCENTRATIONS ARE DUE TO THIS CONTAMINATION LEVEL. THE ACTUAL AIR CONCENTRATIONS ARE MUCH LOWER.
3. THE "<" SYMBOLS REPRESENT COUNTS WHERE NO FIBERS OF THAT TYPE WERE COUNTED. THE VALUE ON THE TABLE IS THE CONCENTRATION WHICH ONE WOULD OBTAIN IF ONLY ONE FIBER WERE COUNTED.

LOCATION: SILVER BAY SCHOOL
SITE NUMBER: 202

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109008	09/24/79	24600.	8200.	60680.
109009	10/12/79	2430.	810.	5535.
109010	10/30/79	2847.	3066.	9636.
109049	11/17/79	9975.	3325.	18525.
109029	12/05/79	4750.	3000.	11000.
109056	12/23/79	3776.	1416.	8732.
109037	01/10/80	4255.	1110.	8695.
109037R	01/10/80	3980.	398.	8358.
109043	01/28/80	1030.	1339.	4738.
109298	02/15/80	8046.	894.	21009.
109331	03/04/80	13020.	8680.	30380.
109385	04/09/80	8080.	2424.	15352.
109414	04/27/80	35000.	1400.	53200.
109444	05/15/80	13470.	1796.	20205.
109475	06/02/80	18844.	8076.	31631.
109579	06/20/80	5640.	564.	11280.
109512	07/08/80	27000.	4320.	46440.
109506	07/26/80	20840.	< 521.	28134.
109618	08/13/80	9178.	1765.	16591.
109640	08/31/80	5092.	1340.	10452.
109653	09/18/80	8602.	8096.	21758.
109659	10/06/80	7980.	8512.	22876.
109664	10/24/80	1469.	1808.	5424.
109670	11/11/80	21630.	6180.	43260.
109675	11/29/80	682.	937.	3493.
109675R	11/29/80	2483.	2292.	8595.
109681	12/17/80	2106.	2340.	9828.
109875	01/04/81	5110.	5475.	14965.
109917	01/22/81	16160.	5050.	53530.
109952	02/09/81	8840.	2210.	18564.
109952R	02/09/81	4312.	3388.	12320.
109001	02/27/81	18720.	3120.	45760.
109037	03/17/81	10143.	4347.	23184.
109073	04/04/81	15260.	4578.	32809.
109112	04/22/81	1572.	6026.	11528.
109149	05/10/81	30000.	2400.	54000.
109185	05/28/81	27621.	4455.	38313.
109221	06/15/81	51240.	1830.	71370.
109251	07/03/81	95550.	2450.	124950.
109251R	07/03/81	75050.	15800.	146150.
109278	07/21/81	28340.	4360.	38150.
109307	08/08/81	6240.	1248.	11856.
109341	08/26/81	2862.	6360.	13356.
109341R	08/26/81	1974.	2538.	6204.
109377	09/13/81	10920.	1560.	21840.
109408	10/01/81	31200.	33280.	79040.
109440	10/19/81	1661.	2567.	7097.
109440R	10/19/81	2119.	3423.	7987.
109526	11/06/81	4718.	2696.	17187.

BASIN NEAR SILVER BAY

LOCATION: SILVER BAY SCHOOL
SITE NUMBER: 202

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109552	11/24/81	28280.	1010.	45450.
109471	12/12/81	5072.	2853.	12363.
109500	12/30/81	12420.	4320.	23760.
109500R	12/30/81	15264.	3392.	30528.
109574	01/17/82	4940.	1900.	14820.
109574R	01/17/82	5868.	4564.	13692.
109600	02/04/82	13428.	2238.	29840.
109617	02/19/82	9045.	< 335.	13400.
109647	03/12/82	5220.	783.	10701.
109676	03/30/82	3219.	222.	4884.
109705	04/17/82	1735.	4164.	14227.
109736	05/05/82	1364.	868.	5084.
109763	05/23/82	18480.	< 560.	25200.
109783	06/10/82	3420.	342.	6669.
109825	07/01/82	7820.	4692.	23069.
109827	07/13/82	1442.	927.	4635.
109802	08/03/82	3096.	5934.	13158.
109808	09/08/82	522.	3132.	10962.
109829	09/26/82	1715.	1715.	10290.
109835	10/14/82	640.	1188.	3839.
109841	11/01/82	3913.	17329.	32422.
109847	11/19/82	245.	980.	3840.
109853	12/07/82	458.	1297.	3434.
109859	12/25/82	293.	403.	1281.
109865	01/12/83	4860.	1458.	9963.
109871	02/02/83	2092.	398.	4084.
109877	02/17/83	3276.	728.	7098.
109883	03/07/83	1192.	3725.	6854.
109883R	03/07/83	3900.	5100.	13800.
109896	04/30/83	3735.	2739.	11703.
109906	05/21/83	1971.	3942.	9855.
109923	06/02/83	3680.	1440.	6400.
109955	06/20/83	4788.	3078.	14364.
109908	06/23/83	11596.	1784.	20962.
109963	07/08/83	946.	946.	3388.
109918	07/14/83	5808.	528.	10296.
109932	08/04/83	4065.	3794.	10840.
109933	08/16/83	2088.	696.	5220.
AVERAGE CONCENTRATION		10555.	3440.	21590.
HIGH CONCENTRATION		95550.	33280.	146150.
LOW CONCENTRATION		245.	222.	1281.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
2. FIBER CONCENTRATIONS INCLUDE CONTAMINATION FROM FILTERS AND THE LABORATORY. MOST OF THE REPORTED CHRYSOTILE CONCENTRATIONS ARE DUE TO THIS CONTAMINATION LEVEL. THE ACTUAL AIR CONCENTRATIONS ARE MUCH LOWER.
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LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 203

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109001	08/19/79	2178.	3630.	14157.
109003	09/06/79	994.	1656.	4802.
109011	09/24/79	1392.	8120.	13456.
109011R	09/24/79	2208.	1472.	7544.
109012	10/12/79	389.	3574.	5750.
109013	10/30/79	862.	1568.	4390.
109050	11/17/79	3675.	3185.	10045.
109050R	11/17/79	5130.	810.	11610.
109030	12/05/79	518.	138.	1449.
109032	12/23/79	611.	163.	1669.
109038	01/10/80	1230.	1353.	5412.
109044	01/28/80	804.	6432.	12060.
109299	02/15/80	4278.	3906.	10974.
109332	03/04/80	4212.	648.	11664.
109360	03/22/80	1470.	147.	5733.
109386	04/09/80	641.	1495.	2990.
109445	05/15/80	1884.	1413.	6751.
109580	06/20/80	1221.	814.	3093.
109513	07/08/80	2299.	2090.	8569.
109507	07/26/80	2816.	768.	5632.
109617	08/13/80	1547.	833.	4641.
109617R	08/13/80	1998.	1271.	4358.
109637	08/28/80	3546.	985.	7683.
109654	09/18/80	666.	6660.	7881.
109660	10/06/80	4288.	2948.	13668.
109660R	10/06/80	4947.	2619.	13677.
109666	10/24/80	1489.	876.	3767.
109671	11/11/80	1853.	654.	4360.
109676	11/29/80	1476.	2132.	6888.
109682	12/17/80	3132.	4176.	11484.
109876	01/04/81	1275.	5100.	11220.
109918	01/22/81	2340.	780.	6240.
109953	02/09/81	4848.	3333.	13029.
109002	02/27/81	446.	1412.	2972.
109113	04/22/81	1639.	745.	2980.
AVERAGE CONCENTRATION		2123.	2226.	7503.
HIGH CONCENTRATION		5130.	8120.	14157.
LOW CONCENTRATION		389.	138.	1449.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
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3. THE "<" SYMBOLS REPRESENT COUNTS WHERE NO FIBERS OF THAT TYPE WERE COUNTED. THE VALUE ON THE TABLE IS THE CONCENTRATION WHICH ONE WOULD OBTAIN IF ONLY ONE FIBER WERE COUNTED.

BASIN NEAR SILVER BAY

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 204

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109014	10/12/79	9528.	11116.	36524.
109015	10/30/79	2790.	5890.	14570.
109053	12/05/79	1683.	3179.	7480.
109033	12/23/79	538.	911.	1697.
109039	01/10/80	406.	934.	1665.
109045	01/28/80	166.	2905.	3984.
109387	04/09/80	869.	1665.	4054.
109387R	04/09/80	566.	189.	1463.
109415	04/27/80	1727.	157.	3219.
109446	05/15/80	3718.	676.	6591.
109476	06/02/80	6820.	2790.	12710.
109581	06/20/80	1824.	1672.	6080.
109514	07/08/80	2618.	462.	5544.
109508	07/26/80	6346.	501.	8183.
109616	08/13/80	5481.	3132.	11223.
109641	08/31/80	3380.	2028.	6591.
109655	09/18/80	2050.	2144.	5499.
109835	10/03/80	1068.	7476.	13083.
109668	10/24/80	2096.	2620.	5633.
109672	11/11/80	8188.	2848.	13528.
109677	11/29/80	5500.	2200.	12100.
109683	12/17/80	6110.	2350.	11515.
109877	01/04/81	21240.	4956.	37524.
109919	01/22/81	20200.	10100.	48480.
109954	02/09/81	11460.	10314.	33234.
109003	02/27/81	1333.	1254.	3371.
109003R	02/27/81	2268.	2430.	6804.
109039	03/17/81	5951.	22722.	36788.
109075	04/04/81	14476.	5922.	32900.
109114	04/22/81	3256.	1036.	5772.
109151	05/10/81	6369.	772.	8878.
109187	05/28/81	11235.	963.	14766.
109217	06/12/81	17442.	< 513.	22059.
109252	07/03/81	21576.	< 696.	27840.
109279	07/21/81	4324.	188.	7708.
109308	08/08/81	1236.	1236.	6386.
109342	08/26/81	6188.	< 221.	8177.
109372	09/10/81	4878.	1355.	10840.
109441	10/19/81	833.	714.	2499.
109521	11/03/81	4466.	609.	8120.
109553	11/24/81	1260.	945.	2835.
109472	12/12/81	8844.	4020.	20502.
109495	12/27/81	1331.	1815.	4840.
109511	01/14/82	2430.	675.	5400.
109598	02/01/82	4368.	1008.	7056.
109618	02/19/82	2996.	< 107.	4173.
109618R	02/19/82	5100.	408.	7752.
109642	03/09/82	1205.	4820.	9881.
109672	03/27/82	1632.	2720.	10880.

BASIN NEAR SILVER BAY

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 204

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109700	04/14/82	452.	1130.	4520.
109731	05/02/82	576.	1008.	6192.
109759	05/20/82	2712.	1808.	8814.
109774	06/01/82	1800.	4000.	8400.
109793	06/28/82	3204.	1246.	6586.
109797	07/16/82	427.	498.	1635.
109803	08/03/82	1364.	818.	4000.
109809	09/08/82	546.	6006.	11102.
109830	09/26/82	473.	1607.	4064.
109830R	09/26/82	2240.	3584.	8960.
109836	10/14/82	1960.	2100.	6440.
109836R	10/14/82	1816.	2581.	5162.
109842	11/01/82	672.	3696.	7392.
109848	11/19/82	520.	1820.	5330.
109854	12/07/82	2961.	564.	6204.
109860	12/25/82	1352.	1560.	4472.
109866	01/12/83	732.	6588.	9516.
109872	02/02/83	411.	1057.	2348.
109878	02/17/83	904.	339.	2317.
109884	03/07/83	948.	3002.	8374.
109888	03/25/83	2604.	465.	3720.
109939	10/27/83	212.	1378.	1908.
109979	11/15/83	< 51.	614.	1024.
109940	12/05/83	< 59.	1529.	2352.
109974	12/21/83	128.	1193.	1406.
AVERAGE CONCENTRATION		3926.	2575.	9738.
HIGH CONCENTRATION		21576.	22722.	48480.
LOW CONCENTRATION		51.	107.	1024.

NOTES

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3. THE "<" SYMBOLS REPRESENT COUNTS WHERE NO FIBERS OF THAT TYPE WERE COUNTED. THE VALUE ON THE TABLE IS THE CONCENTRATION WHICH ONE WOULD OBTAIN IF ONLY ONE FIBER WERE COUNTED.

... TAILINGS REPORT PREPARED 03/2...
BASIN NEAR SILVER BAY

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 205

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109000	08/19/79	38400.	1600.	73600.
109016	09/24/79	51300.	27360.	123120.
109017	10/12/79	1722.	4018.	12915.
109018	10/30/79	1930.	15826.	20458.
109051	11/17/79	4545.	1212.	12120.
109051R	11/17/79	3749.	1630.	8802.
109054	12/05/79	3075.	4920.	10250.
109034	12/23/79	397.	546.	1364.
109040	01/10/80	517.	414.	1965.
109300	02/15/80	4525.	905.	7602.
109333	03/04/80	6990.	1398.	18640.
109361	03/22/80	2800.	1260.	6020.
109388	04/09/80	714.	401.	1784.
109416	04/27/80	20387.	< 703.	31635.
109447	05/15/80	23055.	< 795.	31800.
109477	06/02/80	7200.	2700.	18000.
109582	06/20/80	6716.	292.	11972.
109515	07/08/80	25772.	758.	36384.
109509	07/26/80	18042.	582.	23280.
109642	08/31/80	5784.	482.	9158.
109656	09/18/80	3888.	11664.	17280.
109661	10/06/80	10920.	10920.	32032.
109661R	10/06/80	9630.	6420.	27606.
109667	10/24/80	1510.	2131.	4529.
109673	11/11/80	988.	1235.	3704.
109678	11/29/80	2431.	5525.	11492.
109684	12/17/80	7480.	10846.	21318.
109878	01/04/81	16506.	7860.	36942.
109920	01/22/81	4500.	1250.	9250.
109955	02/09/81	8880.	1776.	19980.
109004	02/27/81	959.	1518.	3436.
109040	03/17/81	4186.	3289.	13455.
109076	04/04/81	11760.	7644.	26460.
109115	04/22/81	751.	2629.	4601.
109152	05/10/81	12888.	2864.	28640.
109188	05/28/81	8092.	< 289.	10982.
109224	06/15/81	17680.	520.	24960.
109253	07/03/81	45820.	3160.	60040.
109275	07/18/81	12731.	2634.	22389.
109309	08/08/81	886.	975.	3367.
109343	08/26/81	2640.	240.	3960.
109343R	08/26/81	6440.	3220.	13524.
109378	09/13/81	9844.	1284.	16264.
109410	10/01/81	6867.	3924.	16023.
109442	10/19/81	1162.	913.	3652.
109527	11/06/81	9648.	6633.	25929.
109527R	11/06/81	15200.	4864.	29792.
109554	11/24/81	1337.	382.	2674.
109473	12/12/81	6575.	3945.	13413.

FIBER CONCENTRATIONS FOR MPCA MILEPOST 7 TAILINGS BASIN NEAR SILVER BAY

REPORT PREPARED 03/29/8

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 205

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION		CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109501	12/30/81	10296.		2288.	21736.
109575	01/17/82	5256.		1752.	11096.
109601	02/04/82	8172.		3632.	19522.
109622	02/22/82	8211.		5865.	17595.
109648	03/12/82	849.		113.	1698.
109677	03/30/82	8775.	<	195.	10140.
109706	04/17/82	970.		1323.	5204.
109732	05/02/82	2196.		366.	7686.
109737	05/05/82	1596.		399.	5187.
109764	05/23/82	3358.		292.	6132.
109784	06/10/82	1588.		418.	3846.
109826	07/01/82	173460.		49560.	338660.
109798	07/16/82	623.		2151.	3226.
109804	08/03/82	1236.		872.	2981.
109810	09/08/82	622.		711.	4001.
109831	09/26/82	1072.		1608.	5494.
109837	10/14/82	1451.		816.	3537.
109843	11/01/82	788.		6895.	10244.
109849	11/19/82	386.		601.	1888.
109849R	11/19/82	336.		112.	1792.
109855	12/07/82	834.		1390.	4171.
109861	12/25/82	702.		594.	2160.
109867	01/12/83	456.		2186.	4008.
109873	01/30/83	48.		48.	95.
109873R	01/30/83	116.		1004.	1544.
109879	02/17/83	711.		474.	1896.
109885	03/07/83	254.		406.	1572.
109889	03/25/83	1254.		502.	2195.
109893	04/12/83	1381.		460.	3145.
109893R	04/12/83	4278.		1116.	8556.
109898	04/30/83	2224.		5282.	11120.
109905	05/18/83	1878.		9390.	16589.
109921	06/05/83	1400.		600.	4100.
109957	06/20/83	927.		1030.	4120.
109910	06/23/83	6370.		1225.	10780.
109960	07/08/83	875.		4375.	7525.
109915	07/11/83	2226.		2862.	12720.
109942	08/19/83	1430.		1210.	5170.
109943	09/03/83	888.		1554.	4440.
109944	09/21/83	1441.		917.	5240.
AVERAGE CONCENTRATION		8211.		3314.	17543.
HIGH CONCENTRATION		173460.		49560.	338660.
LOW CONCENTRATION		48.		48.	95.

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 206

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109002	09/06/79	12885.	4295.	32642.
109002R	09/06/79	5890.	3534.	23560.
109020	09/24/79	5103.	2916.	9477.
109019	10/12/79	618.	721.	3914.
109021	10/30/79	1260.	1575.	4935.
109052	11/17/79	7210.	5150.	23175.
109055	12/05/79	728.	874.	3130.
109035	12/23/79	2368.	592.	6068.
109041	01/10/80	4485.	3105.	14835.
109047	01/28/80	4056.	4992.	12792.
109301	02/15/80	2943.	109.	4905.
109334	03/04/80	3154.	166.	6972.
109362	03/22/80	1309.	800.	3417.
109389	04/09/80	988.	346.	2075.
109417	04/27/80	3264.	408.	7752.
109448	05/15/80	5620.	4496.	12926.
109478	06/02/80	3008.	2444.	9024.
109583	06/20/80	2868.	2390.	9799.
109516	07/08/80	1350.	540.	5265.
109510	07/26/80	4224.	768.	7680.
109510R	07/26/80	3552.	2886.	9546.
109614	08/13/80	4896.	5168.	11424.
109643	08/31/80	2530.	1380.	4830.
109657	09/18/80	2484.	7866.	12006.
109662	10/06/80	1240.	2976.	11656.
109665	10/24/80	1845.	6355.	9635.
109674	11/11/80	2420.	770.	3960.
109679	11/29/80	3740.	1760.	9020.
109685	12/17/80	1320.	1584.	5544.
109879	01/04/81	1788.	2235.	6407.
109921	01/22/81	10800.	3888.	19008.
109956	02/09/81	3108.	4403.	11655.
109005	02/27/81	2898.	4761.	9522.
109041	03/17/81	7389.	5747.	33661.
109071	04/01/81	2085.	1112.	5977.
109116	04/22/81	996.	689.	3294.
109153	05/10/81	3750.	375.	4875.
109189	05/28/81	7750.	310.	12090.
109225	06/15/81	6644.	8456.	24160.
109225R	06/15/81	5377.	< 283.	11320.
109254	07/03/81	3948.	564.	7896.
109280	07/21/81	2678.	< 103.	4429.
109310	08/08/81	2988.	1494.	6640.
109344	08/26/81	4324.	564.	7332.
109379	09/13/81	2648.	5958.	14895.
109411	10/01/81	4452.	3816.	13992.
109443	10/19/81	1521.	3887.	7267.
109523	11/03/81	809.	202.	2831.
109548	11/21/81	2472.	824.	4429.

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 206

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109571	12/03/81	3105.	2070.	8073.
109497	12/27/81	2700.	135.	5400.
109513	01/14/82	2080.	910.	5200.
109605	02/07/82	1358.	634.	3530.
109620	02/19/82	3612.	172.	6880.
109644	03/09/82	441.	2203.	4405.
109682	04/02/82	351.	527.	1989.
109702	04/14/82	1694.	770.	6006.
109733	05/02/82	588.	1372.	9212.
109794	06/28/82	673.	673.	2383.
109799	07/16/82	575.	3680.	5980.
109805	08/03/82	738.	1569.	3692.
109811	09/08/82	279.	652.	4096.
109832	09/26/82	1015.	4872.	9338.
109838	10/14/82	265.	795.	1749.
109844	11/01/82	372.	4092.	7440.
109851	11/19/82	191.	1654.	2608.
109856	12/07/82	658.	494.	3539.
109856R	12/07/82	641.	789.	1873.
109862	12/25/82	554.	1661.	3183.
109868	01/12/83	470.	739.	2755.
109874	01/30/83	408.	2992.	5304.
109880	02/17/83	1210.	545.	2662.
109886	03/07/83	791.	2938.	5311.
109890	03/25/83	2304.	2016.	5760.
AVERAGE CONCENTRATION		2741.	2157.	8270.
HIGH CONCENTRATION		12885.	8456.	33661.
LOW CONCENTRATION		191.	103.	1749.

NOTES

1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
2. FIBER CONCENTRATIONS INCLUDE CONTAMINATION FROM FILTERS AND THE LABORATORY. MOST OF THE REPORTED CHRYSOTILE CONCENTRATIONS ARE DUE TO THIS CONTAMINATION LEVEL. THE ACTUAL AIR CONCENTRATIONS ARE MUCH LOWER.
3. THE "<" SYMBOLS REPRESENT COUNTS WHERE NO FIBERS OF THAT TYPE WERE COUNTED. THE VALUE ON THE TABLE IS THE CONCENTRATION WHICH ONE WOULD OBTAIN IF ONLY ONE FIBER WERE COUNTED.

CITY: DULUTH
LOCATION: HIGH SCHOOL ROOF

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55496	10/16/78	512.	11264.	25600.
55499	12/21/78	75.	828.	1255.
55100	02/02/79	817.	245.	3186.
55100R	02/02/79	1232.	2002.	6776.
55103	04/10/79	930.	8742.	11532.
55108	06/14/79	952.	9996.	14518.
55105	08/09/79	1548.	5676.	10836.
AVERAGE CONCENTRATION		867.	5536.	10529.
HIGH CONCENTRATION		1548.	11264.	25600.
LOW CONCENTRATION		75.	245.	1255.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
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BASIN NEAR SILVER BAY

LOCATION: NEAR TAILINGS BASIN
SITE NUMBER: 208

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
109311	08/08/81	4761.	4232.	21160.
109345	08/26/81	623.	1335.	2937.
109375	09/10/81	8099.	4361.	26166.
109406	09/28/81	798.	1938.	4902.
109444	10/19/81	2155.	449.	3412.
109524	11/03/81	4968.	207.	8694.
109555	11/24/81	786.	688.	3834.
109474	12/12/81	4148.	1220.	9272.
109502	12/30/81	928.	2784.	4872.
109576	01/17/82	1043.	2533.	6258.
109602	02/04/82	8360.	1520.	16340.
109623	02/22/82	2904.	1848.	11616.
109649	03/12/82	774.	532.	2081.
109678	03/30/82	2625.	210.	4200.
109707	04/17/82	599.	333.	1796.
109738	05/05/82	1304.	1304.	7172.
109765	05/23/82	2160.	< 180.	6660.
109785	06/10/82	1808.	689.	3702.
109795	06/28/82	330.	725.	2636.
109800	07/16/82	246.	1412.	2702.
109806	08/03/82	1488.	1240.	10416.
109812	09/08/82	195.	1365.	7995.
109833	09/26/82	435.	3190.	6815.
109839	10/14/82	331.	1322.	2644.
109845	11/01/82	987.	8883.	17437.
109850	11/19/82	47.	1034.	1786.
109857	12/07/82	238.	267.	1069.
109863	12/25/82	72.	1155.	1408.
109869	01/12/83	231.	647.	1478.
109875	01/30/83	588.	3822.	6762.
109887	03/07/83	236.	3658.	5546.
109881	03/18/83	1470.	3822.	6174.
109900	04/30/83	1840.	1495.	4715.
109903	05/18/83	1880.	6016.	15792.
109922	06/05/83	6292.	2662.	11858.
109912	06/23/83	1392.	418.	2854.
109962	07/08/83	157.	2198.	3297.
109917	07/11/83	510.	1870.	6970.
109949	07/29/83	519.	1113.	2968.
109950	08/19/83	512.	4608.	7296.
109951	09/03/83	375.	657.	2204.
109952	10/27/83	501.	319.	1320.
109953	12/05/83	276.	883.	1656.
109975	12/21/83	186.	699.	1118.
AVERAGE CONCENTRATION		1595.	1860.	6409.
HIGH CONCENTRATION		8360.	8883.	26166.
LOW CONCENTRATION		47.	180.	1069.

