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Final Report of the Northeast Minneapolis Community Vermiculite Investigation (NMCVI) and Worker/Household Study: Cohort Identification and Characterization

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I. Summary

The Minnesota Department of Health (MDH) conducted an investigation of community and occupational asbestos exposure from a vermiculite processing facility that operated from 1938 to 1989 in Northeast Minneapolis and received over 100,000 tons of vermiculite ore from Libby, Montana. Processing waste rock was piled outside the plant and offered as free "crush rock" to the community, and asbestos contamination was discovered on 259 properties during the course of this investigation. Interviews were conducted with 6,714 people to characterize the exposure pathways and to identify and enumerate a cohort with a wide range of exposures (including 80 people who were interviewed both as current or former residents and as workers or family members). The study population includes 3,934 current residents living in the study area near the facility, 2,499 former residents, 136 former workers employed at the facility, and 225 family members of workers. Proxy interviews with the next-of-kin were conducted for deceased individuals who met eligibility criteria. Just over one half of the participants (56%) reported no community or work-related exposure to asbestos from the facility through the 8 exposure pathways identified in this report. Among people reporting exposures, MDH found (not mutually exclusive categories): 1) 690 people who reported direct contact with the processing waste from playing on or around the waste rock piles; 2) 820 people who lived within one block of the plant during the years it was operating (1938-1989); and 3) 1,746 people who reported having lived on a property contaminated with vermiculite waste rock. There were 432 people who reported exposure through 3 or more exposure pathways, and 677 people who reported 35 or more years of residential history in the study area. Among workers, the study identified 70 people who worked in the vermiculite production areas as laborers, foremen or maintenance workers and 56 who worked in non-production areas. The duration of employment among workers ranged widely from a few weeks to 42 years. Working conditions, industrial hygiene sampling data, job tasks, and use of respiratory protection are described. Examination of death certificates of workers at the Minneapolis WM/WRG plant indicates that 18 out of 46 worker deaths were from respiratory cancers or non-malignant respiratory disease. Household contacts of workers included 79 spouses or ex-spouses and 146 children of former workers. Exposures to household contacts include laundering of worker clothing and visiting or helping with work tasks at the plant. A comprehensive community health education and communication program was provided to address community concerns, provide appropriate health recommendations, and inform area health care providers. Cohort follow-up to evaluate cause-specific mortality and cancer incidence, and medical screening of exposed groups is recommended to measure the occurrence of asbestos-related health outcomes in this population. Findings from this investigation will be useful for assessing exposures and potential health risks in other communities with processing facilities that received Libby vermiculite ore.

II. Background

The Western Minerals/WR Grace (WM/WRG) facility, located at 1720 Madison St. NE in the city of Minneapolis, processed vermiculite ore mined in Libby, Montana, from about 1938 to 1989. The ore was contaminated with amphibole asbestos, including tremolite and actinolite. Amphiboles are generally considered to be more toxic than serpentine fibers (such as chrysotile). A more detailed discussion of asbestos mineralogy and toxicology can be found in ATSDR

(1999). At the facility, the vermiculite ore was heated and expanded in a process known as "exfoliation" to make Zonolite® insulation, Monokote® fireproofing, and other building materials. In addition to the vermiculite product, the exfoliation produced a waste rock (known as "stoner rock" and "crush rock") that contained up to 10% amphibole asbestos (Weston, 2001), hereafter referred to as "Libby asbestos". The waste rock was piled on the WM/WRG property and offered freely to the public.

In 2000, the Minnesota Department of Health (MDH), the Minnesota Pollution Control Agency (MPCA), the U.S. Environmental Protection Agency (EPA), and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) received reports of asbestos-related disease among former employees of WM/WRG in Northeast Minneapolis. In addition, asbestos-related diseases among current and former residents of the surrounding community were reported (Gordon, 2000). Visible asbestos contamination of residential properties in the area was also discovered. Laboratory analyses by EPA found up to 95% amphibole asbestos in rock samples taken from residences near the WM/WRG property (MDH, 2001).

The neighborhood surrounding the plant is predominantly residential with a mix of single-family homes, multi-family homes, and apartments. Neighborhood residents used the rock for gardening and as fill material for driveways and yards; neighborhood children played on the piles of vermiculite processing waste. From 2000-2003, over 1,600 property inspections were conducted by EPA and by MDH Northeast Minneapolis Community Vermiculite Investigation (NMCVI) staff. Libby asbestos contamination from this facility was found on 259 properties and subsequently cleaned by EPA.

MDH Health Consultations (2001, 2003), conducted through a cooperative agreement with the ATSDR, have provided an assessment of the past and present Libby asbestos exposure pathways for workers and community members, including relative fiber levels and exposure duration. Exposure pathways and/or scenarios identified include inhalation of asbestos dust from occupational activities, being a household contact of a former worker, moving waste rock or gardening in waste rock, recreational activities (playing on piles), ambient air exposures in close proximity to WM/WRG facility, disturbing contaminated soils or driveways, and installation/removal of vermiculite insulation.

To assess exposures from direct contact, EPA conducted simulations of activities that disturb the waste rock and measured fiber concentrations in the range of 0.07 to 1.7 f/cc (Weis, 2001). These levels likely represent short-term exposures that children playing in the piles or adults moving the waste rock would have experienced.

MDH and MPCA completed air dispersion and deposition modeling for the processing facility emissions in Northeast Minneapolis in order to estimate ambient air exposures during the years the plant was operating (MDH, 2003). Results indicate ambient fiber concentrations within 1-2 blocks of the plant reached peak short-term concentrations as high as 0.89 f/cc, and long-term concentrations as high as 0.026 f/cc in the years prior to installation of air pollution control equipment (1938 - 1972). ATSDR, in its Toxicological Profile for asbestos, reported that ambient levels of asbestos in urban air in the U.S. typically range from 0.000003 f/cc to 0.0003 f/cc (ATSDR, 1999).

MDH Health Consultations (2001, 2003) also examined available industrial hygiene data for WM/WRG. Asbestos fiber concentrations exceeded occupational exposure levels, particularly prior to enforcement of Occupational Safety and Health Administration (OSHA) regulations and dust control measures in the 1970's.

A respiratory health screening investigation conducted in Libby, Montana (Peipins et al, 2003) found radiographic pleural and interstitial abnormalities associated with occupational exposure among former WRG employees. Increased risk of pleural abnormalities was also found among household contacts of WRG employees, people who played on waste piles, or among long-time residents of Libby. A report of 123 Libby patients with occupational and non-occupational exposure indicated progressive loss of pulmonary function associated with pleural changes in 94 individuals (Whitehouse, 2004). Another report, comparing 50 asbestos-exposed individuals in Libby with a control group in Missoula, suggested that auto-immunity may be involved in progression of asbestos-related lung disease (Pfau et al, 2005). ATSDR (2002) found a 40-60 fold elevation in asbestosis deaths in Libby, primarily among former employees. In a cohort of 406 Libby vermiculite miners, McDonald et al (2004) found excess mortality from lung cancer, which increased sharply with cumulative exposure, and 12 mesothelioma deaths (4.2% of 285 deaths).

A case report that included scanning electron microscope analysis of pulmonary mineral fibers (Srebo and Roggli, 1994) supported a role for tremolite asbestos in a case of asbestosis and lung cancer in a 44 year old male who lived near a vermiculite plant and played in the waste piles, but had no documented occupational exposure.

No studies outside of Libby have been done to assess exposures and health of people living in communities where the Libby ore was processed. The operations of the WM/WRG facility, and the use and dispersion of vermiculite waste material in the community, were a source of past asbestos exposure to workers and the community. This investigation was designed to characterize the extent of community exposures and exposures to workers and their families, identify the affected population, and make recommendations for future health studies.

The study was conducted in two parts:

1) The Northeast Minneapolis Community Vermiculite Investigation (NMCVI) focused on exposures to community members who lived near the WM/WRG plant or had a history of direct contact with the vermiculite processing waste.
2) The Western Minerals/W.R.Grace Worker/Household Study focused on exposures to the workers and their family members (spouses and children) living in the same household during their employment at WM/WRG.

Each cohort is described separately in the following two sections (III and IV) of this report including study methods, participation, demographics, and unique exposure characteristics. Results for the two cohorts are then combined in Section V to provide a complete tabulation of all participants. Section VI describes the extensive education and communication efforts that were integral to this investigation.