CITY: HIBBING
LOCATION: COUNTY COURTHOUSE

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55364	07/26/78	2912.	5460.	16744.
55398	09/06/78	1758.	8790.	14650.
55402	10/13/78	1638.	16926.	36036.
55393	10/31/78	825.	2200.	11825.
55726	12/05/78	638.	9570.	12122.
55728	03/30/79	< 1360.	62560.	70720.
AVERAGE CONCENTRATION		1522.	17584.	27016.
HIGH CONCENTRATION		2912.	62560.	70720.
LOW CONCENTRATION		638.	2200.	11825.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
2. FIBER CONCENTRATIONS INCLUDE CONTAMINATION FROM FILTERS AND THE LABORATORY. MOST OF THE REPORTED CHRYSOTILE CONCENTRATIONS ARE DUE TO THIS CONTAMINATION LEVEL. THE ACTUAL AIR CONCENTRATIONS ARE MUCH LOWER.
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CITY: VIRGINIA
LOCATION: CITY HALL ROOF

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55365	07/26/78	267.	2136.	10146.
55392	10/31/78	633.	2532.	25320.
55720	12/05/78	636.	2544.	8480.
55722	01/16/79	884.	8398.	23868.
55274	03/13/79	< 245.	4655.	13475.
55276	04/18/79	6282.	9772.	32806.
55278	06/18/79	2136.	3560.	17444.
55272	08/14/79	974.	7305.	22402.
AVERAGE CONCENTRATION		1507.	5113.	19243.
HIGH CONCENTRATION		6282.	9772.	32806.
LOW CONCENTRATION		245.	2136.	8480.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
2. FIBER CONCENTRATIONS INCLUDE CONTAMINATION FROM FILTERS AND THE LABORATORY. MOST OF THE REPORTED CHRYSOTILE CONCENTRATIONS ARE DUE TO THIS CONTAMINATION LEVEL. THE ACTUAL AIR CONCENTRATIONS ARE MUCH LOWER.
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CITY: DULUTH
LOCATION: DOWNTOWN

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55397	09/26/78	2886.	34632.	59644.
55397R	09/26/78	1835.	10276.	17616.
55395	10/31/78	4350.	15950.	56550.
55715	12/26/78	1119.	7460.	17904.
55718	02/23/79	1136.	5112.	13064.
55282	06/14/79	18480.	30360.	64680.
55284	08/27/79	3516.	10548.	24026.
AVERAGE CONCENTRATION		4760.	16334.	36212.
HIGH CONCENTRATION		18480.	34632.	64680.
LOW CONCENTRATION		1119.	5112.	13064.

NOTES
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CITY: ST. PAUL
LOCATION: RESIDENTIAL

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55372	08/11/78	892.	1784.	16056.
55411	12/01/78	362.	3801.	9955.
55519	01/25/79	490.	19110.	23520.
AVERAGE CONCENTRATION		581.	8232.	16510.
HIGH CONCENTRATION		892.	19110.	23520.
LOW CONCENTRATION		362.	1784.	9955.

NOTES
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CITY: ST. PAUL
LOCATION: DOWNTOWN

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55371	08/11/78	1170.	14040.	45630.
55371A	08/11/78	7300.	30660.	68620.
55371B	09/01/78	639.	8946.	28116.
55404	11/07/78	< 455.	10920.	20930.
55427	12/28/78	820.	10250.	20500.
55883	05/15/79	1774.	15079.	40802.
55094	07/18/79	1344.	6048.	19152.
AVERAGE CONCENTRATION		1929.	13706.	34821.
HIGH CONCENTRATION		7300.	30660.	68620.
LOW CONCENTRATION		455.	6048.	19152.

NOTES

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CITY: MINNEAPOLIS
LOCATION: COMMERCIAL DISTRICT

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55390	10/17/78	84.	928.	1646.
55425	12/26/78	943.	62238.	70725.
55580	02/23/79	558.	5580.	19530.
55815	04/27/79	1160.	41760.	53360.
55996	06/25/79	845.	19435.	44785.
55262	09/10/79	1822.	13665.	38262.
AVERAGE CONCENTRATION		902.	23934.	38051.
HIGH CONCENTRATION		1822.	62238.	70725.
LOW CONCENTRATION		84.	928.	1646.

NOTES

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CITY: MINNEAPOLIS
LOCATION: RESIDENTIAL

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
55370	08/16/78	2180.	3488.	20928.
55381	09/19/78	634.	1902.	13631.
AVERAGE CONCENTRATION		1407.	2695.	17280.
HIGH CONCENTRATION		2180.	3488.	20928.
LOW CONCENTRATION		634.	1902.	13631.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
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FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM   REPORT PREPARED 03/29/85

CITY: BABBITT
LOCATION: CITY HALL

SAMPLE NUMBER	DATE COLLECTED		AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
111454	10/05/78		3344.	6384.	15504.
108005	09/06/79		640.	2011.	3930.
108007	10/12/79		15600.	12600.	33000.
108039	10/30/79		6282.	3490.	16054.
108040	11/17/79		20938.	15162.	59204.
108041	12/05/79		6006.	1638.	14742.
108042	12/23/79	<	525.	1050.	19425.
108084	01/10/80		2232.	6200.	11656.
108085	01/28/80		587.	1468.	3597.
108086	02/15/80		1575.	945.	4200.
108087	03/05/80		10192.	3920.	17640.
108088	03/22/80		3480.	1450.	11600.
108096	04/09/80		449.	2514.	4759.
108096R	04/09/80		852.	7952.	12496.
108109	04/27/80		3952.	624.	7904.
108125	05/15/80		2145.	660.	8085.
108126	07/08/80		2926.	2508.	10868.
108131	08/13/80		4578.	1526.	8938.
AVERAGE CONCENTRATION			4795.	4006.	14645.
HIGH CONCENTRATION			20938.	15162.	59204.
LOW CONCENTRATION			449.	624.	3597.

NOTES

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FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM REPORT PREPARED 03/29/85

CITY: HOYT LAKES
LOCATION: POLICE STATION

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
111462	10/29/78	2496.	14976.	21632.
108000	08/19/79	12038.	5093.	23150.
108001	09/06/79	7856.	6383.	23563.
108003	10/12/79	3040.	9120.	20140.
108043	10/30/79	7658.	5470.	21880.
108044	11/17/79	9405.	3762.	23826.
108045	12/05/79	3040.	2736.	6840.
108046	12/23/79	9180.	6120.	31620.
108047	01/10/80	610.	1098.	5246.
108080	01/28/80	8993.	7406.	23805.
108081	02/15/80	2904.	3267.	14157.
108082	03/05/80	8694.	2484.	26703.
108083	03/22/80	20352.	15264.	54272.
108097	04/09/80	8220.	5754.	19728.
108108	04/27/80	17120.	14980.	53500.
108122	05/15/80	14145.	6150.	29520.
108123	06/20/80	15240.	3810.	32385.
108124	07/08/80	7860.	3144.	20960.
108128	07/26/80	4311.	3353.	19160.
108129	08/13/80	16560.	4968.	33948.
AVERAGE CONCENTRATION		8986.	6267.	25302.
HIGH CONCENTRATION		20352.	15264.	54272.
LOW CONCENTRATION		610.	1098.	5246.

NOTES

1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
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FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM   REPORT PREPARED 03/29/85

CITY: CLOQUET
LOCATION: POLICE STATION

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
111448	10/05/78	1404.	16380.	25272.
108022	08/19/79	5140.	514.	11565.
108023	09/06/79	11500.	16100.	55200.
108019	09/24/79	3012.	10542.	33132.
108031	10/12/79	1368.	4788.	9348.
108032	10/30/79	1180.	4484.	9440.
108033	11/17/79	4420.	6630.	18564.
108034	12/05/79	3773.	15092.	32340.
108035	12/23/79	6372.	6372.	30444.
108076	01/10/80	807.	4573.	13181.
108077	01/28/80	610.	8540.	23790.
108078	02/15/80	1752.	3796.	13724.
108079	03/04/80	10153.	17537.	52611.
108110	03/22/80	4472.	11739.	24596.
108111	04/09/80	2601.	2890.	12427.
108112	04/27/80	5652.	10362.	39564.
108113	05/15/80	6786.	13572.	45240.
108114	06/02/80	4750.	6650.	34200.
108115	06/20/80	2724.	11577.	34050.
108120	07/08/80	4795.	7535.	26715.
108121	07/26/80	3745.	8239.	29960.
108132	08/13/80	< 1450.	< 1450.	53650.
AVERAGE CONCENTRATION		4021.	8607.	28592.
HIGH CONCENTRATION		11500.	17537.	55200.
LOW CONCENTRATION		610.	514.	9348.

NOTES
1. FIBER CONCENTRATIONS ARE GIVEN IN FIBERS PER CUBIC METER.
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FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM REPORT PREPARED 03/29/85

CITY: ST. PAUL
LOCATION: COMMERCIAL DISTRICT

SAMPLE NUMBER	DATE COLLECTED		AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
111442	10/05/78		844.	14343.	21944.
108016	08/19/79	<	1960.	98000.	107800.
108018	09/06/79		1990.	47760.	91540.
108018R	09/06/79	<	3000.	117000.	153000.
108008	10/12/79		8670.	63580.	104040.
108009	10/30/79	<	1220.	43920.	57340.
108024	11/17/79		7080.	50740.	63720.
108028	12/23/79		3224.	6851.	18538.
108036	01/10/80		1269.	8460.	22419.
108074	02/15/80		1984.	12400.	22320.
108089	03/04/80	<	1940.	54320.	69840.
108075	03/22/80		1520.	57760.	79040.
108090	04/09/80		3420.	35340.	52440.
108091	04/27/80	<	11900.	249900.	440300.
108091R	04/27/80		10650.	134900.	223650.
108098	05/15/80		6760.	40560.	81120.
108098R	05/15/80		6200.	34720.	73160.
108099	06/02/80		4640.	38280.	52200.
108100	06/20/80	<	1280.	33280.	58880.
108118	07/08/80		7200.	20700.	50400.
108119	07/26/80		1410.	4935.	12220.
AVERAGE CONCENTRATION			4198.	55607.	88377.
HIGH CONCENTRATION			11900.	249900.	440300.
LOW CONCENTRATION			844.	4935.	12220.

NOTES
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FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM REPORT PREPARED 03/29/85

CITY: ST.CLOUD
LOCATION: HEALTH DEPT.

SAMPLE NUMBER	DATE COLLECTED	AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
108021	08/19/79	963.	1605.	4387.
108020	09/06/79	4806.	5874.	22428.
108012	09/24/79	1730.	17300.	67470.
108013	10/12/79	1656.	3933.	8901.
108014	10/30/79	1728.	4320.	12672.
108027	11/17/79	2885.	17887.	25965.
108026	12/05/79	9590.	27400.	57540.
108038	12/23/79	978.	1793.	6031.
108069	01/10/80	1124.	2248.	24166.
108070	01/26/80	1220.	1708.	7564.
108094	03/04/80	6419.	11004.	37597.
108095	03/22/80	10128.	15192.	42200.
108104	04/09/80	12900.	20640.	54180.
108105	04/27/80	5600.	12800.	32000.
108106	05/15/80	6512.	4144.	26640.
108107	06/02/80	4528.	12452.	28300.
108134	06/20/80	2800.	29400.	61600.
108127	07/08/80	9220.	18440.	47022.
108133	08/31/80	1050.	9800.	16450.
AVERAGE CONCENTRATION		4518.	11471.	30690.
HIGH CONCENTRATION		12900.	29400.	67470.
LOW CONCENTRATION		963.	1605.	4387.

NOTES

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3. THE "<" SYMBOLS REPRESENT COUNTS WHERE NO FIBERS OF THAT TYPE WERE COUNTED. THE VALUE ON THE TABLE IS THE CONCENTRATION WHICH ONE WOULD OBTAIN IF ONLY ONE FIBER WERE COUNTED.

FIBER CONCENTRATIONS FOR MPCA COMUNITY AIR PROGRAM REPORT PREPARED 03/29/85

CITY: ST. PAUL
LOCATION: DOWNTOWN

SAMPLE NUMBER	DATE COLLECTED		AMPHIBOLE CONCENTRATION	CHRYSOTILE CONCENTRATION	TOTAL FIBERS CONCENTRATION
108015	08/19/79		1536.	33306.	42822.
108017	09/06/79	<	769.	26146.	36143.
108011	10/30/79		3460.	30275.	49305.
108025	11/17/79		2196.	15921.	29646.
108029	12/05/79		684.	9918.	18468.
108030	12/23/79		519.	6574.	8996.
108030R	12/23/79		820.	4756.	8036.
108037	01/10/80	<	695.	21545.	30580.
108048	01/30/80		3715.	11145.	27491.
108072	02/15/80		3568.	11596.	35680.
108071	03/04/80		1930.	22195.	39565.
108073	03/22/80		5280.	30360.	63360.
108092	04/09/80		6040.	34730.	63420.
108093	04/27/80	<	1870.	65450.	125290.
108101	05/15/80		5220.	40020.	74820.
108102	06/02/80		12600.	21000.	92400.
108103	06/20/80		1914.	16269.	36366.
108116	07/08/80		2376.	4752.	15840.
108116R	07/08/80		2320.	29000.	64960.
108117	07/26/80		888.	5032.	8288.
AVERAGE CONCENTRATION			2923.	22000.	43574.
HIGH CONCENTRATION			12600.	65450.	125290.
LOW CONCENTRATION			519.	4752.	8036.

NOTES

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Appendix F

Description of the ILO Roentgenographic Evaluation Form

DESCRIPTION OF ILO ROENTGENOGRAPHIC EVALUATION FORM

Radiographic abnormalities due to dust exposure are recorded according to an International Labor Office (ILO) classification system. The ILO forms (Figure 1) were developed to facilitate documentation of pleural and parenchymal changes associated with the pneumoconioses and to standardize the evaluation of these abnormalities. Any changes noted are evaluated in relation to a set of "standard radiographs." These standards, upon which the classification system has been based, were chosen because they were felt to typify the different stages of these dust related diseases.

Any parenchymal changes (change in the lung tissue) consistent with the pneumoconioses are recorded. These changes can appear as either small or large areas of increased density (less transparent) in the lung parenchyma. The small opacities are recorded according to size, shape, location, and approximate number. Each of these characteristics help define the type and severity of a disease. P, Q, and R represent the round opacities according to size; less than 1.5mm in diameter (P), 1.5 to 3.0mm in diameter (Q) and 3-10mm in diameter (R). S, T, and U represent the irregularly shaped opacities with the same size designations as P, Q, and R, respectively (e.g., S = opacities less than 1.5mm in width). The small opacities are recorded as primary or secondary, allowing for the identification of two different types and/or size lesions. The size and shape of the predominant lesion is recorded as primary, a less prevalent lesion is recorded as secondary. If all the opacities are similar in size and shape then the same letter is checked for both primary and secondary.

Each lung is divided into 3 zones; upper, middle, and lower. These 6 zones are designated on the form by six small boxes. The location of the small opacities is recorded by checking one or more of the appropriate boxes.

The number of opacities present is judged in relation to the number present on the standard radiographs and is noted under profusion. Profusion is described by 4 major categories, 0,1,2, and 3, as defined by the standard films. The numerator indicates the major category most similar to the radiograph being evaluated. The denominator represents the other major category considered when recording profusion, e.g., 1/0 represents profusion of grade 1 but at the lower end of the scale and so grade 0 was also considered.

Large opacities, those 10mm in width, are recorded according to size only, ranging from (0) not present, to (C) opacity size equivalent to the size of the right upper zone.

The presence of any pleural abnormalities is also recorded. Pleural thickening is recorded according to the side(s) affected and the location, i.e., on the diaphragm, at the costophrenic angle or on the chest wall. Pleural thickening on the chest wall is defined as either circumscribed (defined areas of fibrous thickening, or plaques) or diffuse, each of which is further described according to the width and extent of the thickening and if it is seen on the anterior chest wall (face on). The width of the pleural thickening is described according to 1 of 3 categories; (A) width up to 5mm, (B) width 5-10mm, or (C) width greater than 10mm. The extent can vary from (1) one quarter the projection of the lateral chest wall, to (3) greater than half the projection of the lateral chest wall.

Pleural calcification is recorded, if present, according to both extent and location. Extent is designated by (1) a calcified area(s) up to approximately 20mm in diameter in total (2) area(s) 20-100mm in total diameter or (3) calcified area(s) with total diameter exceeding 100mm. It is recorded as occuring on the diaphragm, along the chest wall, or at other sites.

Additional changes noted on the radiograph, e.g., emphysema may be recorded by marking off the appropriate symbol or by using the comment section at the bottom of the form. The comment section is often used to note changes which need further explanation, for example, if the parenchymal changes seen may be due to heart failure and not to dust exposure.

Figure 1

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE

OMB No. 68-5 1322
Expires 9/84

CENTERS FOR DISEASE CONTROL
National Institute for Occupational Safety and Health
Federal Mine Safety and Health Act of 1977
Medical Examination Program
ROENTGENOGRAPHIC INTERPRETATION

NOTE: Please record your interpretation of a single film by placing an "x" in the appropriate boxes on this form and return it promptly to:

Receiving Center
Appalachian Laboratory for
Occupational Safety and Health
Box 4258
Morgantown, West Virginia 26505

WORKER'S Social Security Number [ ]

TYPE OF READING [A] [B] [P]

FACILITY IDENTIFICATION [ ]

1A. DATE OF X-RAY MONTH | DAY | YR

1B. FILM QUALITY [1] [2] [3] [U/R] If Not Grade 1 Give Reason: ______

1C. IS FILM COMPLETELY NEGATIVE? YES [ ] Proceed to Section 5 NO [ ] Proceed to Section 2

2A. ANY PARENCHYMAL ABNORMALITIES CONSISTENT WITH PNEUMOCONIOSIS? YES [ ] COMPLETE 2B and 2C NO [ ] PROCEED TO SECTION 3

2B. SMALL OPACITIES

a. SHAPE/SIZE
PRIMARY [p] [s] [q] [t] [r] [u]
SECONDARY [p] [s] [q] [t] [r] [u]

b. ZONES R L

c. PROFUSION [0/-] [0/0] [0/1] [1/0] [1/1] [1/2] [2/1] [2/2] [2/3] [3/2] [3/3] [3/+]

2C. LARGE OPACITIES

SIZE [0] [A] [B] [C]

PROCEED TO SECTION 3

3A. ANY PLEURAL ABNORMALITIES CONSISTENT WITH PNEUMOCONIOSIS? YES [ ] COMPLETE 3B, 3C and 3D NO [ ] PROCEED TO SECTION 4

3B. PLEURAL THICKENING

a. DIAPHRAGM (plaque)
SITE [0] [R] [L]

b. COSTOPHRENIC ANGLE
SITE [0] [R] [L]

3C. PLEURAL THICKENING . . . Chest Wall

a. CIRCUMSCRIBED (plaque)

SITE	0 R	0 L
IN PROFILE i. WIDTH	0 A B C	0 A B C
ii. EXTENT	0 1 2 3	0 1 2 3
FACE ON iii. EXTENT	0 1 2 3	0 1 2 3

b. DIFFUSE

SITE	0 R	0 L
IN PROFILE i. WIDTH	0 A B C	0 A B C
ii. EXTENT	0 1 2 3	0 1 2 3
FACE ON iii. EXTENT	0 1 2 3	0 1 2 3

3D. PLEURAL CALCIFICATION

SITE	0 R EXTENT	0 L EXTENT
a. DIAPHRAGM	0 1 2 3	0 1 2 3
b. WALL	0 1 2 3	0 1 2 3
c. OTHER SITES	0 1 2 3	0 1 2 3

PROCEED TO SECTION 4

4A. ANY OTHER ABNORMALITIES? YES [ ] COMPLETE 4B and 4C NO [ ] PROCEED TO SECTION 5

4B. OTHER SYMBOLS (OBLIGATORY)

[0] [ax] [bu] [ca] [cn] [co] [cp] [cv] [di] [ef] [em] [es] [fr] [hi] [ho] [id] [ih] [kl] [pi] [px] [rp] [tb]

Report items which may be of present clinical significance in this section.

[OD] (SPECIFY od.) ______

Date Personal Physician notified? MONTH | DAY | YR

4C. OTHER COMMENTS ______

SHOULD WORKER SEE PERSONAL PHYSICIAN BECAUSE OF COMMENTS IN SECTION 4C. [YES] [NO] PROCEED TO SECTION 5

5. FILM READER'S INITIALS [ ]

PHYSICIAN'S SOCIAL SECURITY NUMBER* [ ]

DATE OF READING MONTH | DAY | YR

Complete if social security number is not furnished:

NAME (LAST—FIRST—MIDDLE)

STREET ADDRESS CITY STATE ZIP CODE

*Furnishing your social security number is voluntary. Your refusal to provide this number will not affect your right to participate in this program.

CDC/NIOSH (M) 2.8
REV. 4/80
☆ U.S. GOVERNMENT PRINTING OFFICE: 1984 -- 781-140

Appendix G

Radiographic Findings

(G-TABLES)

CONTENTS

Introduction

The tables in this appendix summarize the results of the three radiographic evaluations. This information was presented to the Range Studies Advisory Committee on April 11-12, 1985. Throughout the appendix the three radiographic evaluations are referred to as the first review (by Dr. T. Hodous), the second review (by Dr. R. Lillis), and the third review (by the NIOSH panel). Information given in these tables includes source of the films and manner in which they were selected, pleural and parenchymal findings according to each of the three reviewers, and concordance between the reviewers. Additional text describing the information presented is given at the bottom of many of the tables.

TABLE 1

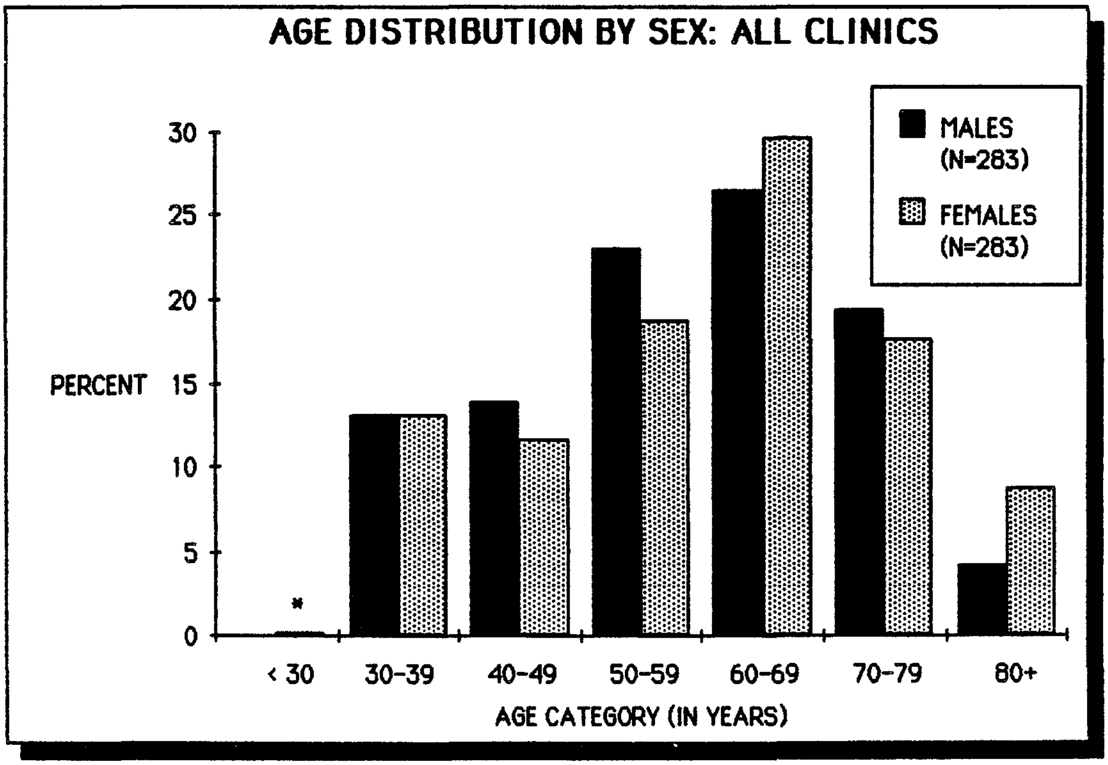
Number of radiographs read by selection method and clinic

Sequentially selected

	First review	Second review and NIOSH panel
Grand Rapids Clinic	41	39
Itasca Clinic	39	39
North Star Clinic	20	20
Hibbing Clinic	102	102
Duluth Clinic	101	98
Aurora Clinic	23	16
	326	**314**
Non-sequentially selected		
East Range Clinic	**243**	**252**
Total number read:	**569**	**566**

NOTE: The films were collected from seven clinics in Northeast Minnesota. They were chosen sequentially at six clinics, ie. all chest films taken during a period of time were examined. At the East Range Clinic approximately half of the radiographs were selected sequentially; because of time constraints approximately 155 films previously read as negative for pleural disease were not selected. A total of 556 films were read by all three reviewers.

TABLE 2



*ONE FEMALE SUBJECT WAS UNDER 30 YEARS

TABLE 3

Concordance of first two radiographic readings on pleural status (n=259)

Pleural disease status

Initial reading	First review: Disease absent	Disease present	Total
Disease absent	97	23	120
Disease present	32	107	139
Total	129	130	

NOTE: The physician who reported the excess of pleural changes did a partial B reading for these changes (initial reading). This table indicates the concordance on pleural status between this initial reading and the first reviewer. All films were from the East Range or Aurora clinics.

Table 4

First review: radiographic changes by sex

Radiographic changes	Sex: Males (%)	Sex: Females (%)	Total (%)
Negative	120 (43.1)	232 (79.7)	352 (61.9)
Pleural changes only	125 (45.0)	42 (14.5)	167 (29.3)
Parenchymal changes only	8 (2.9)	14 (4.8)	22 (3.9)
Pleural and parenchymal changes	25 (9.0)	3 (1.0)	28 (4.9)
	278 (100.0)	291 (100.0)	569 (100.0)

Note: The first reviewer found 167 patients with evidence of pleural changes on X-ray, 22 patients with parenchymal changes, and 28 patients with both pleural and parenchymal changes. This table also indicates the sex distribution of patients with these findings. The parenchymal changes not specific to pneumoconioses are not excluded.

Table 5

Second review: radiographic changes by sex

Radiographic Changes	Sex: Males (%)	Sex: Females (%)	Total (%)
Negative	188 (66.4)	260 (91.9)	448 (79.2)
Pleural changes only	51 (18.0)	12 (4.2)	63 (11.1)
Parenchymal changes only	20 (7.1)	9 (3.2)	29 (5.1)
Pleural and parenchymal changes	24 (8.5)	2 (0.7)	26 (4.6)
	283 (100.0)	283 (100.0)	566 (100.0)

Note: The second reviewer found 63 patients with evidence of pleural changes on X-ray, 29 patients with parenchymal changes, and 26 patients with both pleural and parenchymal changes. This table also indicates the sex distribution of patients with these findings. There is no exclusion of changes not consistent with pneumoconioses.

TABLE 6

Second review : width of circumscribed pleural thickening by age for males

Width of circumscribed pleural thickening

Age (years)	BOTH 0	UNILAT 1,0	BILAT 1,1	UNILAT 2,0	BILAT 2,1	BILAT 2,2	UNILAT 3,0	Row Total (Percent)
30-39	36	0	0	0	0	0	1	37 (13.1)
40-49	35	2	0	0	1	1	0	39 (13.8)
50-59	54	8	2	0	0	1	0	65 (23.0)
60-69	60	6	3	4	1	1	0	75 (26.5)
70-79	41	8	3	3	0	0	0	55 (19.4)
80+	9	0	0	2	1	0	0	12 (4.2)
Column Total (Percent)	235 (83.0)	24 (8.5)	8 (2.8)	9 (3.2)	3 (1.1)	3 (1.1)	1 (.4)	283 (100.0)

Unilat: unilateral findings
Bilat: bilateral findings

Width: 0 - no pleural thickening
1 - maximum width up to 5 mm
2 - maximum width 5 - 10 mm
3 - maximum width greater than 10 mm

NOTE: This table presents the severity of the circumscribed pleural thickening (as measured by width of the plaques) in the male patients by age. Seventeen percent (17%) of the male patients were found to have circumscribed pleural thickening.

TABLE 7

Second review: width of circumscribed pleural thickening by age for females

Age (years)	Width of circumscribed pleural thickening: BOTH 0	UNILAT 1,0	BILAT 1,1	Row Total (Percent)
LT 30	1	0	0	1 (.4)
30 - 39	37	0	0	37 (13.1)
40 - 49	33	0	0	33 (11.7)
50 - 59	51	1	1	53 (18.7)
60 - 69	82	1	1	84 (29.7)
70 - 79	50	0	0	50 (17.7)
80+	25	0	0	25 (8.8)
Column Total (Percent)	279 (98.6)	2 (.7)	2 (.7)	283 (100.0)

Unilat: unilateral findings
Bilat: bilateral findings

Width: 0 - no pleural thickening
1 - maximum width up to 5 mm
2 - maximum width 5 - 10 mm
3 - maximum width greater than 10 mm

NOTE: This table presents the severity of the circumscribed pleural thickening (as measured by plaque width) in the females by their age. Four of the females (1.4%) were found to have circumscribed pleural thickening.

Table 8

Presence of pleural changes: concordance between the first and second reviews

		Presence of pleural changes (second review)		
		Negative	Positive	Row Total (Percent)
Presence of pleural changes (first review)	Negative	351	13	364 (65.5)
	Positive	122	70	192 (34.5)
	Column Total (Percent)	473 (85.1)	83 (14.9)	556 (100.0)

Note: The first and second reviewers read 556 identical films. The first reviewer found 192 films with evidence of pleural changes, (e.g., diffuse pleural thickening, circumscribed pleural thickening), 70 (37%) of those were also judged as positive by the second reviewer. The second reviewer found 83 films with pleural changes.

Table 9a

Parenchymal abnormalities (second review): small, irregularly shaped opacities in cases where profusion was graded as 1/0 or greater

	Primary Opacities (n=18) Width (mm)			Secondary Opacities Width (mm)		
	<1.5	1.5-3.0	>3.0	<1.5	1.5-3.0	>3.0
Males Age (years)						
30-39	0	1	0	0	2	0
40-49	1	1	0	1	3	0
50-59	0	0	0	1	0	0
60-69	5	3(F)	0	0	5	1(F)
70-79	3	1	0	2	1	0
80+	1	0	0	0	1	0
Females Age (years)						
30-39	0	0	0	0	0	0
40-49	0	0	0	0	0	0
50-59	0	1	0	0	0	0
60-69	1	0	0	1	0	0
70-79	0	0	0	0	0	0
80+	0	0	0	1(B)	1(E)	0
TOTAL	11	7	0	6	13	1

Reader's statements qualifying radiographic findings of those cases listed in parentheses:

Case (B): Large cardiomegaly, possibly related to infiltrates in lower lung fields. Large opacity measuring 4x2 cm in left upper lobe; lung cancer is a definite possibility.

Case (E): Radiographic abnormalities could be due to other etiology than dust exposure.

Case (F): Changes in right lower lobe possibly due to pneumonitis or other infiltrative process; most probably not dust related.

Table 9b

Parenchymal abnormalities (second review): small round opacities in cases where profusion was graded as 1/0 or greater

	Primary Opacities (n=19) Width (mm)			Secondary Opacities Width (mm)		
	<1.5	1.5-3.0	>3.0	<1.5	1.5-3.0	>3.0
Males Age (years)						
30-39	0	2	0	1	0	0
40-49	2	2	0	1	1	0
50-59	1	1	0	1	0	0
60-69	2	0	1	5	0	0
70-79	0	2(D)	0	1	2(D)	0
80+	0	0	0	0	0	0
Females Age (years)						
30-39	0	1	0	0	1	0
40-49	0	0	0	0	0	0
50-59	0	1(G)	0	0	2(G)	0
60-69	1(C)	0	0	0	1(C)	0
70-79	0	0	0	0	0	0
80+	1(B)	1(E)	1(A)	0	0	1(A)
TOTAL	7	10	2	9	7	1

Reader's statements qualifying radiographic findings of those cases listed in parentheses:

Case (A): Opacities present mainly in left hemithorax are probably of a different etiology than dust inhalation.

Case (B): Large cardiomegaly possibly related to infiltrates in lower lung fields. Large opacity measuring 4x2 cm in left upper lobe; lung cancer is a definite possibility.

Case (C): Abnormalities present could be due to causes other than pneumoconiosis (sarcoid, etc.) The pattern of hilar enlargement and infiltrates in the lung parenchyma is not typical of pneumoconiosis.

Case (D): Huge cardiomegaly; all abnormalities could be due to heart failure.

Case (E): Radiographic abnormalities could be due to other etiology than dust exposure.

Case (G): Parenchymal infiltrates possibly due to other etiology than dust exposure.

Note: Table 9a describes those patients found to have irregularly shaped opacities, graded 1/0 or greater, either primary or secondary, by their age and sex (refer to Appendix F for description of grading of opacities).

Table 9b describes those patients found to have rounded opacities, either primary or secondary, graded 1/0 or greater. Seven patients with parenchymal abnormalities were judged to have changes inconsistent with a pneumoconiosis; these patients are denoted in the tables by the letters A-G. The reader's statements qualifying the findings for these cases are given immediately below each table.

Table 10

Second review: presence of small opacities by shape and degree of profusion and sex* (n=566)

Shape of small opacities		Degree of Profusion	Sex: Male	Female
None			241	277
Irregular	(total)		(23)	(2)
		0/1	12	1
		1/0	7	1
		1/1	4	0
		1/2	0	0
		2/1	0	0
		2/2	0	0
		2/3	0	0
Rounded	(total)		(9)	(2)
		0/1	2	1
		1/0	4	0
		1/1	2	1
		1/2	1	0
		2/1	0	0
		2/2	0	0
		2/3	0	0
Mixed	(total)		(10)	(2)
		0/1	1	1
		1/0	6	1
		1/1	0	0
		1/2	1	0
		2/1	0	0
		2/2	1	0
		2/3	1	0

Note: The irregularly shaped opacities are those where both the primary and secondary opacities were irregularly shaped. The rounded small opacities represent those films where both primary and secondary opacities were round. The mixed category represents those films that showed evidence of both round and irregularly shaped opacities. A description of how degree of profusion is graded can be found in Appendix F.

* Those cases where the reader felt the parenchymal abnormalities were not dust related (n=7) are included in the NONE category. (Reader's statements qualifying these findings are on pages 10-12.)

Table 11

Presence of parenchymal changes: concordance between the first and second reviews

		Presence of parenchymal changes (second review)		
		Negative	Positive	Row Total (Percent)
Presence of parenchymal changes (first review)	Negative	475	31	506 (91.0)
	Positive	29	21	50 (9.0)
	Column Total (Percent)	504 (90.6)	52 (9.4)	556 (100.0)

Note: The first and second reviewers read 556 identical films. The first reviewer found 50 films with evidence of parenchymal changes, 21 (42%) of those were also judged as positive by the second reviewer. The second reviewer found 52 films with parenchymal changes.

TABLE 12

THIRD REVIEW: SOURCE OF FILMS

AURORA	16
DULUTH	98
GRAND RAPIDS	39
ITASCA	39
NORTH STAR	20
HIBBING	102
EAST RANGE	252
MORGANTOWN, - CONTROL	400
MORGANTOWN, + CONTROL	34
TOTAL	1000

Note: The NIOSH panel (third reviewer) read 566 films from Minnesota and 434 control films collected as part of another study. All 434 control films had been previously evaluated by several B readers. Thirty-four of the control films had been previously found to have evidence of pleural thickening, the remainder were previously found to be negative.

TABLE 13

THIRD REVIEW: DESIGN

RANDOMIZED BALANCED INCOMPLETE BLOCK DESIGN

NEGATIVE CONTROLS SELECTED BY PROPORTIONATE GROUP MATCHING ON AGE AND SEX

10 BATCHES OF 100 FILMS EACH

FILMS ALLOCATED RANDOMLY TO BATCHES

ALL IDENTIFIERS OBSCURED

5 INTERPRETERS (ALL B READERS)

INDEPENDENT INTERPRETATIONS

1980 ILO CLASSIFICATION SYSTEM USED

SECRETARY RECORDERS TO MINIMIZE FATIGUE

TABLE 14

THIRD REVIEW: PLEURAL ABNORMALITIES

(2 OR MORE RADIOLOGISTS AGREEING)

FACILITY	YES	NO	UNREADABLE	UNRESOLVED
EAST RANGE	13	232	4	3
HIBBING	3	97	2	0
NORTH STAR	0	18	0	2
ITASCA	1	38	0	0
GRAND RAPIDS	2	37	0	0
DULUTH	4	93	1	0
AURORA	1	15	0	0
TOTAL MINN.	24	530	7	5
POSITIVE CONTROLS	18	16	0	0
NEGATIVE CONTROLS	1	399	0	0
TOTAL	43	945	7	5

Note: This table indicates the number of patients at each clinic found to have pleural abnormalities, the number of films felt to be unreadable, and the number where the presence of pleural changes remained unresolved. Twenty four of the Minnesota films showed evidence of pleural abnormalities according to at least two of the three B readers reviewing the films. Also shown on this table is the number of pleural findings among the positive and negative control films. Only 18 of the 34 positive control films were found to have pleural changes by this panel.

TABLE 15

THIRD REVIEW: PARENCHYMAL ABNORMALITIES

(2 OR MORE RADIOLOGISTS AGREEING)

FACILITY	YES	NO	UNREADABLE	UNRESOLVED
EAST RANGE	12	233	4	3
HIBBING	5	95	2	0
NORTH STAR	1	18	0	1
ITASCA	0	39	0	0
GRAND RAPIDS	4	35	0	0
DULUTH	3	94	1	0
AURORA	1	15	0	0
TOTAL MINN.	26	529	7	4
POSITIVE CONTROLS	3	30	0	1
NEGATIVE CONTROLS	0	400	0	0
TOTAL	29	959	7	5

Note: Shown here are the number of films at each clinic found to have parenchymal abnormalities, the number of films determined to be unreadable, and the number where the presence of parenchymal abnormalities remained unresolved. In all, 26 of the Minnesota films were found to have parenchymal abnormalities.

Appendix H

Occupational Health Risk Assessment of Iron-Ore Mining in Minnesota

CONTENTS

Tables

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III. Iron-Ore Mining (Hematite)

A. Historical Perspective

Iron is the most abundant metal in the earth's crust. It is widely distributed in soil and water. Iron is an essential element present in the heme molecule, in myoglobin, and in certain enzymes. Iron is found principally in the minerals hematite Fe_2O_3, magnetite Fe_3O_4 and siderite $FeCO_3$ (IARC, 1972).

Hematite (or haematite as in the British spelling) can be used to describe an iron plus silicon ore to which miners are exposed or as a synonym for ferric oxide, Fe_2O_3. The ore is a mineral found mainly in two forms: red hematite or red iron ore, which consists mainly of Fe_2O_3 and contains approximately 70% iron, and brown hematite, or brown iron ore which consists mainly of hydrated sesquioxide of iron, $HFeO_2$ (limonite), and contains 42% iron. The hematite ore of the Mesabi Range in Minnesota is a mixture of hematite-limonite and is commonly called "natural" iron-ore (Gruner, 1946).

Deposits of hematite ore are found in parts of Lancashire, Cumberland, and Cornwall in the British Isles; in Northern Spain in the region of Bilbao; in Minnesota, USA, near Lake Superior; in Italy in the Apian Alps between Mussa and Lucca; in Sweden; and in the Ukraine in the Kroivoi Rog iron district and the Kertch district. Occupational exposure to iron compounds is common in mining, iron and steel foundry work, and ore welding.

As described by Faulds (1), iron-ore mining in England began before the Roman invasion. Archeologic evidence of this exists in West Cumberland. The ore was smelted with charcoal made from the adjacent woods. The earliest written records of iron-ore mining date from 1127 when monks of Furness Abbey introduced iron-working into the area. Because of the depletion of the forests and a shortage of fuel, the local smelting of ore ceased between the fifteenth and eighteenth centuries. Around the middle of the eighteenth century, the process of coking coal was discovered. With the onset of the industrial revolution in the beginning of the nineteenth century, the development of railroads, and the building of steel ships, the demand for iron-ore greatly expanded.

The iron-ore in the northwest of England exists in two forms of hematite. In Lancashire and southwest Cumberland, it is soft with a high moisture content, and can be dug out with a pick and a shovel. There is little blasting and little dust. In north-west Cumberland, the hematite is dry and crystalline and is as hard as pure quartz.

Until the introduction of the pneumatic drill in 1913, no drills could penetrate the hardness of crystalline hematite. The ore was mined by a method known as "hammer and jumper", where explosives were placed in a hole 3 feet deep which had been hammered into the ore by the miner with a long rod-like chisel. About six such holes a day could be hammered by the average miner. Explosives were placed in the hole after drilling, detonated, and the miner shoveled the ore into a tub. With the pneumatic drill, a miner could drill up to 28 holes, 4 feet deep, increasing dust volumes up to 500 times and decreasing particle size. Dust suppression measures were not instituted until 1925 in the form of wet drills; however, these sprayed water over the miner and were often not used because of discomfort. Before mechanization, 4.6 tons were mined per man per week; after mechanization, 14 tons per man per week were mined, a threefold increase.

A description of the discovery and early development of the Lake Superior iron-ore ranges is found in Volume One of "Lake Superior Iron Ores" (LSIO, 1938). Iron ores occur to some extent in most of the United States, and in earlier days, small manufacture of pig iron was done locally from local sources. The effect of mass production and the industrial revolution created a demand for a large source. Large-scale iron-ore mining had begun in Michigan on the Marquette Range in 1852 and the ore had been shipped via railroad to Marquette, Michigan on Lake Superior and by ship to Cleveland, Ohio and then by rail to furnaces in Ohio and Pennsylvania. As early as 1866, geologists had seen the full extent of the Mesabi Range in Northern Minnesota, and the state geologist reported "immense bodies of iron-ore, both magnetic and hematite" and said that "in some of these formations, iron enters so largely into its composition as to affect the magnetic needle". In 1882, mining of a high quality iron-ore (65-66% iron) was begun at the site of the Soudan mine which is at the eastern end of St. Louis County in what is called the Vermilion Range. A railroad had been built and ore docks erected on Lake Superior at what is now Two Harbors, Minnesota. In 1892-93, the Duluth, Mesabi and Northern railroad was completed from Mountain Iron, Minnesota in the central Mesabi area, to Duluth, Minnesota on Lake Superior. Combined shipping of Minnesota hematite iron-ore went from 9 million tons in 1900 to 34 million tons in 1930 to 79 million tons in 1951. (Lake Superior Iron Ore, 1952).

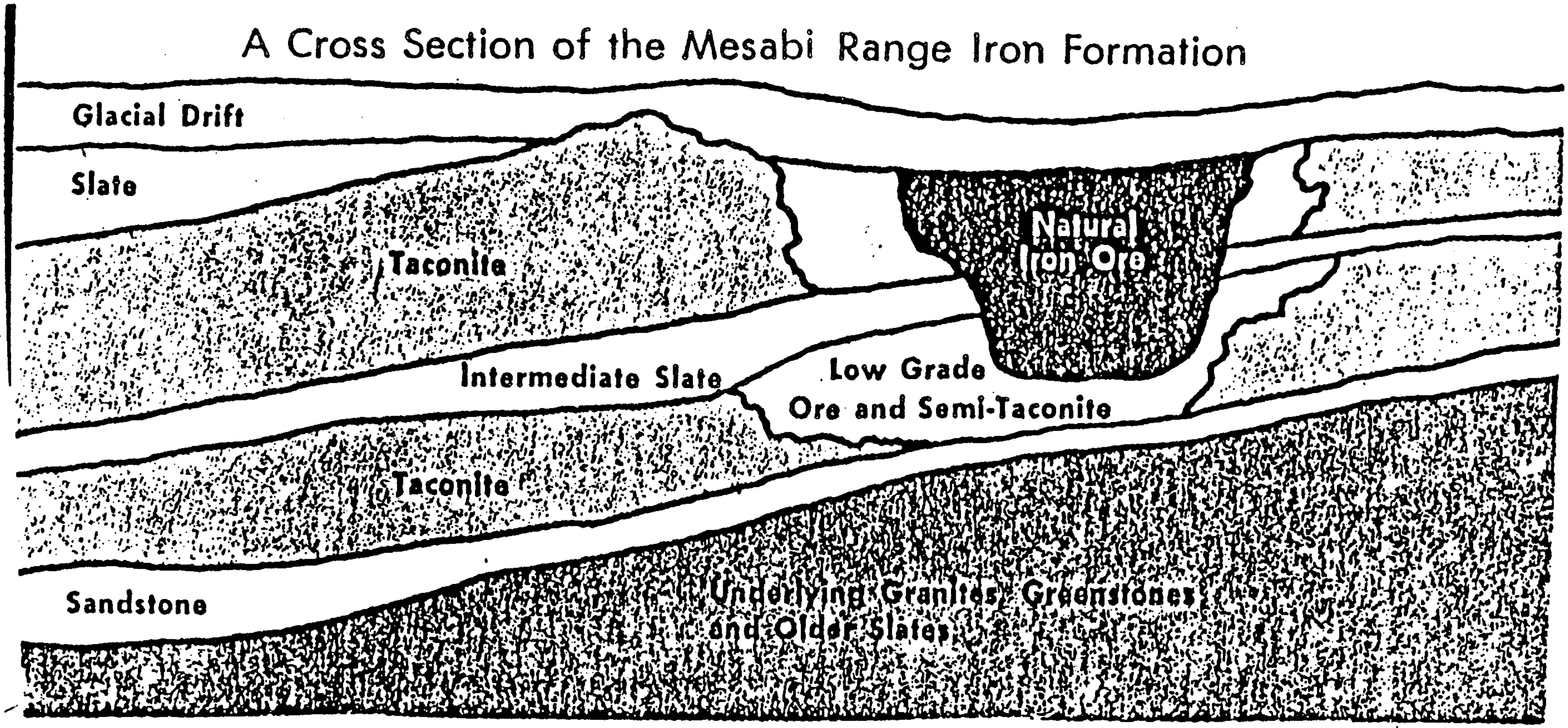
The geological features of the Mesabi produced shallow, soft ore bodies (Figure 1) which were in large part available for open pit mining, using large mechanical shovels loading directly into standard gauge railroad cars, conveyor belts or trucks after blasting out the ore. Open pit mining cannot be done when the movement of the ore and surface material becomes too expensive.

In the Vermilion Range, geologic changes formed a younger iron formation which is relatively soft and pliable, and a deeper formation which changed the soft, earthy ore to a type of hematite known as specular hematite, which is a hard, tough, dark blue material as hard as steel. Most mining there was done by underground mining methods. Methods of mining were brought to the U.S., mainly from England, in the early years of the U.S. mining industry.

Mining of hematite continues in Minnesota, but on a very small scale, because the supply of hematite that is economically feasible to mine has been depleted, and because, since 1965, iron-ore (taconite) Fe_3O_4 has become the major source of iron-ore for shipment (Figure 2).

Figure 1

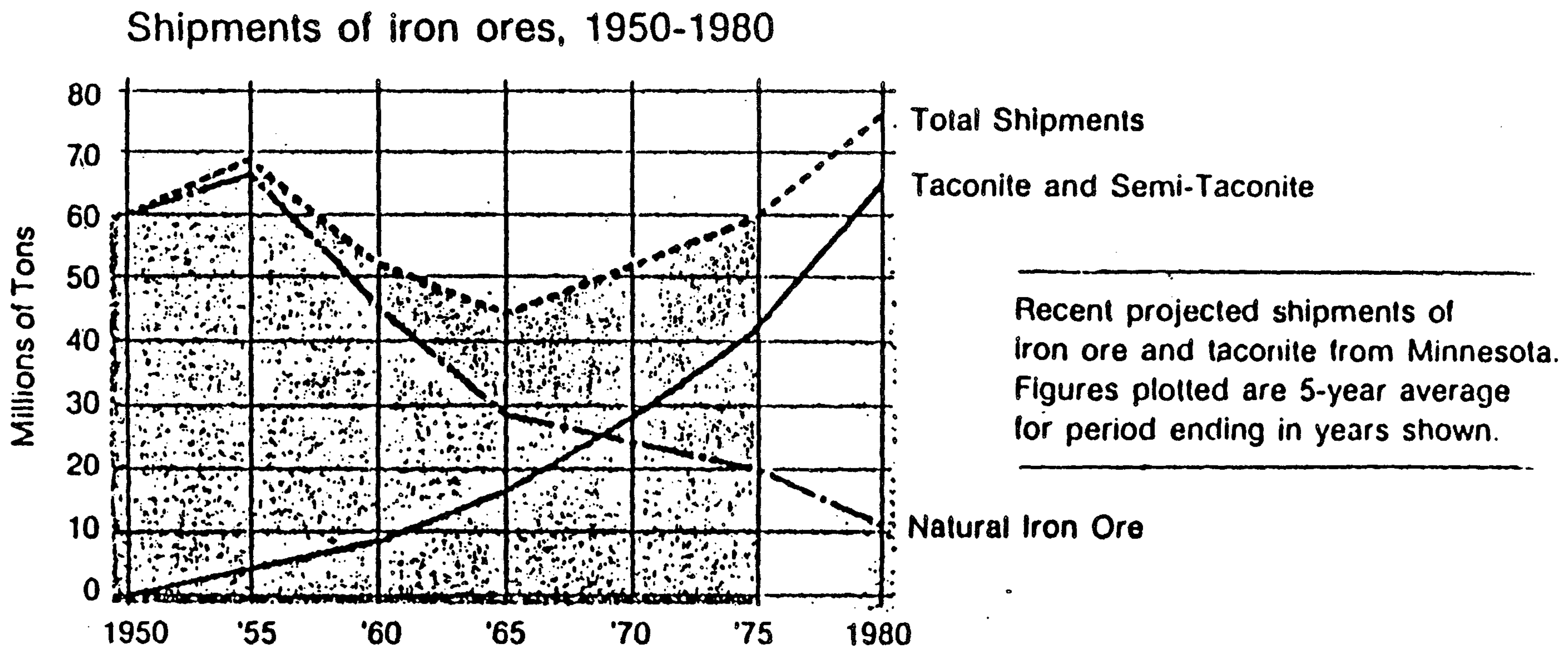
Minnesota Iron-Ore (Hematite) Miners Study, 1937-1978



SOURCE: Minnesota's Iron Mining Industry (pamphlet)
The Iron Mining Industry of Minnesota, 1978

Figure 2

Shipments of iron ores, 1950-1980. Minnesota Iron-Ore (Hematite) Miners Study, 1937-1978.