III. Community Cohort

A. Objectives

The objectives of the NMCVI Cohort Identification and Characterization were as follows:

1) Determine the number and location of residential properties impacted by dispersion of vermiculite waste material from the industrial site, and facilitate remediation of the asbestos contamination.
2) Measure the size and demographics of the residential population potentially exposed to Libby asbestos from the Western Minerals vermiculite waste material; identify those individuals who are currently exposed and those with past exposure.
3) Measure the prevalence of smoking, potential occupational asbestos exposure, and reported history of respiratory disease in the adult study population.
4) Characterize the ways in which vermiculite waste material was used off the industrial site, and describe the current or historical exposure pathways.
5) Qualitatively assess health risks to the community associated with past exposures to the vermiculite waste.
6) Communicate asbestos exposure and health risk information to study participants and health care providers so that appropriate medical evaluation and care are provided.
7) Evaluate the need and feasibility of assessing health outcomes in the exposed population, and make recommendations for future health studies.

B. Methods

Identification of Study Area and Target Properties

City property records were used to identify all target properties within a defined study area (n=2,313). The study area boundaries were Broadway St. NE, Central Ave. NE, 27th Ave. NE, and University Ave. NE in Minneapolis, MN (Figure 1). This area was selected because it encompasses all properties within approximately ½ mile of the facility. It incorporates 2 complete neighborhoods (Logan Park and Holland) and a portion of a third neighborhood (Sheridan). In addition, the EPA confirmed the presence of Libby asbestos contamination on thirty-eight residential properties located outside the study area (EPA, 2003), and they are included as target properties for this study. Of the 38 residential contaminated properties outside the study area, 22 are located within about 1/2 mile of the study area boundaries. The rest are located primarily in the northern suburbs of Minneapolis. Non-residential and unoccupied properties (n=368 or 16%) within the study area were excluded leaving 1,983 properties eligible for the study. More information about the location of contaminated properties is available in an MDH Health Consultation (MDH, 2003).

Current Households and Resident Interviews

Current and former residents, living and deceased, of eligible target properties at any time from 1938-2001 comprise the target population. All current households living on target properties were contacted and, if eligible, invited to participate in an in-home survey conducted by trained interviewers. Households were ineligible if no member of the household lived on the property before January 1, 2002. Before conducting interviews, the MDH and the Centers for Disease Control and Prevention Institutional Review Boards reviewed the study protocol, consent

documents, and questionnaires for compliance with legal and ethical standards for human subjects research.

The study was explained in a letter and fact sheet mailed to the property owner by study staff prior to the interview. With the informed consent of one adult member of the household, the *NMCVI Household Questionnaire* gathered demographic information on current and former household members who lived at the residence at any time from 1938-2001. Residents were also asked about their knowledge of vermiculite waste use on their property and other locations. Interviews were conducted in English or Spanish.

Following the household questionnaire, the *NMCVI Individual Adult Questionnaire* gathered information about history of exposure from all consenting adults living in the household at the time of the interview. Exposure variables measured included residential history in the study area (address and time in years from 1938-2001), frequency of direct contact activities with processing waste materials, occupational history as a vermiculite processing worker, household contact with a worker, frequency of handling vermiculite insulation, and age at first exposure (playing in waste piles). Covariates included age, gender, smoking history, self-reported history of lung disease or pleural changes, and other occupational history with asbestos. Information about date, state, and cause of death were collected for deceased former residents through interviews with next-of-kin. Dependent adults were interviewed with an adult guardian or legal representative as proxy.

At the conclusion of each interview, staff provided information and resources to address questions about asbestos and health, vermiculite products, asbestos removal contractors, smoking cessation programs, and low cost health care. Informational materials were available in English and Spanish versions.

Property Inspections

All residents who agreed to participate in the study were offered an inspection of the outside property (yards, gardens, driveways) for visible signs of surface contamination from the vermiculite ore or waste. If surface contamination was found, MDH referred the property to the EPA. EPA arranged with the owner or resident to re-inspect and, if needed, to collect soil samples. If the contamination was confirmed, EPA offered removal of the contamination and restoration of the property at no cost to the homeowner under a Superfund removal program.

Telephone Interviews of Former Residents and Others with Direct Contact Exposure

In addition to current household residents, adult former residents of target properties who lived on the property at any time from 1938-2001 were eligible to participate in the study through a telephone interview. Persons who reported a history of direct contact with the vermiculite waste at the facility, from playing on the piles as a child or hauling and using the waste as an adult, were also eligible for the telephone interview even if they were not current or former residents of a target property. A high school and elementary school were located within several blocks of the facility, providing access to the waste piles for many children living outside the study area. Also, non-resident property owners (landlords) may have had direct contact with the waste.

Former residents of target properties and other eligible participants were identified through 3 mechanisms:

1) During household interviews, names, addresses, and demographic information about former members of the household were gathered as part of the NMCVI Household Questionnaire.
2) Passive search methods such as media announcements and public meetings were used to encourage former residents and owners of study area properties, and others with direct contact or occupational exposure, to contact MDH for self-referral into the study.
3) For all properties with confirmed waste contamination, an active search was conducted using reverse telephone directories and public property records to identify persons who lived on the properties at any time from 1938-2001.

Telephone interviewers contacted and interviewed adult former residents, and others who reported direct contact exposure, using the *NMCVI Former Resident/Owner Telephone Questionnaire*. This questionnaire collected the same exposure variables and covariates as the NMCVI Individual Adult Questionnaire described above. Due to the large number of former residents identified, priority for interviews was given to eligible persons who were identified passively through self-referral (volunteers), to former residents of contaminated properties, and to former residents of properties in close proximity (on city blocks adjacent to the facility block).

Follow-up Consent

At the conclusion of each interview, participants were asked for consent to future cohort follow-up for health outcomes through record linkages with death records and cancer registries. To assist in the follow-up, they were asked to provide their Social Security Number, and to agree that cancer registries may provide information to NMCVI investigators to determine asbestos-related disease outcomes.

Data Entry and Quality Control

Unique identification codes were assigned to each individual participant to allow for linking of the various components of the study. All questionnaires and forms were edited for completeness and proper coding before entry into a relational database by trained project staff. Following data entry, the data were checked for duplicate entries, proper response ranges and internal consistency to further identify and correct errors in data entry or coding before data analysis.

Data Analysis and Outcomes

The principal analysis consisted of summary tabulations characterizing the distributions of key demographic and community exposure measures including the following:

1) Vital status (dead or alive), age, gender
2) Years of residence in the study area and proximity to the facility
3) Frequency of direct contact with waste
4) Age at first exposure for playing on the waste rock piles
5) Exposure through multiple pathways

Key covariates summarized in the analysis include the following:

1) Smoking history
2) Occupational history with commercial asbestos exposure
3) Chest x-ray and respiratory disease history
4) Medical insurance status

C. Community Cohort Participation and Demographics

Property Identification, Household Participation, and Inspection

Out of 1,983 occupied residential properties identified, 254 (13%) had no household interview (Table 1). Reasons for not completing at least one interview were as follows: 24 properties did not have any household meeting eligibility criteria for a household interview; resident households refused to be interviewed for 138 properties; 69 had no household contact responding; 15 needed a foreign language interpreter (the interview could not be conducted in English or Spanish); and 8 had multiple households with no household interview for a combination of the above reasons (refusal, ineligible, no response, foreign language). The remaining 1,729 properties (87%) had at least one household that agreed to complete the household interview.

Of the 1,729 properties with at least one household participating, 1,596 were inspected by NMCVI staff for vermiculite waste contamination. No contamination was observed on 1,386 properties (87%), and visible Libby asbestos or vermiculite ore contamination was found on 210 of these properties (13%). EPA confirmed the presence of asbestos contamination on 154 of the 210 properties referred and remediation of the property was completed. There were 133 properties where the household contact or property owner declined the inspection offered by NMCVI staff. Sixty-two of these properties were not inspected by NMCVI staff because the property resident reported a previous inspection, and no further inspection was necessary.

Participation Among Households in the Household Interview

On the 1,729 properties with at least one household participating, there were 3,122 total households identified during property visits (Table 2). Among these, 140 households did not meet eligibility criteria for the household interview (moved to the property after 12/31/2001), 262 had no response from a household contact, 53 needed a foreign language interpreter, and 2,667 were successfully contacted and determined to be eligible. Among these 2,667 eligible households, 318 (12%) refused to participate, 164 (6%) completed the household interview but did not complete all individual adult interviews, and 2,185 (82%) completed all interviews.

Participation Among Current Residents

From household interviews, a total of 5,430 current residents were named by a household contact (Table 3). Of these, 1,332 were ineligible (1,247 were under the age of 18 and the remainder were of either unknown age or did not live on the property at anytime from 1938-2001). Sixty-four were not contacted or did not respond to multiple attempts such that eligibility is unknown, and 4,034 (including proxies for the deceased) were contacted and determined to be eligible for the individual adult interview. Individual adult interviews were refused by 100 current residents and completed for 3,934 people (98% of those contacted and eligible, 72% of the total current resident population identified).