SOURCE: Minnesota's Iron Mining Industry (pamphlet)
The Iron Mining Industry of Minnesota, 1978

B. Literature Review

Metallic iron implants in rats (2), inhalation of Fe_2O_3 dust in rats (3, 4) and intratracheal instillation of Fe_2O_3 in hamsters (5), have failed to show carcinogenic activity for iron or for hematite dust.

Iron oxide has been shown to act synergistically in the production of lung tumors when given intratracheally to hamsters together with the known carcinogens benzo(a)pyrene (5,6), and following inhalation after systematic administration of diethylnitrosamine (7) suggesting that ferric oxide could serve as a carcinogenic cofactor.

Mutagenic activity of iron salts was found only at concentrations of 0.9 mM or more when looking at enhancement of the transformation frequency of hamster embryo cells by simian adenovirus (8). The metal salt $FeCl_2$ was negative when tested for the ability to decrease the fidelity of DNA synthesis (9).

Studies done on lung tissues of silver finishers (10), patients with welders' siderosis (11), and iron-ore (geothite) miners from Salzgitter, Germany (12), showed little fibrotic lung reaction that could be attributed to the presence of iron oxide in the lungs even when pulmonary clearance mechanisms were overwhelmed and the percent of iron oxide in the dry lung ash ranged from 18 - 300% higher than in normal lung. Several series of studies performed on Cumberland, England iron-ore miners' lung tissue classified by grade of fibrosis (Faulds, 1957, 1962) seemed to show that the dust from hematite mines was more fibrogenic the more quartz (silica) it contained. Eight of the lungs from this series were from miners with broncheal carcinoma and they did not differ in any way from the other lungs as far as amount or composition of dust. Annual dust accumulation was calculated, and 1.6 g of dust per year for the miners with ++ and +++ fibrosis compared with 0.69 g of dust per year for the miners with 0 and + fibrosis. The average hematite content of the lung dust was fairly consistent among fibrosis grades (79.0 - 83.9%) while the quartz content did decrease from grade +++ to grade + fibrosis. In the histological investigation of the lungs of 22 of the iron-ore (hematite) miners with carcinoma (1), since the tumors arose where the fibrosis was most common, the author suggests that in hematite miners, lung cancer appeared to arise from damaged epithelial cells at the edge of a fibrotic mass which was caused by a combined exposure of silica and iron acting as an irritant.

A study of 68 lungs by Mossbauer spectroscopy (Guest, 1978) for exogenous iron (hematite) and endogenous iron compounds (blood and storage iron) in the lung found that the endogenous iron content of bronchitics and occupationally exposed groups were, on the average, between 6 to 33 times higher than a "normal" group and was due to the presence of significant amounts of storage iron. The author suggests that a partial conversion of the exogenous iron to storage iron in dust-exposed workers occurs as a result of solution of the dust in the lysosomes of the macrophage and that observed opacities in the pneumoconiosis groups are significantly due to the storage iron.

Comparisons were made (13) between the x-ray findings among 191 hematite miners from the Egremont district of Cumberland, England which showed, with increasing years of exposure, abnormal findings of the reticulation type in up to 35%, and among 84 Furness district hematite miners who showed no evidence of massive shadows or reticulation. The chemical composition of the ore in both districts was similar but the physical composition was very different, with the Egremont district ore being very hard with dust of very small particulate size formed in drilling and blasting, and Furness ore being soft and not broken up into such small particles. A study of the possible causes and the prevalence of silicosis in active metal miners in the U.S. in 1958 (14) revealed a 4.2% prevalence of silicosis in iron-ore miners working in high silica (2-10%) host rock, compared to 0.3% prevalence in iron-ore miners working in low free-silica limestone host rock. Dose response effects were seen with the number of years worked. A retrospective study of medical data from one of the iron mines, a hematite mine in Wisconsin, in which the ore was analyzed as 60% iron and 7-9% silica, showed 20.3% prevalence of silicosis in 1933, dropping to 1.5% prevalence in 1960 with no case found in miners who started work after 1933 when dust control measures began.

Pulmonary function and respiratory tract symptoms of a group of underground and aboveground iron-ore miners in Kiruna, Sweden were compared (15) within two age groups (under and over 40 years) and smoker/non-smoker status. Bronchitic symptoms were more common among underground workers than surface workers and there was a difference between smokers and non-smokers underground which became apparent after 5 years. No differences were found between underground and aboveground workers with respect to lung changes which could be demonstrated by spectrometry. Dust analysis revealed 6-7% quartz in the iron-ore dust. Diesel fuel had been increasingly used for underground vehicles over the last 10 years. Based on answers to the bronchitis questionnaire, the author concluded that the effect of underground work (dust, irritating gases, or other) and smoking seemed to be synergic.

A study of iron-ore miners in Lorraine, France (16) on pulmonary function and carbon monoxide transfer factor also revealed a higher frequency of bronchitis in underground workers who smoked than in aboveground workers who smoked, and a synergistic effect on underground workers who smoked. However, a further breakdown of these populations showed that bronchitis was more frequent in miners working aboveground less than 10 years (34%) than in miners working aboveground more than 10 years (10%) probably due to transfer of underground miners with symptoms. Among the underground miners, bronchitis was most common among men working on Joy Loaders at the mine face who were exposed to the fumes from the liquid oxygen explosives (55%).

A proportionate mortality study of hematite iron-ore miners in West Cumberland, England (13) revealed that deaths due to pulmonary tuberculosis and silicosis which comprised 23.5% of the total deaths in 1900-1903 dropped to 14.9% in 1910-1912 but gradually increased to 26.1% in 1940-1942, while percentages of deaths due to bronchitis and pneumonia/influenza essentially stayed the same. The author suggests that deaths due to respiratory disease were not, as had been suggested, a result of the introduction of pneumatic drills in 1913, but had been a long-term problem. The death rate from respiratory disease in 1910 in coal miners in the Cumberland area was 1.6/1000 miners compared to 5.5/1000 of the West Cumberland hematite iron-ore miners.

A study among West Cumberland hematite iron-ore miners (17) utilizing post-mortem records of men coming to autopsy between 1932-1953, found a 4.7 fold increase in lung cancer in hematite miners over other males. In a continuation of this study (Faulds, 1957), an analysis of causes of death of hematite iron-ore miners of Cumberland revealed a high incidence of carcinoma of the lung and that thirty percent of the 58 iron-ore miners autopsied between 1954-1956 died of pulmonary tuberculosis despite active treatment by modern methods. When lung cancer cases in the new series were combined with those previously discussed, 14% of iron-ore miners' autopsies revealed lung cancer compared to 2.7% of other Cumberland males. Possible bias inherent in percentages of miners who come to autopsy because of compensation laws compared to other workers was not resolved in these studies. Because the primary tumor was usually found in the area of the lung that was the chief seat of fibrosis due to silico-siderosis, and because there was an absence of any "known" carcinogenic agent, the authors concluded that sidero-silicosis predisposes to carcinoma of the lung.

A study of patients seen at two medical centers in Lorraine, France revealed (18) that 3.3% of the iron-ore miners seen by a lung specialist at Briey were found to have lung cancer compared to 1.5% found in other males in his patient population. A second group seen by the lung specialists between 1954-1959 at the Study Center of Pneumoconioses at Nancy found 1.8% of the miners seen had lung cancer compared to 0.36% in other patients who had silicosis. These differences were statistically significant. The authors felt referral practices did not bias their study. Of the factors which might affect these results, smoking seemed most important since iron-ore miners were allowed to smoke underground while coal miners were not. The iron-ore miners usually presented with siderosis and not silicosis since the iron-ore was not of high silica content. When the 60 lung cancers of iron-ore miners were histologically typed, 51% of them were of the anaplastic (undifferentiated) type compared to 31% in 1000 other cases of lung cancer. In another study, cases of lung cancer among approximately 10,000 miners who had worked in seven mines in Lorraine were compared to cases seen in a group of 10,000 metal workers with the same ethnic, socioeconomic and geographic status (19). Cases seen between 1954-1959 revealed a 2.3-fold excess risk for lung cancer for the iron-ore miners. When looking at numbers of silicosis cases and lung cancer cases seen in the iron-ore miners, no correlation was found. No tests for the presence of arsenic (found in some metal mining) or radioactivity were done.

In a retrospective mortality study of 1,759 metal miners who had completed 15 years underground mining experience between 1937-1948 (20), comparisons with other white males of the states in which the mines were located revealed significant excesses in standardized mortality ratios (SMRs) for respiratory diseases, heart disease, all causes, and neoplasia of the respiratory system. The excess in lung cancer in the absence of radioactive exposure was unexplained. The excess was not attributable to effects of age, smoking, nativity, urbanization, SES, heredity, diagnostic accuracy, or silicosis, according to the authors. When the cohort was stratified as to native-born or foreign-born, digestive cancer was significantly in excess in the foreign-born but not the native-born. Constituents of the ore in this study, in addition to silica dust, were: sulfur, iron, copper, zinc, manganese, lead, arsenic, calcium, fluorine, antimony, and silver.

Lung cancer cases of iron-ore miners and lung cancer cases of other males seen at the Cancer Center of Lorraine in France were compared (21). Cell type of the lung cancer cases of the iron-ore miners were 43.8% anaplastic (undifferentiated) compared to 28.12% in the other cases. The iron-ore miners also had twice the percentage of tumors in the inferior lobe of the lung as the other cases. Smoking histories were 70-80% complete and non-miner cases had a higher frequency of heavy smoking than the miners. In a concurrent smoking survey of active iron-ore miners, 81% were smokers and 58% smoked more than 10 cigarettes/day. The incidence of lung cancer among the iron-ore miners of Lorraine coming to autopsy at the Pathology Center of Nancy was also compared with that among other workers. The percent of lung cancer cases by occupational group was divided by the percent of persons in the occupational group to derive an "index of morbidity". The highest index of morbidity was found in the iron-ore miner group and was 3.47 compared to 1.97 in transport workers, and 1.34 in printing. Radiation was eliminated as a possible cause by the author since measurements showed a non-significant percent of radiation in the several mines.

Mortality rates for underground iron-ore miners who died of lung cancer in 1964 in the Krivoi Rog region of Russia were 26.7/100,000 compared to 4.8 in aboveground miners, 3.2 for metallurgical workers, and 2.8 for construction workers (22). The rate for the general population of the region was 3.6/100,000. Among miners with siderosilicosis and siderosilico-tuberculosis seen between 1958-1964, the frequency of lung cancer was 18.3% while among city inhabitants over age 20 without pneumoconiosis it was 5.8%. The author discussed the possible enhancing effect of iron-ore dust, especially as it related to high levels of benzo(a)pyrene air pollution in Krivoi Rog. Because of the possibility of bias in studies done on cases who come to autopsy and because recent measurements in West Cumberland underground iron mines had shown unexpectedly high levels of radon, a proportional mortality study using death certififcate data was done of iron-ore (hematite) miners of West Cumberland who died between 1948-1967 (22). Among all iron-ore miners, observed deaths due to lung cancer, adjusted for age, was significantly higher (50%) than expected in other local males. The significant excess (75%) persisted only in the underground miner analysis with no excess found in aboveground miners. A cell type analysis of the lung cancers which came to autopsy in the region during the same period revealed 42% undifferentiated cell type in the iron-ore miners compared to 23% among the lung cancers in other local males. Underground iron-ore miners also had a marked excess of deaths due to respiratory disease other than lung cancer (166%) while among underground coal miners in the area the excess was much smaller (16%). Smoking patterns of the iron-ore miners were not known but there was no prohibition of smoking in the iron-ore underground mines. Although no uranium is mined in the United Kingdom, concentrations of radon up to 300 pCi/liter were found which is ten times higher than the maximum permissible level (24).

In a proportional cancer mortality study of iron-ore miners in Kiruna, Sweden who died between 1950-1970 (25), underground miners showed a significant excess of lung cancer when compared to other Kiruna males. After age adjustment the observed number of lung cancer deaths was three times that expected when compared to both Kiruna and all Swedish males. Aboveground miners had a 30% excess. Smoking histories done in 1966 showed no smoking habit differences between above and underground miners. Diesel motor vehicles had been used in Kiruna mines since 1950. In 1970, unexpectedly high radon levels (numbers not given) were measured in some unventilated areas.

A ten-fold increase in lung cancer was found when iron-ore miners who died between 1961-1972 in the twin cities of Gallivare-Malmberget, Sweden were compared to the population of the local district and to all Swedish males (26). Smoking histories revealed that numbers of current smokers (76%) among miners dying of lung cancer were significantly higher than the Swedish population at large (50%). Radon measurements in 1970 also revealed readings of 1-2 working levels (WL) (One working level is defined as any combination of ^{222}Rn daughters in 1 liter of air that will result in the ultimate emission of 1.3 X 10^5eV of potential alpha energy per liter. One working level corresponds to a concentration of 100 pCi/liter of ^{222}Rn in air if it is assured that the ^{222}Rn is in equilibrium with its short-lived daughters.) in the mine at Malmberget which were 3-7 times higher than the recommended maximum level. Mine water flowing into the mines and "enrichment" by radon of ventilatory air forces through crushed rock were implicated as the cause of high radon levels since the level of uranium was insignificant.

A retrospective mortality study (27) of 1,415 Swedish (Malmberget) iron miners exposed to an average of 4.8 Working Level Months (WLM) per year of radon daughters showed a three-fold significant excess of lung cancer mortality between 1951-1976 in comparison with national rates. One WLM results from an inhalation of 1 WL for one month (170 hours). The effects of smoking and exposure to radon daughters showed a relative risk of 2.9 for smokers and 10.0 for non-smokers. The risk estimates were independent of calendar year or age started work and other factors such as diesel-exhaust fumes, arsenic, asbestos and silicosis were ruled out as contributing factors.

Review articles (28-30) conclude that sufficient evidence exists that participation in underground hematite mining increases the risk of lung cancer in man, but the amount of evidence is still inadequate to classify hematite itself as a carcinogen since the exposures incurred by the underground miners are multiple. Although the results of the studies reviewed could not be generalized to all situations, a presumption of carcinogenic risk is recommended by IARC for underground hematite mining unless proven otherwise. A review article (IARC, 1973) evaluating the possible carcinogenic risk for man of the iron-carbohydrate complexes concludes that iron-dextran may be carcinogenic to man.

C. Exposures

Potential exposures for iron-ore (hematite) miners which may have resulted in adverse health effects included iron-ore dust, ancillary dusts, fumes from explosives, physical injuries associated with the massive movements of earth and rock involved in mining and with the use of heavy machine equipment, and radon-radon daughter exposures. For aboveground miners exposure to diesel fuel fumes could also have presented some risk.

1. Iron-ore

The United Nations report on World Iron Ore Resources (1955) classified iron ore deposits by generic type. The "Bedded" iron deposits are characterized by a layered or stratified arrangement in which the iron-bearing minerals were constituents of sediments that accumulated over relatively large submerged basins and often were improved by geologic processes. Among the principal types of bedded deposits are those of the Lake Superior region of the United States and those of the Lorraine area of France (commonly called "minette" ores). "Massive" iron ore deposits in contrast are characterized by irregular shape and in general absence of bedded structure. The deposits are of smaller size than the main "bedded" deposits with the exception of the massive magnetite deposits in Kiruna, Sweden. Another massive type of iron deposit is the Bilbao type which comprises iron deposits of irregular shape occurring as iron carbonate below the water table and as limonite (geothite) and hematite above. In Cumberland, England the low-phosphorus ores of the Bilbao type do not "pass into" carbonate at depth but terminate still as hematite. In the West Cumberland area barytes ($BaSO_4$) are present in some places in amounts up to 5-10%. Fluorspar, dolomite, calcite and occasionally galena, pyrite, arsenopyrite, and chalcopyrite are present in these Bilbao ores. A third massive type is the Tabery type which are titaniferous iron deposits as for example in Tabery in Sweden and in Allard Lake, Quebec.

The Lake Superior type of bedded deposit is further classified as to original mother rock (taconite) and the ores were derived from the banded iron formations by geologic leaching of the silica bands (hematite). The Mesabi district in Minnesota is the most important iron ore producing part of the Lake Superior region. The known length of the Mesabi district is 110 miles and the iron formation is 400-750 feet thick. The average analysis of shipments from the Mesabi range in Minnesota from 1943-1952 showed 50.96% iron, 0.065% phosphorous, 9.04% silica, 0.88% manganese and 11.5% moisture. Taconite is a designation for the relatively lean iron formation from which the high grade ore of the Mesabi district was formed.

Table 1 shows iron-ore deposits by location, type, mineral and chemical content for the Mesabi and Vermilion Ranges of Minnesota as well as other geographic areas in which health risk studies have been done on iron-ore miners. In column one of the table it is noted that the percent of iron in dry ore ranged from 20% in the taconite ore of Minnesota to 68% in Kiruna ore. Higher silica ores are currently being mined. Iron ores are divided into two general classes: "hard" and "soft" and each class is divided into five sub-divisions: Bessemer, non-Bessemer, high phosphorus, manganiferous, and siliceous. "Hard" ore is dense or massive and breaks into lumps, whereas "soft" ore is earthy and granular. A Bessemer ore is one in which the phosphorous is low enough to make Bessemere iron, usually 0.045% or less phosphorous in dry ore, and high phosphorous ores contain from 0.17 - 0.25% phosphorous.

As described in the volume "Lake Superior Iron Ores" (1938) the six principal productive iron ore districts (ranges) of the Lake Superior region in the United States are the Marquette Range in Michigan, the Menominee and Gogebic Ranges in Michigan and Wisconsin, and the Mesabi, Vermilion and Cuyuna Ranges in Minnesota. The iron ores of the Lake Superior region vary widely in their physical and chemical characteristics.

Table 1

Iron-ore deposits by location, type, mineral and content for geographic areas in which health risk studies have been done.

Deposit and Location	Type	Mineral	Content (Per Cent) Fe	SiO_2	P	S	Al_2O_3	Mn	CaO	MgO	TiO_2	V
U.S.A.												
Minnesota		Hematite, Limonite	51	9.04	.06	.02	.37-9.51	.68	.04-.22	.07-.22	-	-
Mesabi	Lake Superior	Magnetite (Taconite)	20-27	-	-	-	-	-	-	-	-	-
Vermillion	Lake Superior	Hematite	57	7.7	.08	.23-.75	1.8-4.4	.10	.21-.90	.18-.58	-	-
United Kingdom												
West Coast												
Cumberland Workington	Bilbao	Non-Phosphorus Hematite	44	15	.01	-	-	Trace	2	-	-	-
Lancashire Barrow; Milom; Furness	Bilbao	Non-Phosphorus Hematite	55	7	<.01	-	-	0.2	2	-	-	-
France												
Lorraine Briey Basin; Longwy	Minette	"Minette" - oolitic	31-36	-	0.6-0.8	0.1-0.2	4-5	0.3-0.4	-	1.5-2.3	-	-
Basin, Landres-Ottange Basin Orne Basin; Ara Basin		Limonite										
		Red Layer, Grey Layer: Calcerous	-	7-8	-	-	-	-	13-19	-	-	-
		Black Layer, Green Layer: Siliceous	-	13-24	-	-	-	-	5-10	-	-	-
Nancy Basin	Minette	"Minette" (See Briey Basin)	32	13-24	-	-	-	-	-	-	-	-
Sweden												
Kiruna	Kiruna	Magnetite with some Hematite and Apatite	65-68	2	.01-0.2	-	0.5	0.1-0.2	1-3	-	0.3	0.15
Taberg	Taberg	Titaniferous Magnetite	32	-	0.1	-	-	-	-	-	6.7	0.16
USSR												
Krivoi-Rog Region	Lake Superior	Martite, Hematite Small Quantity Magnetite	63	5	0.03	-	0.8	-	0.3	0.04	-	-

Source: U.N. Survey of World Iron-Ore Resources (1954.)

They contain practically all the iron minerals including hematite, limonite, magnetite, carbonates, and sulphides. In Minnesota the Mesabi Range is characterized by the relatively shallow and widespread occurrence of the soft ore bodies which are in large part, available for open-pit mining. The Vermilion Range is characterized by ores which vary from a soft, sticky mass to a hard, tough, dark blue material known as specular hematite, which ores can reach depths of from 3,000 to 4,000 feet and were mined mainly by underground methods. In the Cuyuna Range the "fold" iron ore bodies are prevailingly shallow, rarely extending 500 feet in depth with ore that is soft and hydrated and which, after extraction is usually washed to remove free silica.

Mining hematite in the Vermilion Range began in 1884 and continued until 1967. Combined grades of Vermilion Range showed averages of from 62% iron and 4% silica in the early 1900's to 57% iron and 8% silica in the early 1950's. Mining of "natural ore", a combination of hematite-limonite began on the Mesabi Range in 1892 and continues today but on a very small scale. Average analysis of Mesabi Range "natural" ores, combined grades, showed 55% iron and 5% silica in the early 1900's to 50% iron and 10% silica in 1950.

From 1892-1958, of the 2,234 thousand tons of iron ore shipped from the Mesabi Range, 1,947 thousand tons (87%) was mined using open-pit (aboveground) methods and 287 thousand tons (13%) was mined using underground mining methods. From 1884-1959, in the Vermilion Range, of the 97 thousand tons of iron ore mined, 99.6% was mined by underground mining methods.

An average analysis and the gross tons (thousands) of Bessamer ore mined on the Mesabi Range in 1943 showed 84.78% of the ore was Fe_2O_3 (hematite) with 59.29% iron content. Silica averaged 8% among all grades of natural ore mined in 1943 compared to 6.8% in 1909. Analysis of iron ore in the mining industry was standardized and consisted of determination of percentages of those constitutents in the ore which were most important to the iron and steel metallurgist, i.e., iron, phosphorous, silica (SiO_2), manganese, alumina (AI_2O_3), lime (CaO), magnesia (MgO), sulphur and moisture. Also, in special instances, determinations were made of titanium, lead, zinc, copper, and arsenic. Arsenic is found in the iron-bearing minerals arsenopyrite (FeAsS), galena (PbS), and marcasite (FeS_2). Whether any of these minerals were contaminants, encountered during the mining of hematite in St. Louis County is not apparent from the literature reviewed.

2. Radon and radon-daughters

According to the BIER report (1972) the principal series of radiation-induced lung cancers which have been observed in underground miners exposed to radon-decay products in the mine atmosphere were mainly in uranium miners. Because of the presence of a number of potential occupational carcinogens in the dust of underground mines, there is difficulty in isolating radon and radon-daughters as the principal cause of lung cancer among the miners who have been studied. Underground mining per se does not necessarily lead to an increase in lung cancer as has been documented in studies on coal-miners (23).

The current BIER report (1980) concluded after an update of data on miners and radon-daughter risks that the risk estimates for lung cancer in underground miners from exposure to radon daughters now range from about 6 to 47 cases per 106 person-years (PY) per Working Level Month (WLM). The range reflects in large part the effect of age at exposure or age at onset of the cancer. On the basis of average data, the report presents a conversion figure of 1WLM = 0.4-0.8 rads, the range reflecting the variables of the fraction of ions bound to dust particles, whether the subject is a mouth or nose-breather, and the thickness of the epithelium. Comparisons done of the empirical data for risks per WLM with risks per rem yielded 6 rem/WLM.

Before 1950 very few radon measurements were made in underground mines and estimates must be made from ventilation and other data. From 1950 to 1970 in the U.S. measurements for radon and radon-daughters were mainly done in uranium mines. With the passage of the Miners Safety and Health Act (MSHA), measurement of radon-daughter concentrations were mandated for all underground mines. In 1967 the United States Public Health Service, using the Kusnetz method (31) for measuring the concentration of ^{222}Rn daughter-products expressed the result in terms of "working level" (WL). One Working Level is defined as any combination of ^{222}Rn daughters in 1 liter of air that will result in the ultimate emission of 1.3 X 10^5MeV of potential alpha energy per liter. One working level corresponds to a concentration of 100 pCi/liter of ^{222}Rn in air if it is assumed that the ^{222}Rn is in equilibrium with its short-lived daughters. In 1968 the U.S. Department of Labor issued regulations of "radiation standards for mining" which require that no individual shall receive an exposure of more than 2 working level months (WLM) in any consecutive 3-month period and no more than 4 WLM in any consecutive 12 month period. An exposure of 1 WLM results from the inhalation for one working month (170 hours) of air containing a ^{222}Rn daughter concentration of 1 WL, or from two months exposure at a concentration of 0.5 WL, etc. The maximum permissable level of 4 WLM per year is equivalent to an average concentration of ^{222}Rn daughters are in radioactive equilibrium with the parent ^{222}Rn, 0.3 WL corresponds to a ^{222}Rn concentration of 30pCi/liter. The 1980 MSHA standard adds that no person shall be exposed to air concentrations of radon-daughters in excess of 1.0 WL in active workings.

Information obtained by personal communication with the University of Minnesota Department of Civil and Mineral Engineering faculty, the Minnesota Department of Natural Resouorces, University of Minnesota Department of Geology faculty and geologists of the mining companies, revealed that among professionals involved in iron-ore mining the belief was that there was no radon or radon-daughter exposure risk in the underground iron-ore mines of the Mesabi or Vermilion iron ranges. However, no documentation of measurements could be provided to substantiate these assertions. They generally were based on assumptions relating to the geologic and mineral formations involved. All underground iron-ore mining operations in Minnesota ceased in 1967 before MSHA had mandated radon and radon-daughter measurements. A literature search and inquiries to several state and federal agencies did not produce any further information regarding radon and radon-daughter measurements in any Minnesota iron-ore (hematite) mines.

A pilot study was initiated, and with the cooperation of the Division of Environmental Health of the School of Public Health of the University of Minnesota, measurements for radon and radon-daughters were made in August, 1980. Results are seen on Table 2.

The conclusion was that radon does not appear to have been a significant risk factor during the actual mining. However, we cannot be certain that conditions were comparable, particularly during underground mining. A much more extensive study would be required to answer that question satisfactorily.

D. A Retrospective cohort mortality study of Minnesota iron-ore (hematite) miners

A retrospective cohort of 10,403 iron-ore (hematite) miners was derived from the personnel records of the Minnesota mining division of a large U.S. corporation (32). (The data base for this study is presented in III. A.). This cohort included all hourly-wage male employees who had worked at least 12 months in hematite iron-ore mining in St. Louis County, Minnesota and who were employed by the company between January 1, 1937 and December 31, 1965. Stratification into aboveground and underground miners further delineated exposure status. The age-sex-time-cause-specific mortality experiences of the total cohort, the underground miners, and the aboveground miners were compared to the expected mortality (33) as derived from mortality rates of U.S. white, and St. Louis County males from January 1, 1937 to December 31, 1978. Further stratification was done by date of hire, place of birth, and total years worked.

2. Results

Results of the study for all causes of death, arteriosclerotic heart disease and non-malignant respiratory disease are shown on Table 3. Analysis was done by country of birth, by underground and aboveground miner status and comparisons were made with both U.S. white and St. Louis County males. A significant excess was seen for non-malignant respiratory disease in aboveground Finnish miners. Results for all malignancies, lung cancer and stomach cancer are seen in Table 4. Significant excesses in lung cancer among the foreign-born were seen mainly in the Yugoslav-born miners both aboveground and underground while an excess in stomach cancer remained only in Finnish-born miners when the St. Louis County comparison was made.

3. Conclusions

A major conclusion of this study was that, the Minnesota hematite iron-ore miners, whether working underground or aboveground, did not incur an excess risk of lung cancer when compared to U.S. or St. Louis County males. This is in contrast to studies done among hematite iron-ore miners in England, France, Sweden, and Russia. In the apparent absence of significant radon-

Table 2

Radon and Radon Daughter Measurements, Pilot Study Results.
Minnesota Iron-Ore (Hematite) Miners Study, 1937-1978.

Air Sampling (Kuznitz Method)

Underground Mine A	
27th level	0.017 WL
23rd level	0.01 WL
22nd level	0.005 WL
12th level	0.02 WL
Open-Pit Mine B	
Recently worked area	0.005 WL
Old area	0.001 WL
Open-Pit Mine C	
Old area	$<$0.001 WL

Hematite Ore Sampling (gamma ray spectometry)

	Weight	Counting period	Results
Bulk Sample #1 Bulk Sample #2 Bulk Sample #3	3.2-3.8 kg	40 ks	Activity above background but comparable with ordinary soils.

Table 3

STANDARDIZED MORTALITY RATIOS FOR ALL CAUSES OF DEATH, ARTERIOSCLEROTIC HEART DISEASE, AND NON-MALIGNANT RESPIRATORY DISEASE AMONG HEMATITE IRON-ORE MINERS BY PLACE OF BIRTH, 1937-1978.

	ALL CAUSES			ARTERIOSCLEROTIC HEART DISEASE			NON-MALIGNANT RESPIRATORY DISEASE		
	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUIS COUNTY SMR (2)	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUIS COUNTY SMR (2)	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUI COUNTY SMR (2
All Native-Born Miners (N=7,886)	2645	96	94*	1034	107†	96	119	76*	93
Underground Native-Born Miners	1066	90*	89*	446	107	95	46	66*	80
Aboveground Native-Born Miners	1579	101	99	588	107	96	73	84	103
All Foreign-Born Miners (N=2,517)	2054	89*	87*	749	97	81*	115	83†	88
Underground Foreign-Born Miners	1576	89*	88*	574	98	81*	81	76†	82
Aboveground Foreign-Born Miners	478	88*	86*	175	93	79*	34	104	110
All Yugoslav-Born Miners (N=937)	843	83*	82*	288	84*	72*	49	80	84
Underground Yugoslav-Born Miners	725	83*	82*	249	84*	72*	43	81	85
Aboveground Yugoslav-Born Miners	109	83	80†	39	84	73	6	74	76
All Finnish-Born Miners (N=607)	511	110†	109	194	126*	105	36	133	151†
Underground Finnish-Born Miners	354	109	108	133	127*	103	19	101	115
Aboveground Finnish-Born Miners	157	112	111	61	125	109	17	206*	231*
All Other Foreign-Born Miners (N=923)	709	84*	82*	267	96	78*	30	59*	63†
Underground Other Foreign-Born Miners	497	87*	85*	192	103	84†	19	56†	59†
Aboveground Other Foreign-Born Miners	212	78*	75*	75	81	68*	11	67	70
All Miners (N=10,403)	4699	93*	91*	1783	102	89*	234	79*	91
All Underground Miners	2642	90*	88*	1020	101	87*	127	72*	81†
All Aboveground Miners	2057	98	95†	763	103	92†	107	89	105

SMR (1) Expected deaths computed on the basis of age-time-cause specific mortality rates for U.S. white males
SMR (2) Expected deaths computed on the basis of age-time-cause specific mortality rates for St. Louis County males

* Significant at 1% level
† Significant at 5% level

Table 4

STANDARDIZED MORTALITY RATIOS FOR ALL CANCERS, LUNG CANCER AND STOMACH CANCER AMONG HEMATITE IRON-ORE MINERS BY PLACE OF BIRTH, 1937-1978.

	ALL MALIGNANCIES			LUNG CANCER			STOMACH CANCER		
	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUIS COUNTY SMR (2)	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUIS COUNTY SMR (2)	OBSERVED DEATHS	UNITED STATES SMR (1)	ST. LOUI COUNTY SMR (2
All Native-Born Miners (N=7,886)	451	87*	86*	116	74*	85	46	142+	92
Underground Native-Born Miners	167	76*	74*	42	63*	73+	18	125	80
Aboveground Native-Born Miners	284	96	95	74	82	94	28	155†	101
All Foreign-Born Miners (N=2,517)	403	111†	98	96	139*	144*	80	196*	115
Underground Foreign-Born Miners	301	109	96	75	147*	151*	59	186*	109
Aboveground Foreign-Born Miners	102	117	104	21	117	123	21	234*	134
All Yugoslav-Born Miners (N=987)	193	123*	108	61	208*	211*	29	165*	96
Underground Yugoslav-Born Miners	155	114	100	50	198*	202*	24	156†	91
Aboveground Yugoslav-Born Miners	38	182*	159*	11	270*	271*	5	228	130
All Finnish-Born Miners (N=607)	89	118	105	16	108	113	25	292*	173*
Underground Finnish-Born Miners	64	123	109	12	123	127	17	275*	165
Aboveground Finnish-Born Miners	25	107	97	4	79	84	8	336*	196
All Other Foreign-Born Miners (N=923)	121	92	81†	19	77	80	26	178*	103
Underground Other Foreign-Born Miners	82	93	82	13	81	84	18	177†	103
Aboveground Other Foreign-Born Miners	39	91	80	6	68	72	8	181	104
All Miners (N=10,403)	854	97	91*	212	94	104	126	172*	105
All Underground Miners	468	94	87*	117	100	109	77	167*	100
All Aboveground Miners	386	101	97	95	88	99	49	181*	113

SMR (1) Expected deaths computed on the basis of age-time-cause specific mortality rates for U.S. white males
SMR (2) Expected deaths computed on the basis of age-time-cause specific mortality rates for St. Louis County males

* Significant at 1% level
† Significant at 5% level

radon daughter exposure, with a smoking prohibition enforced on all underground miners while working, with an aggressive silicosis control program, and without the use of diesel motors underground, the exposure to hematite iron-ore dust, in and of itself, did not produce an excess lung cancer risk in Minnesota underground hematite miners as a group.

An analysis of specific exposures incurred by the hematite miners was not possible with the data abstracted for this study.

Stratification by total years worked for the company as an indicator of cumulative exposure revealed no significant excesses in lung cancer when compared to U.S. white males for either aboveground or underground miners who worked less than five years, or more than five, fifteen, or thirty years.

The role of hematite (Fe_2O_3) as a possible co-carcinogen has not been disproven by this study. The Minnesota hematite miners did not appear to incur the combination of exposures or "sufficient" causes to increase significantly their lung cancer mortality over that for U.S. or St. Louis County males. These circumstances could differ in other settings.

A significant lung cancer excess found in both aboveground and underground Yugoslav-born miners appears to be related to some factor associated with their ethnicity rather than their exposure to hematite iron-ore mining. Several other studies have identified a lung cancer excess among Yugoslav-born migrants. Risk factors incurred before migration, reasons for and timing of migration, and conditions prevailing following migration must be considered when looking at possible cancer etiology among the foreign-born. These risk factors include other occupational exposures, smoking, and dietary practices. In this study the excess did not appear to be exposure-specific since it was seen in both underground and aboveground miners. However, since the ethnic groups of the Minnesota Iron Range settled, lived, and worked in communities centered around a church or community support group, the Yugoslav-born miner may have had exposures at specific mines that the other miners did not.

Excesses of gastric cancer among the hematite iron-ore miners in the comparisons with U.S. white males which were not seen in the St. Louis County comparison appear related to particular factors held in common with other St. Louis County residents rather than to risks incurred in iron-ore mining. Why St. Louis County white males had, from 1950 to 1969, a mortality rate for stomach cancer 70% higher than for the U.S. white males and 40% higher than for Minnesota white males has not been satisfactorily explained. Place-of-birth, ethnicity, certain dietary practices, pre-existing medical conditions, and specific occupational exposures have been suggested in the literature as possible risk factors and all are present to some degree in the St. Louis County population. Exposures incurred while working in hematite iron-ore mining do not appear to be causally related to the St. Louis County excess. Further information on more precise exposure groups would be necessary to isolate any possible effect due to mining or iron-oxide dust exposures.

Why Finnish-born miners incurred a significant excess risk for gastric cancer over and above that of the St. Louis County males has not been explained by this study. Further studies of gastric cancer in St. Louis

County should attempt to ascertain whether the Finnish-born and native-born with Finnish parentage had similar risks and whether occupational exposures were associated with the gastric cancer excess.

Prohibition of smoking for underground miners while working may have reduced their mortality for several smoking related diseases. Significant deficits were seen among the underground miners and not the aboveground miners in all causes of death combined, emphysema in miners hired before 1937, non-cancer respiratory diseases, all cancers combined, cancer of the buccal cavity, and in lung cancer in the native-born underground miner (compared to U.S. white males).

IV. Iron-ore Mining (Taconite)

A. Historical Perspective

Taconite is the name given by geologists to a type of hard rock containing fine particles of iron-ore. The name was first used in 1892 by a Minnesota geologist who applied it to the magnetic iron formulation on the states eastern Mesabi Range. Taconite is not useful as it comes from the mine, but the fine iron particles embedded in it can be removed and made into excellent ore. The particles may be magnetic (Fe_3O_4) or hematite (Fe_2O_3), magnetic or non-magnetic, fine or coarse. High grade ores contain from 5-10% impurities such as silica, alumina, and magnesea while lean or low-grade ore contains from 10-20%. These ores (natural ore) were mainly hematite and limonite and were the major source of iron-ore for shipment on the Minnesota iron ranges from 1865 to the early 1960's. Taconite, in which the impurities amounted to 50-70% of the ore, was not considered for iron ore production while high-quality natural ores were available and economically extracted and shipped. In the early 1940's, Dr. Edward W. Davis, Director of the University of Minnesota Mineral Research Center began research to demonstrate that an economical method of removing the worthless material from taconite by mechanical means (called benefication) was possible (1). Dr. Davis was aware that hematite and natural ore stocks would be greatly depleted by the 1960's and that a method of using the huge stores of taconite on the iron range was the only way to continue the iron mining industry in Minnesota.

The staff of the Mineral Research Center, working with several of the various companies who had set up pilot plants on the range, developed a process in which the taconite ore was ground into a powder and the magnetic iron was separated from the largely quartz rock by a strong magnetic field. The concentrate was then rolled in a chamber until it stuck together in marble-sized pellets and the pellets were then fired for hardening. The development of the pelletizing process was the major breakthrough. Metallic iron is made from iron ore during the smelting process. The use of the pellets greatly increased the efficiency of the blast furnace since they allowed a more efficient circulation of air and therefore, the increased price of taconite ore processing was offset by the up to 60% increase in production at the smelters with an additional 25% decrease in fuel consumption. Currently, over 95% of all ore shipped from Minnesota is in the form of taconite concentrates (pellets) (Table 5). Taconite

TABLE 5
IRON ORE SHIPMENTS FROM MINNESOTA
Total Minnesota

	Thousands of Gross Tons			
Year	Direct Ore	Gravity Conc.[1]	Taconite Conc.[2]	Total Shipment[3]
1884-1940......	1,086,173	144,422	219	1,230,813
1941-1945......	260,125	78,622	....	338,749
1946-1950......	221,623	83,094	78	304,794
1951...........	56,098	22,833	138	79,069
1952...........	45,073	19,540	106	64,720
1953...........	54,509	26,441	561	81,511
1954...........	30,451	17,740	889	49,081
1955...........	43,622	25,414	1,155	70,192
1956...........	35,502	22,884	4,817	63,203
1957...........	37,531	24,418	6,348	68,296
1958...........	19,278	15,136	8,422	42,836
1959...........	16,269	11,878	8,347	36,493
1960...........	21,445	22,284	11,368	55,097
1961...........	12,697	17,657	14,529	44,883
1962...........	11,559	18,740	14,257	44,556
1963...........	9,401	19,267	17,077	45,745
1964...........	10,410	20,012	19,372	49,794
1965...........	11,102	21,156	18,868	51,126
1966...........	12,834	20,802	21,679	55,315
1967...........	11,102	14,458	24,060	49,720
1968...........	5,570	15,983	29,883	51,436
1969...........	5,595	18,010	33,687	57,292
1970...........	4,122	17,078	33,957	55,157
1971...........	3,472	12,990	32,674	49,136
1972...........	3,695	11,638	35,878	51,211
1973...........	1,673	17,285	43,944	62,902
1974...........	2,606	15,751	40,553	58,910
1975...........	953	9,674	38,197	48,824
1976....................		9,157	38,820	47,977
1977...........	168	5,186	25,692	31,046
1978...........	170	5,468	50,644	56,282
1979...........	294	3,444	56,223	59,961
1980...........	102	2,446	42,697	45,245
1981...........	113	2,642	46,959	49,714
1982...........	45	720	23,237	24,002
Total........	2,035,485	794,270	745,334	3,575,089

[1]Includes washed, jigged, hi-density, other gravity, sinter, dried, and sinter-dried concentrates.
[2]Includes taconite and semitaconite concentrates.
[3]In some instances data do not add to totals because of rounding.
Table from Minnesota Mining Directory, 1983. Mineral Resources Research Center, University of Minnesota, Minneapolis, MN 55455.

pelletizing plants have been established around the world and it is a major method of iron ore production in use today.

B. Literature Review

Exposures incurred by workers employed in taconite iron-ore processing vary dependent upon the job assignment along the route from hard rock to pellet. Although the generic term "iron ore miner" is generally used by those outside the industry to describe all hourly-wage employees involved in the taconite iron-ore inidustry, the actual removal of the rock from the earth using traditional open-pit mining techniques is done by less than half of the hourly-wage employees. The other half are involved in the benefication of the ore which involves the crushing, concentrating and pelletizing of the ore. Depending upon the company, coarse crushing of the taconite iron-ore is done as part of the open-pit mining process. The major exposures that have been investigated and reported have been those involving the dust which results from these activities and, since 1980, exposure to radon daughters have been required by federal law in the United States. The dust exposure are dependent upon where along the Mesabi Range the ore is being processed but the major components of quartz, numerous silicates, and iron oxide are common to all taconite ore mining and processing in Minnesota. In addition, clearage fragments of an amphibole in the cummingtonite-grunerite series found in the taconite from the eastern tip of the Mesabi Range, are considered by some "asbestiform fibers" related to amasite asbestos, a known carcinogen, and therefore, studies have looked at the possible carcinogenic effects of taconite mining and processing.

A study to assess the prevalence of respiratory abnormalities in men exposed to taconite iron-ore dust (Fe_3O_4) over 20 years in Minnesota (2) revealed no significant differences between dust-exposed and non-dust exposed groups in history of respiratory illness, bronchitic symptoms, or spirometric tests when controlled for smoking status. Three cases with small, rounded opacities were found in the dust-exposed group which might have represented early silicosis. (Silica represents 25-40% of the dust from taconite ore).

In 1980, a study was done for the Reserve Mining Company by the Department of Epidemiology of the University of Michigan's School of Public Health (3) to evaluate possible health effects related to taconite and mining and processing. A mortality study of men employed for one year or more by the company between 1952-1976, a prevalence study of respiratory symptoms among all male employees on July 1, 1976, and a review of a representative sample of the most recent chest radiographs taken of all employees employed more than one year between 1952-1976 was reported.

The mortality study showed no risk of mortality associated with the mining or processing of taconite. The all causes SMR was 87 when expected deaths were derived from mortality rates of all white males in Minnesota. Overall, there were no increased mortality rates for cancer in general or for any particular set of cancer. The prevalence of respiratory symptoms was found to be higher at the mining operation than at the processing plant but there was no consistant relationship between dust exposure estimates and the prevalence of any symptoms. The stratified sample of the chest radiograph, compressed 100% of those men with over 20 years, 30% of those with 10-14 years, 25% of those with 1-4 years of experience with the company as of July 1, 1976. A total of 1767 films were reviewed and classified according to the ILO/UC 1971 criteria by three experienced readers. Considerable reader variation limited agreement on the proportion of the radiographs which showed changes of category 1/1 and over. Sixteen films were categorized by at least one reader as showing small opacities of 2/1 but only 11 of these were read as showing small opacities of 1/0 or more by all three readers. Pleural thickening was reported in 148 radiographs (8.4%) by at least one reader, but there was agreement of all readers in only 23 (1.3%) of the films. There was a weak association found between profusion of small opacities and cumulative dust exposure and appeared to be no association between pleural thickening and either cumulative total or cumulative silica dust exposure.

V. Data Base

A large data base on the iron-ore miner population has been collected by the Division of Epidemiology, University of Minnesota, Minneapolis under the supervision of L.M. Schuman, M.D. The data base has two components, the data tape of the Retrospective Cohort Mortality Study of Minnesota Iron-Ore (Hematite) Miners described in Section I(D) and the data tape and microfilm of the Mineral Worker Cohort Data Base created by a grant from the IRRB of all records on employees of taconite iron mining companies operating on the Minnesota Iron Range in 1981. Outlined below is the format and availability of data variables.

A. Retrospective cohort mortality study of Minnesota iron-ore (hematite) miners data tape

1. Study population (N=10,403)

    a. All hourly-wage employees of the Minnesota Mining Division of U.S. Steel that worked at least 12 months in hematite mining in St. Louis County prior to January 1, 1966 and whose last day of employment was after December 31, 1936.

2. Demographic data

    a. Name
    b. Address
    c. City/town
    d. Date of birth (m-d-y)
    e. Country of birth
    f. (Cohort number)

3. Mortality data (death certificate)

   a. Date of death
   b. Place of death (state/country)
   c. Cause of death (ICD, 8th revision)
      i. underlying cause
      ii. contributing causes (up to 4)
      iii. special code for any cancer

4. Exposure Data

   a. first date of hourly-wage employment
   b. last date of hourly-wage employment
   c. underground miner code (worked at least 12 months underground)
   d. aboveground miner code (worked less than 12 months underground)
   e. underground mining experience (in total number of years)
   f. gaps of more than one year in employment

5. Follow-up data

   a. coded (as of January 1, 1979)

      1. Dead
      2. Alive
      3. Lost to follow-up

B. Mineral Worker Cohort Study Data Base

1. <u>Background</u>

The Mineral Workers Cohort Data Base was created at the University of Minnesota for use by interested investigators including the IRRRB, who may wish to collaborate in epidemiologic studies of the health effects, if any, associated with occupational hazards, of mining and milling, particularly exposures to dusts and welding fumes.

The data base was established as part of the Mineral Resources Health Assessment Program (MRHAP) by the Division of Epidemiology of the University of Minnesota with the support of a grant from the Iron Range Resources and Rehabilitation Board (IRRRB), State of Minnesota under the direction of the Principal Investigator, Leonard M. Schuman, M.D. All data is stored at the University of Minnesota under Dr. Schuman's supervision.

2. <u>Data Base Population</u>

All personnel records of seven of the ten iron-mining companies in operation in 1981. All taconite operations are represented in these seven companies as well as the sole remaining hematite operation on the Mesabi Range. The three companies not included were hematite operations.

3. Records

A. Type

Only personnel records with demographic and occupational history information salary information was collected, photocopies of death certificates on file (N=1,902) were provided by some companies. Table 6 lists the companies and number of records in the data base.

B. Roster format

i. microfilm
ii. photocopy
iii. abstracting sheets
iv. computer tape

4. Coded Data (N=71,649)

A. Computer file was established of employee characteristics on all records. These include

a. social security number
b. name (l-f-m)
c. suffix code (jr.)
d. birth date (Table 7)
e. individual number (company number, film reel number, microfilm "address")

B. Death Certificates or Document (N=6,601, including 4,699 from Hematite miners study)

a. name
b. date of birth
c. date of death
d. place (state/country) of death
e. social security number

Table 6 Roster of Employees For Each Mining Company Which Participated (Mineral Resources Health Assessment Program, University of Minnesota, 1981-84)

Mining Company		Total Employees For Each Company**
Inland Steel Company		615
Eveleth Taconite Company		2,276
Jones and Laughlin Company		5,822
Reserve Mining Company		10,229
Hanna Mining Company		11,772
Erie Mining Company/Hibbing Taconite Company		13,985
United States Steel Company		35,935
	Total	80,529

**Each may include employees who also worked for one of the other six companies.

Table 7 Distribution of Mineral Workers Cohort Study Data Base by Year of Birth. (Mineral Resources Health Assessment Program, University of Minnesota, 1981-84)

Year of Birth	Number	Interval Percent	Cumulative Percent
1880	935	1.3	1.3
1880-84	1172	1.7	3.0
1885-89	1602	2.2	5.2
1890-94	1622	2.2	7.4
1895-99	1589	2.3	9.7
1900-04	2141	3.0	12.7
1905-09	3122	4.3	17.0
1910-14	4769	6.6	23.6
1915-19	5704	7.9	31.5
1920-24	6448	8.9	40.4
1925-29	3717	9.3	49.7
1930-34	6214	8.7	58.4
1935-39	5107	7.1	65.5
1940-44	4025	5.7	71.2
1945-49	6045	8.5	79.7
1950-54	6367	8.9	88.6
1955-59	4898	6.8	95.4
1960-63	716	1.1	96.5
Sub-Total	69196	---	96.5
Missing Year of Birth	2453	3.4	99.9
Grand Total	71649	---	100.0 (rounded)

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Appendix I1

MDH Chronology: Asbestos Issues in Northeastern Minnesota

1973 - 1985

MDH DOCUMENTS PERTAINING TO ASBESTOS ANALYSIS AND EXPOSURE IN DIVISION OF E.H. FILES, ARRANGED IN CHRONOLOGICAL ORDER

(Note: Items Without Asterisk Are Data Reports)

* 06/21/73 Summary of meeting held at Division of Environmental Health, MDH, to discuss possible courses of action for the division in monitoring mineral fibers in Lake Superior and northeastern Minnesota. Air and water monitoring were discussed.

* 07/03/73 Memo from Kyle Bishop, MPCA, Studies of Asbestiform Minerals in Waters of Lake Superior Basin. Status memo for agency board.

* 07/10/73 Account of statement by Jim Coleman, Assistant Envir. Health Dir., MDH, to the MPCA Board regarding potential hazard of Duluth drinking water.

* 07/11/73 Memo by Jim Coleman to Warren Lawson, Commissioner of Health, summarizing the Lake Superior asbestos problem. The memo contains preliminary evaluation of optical asbestos counts on lake water, air, and fish samples.