Participation Among Former Residents and Others With Direct Contact

Former residents were identified by 3 methods (Table 3): household interviews, active searching of public records, and passive searching (mostly through self-referral by telephone or at public meetings). During household interviews, each household contact was asked to identify former household members, living and deceased, who had lived in the household at any time from 1938-2001. Household contacts identified a total of 2,782 former residents. Of these, 240 were ineligible, 1,538 were not contacted to determine eligibility, and 1,004 were successfully contacted and found to be eligible. There were 960 interviews completed (96% of those eligible) and 44 refused.

Active searching of public records for former residents of contaminated properties yielded 4,663 names of people putatively identified as having lived at a contaminated target property in the study area at any time from 1938-2001 (see Table 3). However, most people identified through public records searches did not have current contact information available and attempts were made to contact 1,046 (22%). Half of the attempts to contact people identified by active search (524 of 1046; 50%) were successful and an additional 455 residents were interviewed.

Referrals (either self-referrals or referrals from participants) yielded another 1,508 names of persons who were either former residents or had a history of direct contact with the waste (most of these reported playing on the piles as children). Most referrals also included recent contact information (address and telephone number) and 1,084 were successfully contacted and interviewed (99% of eligibles, 72% of total named).

Altogether 2,499 former residents and others with direct contact were interviewed (97% of eligible and 28% of the individuals named).

Demographic Characteristics of Community Participants

Participant characteristics are presented in Table 4. Proxy interviews were conducted with next-of-kin for 879 deceased persons (14% of the study population). The participants were nearly evenly divided by sex, though more of the deceased were male (61%). The majority, 3,934 (61%), were current residents of a study property, while 2,423 (38%) were former residents and 76 (1%) were never residents of a study property (including non-resident property owners and people reporting direct contact with the waste). Approximately half (2,901 or 52%) of the 5,554 living participants were 18-44 years old, while 33% were 45-64 years old, and 15% were 65 or older at the time of the interview.

D. Community Uses of Vermiculite Waste Rock

In the household interview, current residents were asked questions about the free waste rock available from WM/WRG during the course of the facility's operations. Specifically, MDH was interested in knowing when the waste rock was picked up from WM/WRG, how much and where it was taken, and for what purposes it was used. Residents reported removing the free waste rock throughout the decades the facility was operating, with most people taking the waste in the 1950s, 1960s, and 1970s. This time period is also when most of the ore was processed, according to WM/WRG records (Table 5).

The majority of respondents said the waste was hauled to other locations by the truckload (compared to smaller quantities such as buckets or car loads). Commonly, the waste was used at residential properties in Northeast Minneapolis, but it was also taken outside of the community, including area suburbs. MDH attempted to contact residents of these locations to offer an inspection of the property and referral to EPA for remediation if waste was found.

Table 6 describes some of the main uses for the waste reported by community residents. Driveway fill was the most common response, which is consistent with EPA's initial inspections and findings of waste-contaminated properties in Northeast Minneapolis. Waste was also frequently used as a soil amendment in gardens and as foundation or fill for steps, sidewalks, patios, and garages. Several residents reported keeping a container of the material in their cars to use for traction on icy winter roads. Less frequently reported uses included children's sandboxes, barbeque grill liner, fill for window wells, attic insulation, kitty litter, and pet aquariums. A few adults recalled that as children they put the waste into BB guns, used it for sidewalk chalk, or built bike jumps with it. One resident re-bagged the waste with a mixture of dirt and sold it in a garden store.

In addition to individual uses, some people also reported larger community locations where the waste was taken and used. Neighborhood baseball fields, parks, and a school track were among some of the community projects reported. In particular, waste was used for a city park project at Gluek Park. Teenagers in a service project program in the 1970s engaged in planting trees, building steps down the bank to the Mississippi River, and restoring the park with the vermiculite waste from WM/WRG. Gluek Park is currently undergoing EPA cleanup. The EPA inspected other local parks and commercial properties and found no contamination.

Some reported that the waste was used at the local high school on the outdoor running track and in an indoor basement area used for gym classes in the winter. Today the running track has been paved and no evidence of the asbestos was found during inspection and in soil samples collected by the track. Similarly, the indoor basement floor is now covered with concrete.

IV. Worker/Household Cohort

A. Objectives

The objectives of the Worker/Household study were to:

1) Identify and obtain vital status information for former workers, and location information (addresses, telephone numbers) for living former workers; identify and obtain vital status and location information for spouses and children of former workers.
2) Characterize the occupational and non-occupational asbestos exposure of former workers and their household contacts (defined as spouses and children), and other risk factors for asbestos-related disease such as smoking and respiratory health history through telephone interviews or, if deceased, by proxy interview with next-of kin.
3) Determine cause of death for deceased workers and family members through death certificate review.

4) Communicate asbestos exposure and health risk information to study participants and health care providers so that appropriate medical evaluation and care are provided, if indicated.
5) Determine the need for and feasibility of conducting additional asbestos-related disease screening and/or follow-up studies among study participants to measure health outcomes.
6) Communicate study results to the scientific community and to the public.

B. Methods

Eligibility

People who met the following criteria were eligible to participate in the Worker/Household study:

1) Paid employees of the WM/WRG facility in Northeast Minneapolis and worked at 1720 Madison Street location for any period of time from January 1, 1938 to December 31, 1989
2) Contractors hired by the WM/WRG facility whose work required them to spend any part of their work time at the 1720 Madison Street location, and/or
3) Household contacts (defined as spouses, ex-spouses or children of eligible employees or contractors as described above) and who lived in the same household during the months and years they were employed by WM/WRG. These household contacts were only eligible for inclusion if the employee or contractor interview was completed and the employee's work history with WM/WRG was documented in the interview and/or in available records.

Worker/Household Population Identification and Recruitment

The names, social security numbers, and mailing addresses of former workers were obtained from the following sources:

1) Employee data (lists) requested by MDH and the Minnesota Attorney General's Office (AGO) and received from W.R. Grace (WRG)
2) WRG pension lists and W2 information for 1971-1987
3) Quarterly wage detail reports available for 1984-1989 from the MN Department of Economic Security filed by WRG
4) MN Department of Revenue
5) Interviews with current and former residents living near the facility
6) Persons who referred themselves or were referred by others to MDH or to the Minnesota Attorney General
7) A 1965 Western Mineral Products employee roster provided by a study participant
8) Media reports
9) Public legal documents filed in Hennepin County

The above sources were used to obtain social security numbers, vital status, date of birth, date of death, and/or current address information where available. For living workers, MDH attempted to obtain current address information using internet search procedures and telephone directories. For all deceased workers identified in the study who died in Minnesota, MDH obtained death

certificates to aid in identifying next-of-kin and last known address. Attempts were also made to obtain certificates for deaths occurring out of state.

In order to obtain names and address information for household contacts, each worker interviewed (or their next-of–kin) was asked to provide information on spouses and children living with them during the time they worked at the WM/WRG facility. In addition, death certificates, NMCVI interview records, internet searches, telephone directories, and media reports were used.

Worker/Household Telephone Interview

MDH sent introductory letters with information about the study to all workers, or their next-of kin, with current address information. Trained telephone interviewers contacted the worker (or next-of-kin), obtained informed consent, and completed the Worker/Household Interview. The interview gathered information on work history, residential history in Northeast Minneapolis, direct contact with vermiculite waste, smoking history, and respiratory health. Work histories at WM/WRG included primary work location, average hours per week, job titles, duties, use of respiratory protection, and average days per week performing certain high exposure activities. Workers were also asked about medical exams offered by the company.

Interviews of former workers included a question about names and addresses of spouses and children who were living in the worker's household at any time while the worker was employed by WM/WRG. Eligible spouses and children named in interviews of former workers were then contacted for interviews. Interviews of household contacts included questions about years living with a worker, residential history in the study area, frequency of direct contact with the vermiculite waste, smoking history, respiratory health, and additional questions regarding handling of worker clothing and frequency of visits (non-occupational) to the WM/WRG facility.

Follow-up Consent

At the conclusion of each interview, participants were asked for consent to future cohort follow-up for health outcomes through record linkages with death records and cancer registries. To assist in the follow-up, they were asked to provide or verify their Social Security Number, and to agree that cancer registries may provide information to NMCVI investigators to determine asbestos-related disease outcomes.

Data Entry and Quality Control

Unique identification codes were assigned to each individual participant to allow for linking of the various components of the study, and for linking participant data from the NMCVI Community Cohort to the Worker/Household Cohort. All questionnaires and forms were edited for completeness and proper coding before entry into a database by trained project staff. Following data entry, the data were checked for duplicate entries, proper response ranges, and internal consistency to further identify and correct errors in data entry or coding.