* 07/20/73 Memo to Robert Herbst, Commissioner of Natural Resources, Dr. Warren Lawson, Commissioner of Health, Grant Merritt, Exec. Director, MPCA, from Peter L. Gove, Staff Asst. to the Governor, Re: State analytical investigations regarding the Duluth water supply.

* 07/30/73 Memo to Robert Herbst, Commissioner of Natural Resources, Dr. Warren Lawson, Commissioner of Health, MDH, Grant Merritt, Executive Director, MPCA, from Peter L. Gove, Staff Asst. to the Governor, memo accompanying EPA report "Lake Superior Asbestos Study Plan".

* 07/30/73 Letter to Peter Gove, Admin. Asst. to the Governor, from Francis T. Mayo, Regional Admin. EPA, Reg. V, transmitting the report "Lake Superior Asbestos Study Plan".

* 09/13/73 Memo to Jonathan Morgan, Solicitor General, State of Minnesota, from Warren R. Lawson, M.D., Commissioner of Health, discussing "Health Considerations Related to the Asbestos-type Fiber Material in the North Shore Area".

* 1974 Report: "Preliminary Interpretation of Analytical Data Reported to Date on Levels of Asbestiform Fibers in the Water Supplies of the Duluth Area and Western Lake Superior Basin", U.S.E.P.A.

* 03/11/75 Report: "Analysis of Mesabi Iron Range Taconite Plant Stack Samples", by Dr. William Nicholson, Environmental Sciences Laboratory, Mount Sinai School of Medicine.

* 10/22/75 Letter to Dr.A.E.P. Watson, International Joint Commission, responding to his request (08/75) for research needed on Great Lakes water quality. The suggestions pertain to asbestos in Lake Superior.

* 12/03/75 Letter to Mr. Ralph Zumwalde, NIOSH, Cincinnati, Ohio, describing fiber count preparation procedures for air samples collected at Silver Bay.

* 12/05/75 Letter from Warren Lawson stating the position of MDH on matters relation to asbestos-like fibers in Minnesota.

* 01/05/76 Memo to file from David Gray summarizing a meeting at Mt. Sinai with Drs. Nicholson and Langer to discuss fiber counting methods and data.

* 01/06/76 A group of memos, mostly from MDH epidemiologist Barry Levi, M.D., discussing studies of Reserve worker x-rays.

* 01/15/76 Letter from Peter Gove, MPCA, to Warren Lawson, MDH, discussing ambient air sampling and analysis.

* 01/16/76 Letter from Commissioner of DNR to Mayor of Hoyt Lakes conveying the results of fiber analysis of Reserve's pit discharge which flows to Colby Lake, the source of the Hoyt Lake water supply.

* 1/19/76 Memo from Peter Gove and Warren Lawson to the Governor discussing mesothelioma studies and related topics.

* 1/28/76 Memo from Warren Lawson to MPCA containing comments on the Draft EIS for the Mile Post Seven on-land tailings disposal site.

* 02/17/76 Letter to Gary Eckhardt, Chief, Technical Services, MPCA, Div. of Air Quality, from Dr. Philip M. Cook, Research Chemist, Water Quality Laboratory, EPA, Duluth, transmitting and discussing the preliminary results of 11 of the 20 U.S. District Court ordered Silver Bay Air Study samples from Silver Bay.

02/26/76 A series of six reports containing analytical data generated by EPA and private labs on North Shore samples. These reports were probably pulled together for the state's case against Reserve Mining.

* 02/28/76 MPCA memo from Peter Gove to MPCA Board members discussing health evidence presented by Dr. Nicholson during the court case. Includes a discussion of disease incidence near Patterson, N.J., asbestos plant and of the Homestake Gold Mine study.

* 03/01/76 MDH summary of eight North Shore sampling programs including sampling methodology.

* 03/03/76 MDH grant application to EPA for literature review project.

* 03/04/76 Memo to Fredrick F. Heisel, Director, Division of Environmental Health, MDH, transmitting the District Court air samples fiber data. The results were interpreted as being of no use for estimating accurate fiber concentrations.

* 03/11/76 MPCA letter to Mayor of Hoyt Lakes discussing the possible contamination of the Hoyt Lakes drinking water supply by asbestos-like fibers.

* 03/17/76 MDH letter to MPCA with an outline of epidemiolic studies done by MDH, a critique of the Homestake study, and a discussion of tissue studies done on North Shore residents.

04/01/76 Letter to Kyle Bishop, Analytical Services Section, MDH, from Dr. Philip M. Cook, ERL, (EPA), Duluth, transmitting and discussing x-ray diffraction analyses of Silver Bay samples taken between 12/02/74 and 01/09/76.

* 05/19/76 Letter to Peter L. Gove, MPCA, from Matthew R. Banovetz, Exec. Vice Pres., Reserve Mining Co., transmitting the results of fiber analyses by Arthur D. Little Co. on samples collected by MPCA from St. Paul, Silver Bay, Babbit and Isabella. The method used in the analyses has not produced reproducible results.

* 06/23/76 Table presented, by MDH as an exhibit at the MPCA administrative hearing on the construction permit for the Mile Post Seven Disposal Basin containing interlaboratory fiber analyses of split samples from the MDH Silver Bay Air Monitoring Program (December, 1974 and March, May and August, 1975).

* 06/25/76 Table presented as an exhibit at the MPCA administrative hearing on the construction permit for the Mile Post Seven Disposal Basin comparing fiber data for water from Hoyt Lakes, Duluth and Minneapolis.

* 06/25/76 Internal MDH outline of possible study areas for fibrous minerals in Minnesota, Kyle Bishop, MDH.

* 08/03/76 Letter to Kyle Bishop, MDH from Dr. James R. Kramer, McMaster University, Hamilton, Ontario, transmitting results of 12 air samples for TEM analyses for mineral fibers.

09/06/76 Memo from Peter Gove, MPCA. Contains air sampling data ordered by the court.

10/26/76 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting results for Duluth water samples and blanks

* 11/01/76 Table 1 from Arthur D. Little Report: "Fiber Analysis by Electron Microscopy: Comparison of Sample Preparation Procedures", 11/01/76, comparing the interlaboratory results of analyses on twelve Silver Bay air samples from the MDH sampling program.

* 1976 Paper: "X-Ray Diffraction and Electron Beam Analysis of Asbestiform Minerals in Lake Superior Waters" by Philip M. Cook, National Water Quality Laboratory, U.S.E.P.A., Duluth, and Rubin, Maggiore and Nicholson, ESL, Mount Sinai School of Medicine.

12/16/76 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for six Reserve Mining and five Babbitt air samples. Most of these samples were prepared using the micro-pipette technique.

12/29/76 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for four air samples and one composite of a group of nine samples from Babbitt.

* 01/04/77 Memo to Donald A. Wallgren, EPA, Region V from Dr. Philip M. Cook, Research Chemist, ERL, EPA, Duluth, transmitting and discussing the results of x-ray diffraction analyses of EPA air samples at Silver Bay taken during the plant shut-down of July 13-23, 1976.

* 01/24/77 Letter to Dr. Phil Cook, EPA, Duluth, Minnesota, containing sample information (flow rates, sampling time, location, date) for samples collected in Silver Bay and sent to Dr. Cook at an earlier time.

* 02/01/77 Letter to Dr. Richard Lee, U.S. Steel Research, Monroeville, Pa., requesting a confirmation of diffraction pattern identifcation.

* 02/02/77 Letter to K.S. Chopra, Task Group Chairman, ASTM E-4 committee, regarding enclosed comments on a fiber identification report given by Dr. Chopra.

02/07/77 Letter to Kyle Bishop, Analytical Services Section, MDH, from Philip M. Cook, ERL, U.S.E.P.A., Duluth, transmitting and discussing x-ray diffraction analysis for amphibole fibers for Silver Bay air samples from the period of Sept. 20, 1973 and December 2, 1974.

04/01/77 Memo to Dr. Edward Peters, Cambridge, Massachusetts, regarding three enclosed stack sample segments from the Reserve Mining Company plant at Silver Bay. Dr. Peters was to analyze the samples.

04/21/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

05/12/77 Memo to Dr. Edward Peters, Cambridge, Massachusetts, regarding twelve enclosed stack sample segments from the Reserve Mining Company plant at Silver Bay. Dr. Peters was to analyze the samples.

05/16/77 Memo to Paul Johnson, Chief, Section of Water Supply and General Engineering, MDH, transmitting fiber data for split samples of Duluth city water analyzed by both MDH and the city of Duluth Water Department.

05/18/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

05/26/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

06/01/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

* 06/08/77 Memo to Christopher M. Timm, Director, Surveillance and Analysis Division, EPA, from Gerald F. Regan, Chief, Air Surveillance Branch, EPA, discussing a meeting held on 06/02/77 with state personnel on the subject of air monitoring for mineral fibers in the Mile Post Seven Monitoring plan.

07/06/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

* 08/05/77 Memo to David Gray, Asst. Chief, Sect. Health Risk Assessment and Analytical Services, MDH, discussing FY78 work plan for fibrous minerals.

* 08/22/77 MDH grant applications to EPA for a tissue study.

08/23/77 Memo to Peter J. Kreisman, Research Manager, Mn. Environmental Quality Board, Copper Nickel Study, transmitting fiber data for air samples from Copper Nickel study area.

*09/15/77 Memo to Gary Eckhardt, Air Quality Division, MPCA, commenting on the E.P.A. Provisional Methodology Manual for "Electron Microscope Measurement of Airborne Asbestos Concentrations".

* 09/21/77 Letter to Dr. Thomas Doerfler, Arthur D. Little, Inc., regarding enclosed fiber counting data for ASTM chrysotile samples.

* 10/03/77 Letter to Dr. Phil Cook, EPA, Duluth, Minnesota, regarding accompanying mineral standards which Dr. Cook was to analyze using x-ray diffraction.

* 10/17/77 Letter to K.S. Chopra, Union Carbide Corporation, Niagra Falls, New York, regarding his request for split samples from Silver Bay.

10/18/77 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

10/19/77 Memo to Peter J. Kreisman, Research Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for water and air samples from Copper Nickel study area.

* 10/29/77 Letter to Mr. Truman Temple, EPA, Washington, D.C., describing enclosed photographs (slides) of the MDH electron microscopy laboratory.

* 11/14/77 Memo from Leonard Michienzi, M.D., to Richard Wade, MDH, describing his EPA supported asbestos study.

12/01/77 Memo to Peter J. Kreisman, Research Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber analyses data for process ore samples.

12/13/77 Memo to Peter J. Kreisman, Regional EIS Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for process ore samples.

12/20/77 Memo to Peter J. Kreisman, Regional EIS Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for process ore samples.

* 12/21/77 List of Analyses Completed to date for fibrous minerals by MDH Microparticulate Unit.

* 1978 Paper: "Amphibole Fiber Concentration Determination for a Series of Community Air Samples: Use of X-ray Diffraction to Supplement Electron Microscope Analysis", by Philip M. Cook, et. al., in Electron Microscopy and X-Ray Application to Environmental and Occupational Health Analysis, Ann Arbor, Mich., 1978.

01/05/78 Memo to Peter J. Kreisman, Research Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for air samples from the Copper Nickel study area.

* 01/17/78 Letter to Dr. Richard Lee, U.S. Steel Research, Monroeville, Pa., regarding an enclosed grid with a sample of Duluth water on it. Also enclosed were photographs of the grid.

02/07/78 Memo to Peter J. Kreisman, Research Manager, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for process tailing samples of copper nickel ores.

* 03/06/78 Review of a paper by Rich Lee, U.S. Steel. "Basic Concepts of Electron Diffraction and Asbestos Identification Using SAE. Part 1."

* 04/05/78 Letter to Dr. Florence Gleason, Freshwater Biological Institute, Navare, Minnesota, regarding a paper to be delivered by Bob Suchanek, MDH, at the Minnesota Electron Microscopy Society Spring Symposium, "An Approach to the Determination of Counting Error Confidence Intervals for Particulate Counts of 100 or Less".

* 04/10/78 Letter to Dr. Phillip Cook, ERL (Duluth), U.S.E.P.A. accompanying air samples from the Copper-Nickel Study to be analyzed by x-ray diffraction.

05/02/78 Memo to Ed Crowley, Division of Air Quality, MPCA, summarizing and describing the methods used for the Reserve Mining Co. stack samples taken at Silver Bay.

* 05/03/78 Internal MDH memo to Russ Frazier, Chief, Section of Analytical Services, MDH, describing the Microanalysis Unit's proposal for analyzing Silver Bay air samples collected in 1976-77. The proposal was for determining the fiber concentrations during the shutdown period, analyzing 12 composite samples and analyzing one sample per quarter from the samplers a-top each school in Silver Bay.

* 05/08/78 Letter to Mr. James R. Millette, U.S. EPA, Cincinnati, Ohio, regarding fiber analysis discussion and enclosed papers on particle counting statistics..

06/21/78 Memo to Daryl Thingvold, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for road gravel samples from the Copper Nickel study area.

* 07/06/78 Memo to Loren K Voigt, Compliance and Enforcement Section, Division of Water Quality, MPCA, reporting on a meeting held in the MPCA Director's office to discuss the status of the Reserve Mining case and what future activities would be required of the various State agencies involved in the case.

07/13/78 Memo to Ed Crowley, Division of Air Quality, MPCA, summarizing the results of stack samples and replicate samples taken at Silver Bay.

07/14/78 Memo to Daryl Thingvold, Environmental Quality Board, Copper Nickel Study, explaining fiber analyses not yet reported.

* 07/18/78 Letter to SEM, Inc., requesting copies of Kyle Bishop's published paper entitled "Preparation Loses and Size Alterations for Fibrous Mineral Samples".

* 08/? /78 Internal memo by Kyle Bishop documenting meeting with Dave Gray, Russ Frazier and Steve Ring where nine study areas regarding fibrous minerals were discussed.

08/21/78 Memo to Eugene Jordan, EFS Sanitarian, Northeast District Office, MDH, transmitting mineral fiber analysis results for the Gilbert Pit water samples.

08/23/78 Memo to Gary Englund, Chief, Section of Water Supply and General Engineering, MDH, transmitting the fiber data for water from Silver Bay and Two Harbors sampled on 06/06/78 and 07/27/78.

08/24/78 Memo to Daryl Thingvold, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for Ely tap water and Bear Island Lake.

* 08/30/78 Memo to Kyle Bishop from Dave Gray summarizing major issues discussed at the meeting of August 30, 1978 between Phil Cook, Tibor Zoltai, Dave Gray, Steve Ring and Kyle Bishop. These issues related to fibrous mineral exposures and mineralogy in Minnesota.

09/14/78 Memo to Peter Ashbrook, Environmental Quality Board, Copper Nickel Study, transmitting and interpreting fiber blank data for copper-nickel water samples.

09/15/78 Letter to Dr. Iwo Iwasaki, Mineral Resources Research Center, University of Minnesota, transmitting data for process ore sample from the copper-nickel study.

09/27/78 Memo to Peter Ashbrook, Environmental Quality Board, Copper Nickel Study, transmitting corrected fiber data for stream sample.

* 10/16/78 Letter to Dr. C.H. Cheong, Republic of Singapore, regarding enclosed reprints of papers by Kyle Bishop, Steve Ring, and Bob Suchanek. Includes paper: "An Approach to the Determination of Counting Error Confidence Interval for Fiber Count Data".

10/26/78 Memo to David Gray, Chief, Section of Health Risk Assessment, MDH, transmitting data for fibers from Duluth water samples.

11/20/78 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for Silver Bay and Two Harbors water samples collected in September, 1978.

12/01/78 Memo to David Gray, Chief, Section of Health Risk Assessment, MDH, transmitting fiber data from air samples at Silver Bay taken during the shut-down period and composite samples from 1977.

* 12/14/78 Letter to Dr. Robert Carter, Corrales, New Mexico, requesting a paper on tissue sample preparation for mineral fiber analysis.

* 12/19/78 MDH summary to the file of possible studies including fibrous minerals in tissue, asbestiformity (a crystallographic study), and a radiography screening study to be funded by Reserve.

* 12/19/78 Undated draft letter from George Pettersen, Commissioner of Health, to MPCA discussing the need to change the Reserve funded health study from a pulmonary function study to a tissue study.

01/04/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting Milepost 7 well water samples collected in 9/78.

01/05/79 Letter from Matthew Banovetz, Executive Vice President, Reserve Mining Company, Silver Bay, Minnesota, to Kyle Bishop, MDH, requesting electron microscopic data from Department of Health samples collected in Hibbing, Virginia, Duluth, St. Paul and Minneapolis (EPA grant).

* 01/23/79 Letter to Dr. William Taylor, Medical Statistics Section, Mayo Clinic, Rochester, Minnesota, requesting a paper on TEM analysis of mineral fibers in tissue.

02/12/79 Memo to Loren Voigt, Compliance and Enforcement Section, Division of Water Quality, MPCA, transmitting fiber data for air samples from cities of Virginia, Hibbing, St. Paul and Minneapolis.

02/13/79 Letter to Mr. Matthew Banovetz, President, Reserve Mining Company, transmitting fiber data for air samples from cities of Virginia, Hibbing, St. Paul and Minneapolis.

* 03/13/79 Letter to Dr. Charles H. Anderson, Chief of Analytical Chemistry, Environmental Research Laboratory, U.S.E.P.A., Athens, Georgia, requesting a copy of a paper on the analysis of asbestos in water.

03/15/79 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for Duluth, Two Harbors, and Silver Bay water samples collected 01/09/79.

* 03/21/79 Letter to Dr. Ian Stewart, Walter C. McCrone Associates, Inc., Chicago, Illinois, regarding an enclosed abstract of a paper by Steven Ring entitled "Identification of Amphibole Fibers, Including Asbestos, Using Common Electron Diffraction Patterns".

05/04/79 Memo to Robert Poppe, Environmental Quality Board, Copper Nickel Study, transmitting fiber data for treated city water from Duluth.

* 05/10/79 Memo to Richard Wedlund, Division of Air Quality, MPCA, responding to a request for review and criticism of the report "Analysis of Asbestiform Minerals by Thermoluminescence".

06/01/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting results of Milepost 7 Well and surface water analyses from May and September of 1978.

* 06/05/79 Memo from George Pettersen, Commissioner of Health, to MPCA, summarizing current research efforts including epidemiology, monitoring, asbestiformity, and a tissue study and discussing new research needs.

* 06/11/79 Letter to Mr. David Jones, I.I.T. Research Institute, Chicago, Illinois, regarding enclosed excerpts from books pertaining to the mineral Minnesotaite and its distribution in northern Minnesota. A taconite sample containing about 10% Minnesotaite was sent in a separate package.

06/11/79 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting blank level values for Duluth, Two Harbors, and Silver Bay water samples collected 01/09/79.

06/14/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting corrected values for sample no. 120132.

06/29/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting the results of Milepost 7 well and surface water samples collected in March and September, 1978.

07/03/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting the results of mining pit water samples collected 02/02/79.

* 07/10/79 Letter to Clifton Rodenburg, Attorney, Fargo, N.D., regarding the potential for mineral fiber exposure at the Eveleth Mining Co. facilities. This matter was refered from the MPCA.

* 08/10/79 Letter to Jack Wagman, Director, Emissions Measurement and Characterization Division, U.S.E.P.A., discussing inadequate fiber identification protocol in the E.P.A. "Provisional Methodology Manual for Electron Microscope Measurement of Airborne Asbestos Concentrations".

* 08/14/79 Letter to Mr. John Miller, EPA Environmental Research Center, Research Triangle Park, North Carolina, regarding enclosed electron diffraction patterns of minnesotaite and a sample of the mineral in taconite.

* 08/17/79 Letter to Harold B. Leppink, M.D., St. Louis County Health Department, acknowledging a request to analyze Lake Vermillion water samples for fibers.

08/24/79 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant.

08/24/79 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for the Silver Bay and Two Harbors water samples collected 06/28/79.

09/04/79 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for Mt. Iron Iroquet Pit and Biwabik Canton Pit water samples collected 06/08/79.

* 09/04/79 Letter from Jack Wagman, Director, Emissions Measurement and Characterization Division, U.S.E.P.A., to Kyle Bishop, Section of Analytical Services, MDH, responding to letter of 08/10/79 criticizing fiber identification protocol in the E.P.A. "Provisional Methodology Manual for Electron Microscope Measurement of Airborne Asbestos Concentrations".

09/13/79 Letter to Gary Palesh, Environmental Resources Branch, St. Paul District, U.S. Army Corps of Engineers, transmitting and interpreting data for air fiber analyses from Silver Bay.

10/08/79 Letter to Mr. Matthew Banovetz, President, Reserve Mining Company, transmitting fiber data for air samples from cities of Virginia, Hibbing, St. Paul and Duluth.

10/08/79 Memo to Loren Voigt, Division of Water Quality, MPCA, discussing the natural occurrence of amphibole fibers in the Milepost 7 Disposal Basin of Reserve Mining Company.

10/08/79 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting fiber analysis results for Milepost 7 Well and surface water samples collected in 1978.

10/11/79 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for blanks and Silver Bay air samples collected during the Reserve Mining Company Strike of 1977.

* 10/16/79 Letter to Michael Beard, EPA Environmental Research Center, Research Triangle Park, North Carolina, regarding replicate analyses.

10/19/79 Letter to Robert S. Lemire, Reserve Mining Company, Silver Bay Minnesota, including the results of the analysis of Silver Bay air samples collected during the strike of 1977.

11/08/79 Letter to Mr. Philip D. Brick, Environmental Counsel, Pickands Mather Co., transmitting fiber data for air samples from cities of Virginia, Hibbing, St. Paul, Minneapolis and Duluth.

* 12/11/79 Letter to James Webber, New York State Department of Health, regarding enclosed information on TEM analysis of asbestos.

* 01/22/80 Letter to Mr. James R. Millette, U.S. EPA, Cincinnati, Ohio, regarding enclosed samples of laumontite and sepiolite.

* 01/30/80 Memo to George Pettersen, M.D., Commissioner of Health, MDH, from Terry Hoffman, Director, MPCA, responding to his memo of 06/05/79 which outlined need for additional studies related to effects of fibrous minerals.

02/08/80 Letter to Herbert Anderson, St. Louis County Office of Regional Grant and Aid Coordinator, transmitting the fiber data on samples from Lake Vermillion.

* 03/04/80 MDH memo from Roger DeRoos to MPCA discussing future actions to be taken on the asbestos issue.

* 03/17/80 Memo from Lovell Richie, MPCA, to Roger DeRoos, MDH, with a very detailed summary of the Feb. 13, 1980 meeting between the two agencies. A very good summary of a wide range of issues concerning possible future studies.

* 04/02/80 Letter to Philip Russell, University of Denver, regarding the enclosed final draft of Steve Ring's paper entitled "Identification of Amphibole Fibers, Including Asbestos, Using Common Electron Diffraction Patterns".

* 04/04/80 Letter to John Small, National Bureau of Standards, Washington, D.C., regarding Steve Ring's interest in attending the NBS workshop entitled "Preparation of Samples and Standards for Asbestos Analysis".

* 04/07/80 Letter to Robert Woods, Mayor, City of Biwabik interpreting the fiber data reported earlier on the Canton Pit water (proposed water supply).

* 04/07/80 Letter to Frank Cerkvenik, Mayor, City of Mountain Iron, interpreting the fiber data reported earlier on Iroquois Pit water (proposed water supply).

04/09/80 Letter to Dr. Edward Peters and Arthur D. Little, Inc., Cambridge, Massachusetts, regarding enclosed fiber analysis results from ambient air monitoring programs.

04/14/80 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting fiber data for stack samples at Silver Bay benification plant. All but one sample were sampled and prepared on Nuclepore filters, which allowed for direct replication of the filter.

* 04/15/80 Letter to Philip Russell, University of Denver, regarding enclosed correction for Steve Ring's paper entitled "Identification of Amphibole Fibers, Including Asbestos, Using Common Electron Diffraction Patterns".

* 04/22/80 Internal memo to David Gray, Chief, Section of Health Risk Assessment, notifying discontinuation of the MDH air sampling program at Silver Bay.

* 06/05/80 Letter to Kenneth Mackenthun, Director, Criteria of Standards Division, Office of Water Planning and Standards, U.S.E.P.A., commenting on the "Ambient Water Quality Criteria for Asbestos Document".

06/18/80 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting corrected values for stack samples reported 04/14/80.

06/25/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting preliminary analysis results for air samples from the Milepost 7, MPCA, and MDH air sampling networks.

07/11/80 Letter to Mr. Philip D. Brick, Environmental Counsel, Pickands Mather Co., transmitting fiber data for air samples from cities of Virginia, St. Paul, Minneapolis and Duluth.

07/11/80 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1978 and 1979.

* 1980 Draft of recommendations from George Pettersen, Commissioner of Health, MDH, to Terry Hoffman, Executive Director, MPCA, on needed health effects research of fibrous mineral exposures on the northeastern Minnesota.

* 08/01/80 Letter from Vilma Hunt, Deputy Assistant Administrator for Health Research, U.S.E.P.A., to Terry Hoffman, Director, MPCA, responding to letters of 04/21/80 and 07/01/80 that recommended needed research on the health effects of fibrous minerals on the Iron Range.