Data Analysis and Outcomes

The principal analysis for workers consisted of a quantitative summary analysis characterizing the distributions of key demographic and exposure measures, including all of the measures gathered in the community study plus the following additional measures:

1) Duration of employment at the plant
2) Job title and duties
3) Primary work location and average hours worked per week
4) Time in specific high-exposure job activities
5) Use of respiratory protection

The principal analysis for exposures to household contacts consisted of a quantitative description of all of the measures gathered in the community study plus the following additional measures:

1) Months or years living in a household with a worker
2) Frequency of laundering worker clothes
3) Frequency of visits (non-occupational) inside the 1720 Madison Street facility

Death certificates for all workers and household contacts who died in Minnesota were obtained from State Vital Records and reviewed for cause of death. Underlying and contributing causes of death were determined and tabulated.

C. Worker/Household Participation and Demographics

The identification and participation of workers and household members is described in Table 7**.** A total of 277 workers and 267 household contacts (spouses, ex-spouses and children of workers) were identified through the methods described above. Some workers (n=80) and household contacts (n=47) had been previously identified during the community study. There were 69 workers listed on wage reports or other sources who were found to be ineligible for the study because they stated that they had not worked at the 1720 Madison Street NE location but worked at other WR Grace facilities in the area. Many were salesmen who worked at the WRG corporate office in Golden Valley, a suburb of Minneapolis.

Out of 147 workers who were successfully contacted and found to be eligible for the study, 136 (93%) agreed to be interviewed. These included 128 former employees of WM/WRG and 8 contractor employees. Most of the contractors worked as drivers for trucking companies that picked up vermiculite product at WM/WRG and delivered it to warehouses, lumber companies, and construction sites.

Most workers were men (84%), though 22 women who worked at the plant were interviewed (Table 8). All but two of the women reported working in the offices doing clerical tasks or as housekeepers (cleaning offices). Two women reported working part-time in the production area, filling small bags of product samples for mailing, while they were students at a nearby high school (part of a school employment program).

Most of the workers interviewed were age 65 and over (48 out of 85 living). There were 51 workers (38%) who were deceased and proxy interviews were conducted with the next-of-kin.

Interviews were obtained for 225 (96%) of eligible household contacts or their next-of-kin. Most were female (64%) and living (88%). Household contacts were younger overall than the workers. There were 34 aged 18-44, 117 age 45-64, and 46 age 65 and over. The study

identified 15 workers who had also been household contacts of another worker (typically this occurred when a father and son, or husband and wife both worked at the plant). These 15 individuals are not included among the 225 household contacts described in this report. Their exposures are described among the 136 workers.

D. Characterization of Household Contact Exposure to Libby Asbestos

Household contacts included 146 children of workers, 77 spouses or ex-spouses, and 2 individuals who were both child to a worker and later spouse to another worker (Table 9). The majority (59%) reported that they never laundered a worker's clothing, while 65 (29%) reported laundering worker's clothing every week. Of the 65 who laundered clothing every week, 62 were women and 3 were men. Spouses recalled workers coming home with dust on their clothing, hair, and eyelashes. Spouses reported that they would usually shake the dust from the clothing and empty dust from the pant cuffs before washing.

There were 88 (39% of household contacts) who reported living with a worker for over 10 years and 29 reported living with a worker for over 20 years (13%), during the time the worker was employed at the plant. Among those who lived with a worker for over 20 years, most (17 of 29) were children of the worker. Children of workers recalled hugging and playing with their fathers when they came home from work and playing in the laundry area.

Though most household contacts (57%) had never visited or entered the building at 1720 Madison Street, some reported visiting workers inside the plant regularly. Children of workers reported playing in the building and, in a few cases, older children (teenagers) helped with work activities such as shoveling ore from the rail cars, bagging product at the hopper, and loading product into the warehouse.

E. Characteristics of WM/WRG Worker Exposure to Libby Asbestos

Plant Operations and Working Conditions

Starting in 1938, the Northeast Minneapolis facility received over 100,000 tons of vermiculite ore concentrate via rail from the mining operation in Libby, Montana (URS, 2001). Boxcars were originally used to transport the concentrate and had to be unloaded by hand (MDH, 2001). Later (perhaps by the 1950s), the ore was transported in open hopper cars (with an approximate capacity of 96 tons per car) and mechanically unloaded and conveyed into one of the two 45-foot high storage silos (URS, 2000a). The general layout of the plant and recent photos are shown in Figure 2. The quantity of vermiculite ore concentrate received from the mine in Libby ranged from over 8,500 tons per year in 1959 to less than 1,000 tons in 1988 according to W.R. Grace records (HRO, 2000a). The quantities of ore shipped to the site from the mine in Libby, Montana for the time period of 1958 to 1988 are shown in Table 5. The quantity of ore shipped per year declined steadily from the early 1960s until the plant closed in 1989. In the 1970s, the WM/WRG plant operated 24 hours per day, 5 days per week (approximately 250 days per year), and typically employed between 11 and 20 people, according to information submitted by W.R. Grace to the EPA (HRO, 2000b).

The vermiculite ore concentrate was gravity fed into one of two expanding furnaces at a rate of up to 2,400 pounds (1.2 tons) per hour (HRO, 2000c). The furnaces are believed to have been located in the metal addition constructed in 1946 on the north side of the original brick building;

prior to this, one furnace was located on the second floor of the brick building (URS, 2001). The furnaces heated the ore concentrate to a temperature of 2,000 degrees Fahrenheit, boiling the water trapped within the mineral and causing it to expand. The expanded vermiculite was then moved by augers or conveyors and passed through a device known as a "stoner," where the expanded vermiculite was separated from the unexpandable minerals known as "stoner rock." The finished vermiculite was then cooled, dampened, and bagged in three, four, and six cubic foot paper or plastic bags for commercial or consumer use, or further screened into several size ranges for specific applications. Some of the processed vermiculite was mixed with other ingredients, including chrysotile asbestos to form various construction products (i.e. Monokote® spray-on fire proofing). A schematic prepared by W.R. Grace of the plant process and material handling equipment as it existed in 1980 is shown in Figure 2 (HRO, 2000c). Separate buildings located to the north and east of the expansion plant were used as a construction tile manufacturing plant ("Perl Tile") and a product testing laboratory.

The process of exfoliating vermiculite ore concentrate into finished vermiculite was reportedly a dusty one. Past employees have stated that dust was often visible in the air inside of the building and that the windows were often closed (MDH, 2000). A vent system was installed in 1971 at the plant and consisted of a main vent header, branch headers, primary cyclone, fabric filter or bag house, and fan (URS, 2000a). Prior to 1971 a vent system apparently existed, but its design, and whether or not any filters were present, is unknown. Mention is made of the use of furnace cyclone fines (particulate matter) in a product formulation from 1964, so these devices may have been in use prior to 1971. Large bag house filters were installed in 1972 to further improve air quality at and around the facility. Some decline in levels of asbestos fibers in air was seen at the plant through time (as seen in Figure 3), although not necessarily because of the installation of baghouses.

Worker Exposure Monitoring Data (1972-1988)

MDH has obtained workplace exposure monitoring data collected by W.R. Grace from 1972 to 1988 (HRO, 2000d). During that period, area samples and personnel monitoring samples were collected, usually on an annual basis. The air samples were analyzed for total fibers by phase contrast light microscopy (PCM). A summary of all of the available data is provided in the Appendix. For personnel samples, several short-term (30 minutes to 2 hours) air samples were typically collected over the course of a work shift. These were averaged to determine the time-weighted average (TWA) for comparison to the Occupational Safety and Health Administration (OSHA) workplace limit, known as a Permissible Exposure Limit (PEL). Only the highest reported individual sample concentration for a given workday is reported in the Appendix. The concentration therefore likely represents a higher than usual fiber concentration than may have existed for the entire shift. The measured fiber concentrations reported in the Appendix are close to those Amandus et al (1987) estimated to have existed in similar workspaces and work activities in the vermiculite mining and ore processing facilities in Libby, Montana.

Personnel sampling data from 1974-1988 are also displayed graphically in Figure 3, along with the OSHA PEL that was in place at the time of the sample. The PEL for asbestos has been lowered over time, from 5 fibers per cc (f/cc) in the early 1970s to 0.2 f/cc at the time the plant closed in the late 1980s. The current OSHA PEL for asbestos is 0.1 f/cc. Figure 3 shows that

worker exposure to asbestos at times exceeded the applicable OSHA PEL, especially after the PEL was lowered.

Exposures to workers in the vermiculite production areas (as measured by personnel samples) as high as 19 fibers per cubic centimeter of air (f/cc) were found in the early 1970s (HRO, 2000d). Short-term air concentrations in the range of 1 to 10 f/cc were common in the early and mid-1970s. The highest fiber concentration observed in any sample (57.57 f/cc) was found in 1974 in a short-term area sample collected just outside the open door to the ore storage bins during unloading of Libby ore #3. These results generally correspond with data described in an EPA report (EPA 1991), which indicated that the highest airborne fiber exposures in a vermiculite processing facility in Ohio were found in the vermiculite expanders area, and in railroad car and truck unloading areas. The unloading of raw ore from rail cars was described during worker interviews as "the worst job for dust."