08/21/80 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1978 and 1979.

08/21/80 Memo to Gary L. Englund, Public Water Supply Unit, MDH, transmitting analysis results for Biwabik, Chisholm, Virginia, McKinley, Duluth, Eveleth, Winton, and Ely water samples.

09/25/80 Memo to Loren Voigt, Compliance and Enforcement, Div. of Water Qual., MPCA, transmitting fiber data for Dunka Pit dewatering sample, Erie Mining Co.

09/25/80 Memo to Loren Voigt, Compliance and Enforcement, MPCA, transmitting fiber data for Erie Mining Co. pit dewatering sample. First report of fibers that were later determined to be sepiolite (a zeolite mineral, not an amphibole).

09/29/80 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1978 and 1979.

10/09/80 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results from Hibbing Scranton well sample collected 12/18/79.

10/09/80 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for Hoyt Lakes raw water and Aurora raw and finished water collected 11/28/79.

10/10/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for completed samples from the MPCA (10800 series) and Reserve Mining (109000 series) monitoring programs.

10/21/80 Memo to Gary Englund, Section Chief, Water Supply and General Engineering, MDH, transmitting fiber analysis results for Mt. Iron test well sample collected 05/06/80.

10/22/80 Letter to Mr. Peter Baker, Hibbing, Mn., transmitting fiber data on the Mt. Iron test well.

* 10/23/80 Letter to Dr. Philip Russell, University of Denver, Denver Research Institute, accompanying manuscript for the paper: "Amphibole and Chrysotile Blank Contamination in Transmission Electron Microscopy Fiber Count Preparation".

10/23/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting fiber analysis results for Hoyt Lakes, Babbitt, and Milepost 7 air samples.

10/27/80 Letter to Glen Evavold, RREM, Inc., Duluth, transmitting fiber data from Silver Bay and Two Harbors water. Letter also explains analysis categories.

10/31/80 Letter to Dr. Iwo Iwasaki, Mineral Resources Research Center, University of Minnesota, transmitting fiber data for copper-nickel process ores.

10/31/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting fiber analysis results for St. Paul and Milepost 7 air samples.

11/20/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for completed analyses of Babbitt, Milepost 7, and St. Paul air samples.

12/02/80 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples.

01/06/81 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1978, 1979 and 1980.

01/08/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples.

01/13/81 Letter to Dr. Alden Lind, Save Lake Superior Association, transmitting fiber data from the MPCA ambient air fiber monitoring program and the Reserve Mining Co. ambient air fiber monitoring program.

01/22/81 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1978 and 1979.

01/22/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Reserve Mining air samples collected 06/20/80, 07/08/80, and 07/26/80. Results are also given for Babbitt, Hoyt Lakes, and St. Paul samples from the MPCA air sampling network.

01/27/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected 08/13/80.

01/28/81 Letter to Mr. Richard Osterberg, Duluth, explaining results of fiber analysis for Duluth city water taken on 04/25/80.

02/02/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected 08/31/80. Recently completed Babbitt and Hoyt Lakes air samples are also attached.

02/02/81 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of Milepost 7 well and surface water samples collected in 1979 and 1980.

02/24/81 Memo to Ed Crowley, Division of Air Quality, MPCA, transmitting raw data for summary results of stack samples previously reported.

02/26/81 Memo to Gary Englund, Water Supply, MPCA, transmitting northern Minnesota water sample fiber results.

03/05/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Reserve Mining (Milepost 7) air samples collected 10/24/80.

03/11/81 Letter to Dr. Iwo Iwasaki, Mineral Resources Research Center, University of Minnesota, transmitting raw data for copper-nickel process samples.

03/12/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples.

03/12/81 Memo to Gary Englund, Section of Public Water Supply, MDH, transmitting fiber analysis results for the Mt. Iron test well sample collected 02/10/81.

03/23/81 Letter to Mr. Matthew R. Banovetz, President, Reserve Mining Co., from Loren Voigt, Division of Water Quality, MPCA, requesting a sample of fine tailings for fiber analysis.

03/26/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected 12/17/80.

* 03/30/81 Letter to John Hughes, Department of Geography-Earth Science, Northern Michigan University, transmitting results of the Presque Isle sepiolite rock sample collected by Hughes.

04/23/81 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting results of x-ray diffraction analysis of well and surface water samples from the Milepost 7 monitoring program.

05/08/81 Memo to Gary Eddy, Water Quality Enforcement, MPCA, transmitting fiber analysis results from Partridge River, Dunka River, and Langley Creek water samples.

05/08/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Reserve air samples collected October 6, 1980 to January 22, 1981.

05/12/81 Internal MDH memo to David Gray, Chief, Section of Health Risk Assessment, transmitting fiber data from analyses of tailings samples from all Minnesota taconite processing plants.

* 06/17/81 Memo to Gary Eddy, Water Quality Division, MPCA, discussing plans of Microparticulate Unit to analyze and interpret fiber monitoring data from the Mile Post Seven Monitoring Program at Silver Bay.

06/25/81 Letter to Eunice Sigurdson, MDH, from James Millette, EPA, Cincinnati, transmitting the fiber data for city water samples she collected in seven Iowa cities and Minneapolis.

06/26/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 monitoring samples collected February 9, 1981.

* 07/15/81 Internal MDH memo describing telephone conversation with Minneapolis Star and Tribune staff writer regarding the fiberous minerals: palygorskite and sepiolite.

* 07/17/81 Internal MDH memo describing television interview with Tom Hendrix, WCCO, regarding the fibrous minerals, polygorskite and sepiolite.

* 07/17/81 Internal MDH memo to George R. Petterson, M.D., Commissioner of Health, requesting approval to publish acticle entitled: "Abestiform Varieties of Palygorskite and Sepiolite" in the journal Science.

07/17/81 Memo to Gary Eckhardt, Division of Air Quality, MPCA, transmitting results of x-ray diffraction analysis of air samples from the Milepost 7 monitoring program.

* 08/18/81 Letter to Dr. Joseph Shapiro, Department of Geology and Geophysics, University of Minnesota, regarding arrangements for use of the thin section laboratory for work related to research on the structure of fibrous mineral particles from the Peter Mitchell Taconite Mine at Babbitt.

08/20/81 Letter to George Yamate, ITT Research Institute, Chicago, regarding enclosed copy of Steve Ring's paper entitled "Identification of Amphibole Fibers, Including Asbestos, Using Common Electron Diffraction Patterns" and enclosed grids containing non-amphibole fibers.

08/20/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected February 27, March 17, April 4, and April 22, 1981.

08/21/81 Memo to Gary Eddy, Water Quality Enforcement, MPCA, transmitting fiber analysis results from northern Minnesota streams.

08/21/81 Memo to Gary Englund, Water Supply and General Engineering, MDH, transmitting water sample analysis results for Beaver Bay, Silver Bay, and Two Harbors.

10/19/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected May 10 and May 28, 1981.

11/10/81 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for three Reserve Mining air samples.

* 11/13/81 Letter to Kyle Bishop from Charles E. McJilton, Asst. Prof., School of Public Health, Univ. of Minnesota, discussing request for free silica analysis of taconite workers in a study by the School of Public Health to be funded by the IRRRB.

01/08/82 Memo to Gary Eddy, Division of Water Quality, MPCA, transmitting analysis results of water samples collected in 1980.

03/01/82 Memo to Gary Eckhardt, Division of Air Quality, MPCA, transmitting results of X-ray diffraction analysis of air samples from the Milepost 7 monitoring program.

03/01/82 Memo to Gary Eckhardt, Chief, Technical Service, Division of Air Quality, MPCA, transmitting x-ray diffraction data for amphibole mineral from air samples for the cities of Hoyt Lakes, Babbitt, Cloquet, St. Paul and Minneapolis.

03/08/82 Memo to Gary Eckhardt, Chief, Technical Serivice, Division of Air Quality, MPCA, transmitting fiber data from all Hoyt Lakes air samples received.

03/09/82 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Cloquet and St. Cloud air samples.

03/24/82 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected 06/15/81, 07/03/81, and 07/21/81.

04/16/82 Memo to Gary Eddy, Division of Water Quality, MPCA, transmitting analysis results of water samples collected in 1980.

* 05/10/82 Memo to Gary Eckhardt, Chief, Technical Service, Division of Air Quality, MPCA, transmitting fiber data for air samples from the city of St. Paul.

05/10/82 Memo to Gary Eckhardt, Chief, Technical Service, Division of Air Quality, MPCA, transmitting graphs of previously reported St. Cloud and Cloquet air sample fiber data.

* 06/29/82 Letter to Dr. Philip M. Cook, ERL, Duluth, U.S.E.P.A., transmitting the final report "An investigation of the structural and chemical features of PMP-1", conducted under contract to UMD via EPA grant.

06/29/82 Letter to Gary Kimball, Coordinator, Permits Section, MPCA, from D.B. Olin, Manager-Engineering Services, Duluth Missabe and Iron Range Railway Co., transmitting fiber data from the company's settling basin at Two Harbors.

* 07/01/82 Memo to Gary Eckhardt, Air Quality Division, MPCA, discussing the delivery of air samples and air sample analysis costs.

* 08/25/82 Letter to Mr. Frank Snitz, U.S. Army Corps of Engineers, discussing the occurence of copper and zinc in sediment samples from Lutsen harbor of Lake Superior.

* 08/28/82 Letter to Mr. Frank Snitz, U.S. Army Corps of Engineers, discussing the levels of amphibole fiber levels in Lutsen Harbor sediment samples as related to the potential for release of fibers during harbor dredging.

* 09/01/82 Letter to William Telliard, Effluent Guidelines Division, U.S.E.P.A., commenting on the proposed regulation for ore mining and dressing industries. The comments express objection to the proposal to regulate asbestos by monitoring total suspended solids.

09/16/82 Letter to Gary Eddy, Enforcement Division, MPCA, providing analysis results for Peter Mitchell Pit water samples collected 81/10/08 and 82/01/27. These results were reported earlier as Milepost 7 samples and this memo is an attempt to clarify the previous data.

* 09/23/82 Report by Sanford Weisberg on the statistical analysis of fiber data from the Iron Range and other cities in the state. The study was done on contract for the MPCA to help in the evaluation of Mile Post Seven Air data.

* 09/23/82 Memo to Gary Eddy, Division of Water Quality, MPCA, transmitting analysis results of water samples collected in 1978, 1979 and 1980. This memo also discusses the basis for the 'high iron' and 'low iron' catagorization of amphibole fibers as an aid to identify those originating in the mine.

09/30/82 Letter to James Millette, Health Effects Research Laboratory, U.S.E.P.A., transmitting summary reports of fiber data on miscellaneous water supplies in Minnesota.

10/15/82 Letter to Gary Eddy, Enforcement Division, MPCA, providing analysis results for Peter Mitchell Pit water samples collected 82/04/13.

10/20/82 Memo to Gary Eddy, Division of Water Quality, MPCA, transmitting analysis results of water samples collected in 1981 and 1982.

10/26/82 Memo to Gary Eckhardt, Division of Air Quality, MPCA, transmitting results of X-ray diffraction analysis of air samples from the Milepost 7 monitoring program.

11/04/82 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Reserve Mining air samples collected between 08/08/81 and 02/22/82.

* 11/29/82 Memo to Gary Eckhardt, Technical Services, Division of Air Quality, MPCA, responding to a request for comments on mineral fiber monitoring requirements for the Milepost Seven Tailings Basin.

01/27/83 Internal MDH memo transmitting fiber data for city water samples from Biwabik taken 06/16/82.

* 01/31/83 Memo to Kenneth Haberman, Section of Permits, Division of Water Quality, MPCA, reviewing reasons why fiber monitoring for Erie Mining Co. pits #'s 2 and 3 is necessary.

03/04/83 Memo to Loren Voigt, Division of Water Quality, MPCA, transmitting analysis results of water samples collected in 1981 and 1982.

03/10/83 Memo to Gary Eckhardt, Division of Air Quality, MPCA, transmitting results of X-ray diffraction analysis of air samples from the Milepost 7 monitoring program.

04/07/83 Memo to Loren Voigt, Division of Water Quality, MPCA, confirming transfer of Mile Post Seven fiber samples.

04/08/83 Memo to John Seltz, Division of Air Quality, MPCA, confirming transfer of Minnesota Statewide Fibers Network Samples to MPCA.

* 04/18/83 Internal MDH memo to Tim Sherkenbach, Asst. Dir., Div. Air Qual., MPCA, from Sandra L. Larson, Div. Water Qual., MPCA, describing statistical analysis of fiber data from MP-7 Monitoring Program used to determine permit limit exceedences.

06/02/83 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected from August 28, 1980 through August 3, 1982.

06/03/83 Internal MDH memo transmitting fiber data for city water samples from Biwabik taken 08/23/82.

06/03/83 Internal MDH memo transmitting fiber data for Duluth city water (01/28/82, 02/10/82 and 09/20/82).

* 07/01/83 Memo to Arlo Knoll, Div. Minerals, Minnesota Dept. of Natural Resources, accompanying a copy of "Preparation and Analysis of Air, Water and Flotation Samples for Mineral Fibers" used in the analyses of fibers in the Copper-Nickel Study.

* 07/07/83 Memo to Sandra L. Larson, Div. of Water Qual., MPCA, expressing reservations regarding statistical interpretation of fiber data from MP-7 in memorandum of 04/18/83.

* 07/12/83 Letter to Grace Kemper, Mayor, Beaver Bay, Minnesota, from Gary Englund, Water Supply and General Engineering, MDH, transmitting fiber data for the city of Beaver Bay and discussing the necessity to continue treatment for fiber removal.

* 08/04/83 Letter to Michael Beard, Quality Assurance Division, U.S.E.P.A., responding to his request for review and comments on the draft reports "Evaluation of Provisional Methods for the Measurement of Airborne Asbestos by Electron Microscopy" and "Methodology for the Measurement of Airborne Asbestos by Electron Microscopy".

* 08/05/83 MPCA memo to David C. Foster, MDH, from Sandra L. Larson, Research Analyst, Division of Water Quality, MPCA, responding to his memorandum of 07/07/83, commenting on the Reserve Mining Co. permit limits.

08/08/83 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Reserve Mining air samples collected between September 8, 1982 and December 25, 1982.

10/05/83 Internal MDH memo transmitting fiber data for city water from Beaver Bay (07/12/83).

10/05/83 Letter to Loren Voigt, Division of Water Quality, MPCA, providing analysis results for Peter Mitchell Pit water samples collected 04/05/83 and 07/07/83.

10/19/83 Memo to Gary Eckhardt, Air Quality Division, MPCA, reporting the fiber analysis results for Milepost 7 air samples collected from January 12 to February 17, 1983. Analysis results for replicate analyses from samples collected from November 6, 1981 to December 7, 1982 are also included. A preliminary evaluation of laboratory performance on replicate samples is presented.

11/16/83 Memo to Gary Eckhardt, Program Development, Div. Air Quality, MPCA, responding to request for comments on mineral fiber air monitoring for the MP-7 tailings basin operating permit.

12/16/83 Internal MDH memo transmitting fiber data for city water from Beaver Bay (10/26/83).

12/16/83 Internal MDH memo transmitting fiber data for city water from the Scranton Pit, proposed water suppy for Hibbing (10/20/83).

12/29/83 Memo to Jerry Winslow, Monitoring and Analysis, MPCA, reporting the results of samples collected from the Milepost 7 tailings basin on 10/20/83. This memo also includes a description of the preparation technique, analysis protocol, and results report for these samples.

01/15/84 Letter to Mr. C. D. Keith, G.M. Erie Mining Co., transmitting fiber data and explaining chrysotile fiber blank levels for Erie Mining Pit Monitoring Program (MPCA Permit requirement).

01/23/84 Internal MDH memo transmitting fiber data for raw water samples from the cities of Grand Marais and Beaver (12/01/83, 12/19/83).

01/27/84 Memo to Matthew Banovetz, Reserve Mining Company, Silver Bay, Minnesota, reporting the fiber analysis results for air samples collected from March 7 to June 5, 1983.

01/31/84 Letter to Mr. C.D. Keith, G.M. Erie Mining Co., transmitting fiber data and explaining analysis procedures and results for Erie Mining Pit Monitoring Program (MPCA Permit requirement).

02/04/84 Letter to Mr. C.D. Keith, G.M. Erie Mining Co., transmiting fiber data and discussing the occurence of sepiolite and amphibole fibers in the Erie Mining Pit at Dunka Creek.

02/07/84 Letter and data to Matthew Banovetz, Reserve Mining Company, providing results for analyses on Peter Mitchell Pit samples collected 83/08/83.

02/07/84 Letter and data to Matthew Banovetz, Reserve Mining Company, providing results for analyses on Partridge River sediment samples collected 83/06/30.

02/15/84 Letter to Matthew R. Banovetz, Reserve Mining Company, reporting the analysis results of water samples collected from the Milepost 7 tailings basin on 02/01/84.

03/06/84 Letter to Matthew R. Banovetz, Reserve Mining Company, reporting the analysis results of Milepost 7 water samples collected on April 5, 1984.

* 03/27/84 Memo to Walter A. Jankowski, Chief, Section of Analytical Services, MDH, reporting on "Workshop on Asbestos Levels Following an Abatement Program".

04/17/84 Letter to Matthew R. Banovetz, Reserve Mining Company, reporting the analysis results of air samples from the Milepost 7 monitoring program collected in 1983.

04/23/84 Letter to Matthew Banovetz, Reserve Mining Company, providing results for replicate analyses from the Peter Mitchell Pit monitoring program.

06/06/84 Letter to Loren Voigt, Division of Water Quality, MPCA, providing analysis results for Peter Mitchell Pit samples collected from 06/04/82 through 08/02/83. Many sepiolite fibers present in samples.

07/18/84 Letter to Matthew R. Banovetz, Reserve Mining Company, reporting the analysis results of two bench scale filtration samples. These were to test the capabilities of the proposed basin discharge treatment plant.

* 07/30/84 Letter to Dr. Rosemarie C. Russo, Associate Director for Research Operations, ERL Laboratorty, U.S.E.P.A., Duluth, responding to a request for review and comments on cooperative research proposal between ERL and UMD titled: "Multivariate Model Development for Predictions of Fiber Carcinogenicity and Toxic Chemical Bioavailability from Particles".

08/12/84 Letter to Loren Voigt, Division of Water Quality, MPCA, providing analysis results for Partridge River sediment samples collected 09/22/81, 05/18/82, and 12/22/82. A description of the sample preparation technique is included.

10/30/84 Letter to David Marklund, ERL, U.S.E.P.A., Duluth, responding to his request for more information on sepiolite.

12/03/84 Letter to Matthew R. Banovetz, Reserve Mining Company, reporting the analysis results of water samples collected in 1984 for the Milepost 7 monitoring program.

12/03/84 Memo to Mathew Banovetz, Reserve Mining Company, regarding attached tables containing the analysis results for Milepost 7 air samples.

01/14/85 Memo to Mark Tomasek, Division of Water Quality, MPCA, discussing the staus of water samples collected for the Milepost 7 monitoring program in 1983.

* 01/31/85 Internal MDH memo to Raymond Thron, Director, Division of Environmental Health, describing a telephone conversation with a Duluth Hearald reporter regarding fiber levels in Duluth water and the Iron Range.

* 02/28/85 Memo to Eldon G. Kaul, Assistant, Attorney General, MPCA, discussing a proposal for a method of enforcing the one million fiber/L standard for Mile Post Seven Basin discharge.

Appendix I2

Selected Newspaper Articles and Editorials

MINNEAPOLIS STAR AND TRIBUNE SUNDAY, MARCH 31, 1985.

Sister Mary Madonna Ashton

Lung X-ray results raise questions

By Lewis Cope
Staff Writer

Here are answers to some questions raised by the announcement that a high rate of lung abnormalities, suggestive of asbestos exposure, have been found among of residents of the Mesabi Iron Range:

What diseases can be caused by asbestos exposure?

Asbestos has been linked to a high risk of lung cancer, particularly among people who also smoke. Mesothelioma, an unusually deadly cancer of the chest or abdominal lining, is very rare in the general population but more common among asbestos workers.

There appears to be an increased risk of cancer of the digestive system — the esophagus, stomach, colon and rectum — but there is still some scientific debate on this extent of this risk.

Asbestosis, a serious noncancerous

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lung disease, occurs when asbestos fibers cause permanent scarring of lung. It is similar to emphysema and can be fatal.

What are the symptoms of asbestos-related illnesses?

Early symptoms of asbestosis can include coughing and shortness of breath. Chest pain and fatigue after slight exertion also may occur. Later, heart failure can result because of the increased effort required to pump blood through the damaged lungs.

A cough, or a change in coughing habit, occurs in most patients who have lung cancer. Chest pain is the second most common symptom.

When mesothelioma develops, it often causes pain in the chest or abdomen.

What was found in the study of Iron Range residents' X-rays?

The chest X-rays of 579 Range residents, who had come into clinics for treatment of all types of problems, were checked. Doctors found that 171 of them had a thickening of the lining around the outside of the lungs. That's a significantly higher proportion than similar studies have found in other parts of the country where there is no known major source of asbestos.

Previous studies elsewhere have shown that this type of thickening is usually, perhaps always, caused by relatively heavy exposure to asbestos fibers. The thickening typically starts years before any asbestos-related illnesses.

There's no evidence that any of the Range residents with abnormal X-rays actually have any asbestos-related illnesses — yet. And health officials said there is no evidence of any increase in such illnesses on the Range — yet.

What do the findings mean?

Three factors make it difficult to interpret the findings with certainty. First, no one knows whether the people who were X-rayed are representative of Range residents generally. Second, the thickening is slightly different from what has been found in other studies, raising the possibility that some nonasbestos dust or other less risky substance is involved. Third, studies differ on how likely a person with such abnormalities is to develop serious illness later.

How dangerous is exposure to asbestos? How does it compare with the risk of cigarette smoking?

"Among some groups of workers who were heavily exposed to asbestos, as much as 20 to 25 percent of all deaths are due to lung cancer," said a recent U.S. Public Health Service report. "This rate is much higher than would be expected from the effects of cigarette smoking alone."

Among American adults generally, about 5 percent of all deaths are due to lung cancer. Smoking alone raises the risk of lung cancer, but the risk increases dramatically when asbestos exposure and smoking are combined.

A study by doctors at Mt. Sinai Medical School in New York found that asbestos workers who smoke have a risk of lung cancer eight times that of smokers in the general population.

MINNEAPOLIS STAR AND TRIBUNE

What risks face people who are exposed to lower levels of asbestos fibers than those workers?

Most experts believe that if *a lot* of any substance can cause a lot of cancer, *a little* poses some risk, too. That's why health officials have been pushing efforts to remove aging, fraying asbestos insulation from many schools and other buildings.

What can a person exposed to asbestos do to reduce his or her risk?

Don't smoke. While there is no guarantee, studies "suggest that quitting smoking can reduce this extremely high risk in asbestos workers," the Public Health Service report said.

Stopping smoking also can save lung capacity that may help a person cope with lung-damaging asbestosis if it does occur. But it won't end all risks: The danger of asbestosis, mesothelioma and digestive-tract cancer aren't affected by cigarette smoking.

How long after exposure do asbestos-related problems appear?

Typically, 15 to 35 years or more after first exposure.

Exposure over a long period raises the risk, but one study of workers in an asbestos plant found that some who worked there only a month or two developed asbestos-related diseases many years later.

What is asbestos?

It's the common name for a group of natural minerals that have relatively long, needle-like fibers. At least six types of fibrous minerals are classified as asbestos.

It's often difficult to say whether a particular fiber found in the environment should be classified as true asbestos, or as something so close that it can't be distinguished from asbestos. That's why studies of the fibers associated with taconite deposits in northern Minnesota generally have called them "asbestos-like particles."

These fibers *apparently* are a form of asbestos and *apparently* pose the same risks as asbestos. But some scientists still debate whether one type of fiber may be more dangerous that others.

There even is concern that fiberglass particles — which are similar in shape to asbestos particles — may carry some of the same risks.

How does asbestos do its damage?

Scientists still aren't certain. But asbestos fibers — so tiny thata microscope is needed to see an individual fiber — are shaped like needles. They not only penetrate and damage body tissues, but get stuck there and remain for many years.

The apparent increased risk of digestive-tract cancers is believed to occur when asbestos fibers are swallowed. They may get into food or drink. Or they may first be inhaled, then swallowed.

How common is asbestos in the environment?

One study found that in the early 1970s, about 800,000 tons of asbestos was used each year in the United States. There may have been some falloff in use since, but it's still a very common material with about 3,000 different uses in fireproofing, insulating, soundproofing and the like.

As long as asbestos remains in a solid form, it's safe. But when, for example, building materials get old and frayed, fibers flake off and get loose in the air. That's when they can be inhaled — and become a health concern.

Past studies have shown that adults who live in cities commonly have some asbestos fibers in their lungs.