Dust levels from the waste rock were also elevated. In a 1978 short-term sample, fiber concentrations in the area where the stoner rock was loaded into wheelbarrows for disposal (often identified as the "waste rock hopper") were 13.53 f/cc. As late as 1984, fiber concentrations in this area were 1.65 f/cc. A water spray was used to try to reduce dust levels at the time the 1984 air samples were collected. In several W.R. Grace memos, equipment problems were also noted in this area (HRO, 2000d).

Area samples were collected in locations throughout the facility thought to be representative of general exposures, or exposures in specific areas such as the bagging station or lunchroom. They were usually collected within a person's breathing zone. These data are more likely representative of exposures to workers who were not directly engaged in the production of vermiculite. For instance, in a sample collected in 1978, fiber concentrations measured in the lunchroom—located 60 feet from the bagging station—were 3.0 f/cc. A sample collected in 1981 was lower—0.09 f/cc. During interviews, several workers described the constant presence of dust in non-production areas such as the lunchroom, mailroom, and office areas.

PCM is unable to distinguish fiber type. Thus, some of the fibers observed throughout the years of sampling might not have been asbestos or perhaps not Libby asbestos. The Monokote® fire proofing compound contained, in addition to vermiculite, commercial (chrysotile) asbestos. To make Monokote® , workers emptied 100-pound bags of commercial asbestos into open mixers to mix with vermiculite and a white, powdered plaster.

PCM also has fiber detection limitations. Fibers detected and counted by PCM methods are generally equal to or longer than 5 micrometers (μm), have a thickness of approximately 0.25 μm or greater, and an aspect ratio (length to width ratio) of at least 3:1. Although inadequate, current risk assessment methods are based on PCM fiber measurements—the required testing method in occupational settings. Thus, it is likely that more fibers were present than could be detected by this method.

The data from the Minneapolis facility are in the same range as data from other U.S. vermiculite production facilities (W.R. Grace, 1975). Based on the personnel monitoring data, after 1980 worker exposures to asbestos were typically below the current OSHA PEL of 0.1 f/cc. The

lower fiber concentrations were presumably a result of improved ventilation or equipment modifications at the facility.

Worker Interview Results: Work Histories

During interviews, workers were asked to describe their work histories while employed by WM/WRG. The questions included their work location, dates of employment, job titles, work activities, hours of work per week, and personal protective equipment used.

Most of the workers interviewed (93%) had worked primarily at the 1720 Madison Street location while employed by WM/WRG (Table 10). A few reported other locations, such as the Perl Tile plant located on WM/WRG property or the WRG corporate office in Golden Valley. Some workers at the Perl Tile plant reported that they regularly went to the Madison Street facility to pick up the vermiculite product, which was then used at Perl Tile to make lightweight roofing tiles. Sixty-five percent of the workers reported working full time (over 34 hours per week) on average during the time they worked at the 1720 Madison Street facility.

Jobs and Job Categories

Based on the responses of WM/WRG workers to the interview questions and the working conditions described above, we identified 15 jobs held by employees at the plant and grouped them into 2 categories as follows:

1) **Category 1: Production Workers -** The majority of the employees interviewed reported work activities that involved the handling of vermiculite ore, production and bagging of vermiculite and other asbestos containing products, and other activities that resulted in direct contact with vermiculite ore, products, or wastes. These employees spent the majority of their workday in production, handling, and storage areas. These employees would likely have experienced high exposures to Libby asbestos. Seventy employees (55%) reported working in these jobs:
    - Laborer (63)
    - Foreman (3)
    - Plant Maintenance (4)

2) **Category 2: Non-production Workers -** These employees reported work activities that did not involve the direct handling of vermiculite ore, or production and bagging of vermiculite. Employees spent the majority of their workday in offices or other areas of the plant not directly involved in production, or worked primarily at other off-site locations. For example, most sales workers reported regularly visiting the plant offices but spent most of their time working at the corporate office, or with customers and doing product demonstrations on construction job sites. Fifty-eight employees (45%) reported working in the following jobs:
    - Secretarial work (18)
    - Sales/sales management (18)
    - Management (5)
    - Laboratory technician/assistant (4)
    - Truck driver (3)

- Housekeeping (3)
- Architectural representative (2)
- High school program helper (2)
- Research and development officer (1)
- Construction laborer (1)
- Writer (1)

Work Activities Handling Vermiculite Ore, Product, or Wastes

An important factor in determining a worker's exposure to Libby asbestos is the frequency with which the worker did tasks that involved direct contact with vermiculite ore, product, or wastes. A series of questions in the NMCVI survey tool was designed to collect this information and the responses of 118 workers who answered these questions are shown in Table 11. Specifically, the employees interviewed were asked to describe how frequently (never, <1 day per week, 1-4 days per week, >4 days per week) they performed the work activities described below.

Work activities that involved direct contact with the raw vermiculite ore and waste rock likely resulted in the highest exposures. The waste rock was reported by W.R. Grace to contain between 2% and 10% Libby asbestos (HRO, 2000c). Forty-four of the 118 workers (37%) reported that they engaged in these work activities that could have resulted in significant exposure to Libby ore or waste rock one or more days per week:

- Unloading vermiculite ore from rail cars
- Loading or operating expansion furnaces
- Entering silos to loosen ore
- Moving or dumping waste rock

Work activities involving the handling of vermiculite products likely resulted in somewhat lower exposures by comparison, due to the removal of some Libby asbestos during expansion of the ore. Based on EPA tests, vermiculite produced from Libby ore likely contained between <0.5% and 3% Libby asbestos (EPA, 2000). Sixty-two out of 118 workers (53%) reported that they engaged in these activities one or more days per week:

- Bagging vermiculite products from the furnace or stoner
- Mixing and bagging Monokote® or other products from the mixer
- Hauling or loading products in the warehouse, onto trucks or rail cars

Sewing Bagged Vermiculite Product, c. 1960s (Photo used by permission).

Other work activities involved direct contact with fine materials and dusts. W.R. Grace estimated that the fine particulate matter from the baghouse contained between 1% and 3% Libby asbestos (HRO, 2000c). Sixty-three out of 118 workers (53%) reported that they engaged in these activities one or more days per week:

- Cleaning baghouse filters (after 1972)
- Equipment maintenance
- Sweeping or cleaning the plant

Duration of Employment

The total length of employment for employees ranged from less than one month to 507 months (42 years, three months) with a mean of 77.8 months. The 25th, 50th, and 75th percentiles were 11 months, 34.5 months, and 118.5 months, respectively. Figures 4 and 5 show the period of employment for each individual production (Category 1) and non-production (Category 2) worker, respectively. Note that employment for some workers was not continuous. If workers only worked seasonally or had some other break in their employment, work periods were summed to calculate the total length of employment.

Use of Respiratory Protection

Interviewers asked workers to describe their use of respiratory protection (respirators or dust masks) during their employment at the WM/WRG facility. Thirty-five workers reported ever using respiratory protection while performing various work activities including bagging, sweeping, mixing Monokote®, or unloading raw ore, while most (59%) reported never wearing any respiratory protection (Table 10). Among production workers, 27 out of 70 (39%) reported never wearing respiratory protection. All but a few of the workers stated that the type of respirator used was a paper or cotton dust mask. Most of the workers reported wearing the mask less than half of the time, although a few stated they always wore it when doing specific work activities that were particularly dusty. During interviews, a few former workers reported that they could not wear the dust masks for very long periods because the masks quickly became clogged by the dust.

Beginning in 1983, W.R. Grace's air monitoring reports described respirator use by the monitored employees (HRO, 2000d). From 1983 until 1988, the employees were described in the reports as wearing "3M–8710" model respirators. This respirator would provide adequate protection against airborne asbestos fibers if the proper filters are used and if the mask is fitted properly and worn routinely. The interview data suggests that only a small number of employees working in the mid to late 1980s, when overall Libby asbestos exposures in the plant were lowest, routinely wore them.

Mortality Findings from Death Certificate Review

At the time of the interview, a total of 51 workers and 28 household contacts were deceased. These interviews were conducted with the next-of-kin. For all participants who died in Minnesota, NMCVI obtained a copy of the death certificate from State Vital Records and conducted a death certificate review to obtain information on the cause of death. Death certificates were obtained for 46 workers and 26 household contacts. In addition, death certificates were obtained for 2 workers who died outside of Minnesota but cause of death information was not provided. There were 3 workers and 2 household contacts who died outside Minnesota for whom death certificates were not obtained.

Table 12 summarizes mortality by underlying cause of death (UCOD) for workers and household contacts based on the ICD coding scheme at the time of death. Among the 72 deaths reviewed, the earliest death of a worker occurred in 1946 and the earliest death of a household contact occurred in 1955. The underlying cause of death (UCOD) for most deaths were coded according to the 9th revision of the International Classification of Diseases (ICD 9), but there were also deaths coded in the 6th, 7th, 8th, and 10th revisions.

Nearly one fourth (24%) of workers and one half (50%) of household contacts who were deceased by 2004 died from circulatory diseases as the underlying cause of death. Among workers, another 24% died from respiratory cancers, predominantly lung cancer, and 17% died from all other cancers. One worker died from mesothelioma (ICD 10 code C45.9). Among household contacts, there were no respiratory cancer deaths and 4 (15%) died from other cancers. One worker and one household member died from a cancer of unspecified origin (ICD9 199.1). Among the 46 workers who were deceased at the time of the interview, 36 (78%) had ever been smokers. Among the 26 household contacts who were deceased, 18 (69%) had ever been smokers.

There were 7 deaths (15%) among workers and 2 (8%) among household contacts from non-malignant respiratory diseases. Non-malignant respiratory diseases included emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, and asbestosis. Altogether, eight deaths mentioned fibrosis, pneumoconiosis, or asbestosis on the death certificate as underlying or contributing cause of death.

V. Combined Community and Worker/Household Cohorts: Survey Results

Because many workers and household contacts of workers were also members of the community, their community exposure pathways were similar to other community members. Questions

about community exposures on both the worker interviews and the community interviews were the same, allowing their responses to these questions to be combined in the analysis.

In this section, results characterizing residential or community exposures are presented for the combined Worker/Household and Community cohort (total N=6,714 respondents, including 80 participants interviewed in both surveys). Each individual is characterized by their community exposures to asbestos, according to the following criteria:

1) Ambient exposures resulting from living near the site:
    - Years of residence in proximity to the WM/WRG industrial site
    - Years of residence on property contaminated with vermiculite waste

2) Exposures resulting from direct contact with the vermiculite waste material:
    - Ever moving or handling vermiculite waste from the industrial site
    - Ever using vermiculite waste in gardening/landscaping activities
    - Ever playing on vermiculite processing waste piles; frequency of playing on the piles; year and age at first exposure to piles

This section also presents the combined results of interview questions, which characterize the prevalence of other factors associated with respiratory disease in the population. These include:

1) Other occupational exposure to vermiculite
2) Other occupational exposure to commercial asbestos
3) Prevalence of smoking
4) Self-reported history of chest x-ray, pleural changes (indicative of asbestos exposure), and self-reported history of lung disease

A. Residential History in Proximity to the WM/WRG Facility

Living in close proximity to the facility is a potential pathway for exposure to fiber levels in the ambient air from the stack emissions and fugitive dust. Exposure is likely to have been elevated during the years of operation before air pollution controls were installed (prior to 1972) and predominantly within 1-2 blocks of the plant (though peak levels may have occurred periodically at further distances.)

Residential histories in the study area or in close proximity to the facility (within one adjoining block) are described in Table 13. For participants who moved within the study area, years at multiple properties in the study area were summed, and total time from 1938-2001 was calculated. There were 6,221 participants who reported a residential history in the study area within the study time period. Former residents who could not recall the address or years of residence are not included in this tabulation. Forty-two percent reported living in the study area for 5 or less years from 1938-2001. Another 25% lived there 6-15 years, 15% lived there 16-25 years, 7% lived there 26-34 years, and 11% (n=677) reported 35 or more years of residential history in the study area.

In order to identify the population with greatest potential ambient exposure, years living in close proximity (within 1 adjoining block) to the plant during the years the plant was operating (1938-1989), and years living in the area prior to the use of air pollution controls at the plant (1938-1972) were determined. A total of 2,577 participants lived in the study area for some amount of time between 1938 and 1972, and 421 (16%) lived there over 25 years. A total of 818 participants lived within 1 adjoining block and 97 lived there over 25 years.

B. Exposures Resulting from Direct Contact with Vermiculite Processing Waste

The number of participants reporting community exposure to the vermiculite processing waste through each of 8 identified exposure pathways, is shown in Table 14. There were 136 former workers at the facility (including 8 employed by contractors) whose work histories were confirmed through the worker interviews and company records as described in the previous section. An additional 8 people in the community reported working at the plant during their community interview but their work histories could not be confirmed and/or they did not participate in the worker interview. It was determined that 7 of these had worked at another facility where vermiculite product was used. Therefore, their responses are recorded with other community members as "non-workers".

A total of 281 participants (4%) reported that they had lived with someone who worked at the WM/WRG plant. For the community interview, this question was not limited to only spouses and children of workers but included siblings, grandparents, roommates, etc. Therefore, not all persons who reported ever living with a worker were eligible as a "household contact" for the Worker/Household Interview.

Direct contact with the WM/WRG waste rock occurred through several identified pathways. There were 314 (5%) who reported that they moved the rock from the piles at the facility, 315 (5%) who used the rock at home, and 690 (10%) who played in or around the piles at the plant. Participants were also asked about direct handling of the vermiculite insulation product, and 426 (6%) reported that they had installed or removed the insulation product.

The table shows differences in the prevalence of certain pathways among workers and non-workers (community members). Workers were more likely to have had direct contact with the waste rock. Among workers, 18% had lived with another worker, 29% had moved the waste rock, 20% had used it at home, and 25% had installed or removed insulation. Workers were less likely to have reported playing on the piles (6%). There were also some gender differences. Men were more likely to have moved the rock (7%), used the rock at home (6%), and played on the piles (14%). Women were more likely to report that they had lived with a worker (5%).

Another way that people in the community may have been exposed to small amounts of the Libby asbestos was by living on a contaminated property. NMCVI identified 1,746 participants (26%) with a history of living on a contaminated property (confirmed by EPA, n=259 properties) at some time from 1938-2001. It should be noted that, in most cases, the date when the rock was first brought to the property is unknown and so years living on a contaminated property may include years when no exposure was occurring from this source.

Most participants (3,792 or 56%) reported no exposure to Libby asbestos through the 8 pathways identified (Table 15). Another 1,789 (27%) reported exposure through one pathway, and 701 (10%) through 2 pathways. There were 432 participants (6%) who reported exposure through 3 or more exposure pathways. Workers were more likely to report multiple pathways of exposure, with 48 out of 136 (35%) reporting 3 or more pathways (including work at the plant).

Playing on the Piles: Frequency and Age at First Exposure

Residents reported that neighborhood children frequently visited the waste rock piles. Because of the close proximity of the plant to both an elementary school and a high school, some people reported walking through the site and playing there regularly on the way to school. Others reported playing there daily throughout the summer. Of the 690 people who reported playing on the piles of waste rock at the plant, 418 (61%) reported playing there over 50 times and 88 people reported playing there over 500 times (Table 16).

Information about age at first exposure was collected from 403 of the people who reported that they played in or around the waste rock piles. Most (241 or 60%) reported first playing on the piles between 6 and 10 years of age; another 79 (19%) reported first exposure at 5 years of age or younger; and 55 (14%) were between 11 and 15 years old. This activity was reported to have occurred throughout the years of the plant's operation (1938-1989), though most participants recalled first playing on the piles in the 1950's (24%) and 1960's (34%).

Respiratory Health Risks

Table 17 presents the prevalence of other respiratory health risk factors reported by 6,704 out of the 6,714 participants during the interview. (Ten property owners, with no history of residence in the area, did not complete this portion of the interview.) Among living respondents (n = 5,756), 31% were current cigarette smokers and 56% of all participants (living and deceased) had ever been regular cigarette smokers. Among workers, 74% had ever been regular cigarette smokers. There were 1,723 participants (26%), predominantly men, who reported having one or more occupations with potential commercial asbestos exposure at some time in their occupational history. Workers at the plant were more likely than non-workers to report a past occupation with potential exposure to commercial asbestos.

Among 3,713 living respondents who reported ever having had a chest x-ray (64% of living respondents), 367 (10%) reported that a doctor told them they had lung changes observed on the x-ray, and 67 (2%) reported being told by a doctor that they had pleural changes, thickening, or plaques. Workers were more likely to have ever had an x-ray (93%), and of those, 29 (37%) reported being told of lung changes and 9 (11%) reported pleural changes.

Self-Reported History of Respiratory Disease

Respondents were asked whether a doctor had ever told them that they had a lung disease and, if so, were asked to name the disease. A history of respiratory disease may be a risk factor for other future respiratory diseases.

Out of 6,704 participants (or their next-of-kin) who responded to this question, 1,442 self-reported a diagnosis of a lung disease. Table 18 tabulates the most common diseases reported, excluding reports of allergies, influenza, heart/circulatory conditions, symptoms only, and non-

specific clinical findings (e.g "spots on the lung"). The category "bronchitis" includes both acute and chronic bronchitis. The category asthma includes any mention of asthma, including exercise-induced and asthma related to allergies.