Last week, Dr. Abida Haque of the University of Texas Medical Branch in Galveston reported that she had found asbestos fibers in some infants who had died of other causes. She said this indicates that asbestos fibers are "probably everywhere," and that many Americans are being exposed to asbestos from an early age.

MINNEAPOLIS
STAR AND TRIBUNE

Sunday
March 3, 1985

Experts hint asbestos problem, but say further study is needed

By Sharon Schmickle, Pat Doyle and Lewis Cope
Staff Writers

Doctors and political, business and labor leaders responded cautiously Saturday to the news of numerous lung abnormalities among residents of the Mesabi Iron Range, saying the findings were cause for concern but not for alarm.

All said they knew of no unusual patterns of disease associated with asbestos-type fibers, the apparent cause of abnormalities detected in a study of Range residents' X-rays.

■ Legislators say that the potential health threat will increase support for a fund to compensate victims of hazardous waste. **Page 14A.**

"I think that there is a potential health problem," said Sen. Doug Johnson of Cook, a leading Range DFLer who was one of several lawmakers told of the findings Friday night by officials of the state health department.

"But I think that health experts have to give their opinions, and that there have to be further X-rays taken so that people do not become panicky about the situation, so that there is not an overreaction among the public."

Yesterday afternoon, health department officials announced the results of a study of chest X-rays in Iron Range communities that found an

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Iron Range

Continued from page 1A

unexpectedly high rate of a lung condition "commonly associated with asbestos exposure."

Those findings, as reported yesterday morning in the Star and Tribune, were that 171 of the 579 X-rays studied showed a thickening of the lining around the outside of the lungs.

The X-rays showed no evidence of such illnesses as cancer or lung-damaging asbestosis. But because the thickening so strongly indicates asbestos exposure, the health officials voiced serious concern about the future.

"We are pulling together a group of nationally recognized experts who will oversee our investigation," said Sister Mary Madonna Ashton, head of the department. These include experts from the federal Centers for Disease Control, the federal National Institute on Occupational Safety and Health and the Environmental Sciences Laboratory in New York.


Dr. Alan Bender

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MINNEAPOLIS STAR AND TRIBUNE

Iron Range Continued from page 14A

"We have many, many more questions than answers now," said Alan Bender, the department's chief of chronic-disease epidemiology.

The abnormalities are a thickening of the normally cellophane-thin lining around the outside of the lungs. The thickening appeared to be slightly different from that normally found with asbestos exposure, and the significance of this remains unclear, Ashton said.

But despite these small differences, "asbestos appears to be the most likely cause of the unusual X-ray findings," a health department statement said, in part because no other substance has been proved to cause this condition.

The abnormalities were first detected when Dr. Ronald Seningen, a radiologist in Virginia, Minn., who used sophisticated and relatively uncommon techniques to check X-rays routinely taken of 269 people who had come to his clinic for treatment of various problems believed unrelated to asbestos exposure. His findings led to a second study by an expert from the National Institute on Occupational Safety and Health, who found similar abnormalities in X-rays made in Hibbing, Grand Rapids and Duluth.

Their findings together showed abnormalities in about 30 percent of the X-rays checked. Studies elsewhere have shown that in some cities anywhere from 1 to 10 percent of the X-rays show such abnormalities.

Gov. Rudy Perpich, who directed health officials to conduct a press conference to issue the findings, would not comment on them yesterday.

State health officials said they didn't know if the people involved in the study who had lung abnormalities had been notified, because the X-ray readings have just been completed and the doctors are still trying to assess what they mean.

Bender said he sees no reason for people to seek checkups from their doctors simply because of the study's findings, so the health department is not recommending X-rays or other special tests. "But this is a personal matter between people and their personal physicians," he said.

No one knows when Range residents might have first been exposed to asbestos or similar substances capable of causing the abnormalities. However, asbestos-like fibers have been associated with the taconite industry on the Range. One part of the continuing study is expected to look at X-rays taken a number of years ago to try to pinpoint when the problem began.

Al France, president of the Lake Superior Industrial Bureau, a consortium of the iron mining companies on the Iron Range, said that he had not heard of the findings before a reporter contacted him yesterday morning and that he would not comment until he had seen the study.

Eldon Kirsch, District 33 director of the United Steelworkers of America, said that he was not aware of any special lung problems related to asbestos-type fibers among taconite workers.

Some workers have had lung diseases related to dust in the plants, Kirsch said, "but not more than in any other similar industry that I know of." The district Kirsch heads includes locals in Minnesota, Michigan, Wisconsin, North Dakota, South Dakota, Wyoming and Montana.

"Until we know more, we're not going to panic," he said. "It's something we're going to look into right away."

Dr. Terrence Clark, a specialist in lung diseases at the Duluth Clinic, Ltd., said he found no similar abnormalities in a 1980 study of taconite workers at Reserve Mining Co. in Silver Bay, Minn.

There were no significant differences in the thickening of lungs in the X-rays of 300 of Reserve's most senior employees compared with those of 33 workers in the Duluth school system, Clark said. Doctors from Duluth, California and West Virginia examined the X-rays, Clark said. The study was paid for by Reserve.

Clark also said he has been examining X-rays of Reserve employees for about five years, and "I don't see any signs of asbestos-related disease."

Dr. George Skelley, a radiologist at Virginia Regional Medical Center, said he sees such lung conditions primarily among persons 60 to 70 years old, and has noticed no correlation with workers at taconite plants.

Other doctors in Hibbing, Chisholm and Virginia said they had not seen noticeable trends of any special lung abnormalities.

"I don't understand what the rush is to go to the press before the data has been analyzed," said Dr. Norman Yunis, a lung specialist at the Duluth Clinic.

"I haven't had a chance to study anything in the survey, but there doesn't seem to be an undue influx of pulmonary lung disease in the area."

Rep. Willard Munger, DFL-Duluth, said that he has been concerned about the potential for such problems since the litigation over Reserve Mining's discharge of asbestos-like fibers into Lake Superior, and that he was not surprised by the findings.

"I always thought there was going to be a follow-up on the problem and that more than just Reserve would be affected," Munger said.

Johnson said that he would ask next week that U.S. District Judge Miles Lord not be allowed to deal with issues raised by the new findings.

"A lot of people in northeastern Minnesota do not trust Judge Lord because of his adverse rulings on the Reserve Mining case and the Boundary Waters Canoe Area issues, so he does not have a lot of credibility in Northeastern Minnesota where this issue is," Johnson said. "I think he is very biased. He has shown it time and again in Northeastern Minnesota issues."

Lung study may help fund get support

Findings are expected to become part of 'superfund' debate

By Dean Rebuffoni
Staff Writer

The discovery of an unusually large number of lung abnormalities among residents of the Mesabi Iron Range will increase support for a fund to compensate Minnesotans injured by hazardous wastes, several state legislators said Saturday.

Some lawmakers also said that the discovery will increase resistance to a probusiness bill that would repeal provisions of the state's superfund law. Those provisions give Minnesotans claiming injuries from toxic wastes more legal power to collect damages from industries that dumped the substances.

That includes airborne asbestos-type fibers, which the Minnesota Health Department said is a likely cause of the lung abnormalities. Several officials familiar with the superfund law said that asbestos is among the hazardous substances covered by the statute. Some lawmakers pointed out that a likely source of fibers on the Iron Range is the taconite mining industry.

"The blasting, the trucks, the dust, the tailings: they all create a cloud of dust and a lot of those fibers," said Rep. Willard Munger, DFL-Duluth. "It's terrible to think about it, but people on the Range have been breathing those fibers for the last 20 years or more."

The idea of a victim's fund had been promoted by Gov. Rudy Perpich, himself an Iron Ranger, before the Health Department's announcement. He has suggested that such a fund would help people who will lose considerable legal power to recover for their damages if the bill to amend superfund becomes law.

However, Perpich supports that bill, and has strongly indicated that he would sign it into law even if the Legislature fails to create a balancing victim's compensation fund.

Perpich would not comment on the Health Department findings yesterday. Lawmakers closely involved in the superfund issue said the findings will become part of the legislative debate.

"I think that it will build support for a victim's comp fund," said Sen. Gene Merriam, DFL-Coon Rapids. He was the original Senate sponsor of the superfund law and the chief Senate sponsor of the probusiness bill to amend it.

"All of a sudden you have a lot of new potential victims on the Iron Range," he said. "It is going to increase awareness of the need for a victim's comp fund while, on the other hand, raising questions about the cost of compensating victims."

The original House sponsor of the superfund law, Rep. Dee Long, DFL-Minneapolis, also predicted that the health findings will prompt more support for a victim's compensation fund from DFLers and Independent-Republicans. The same prediction came from Rep. John Rose, IR-Roseville, chairman of the House Environment and Natural Resources Committee.

Long said, "Sure, we need a fund, but let's not kid ourselves that it would compensate victims for the provisions they will lose if the bill to amend the (superfund) law gets passed.

"No compensation fund is going to fully compensate victims," she said. "We told Gov. Perpich that last week, when we met with him."

"There probably will now be a great deal of attention focused on the issue of a victim's compensation fund," said Rose, who yesterday attended a Health Department news conference on the health issue.

"What we're talking about here today is victims," he said. "This builds support ... for the concept of a victim's fund. General support for the idea had already been building in the Legislature."

At least three bills that would create a victim's compensation fund, albeit in varying forms, are pending in the Legislature.

One of the state's most outspoken environmentalists, Grant Merritt, yesterday recommended that Perpich act quickly on the superfund issue and to resolve questions about the Health Department's findings.

In a letter to Perpich, Merritt, a Minneapolis attorney, said the governor should call upon the Legislature to "reject all pending amendments which would in any way weaken or adversely affect" the superfund statute, which Perpich signed into law.

He suggested that Perpich call a conference within the next two weeks that would include participants from taconite mining companies, environmentalists and public officials. Its purpose, said Merritt, would be to provide close public scrutiny of any potential health problem on the Iron Range.

Merritt was one of the first environmentalists to call for an end to Reserve Mining Company's discharge of taconite wastes laden with fibers into Lake Superior and the air from its plant at Silver Bay, Minn.

"This news about lung problems on the Range is going to cause a big change in sentiment in the Legislature for that bill," said Munger.

"The bill would gut the superfund law that ... would help those people on the Range," he said. "I hope this news about lung problems causes the governor to change his position on the bill."

The Minnesota Pollution Control Agency (MPCA) said emissions from all taconite plants in northeastern Minnesota meet air-quality standards.

"But we're not sure what role 'fugitive dust' might play in the situation," said Michael Valentine, MPCA air-quality director. "A lot of dust is raised in the taconite pits and a good deal of exposure to asbestos fibers could come from that. Still, I'm not sure that there is a relationship between the work environment on the Range and the lung problems being found there."

Health Department officials said their investigation of the matter was prompted by a January 24 telephone call from Dr. Ronald Seningen of Virginia, Minn. He reported that he had found a large number of lung abnormalities on X-rays of patients in the Virginia area.

The following day, department officials said, U.S. District Judge Miles Lord urged that they investigate whether northeastern Minnesotans were being harmed by asbestos-type fibers. Lord presided over the first part of the Reserve Mining Co. trial in the early 1970s but was removed from the case by a federal appeals court that said he was biased against the company.

One northeastern Minnesota legislator, Rep. David Battaglia, charged that Lord's role in the matter "almost looks like it's a little vendetta."

Battaglia, DFL-Two Harbors, also questioned whether the Health Department had done an adequate job investigating the matter. He said that several studies have shown that northeastern Minnesotans, including taconite workers, have not shown any increased incidences of cancer or other ailments that could be linked to exposure to asbestos-type fibers.

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The Hibbing Daily Tribune

Entered as second class matter October 15, 1909, at the post office at Hibbing, Minnesota, under the act of March, 1899. With it has been merged the Hibbing News, first issued January 19, 1894. The Tribune is therefore a continuation of the first newspaper published in Hibbing and as such is in its ninety-second year. Publication Number USPS 243-120.

Published daily except Saturday by H.T.C., at Hibbing, Minnesota 55746
JOHN B. MURPHY, Publisher
BERNARD J. KRAUTH, General Manager
ALAN T. ZDON, Managing Editor
Member of the United Press International

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Range health

The health problem brought out at a press conference Saturday is potentially a serious one, but it also seems like the state officials that have caused this tumult are not going on much reliable investigation.

The state has launched a research project to find out if asbestoes fibers in the air of the Iron Range has caused widespread lung damage to area people.

The whole thing stems from a series of x-rays of people in Hibbing, Grand Rapids, Duluth and Virginia. The pictures showed a thickening of the lung lining in 34 percent of the people who took the tests. Normally, such thickening is only present in one to 10 percent of the people who have x-rays.

That's what they know. What they don't know includes:

- Whether the thickening is caused by asbestoes or some other reason.
- Whether the sampling is simply a statistical aberration, or whether the figures will hold up for Iron Rangers in general.
- Whether the thickening will lead to other diseases.
- Whether we have an unusual amount of asbestoes in the air we breathe.

In other words, they really don't know very much. It's good that they are looking into this problem, but we wonder if they really had to make such a fuss with as little information as they had.

And if this news is so important for the Range, why was the press conference held in St. Paul?

Our local medical authorities indicate that there is little information of the type of health hazard being touted.

We would urge a quiet and calm investigation. All we have right now is enough information to warrant more research.

We don't know enough to get nervous, despite the sensationalizing by the Twin Cities press.

inneapolis Star and Tribune
ıblished 1867
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Friday, March 8, 1985

Premature reaction to the Iron Range lung study

Conclusion-jumpers are flocking to the preliminary study showing lung abnormalities among some Iron Range residents. Already the study is being used to build support for a compensation fund to aid victims of toxic-waste contamination. But those political conclusions are based on incomplete scientific evidence. State policy makers should give the scientific and health communities adequate time to conduct a thorough, valid investigation.

The unjustified conclusions, accepted even by legislators who should know better, are that a significant number of Iron Range residents suffer from lung abnormalities caused by asbestos fibers from the region's taconite mining. The truth is that chest X-rays from a small group of Iron Range residents, who selected themselves by visiting clinics for a variety of ills, have revealed a high incidence of thickened tissue around the lungs. The thickening is of a type associated with asbestos, but it also differs from the typical asbestos-induced condition. No asbestos-caused diseases have been discovered. At this point, officials are not certain they have even uncovered a health problem, let alone one attributable to asbestos. If a problem does exist and if asbestos is the culprit, additional research will be required to determine if and how taconite mining played a role.

Gov. Rudy Perpich was right to order release of the preliminary data. Word was beginning to spread around the Range, distorted and embellished in the usual word-of-mouth way. Perpich wisely decided to give people what accurate information was available.

But the political reaction to that information has been less responsible. Proponents of a state compensation fund for victims of toxic contamination already are using the lung study to build support. That tactic is worrisome not only because it is built on unwarranted assumptions, but because of what it suggests about the scope of such a fund.

If a compensation fund is established that would aid Iron Range residents who have ingested asbestos from mining dust — presuming that is the case — where would legislators draw the line? Would such a fund, for example, compensate someone contaminated by asbestos from a school building? What about urban parents whose children have ingested high levels of lead from soil contaminated by auto exhausts? Recent research also shows that auto lead emissions contribute to high blood pressure in adults. Would such a fund compensate people who suffer from hypertension?

Legislators should not rush to provide a compensation mechanism for a problem that may not exist and without thinking through the broader implications. Much more investigation, analysis and discussion is needed before the nature of the Iron Range problem comes clear and before policy makers can begin constructing an appropriate response.

12-8

6 national experts to study Range X-rays

By Lewis Cope
Staff Writer

Six national experts have agreed to study the X-rays of Minnesota Iron Range residents that have touched off concern about the possible risk of asbestos-caused cancer there, the Minnesota Department of Health announced Friday.

The department also announced the seven other types of scientific studies that could follow. The X-ray studies will begin next week, but the entire investigation "could take several years — or longer," said Alan Bender, the department's chief of chronic disease epidemiology.

He said there are two reasons that answers could take time:

■ Asbestos-related illnesses — lung cancer, some other malignancies and lung-damaging asbestosis — typically occur decades after exposure to asbestos began. So it might be too early to prove a danger exists — or to rule out a danger.

■ To get maximum scientific value, some studies will be done first to develop possible leads for other types of studies to investigate, he said.

The Health Department announced last Saturday that a preliminary study of X-rays from 579 people on Minnesota's Iron Range had found that almost a third of them showed lung abnormalities normally associated with heavy asbestos exposure. These people do not appear to have asbestos-related illness; they had gone to their doctors for a variety of illnesses.

The concern is that by showing signs of asbestos exposure now, many may develop asbestos-related illnesses in future years. And if the group of X-rays indicates a pattern, the Range might face a widespread health problem.

While Health Department officials have cautioned that asbestos is the "most likely cause" of the lung abnormalities found so far, it is not a confirmed cause. The X-rays showed thickening of tissue around the outside of the lungs, but they differed slightly from what had been found in asbestos-related cases elsewhere.

So the first step is to have top experts assess the meaning of what is on the X-rays, Bender said.

The X-rays will be sent early next week to Dr. Ruth Lilis of the Environmental Sciences Laboratory in New York, the leading expert in this field, Bender said. Her assessment of what the X-rays signify should be completed before the end of March, he said.

The X-rays then will go to five specially trained physicians at the National Institute of Occupational Safety Health in Morgantown, W. Va., who will do what scientists call a "blind study."

They will be given not only the 579 Minnesota X-rays, but a lot of other X-rays from elsewhere in the country. They won't be told which X-rays came from where until they have written the conclusions of their observations. This is to avoid any chance of the experts' expectations affecting their conclusions.

Bender said a group of national experts will serve as an advisory committee to plan what other studies should follow, unless it's concluded at some point that no risk exists. He

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said these studies could include:

■ An evaluation of X-rays from other parts of Minnesota. This will help experts assess how serious the Range situation may be. There is debate about how common these lung abnormalities might be in the general population.

■ Taking new X-rays of a representative sampling of Range residents. The X-rays studied so far have been of people who went to see a doctor for some reason. The rates of lung abnormalities found in that special group may not reflect the over-all situation on the Range.

■ Looking at X-rays and preserved tissue samples taken of patients in past years. This could show when lung abnormalities began to appear. This, in turn, could help experts predict when asbestos-related illnesses might be expected.

■ Examination of lung and related tissue, either from autopsies or from biopsies taken of people with lung ailments. The number of asbestos fibers found would be a direct measure of exposure.

■ Air monitoring for asbestos fibers or possible other health hazards.

■ Systematic monitoring of specific groups of people. For example, do people in certain occupations have higher rates of lung abnormalities? People in certain sections of the Range and not others? These findings could be clues to the source of any air contamination.

■ Similar studies of cancer and other disease patterns on the Range.

He said the advisory committee also may recommend stop-smoking programs for Range residents. Smoking greatly intensifies the risk of lung cancer from asbestos exposure. There could be other educational programs as well, for physicians as well as the public, he said.

Wash Mpls Trib 3/13/85

Legislators attack proposed lung study

Iron Range legislators Tuesday criticized plans by the Minnesota Health Department to hire two panels of experts to look into the causes of abnormal lung X-rays from Iron Range patients.

The department announced March 2 that 195 of 579 patients X-rayed randomly in Iron Range communities showed signs of tissue thickening around the lungs. Such a condition is associated with exposure to a variety of environmental hazards, including asbestos, a by-product of the Iron Range taconite mining industry.

The Health Department, cautioning that the findings were preliminary, has sent the X-rays to readers at the National Institute of Occupational Safety and Health (NIOSH) in Morgantown, W. Va., and to Dr. Ruth Lilis of the Environmental Sciences Laboratory, a New York consulting firm.

State Sen. Doug Johnson, DFL-Cook, one of three Iron Range legislators who participated as guests in a hearing by the House Health and Human Services Committee last night, urged Health Department officials to turn the management of the study over to the Mayo Clinic in order to avoid any political pressure on the studies.

Johnson also questioned the selection of Lilis to read the X-rays because the head of the Environmental Sciences Laboratory, Dr. Irving Selikoff, was a chief witness against Reserve Mining Co. of Silver Bay, Minn., in its pollution trial in the mid-1970s.

Dr. Alan Bender, chief of chronic disease epidemiology of the State Health Department, said Lilis and the readers, who will not know the source of the X-rays, will forward their findings to a committee of five to 15 experts now being interviewed by the Health Department. He said the experts will come from the fields of medicine, epidemiology, geology and other sciences.

Sec C pg 3 News Tribune - Duluth 3/22/85

Expert panel will study X-rays from region for asbestos signs

St. Paul Pioneer Press & Dispatch

A panel of experts has been named by state officials to review a sample of 579 northern Minnesota X-rays for signs of disease related to exposure to asbestos-like fibers.

Several scientific fields are represented on the panel, which will advise the state on appropriate public health follow-up actions — if any are warranted — after the review is completed.

The potential health problem came to light last month, when the department disclosed that about a third — an unusually high percentage — of sample chest X-rays taken in Duluth, Grand Rapids, Hibbing and Virginia showed a thickening of tissue surrounding the lungs.

Officials said the condition appeared generally "consistent with" exposure to asbestos-like fibers, which has been linked with a variety of ailments that develop over 20 years or more, ranging from shortness of breath to cancer. However, state officials say they don't know what caused the lung condition or even if it is medically significant.

Another examination of the X-rays already is under way by six experts who specialize in reading X-rays for signs of asbestos damage. One of the experts is at a private laboratory in New York and the rest are at the National Institute of Occupational Safety and Health in West Virginia.

That group's evaluations will be presented to the broader-based panel that was named Wednesday, which will meet April 11-12 in the Twin Cities, said Buddy Ferguson, a health department spokesman.

Members of the national panel are:

Co-chairmen Henry A. Anderson, chief of environmental and chronic disease epidemiology, Wisconsin Division of Health, and Alan P. Bender, chief of chronic disease epidemiology, Minnesota Health Department; Dr. Thomas A. Hodous, division of respiratory disease studies, National Institute of Occupational Safety and Health; Leonard Kurland, chairman of medical statistics and epidemiology, Mayo Clinic; Philip J. Landrigan, director of surveillance, hazard evaluation and field studies, National Institute of Occupational Safety and Health; Dr. James A. Merchant, professor, Institute of Agricultural Medicine and Occupational Health, University of Iowa; Dr. David Muir, professor of medicine and director of occupational health, McMaster University, Hamilton, Ontario.

Dr. William J. Nicholson, associate director of environmental sciences laboratory, Mount Sinai School of Medicine, New York City; Dr. Tibor Zoltai, professor of mineralogy, University of Minnesota; and Dr. Ronald Seningen, radiologist, Virginia, Minn., who first detected the high rate of X-ray abnormalities in his private practice and notified state officials.

Ex-officio members of the national panel are: Dr. Harold Leppink, Lake and St. Louis counties health officer; and Michael Osterholm, director of acute disease epidemiology, Minnesota Health Department.

National experts to study Iron Range asbestos risk

By Lewis Cope
Staff Writer

The study of suspected health risks from asbestos fibers on the Minnesota Iron Range will move into a new phase April 11 when a committee of national experts meets to assess the apparent hazards and decide what to do next.

Asbestos can cause cancer and other health problems. A preliminary study found X-ray abnormalities, of the type normally associated with asbestos, in about a third of 579 X-rays checked at Range clinics. None of the people appeared to have asbestos-related illnesses yet, but there are concerns about what could happen in the future, and how widespread the problem might be.

Alan Bender, chief of chronic disease epidemiology at the Minnesota Department of Health, who will serve as cochairman of the committee, said two detailed studies of the same X-rays are underway and will be completed by the time the committee meets. The committee will consider those results, with all other available data, to decide whether a problem exists and how serious it might be, he said. Assuming there is a problem, the committee will decide what further studies are needed, and what type of medical help people on the Range might need.

The committee was named by Commissioner of Health Mary Madonna Ashton. The other members are:

Dr. Henry Anderson, chief of environmental and chronic disease epidemiology at the Wisconsin Division of Health. He has extensive experience in asbestos research and will serve as cochairman of the committee. co-chair.

Dr. Thomas A. Hodous and Dr. Philip Landrigan, both asbestos experts with NIOSH.

Dr. Leonard Kurland of the Mayo Clinic in Rochester, Minn., who is noted for his studies of the rates at which various illnesses occur.

Dr. James Merchant, professor of preventive medicine at the University of Iowa in Iowa City and an asbestos expert.

Dr. David D.C.F. Muir, director of occupational health programs at McMaster University in Hamilton, Ontario, who has done studies of asbestos risks involving Canadian mines.

William J. Nicholson, an asbestos expert at the Mount Sinai School of Medicine in New York, where many of the pioneering studies have been done.

Dr. Ronald Seningen, a radiologist at the East Range Clinics in Virginia, Minn., who did the preliminary study of X-rays that raised the concerns.

Tibor Zoltai, a professor of geology at the University of Minnesota. He was a member of the expert committee of the National Academy of Sciences that studied studies asbestos last year.

Dr. Harold Leppink of Duluth, St. Louis County health officer, who will be an ex-officio member to meet with and advise the committee.

Michael Osterholm, state epidemiologist in the Minnesota Department of Health, also an ex-officio committee member.