Among the 1,442 persons who self-reported a lung disease, the 5 most common diseases reported were asthma (7.3%), pneumonia (6.3%), bronchitis (4.3%), emphysema (2.2%), and lung cancer (1.6%). A history of asbestosis was reported by 32 participants and another 12 reported fibrosis of the lung. There were 7 persons (or their next-of-kin) who reported mesothelioma (4 workers and 3 non-workers).

It is important to note that these self-reported conditions are not confirmed or validated through medical record review, nor through death certificates. As such, these reports do not represent a valid measure of disease outcomes. Appropriate methods for measuring disease in the population using mortality and morbidity records are needed to ascertain the frequency of asbestos-related diseases in the cohort.

Consent for Future Follow-up

Among the 6,704 participants who completed the full interview, 6,399 (95%) consented to use of the information for future follow-up through data linkages with disease registries and death records to determine asbestos-related disease outcomes.

VI. Environmental Health Education and Health Promotion

Asbestos exposure and health risk information were provided to study participants. As the study progressed and participant needs were recognized, participant education efforts were expanded to encompass broader environmental health education and health promotion. Environmental health education efforts also took place at the community level to increase study awareness and to engage community organizations in environmental health issues. A robust educational plan for increasing the capacity of health care professionals for recognition, referral, diagnosis and care of asbestos-related disease, particularly for non-occupationally exposed individuals, was included.

Collaboration with other agencies was sought to ensure consistent health messages and long-term planning for the future.

A. Individuals

Interventions

Primary health education interaction with individuals occurred in the course of interviews, both in-person and by telephone. Field analysts and telephone interviewers were trained to recognize participant health concerns and answer questions. Information sheets were written to cover common questions about the study, site, vermiculite, asbestos and health effects, and available resources. Interviewers, where appropriate, also encouraged participants to adopt healthy behaviors and provided information on local smoking cessation resources and groups.

Information Sheets Distributed

- Vermiculite Processing Operations in Northeast Minneapolis (MDH)
- The Northeast Minneapolis Community Vermiculite Investigation (MDH)
- Vermiculite and Gardening (MDH)
- Vermiculite and Insulation (MDH)
- Site Contact Sheet (MDH)
- Study Summary, Contacts, and Timeline (MDH)
- Advice for Homeowners About Cleanup of Asbestos Contaminated Property (MDH)
- Self-referral form with business reply envelope (MDH)
- List of Smoking Cessation Programs for Hennepin County (MDH)
- Asbestos Disease: A Clinician's Overview (MDH/Chronic Disease)
- Licensed Asbestos Contractors (MDH/Asbestos Unit)
- Asbestos Testing Laboratories (MDH/Asbestos Unit)
- Asbestos: Questions and Answers (ATSDR)
- You Can Quit Smoking (HHS/PHS)
- Talking to Your Kids About Tobacco (MN Blue Cross Blue Shield)
- You Can Quit (MN Blue Cross Blue Shield)
- Set Yourself Free Smoker's Guide (ACS)
- Frequently Called Phone Numbers by Subject (MDH)
- Northeast Minneapolis Senior Citizen Resource Center (for those with no health insurance) (NESCRC)
- Lead in Homes brochures (MDH; CDC)

Telephone calls

Communication by telephone with participants, as well as interested non-participants, occurred throughout the study. At times, up to 150 calls occurred in the week following media coverage. Content of telephone communications included explanation of the study, EPA inspections and cleanup, ways to reduce exposure, asbestos health effects, resources for asbestos abatement, health insurance options, and health concerns.

Health Recommendation Letters

Letters describing all the identified exposure pathways were sent to study participants with distinct sets of health recommendations based on reported exposures. All letters recommended smoking cessation.

1) The first and largest group of participants did not report any contact with the asbestos waste. These participants were thanked and reassured that, unless they were experiencing symptoms, there was no need to see their physician.
2) The second group of participants included those whose only exposure was that they lived on a property where contamination was found. Because of the uncertainty, in most cases, as to when waste rock was brought to the property, these participants were notified of the contamination and advised to seek care only if they were experiencing symptoms.
3) The third group of participants included those who reported any of the following exposures:
    - Family or household members who lived with a worker

- People who had direct contact with the waste rock material
- People who installed, removed, or otherwise disturbed vermiculite insulation
- People living within 1-2 blocks of the WM/WRG facility while the facility was operating (1938-1989)

In addition to the recommendation letter, participants in this group received a booklet, "About Exposure to Asbestos from Libby, Montana and the Western Minerals Plant in Northeast Minneapolis." This 23-page booklet describes Libby asbestos, asbestos-related diseases, related health promotion measures, resources for health care, and additional information. They were also advised to describe this asbestos exposure to their physician, especially if they were experiencing symptoms.

4) The fourth group consisted of former workers from the WM/WRG plant. These participants received the same Libby asbestos exposure booklet as the previous group of participants and were advised to seek evaluation and care from a physician. From 2001 until 2003, free medical screening for asbestos-related diseases was offered to former workers and their household contacts through the Minnesota Attorney General's office.

Preliminary Report

A four-page summary of a preliminary study report, change of address form, and evaluation form were mailed to 5,592 participants in October 2004. A total of 352 evaluations were returned. Participants responded to questions about eight specific topics covered in the report. More than 96% of respondents strongly agreed that they understood the information presented about exposure pathways for Libby asbestos in Northeast Minneapolis. More than 94% found the report interesting and easy to understand. An open-ended question about suggested topics for future mailings generated 120 responses, many inquiring about medical care or legal advice.

Outcomes

Health education materials developed for NMCVI were provided to ATSDR for use in the development of a CD of materials to be used for the general community at other vermiculite processing sites as part ATSDR's National Asbestos Exposure Review (NAER) program (Anderson, 2005).

B. Community

Interventions

Environmental health education efforts were directed at the three Minneapolis neighborhood associations represented in the study area: the Logan Park Neighborhood Association, the Holland Neighborhood Improvement Association, and the Sheridan Neighborhood Organization. These associations have monthly meetings and manage numerous committees, semi-annual neighborhood clean ups, garden contests, an area-wide festival celebrating resident artists, and their studios/shops called Art-a-Whirl, crime prevention interventions, re-development plans, and sizable Neighborhood Revitalization Project (NRP) funds from the city.

Throughout the study, staff attended and presented at these three monthly neighborhood meetings. Initial presentations introduced the study and the field analysts who would be out in the neighborhoods going door-to-door for interviews; later presentations gave study updates, answered questions, and often included information about home remodeling issues, reducing exposure while waiting for EPA remediation, other hazardous waste sites in the area, and health

concerns. Staff also participated in neighborhood events such as "Clean Sweep," a children's drawing contest centered on health and other topics. Study staff were invited to talk about the study, and staff participation at local faith community senior events was solicited. Attendance at these events gave added insight into the history of the plant, children's play at and around the plant, and ways in which residents utilized the waste material. Study staff also gave presentations on the preliminary report to three neighborhood associations at their monthly meetings.

The Logan Park/ St. Anthony East Community Health Program, a part of the Northeast Senior Citizen Resource Center (NESCRC), initially advised staff on the nature of the community, entry posture, and contact points. They reviewed the study protocol, gave credibility to the study staff, and continued to provide advice and assistance as the study progressed. NESCRC also served as a resource to assist participants who had no health insurance in obtaining medical care (about 11% of the study population). Staff presented a progress report and tabletop display at a Logan Park/ St. Anthony East Community Health Program community meeting in June 2001 and again at their first health fair in October 2002. The study also provided health prizes for the Community Health Program's contest and one page for the community calendar on lead prevention measures. Study staff have also made presentations at numerous community based organizations active in Northeast Minneapolis including: the Women's Cancer Resource Network; the North; Northeast and Southeast Minneapolis Energy and Environment Forum; the Mississippi Corridor Neighborhood Coalition; and the Holland Highrise residents group.

Outcomes

Although one-page evaluation forms were available at each public meeting hosted by NMCVI, very few were completed. The evaluation forms that were completed mostly contained requests to be included in the study, information about medical referral, or inquiries for social support for someone already experiencing asbestos-related disease.

NMCVI staff participation in neighborhood association monthly meetings resulted in a strong foundation of trust and invitations for future collaboration around environmental health issues in Northeast Minneapolis. The two neighborhood associations that did not have a Health Committee as part of their organizations have opted to join the Northeast Senior Citizen Resource Center's Community Health Program; there is now a plan to expand and include all Northeast Minneapolis neighborhoods in the program. These are unanticipated benefits to the neighborhoods, above and beyond the elimination of asbestos exposure to residents through remediation of residential properties.

C. Health Care Professionals

The objectives of NMCVI related health professional education were to:

1) Increase awareness of local health care providers of the potential for non-occupational exposure to Libby asbestos among community residents
2) Give health care providers information about evaluation of exposed individuals who seek care as a result of a participant letter from NMCVI
3) Provide health professionals with strategies for patient education, counseling, and risk communication

Interventions

A Health Professional Advisory Committee (HPAC), comprised of local family practice, occupational and environmental physician specialists and nurses, was established to offer insight into the medical context and needed clinical resources. The committee prepared an exposure history form specifically for Libby asbestos, suggested a medical evaluation procedure for use by clinicians, and developed appropriate risk communication approaches for discussions with patients.

A local family practice physician's request for resource materials that could be quickly filed away for future reference led to the development of a *Provider Pak* entitled, "Libby Asbestos Exposure in Minnesota: Health Care Provider Resources." The labeled manilla folder included the HPAC medical evaluation guidelines, exposure history forms, topical information sheets, smoking cessation materials, and other ATSDR printed references.

Following the design and development of resource materials, the HPAC assisted in the definition of the healthcare provider target population; this work prioritized pertinent topics. These topics included introducing the concept of non-occupational exposures to asbestos and encouraging clinicians to consider taking an exposure history to identify the number and type of contacts with the waste material. The HPAC committee recommended an initial medical evaluation as outlined in the clinical guidelines in the Provider Pak. The committee also provided practical guidance for clinicians in discussing exposures to asbestos, placing health risks in perspective, and assisting patients in making informed decisions about follow up. Particularly for patients who had non-occupational exposure, the recommendations focused on fostering patient awareness rather than creating alarm, and positive steps that patients can take immediately, such as smoking cessation, healthy diet, regular exercise, flu shots and avoidance of further asbestos exposure.

Three outreach strategies were employed to address the clinical challenges and introduce the concept of environmental exposure to asbestos:

- First, an early morning breakfast seminar for area physicians featured national experts presenting emerging issues arising out of risk assessment research and health screening in Libby, Montana.
- Second, a CME seminar was developed as part of the Minnesota Occupational Medicine Annual Update meeting. Topics included Libby asbestos health screening results and risk communication for talking with patients about community asbestos exposures from contaminated vermiculite. The presentation on risk communication included basic principles and issues unique to community asbestos exposures. With respect to appropriate advice and treatment, a physician panel discussed three hypothetical patient histories. The *Provider Pak* folder of resources was given to each participant.
- Third, a traveling presentation, entitled "Non-Occupational Exposure to Libby Asbestos: What Clinicians Need to Know", was conducted at nine clinics and hospitals serving the Northeast Minneapolis community. The presentation began with a brief review of asbestos toxicology and included a comparison of the epidemiology of different types of

asbestos and related disease outcomes. Attendees were introduced to the resources in the *Provider Pak*, and basic risk communication principles were highlighted.

Evaluation

For the CME course, the Midwest Center for Occupational Health and Safety administered a written questionnaire with attendee profile information. This consisted of 24 questions for each CME attendee to provide a ranked response and several open-ended questions. The Center summarized the results and provided them to participating agencies. Out of 69 registered attendees, 30 completed the evaluation. Of a possible score of 5 indicating overall satisfaction, the average score was 4.5. The average score given by physicians when evaluating the clinical value of the material presented was 4.3 out of a possible 5. Attendees found the description of the NMCVI study, the *Provider Pak*, and the case studies to be of most interest and help.

For both the breakfast seminar and the clinic presentations, participants completed a one-page evaluation similar to the CME course evaluation. Oral and written comments following the presentations indicate that while physicians are familiar with asbestos exposure in an occupational context, community or environmental exposures are unanticipated. The common view that asbestos-related disease is associated with specific occupations prevents consideration of asbestos exposure to other populations, including women and children. Additionally, the lack of clear benefits for the patient increases the clinician's reluctance to screen for a group of diseases with limited treatment options.

Outcome

ATSDR used the *Provider Pak* materials to develop health care professional resources for other NAER sites.

D. Collaboration

Collaborations on this project were established with the following partners:

1) **City of Minneapolis** - Periodically, NMCVI staff have met with city officials (both Environmental Management and Health and Family Support departments) to provide updates, publicize the availability of free remediation for properties with Libby asbestos contamination, and the final date to request a property inspection. Regular communication and updates have also been provided to City Council members who represent the study area.
2) **US EPA** - EPA and MDH have collaborated on site and neighborhood activities since the summer of 2000. This partnership has included three public meetings, verbal communications with residents and neighborhood associations, and written communications regarding the WM/WRG site and residential cleanups. Throughout the field interviews and residential cleanup, staff met with the EPA On Scene Coordinator every other week to share updates on cleanup and study progress.

Outcomes

Collaboration between Minneapolis, US EPA, and NMCVI has led to creating a public repository within the city government that will hold records of individual property remediations. The three entities also developed a plan for managing and remediating contaminated properties

that may be discovered in the future. The National Asbestos Exposure Review (NAER) team from ATSDR visited the NMCVI study team and area before beginning their investigation of the 28 sites across the nation (Anderson, 2005). More recently, samples of Libby asbestos, vermiculite insulation, and waste rock from this site have been used by US EPA to train inspectors at other WR Grace vermiculite processing sites. Partnerships established through NMCVI with the City of Minneapolis and the US EPA have fostered collaboration on other sites.

VII. Discussion

This investigation serves as a model for success in working in close collaboration with a community and with EPA to remedy a neighborhood with environmental contamination and to rapidly provide information and resources to address community concerns. The Northeast Minneapolis vermiculite processing facility operated in an urban residential community for over 50 years in close proximity to homes, schools, churches, and businesses. Waste rock from the facility was used widely in the neighborhood and contaminated over 259 residential properties (more contaminated properties were discovered by EPA after completion of the MDH investigation).

This investigation identified a population with a wide range of past occupational and non-occupational exposure to Libby asbestos. The exposure pathways found are similar to those identified in the Libby, Montana community health study (Peipins, 2003). In the Libby study, increased risk of pleural abnormalities was associated with being a WRG worker, being a female household contact of a WRG worker, and playing in vermiculite piles (among other risk factors). Living in the Libby community for 35+ years and exposure through multiple exposure pathways were also identified as risk factors for pleural abnormalities.

Over 10% of the Northeast Minneapolis study population was found to have had direct contact with vermiculite processing waste rock containing between 2 and 10% Libby asbestos that was freely accessible to the community. Most adults who reported playing on the waste rock piles at the plant (93% of the 387 for whom this information was collected) were first exposed in childhood 25 to 50 years ago.

Living for many years in the community may represent long-term exposure to contaminants from the ambient or home environment, particularly in the years before pollution controls were implemented, and potentially through multiple pathways. This investigation identified a large population who lived near the facility for over 25 years and 818 people who lived within one adjoining block where air dispersion models predict that ambient levels were elevated in the past.

The Worker/Household Study identified 136 individuals with a history of working at the facility. Industrial sampling data confirm that occupational exposures to production workers in the plant (70 of the 136 identified) at times exceeded current safe levels for asbestos (0.1 f/cc), particularly in the years prior to the installation of dust control, and in certain jobs where dust control was difficult (e.g. moving ore from railcars and storage silos). This study has further documented that about 30% of workers were at increased risk from multiple exposure pathways, including moving and using waste rock at home and installing or removing vermiculite insulation. In

addition, 70% of workers reported a history of smoking and 58% reported a work history in jobs likely to have exposure to commercial asbestos, further contributing to an increased risk for asbestos-related disease.

The duration of employment among workers ranged widely from a few weeks to 42 years. This study identified a number of short-term, temporary employees (particularly summer help and youth) from the neighborhood whose names did not appear on official records of employees. Short-term exposure to high levels of asbestos in a vermiculite processing plant has been associated with the occurrence of asbestos-related disease many years later (Wright et al., 2002).

This study identified differences in exposure related to gender and age. Men were more likely to be exposed occupationally and through direct contact with waste rock. However, female household contacts of workers were more likely to be exposed through laundering of clothes. Gender differences in other domestic exposure measures, such as time spent in the home or neighborhood and routine housekeeping activities (particularly in 1950's and 1960's) with potential for exposure to contaminated soils and house dust, may also contribute to exposures among women which have not been addressed in this study. Short-term exposures to some children of workers may be similar to occupational exposures based on reports of children who frequently visited the plant or helped their parents with work tasks.

There are several limitations to the findings in this report. Despite attempts to reach all past and current residents of the NMCVI study area, a large portion of former residents were not identified and/or could not be contacted. Resources for this investigation were directed preferentially to current residents and past residents who self-referred (volunteers) or were easier to locate (still living in Minnesota), though active efforts were made to reach past residents of all 259 contaminated properties. Therefore, the prevalence of exposure in this community study population does not represent the true prevalence of exposure for the entire community (1938 to present). However, the intent of this study was to identify and characterize a population with a wide range of exposures, past and present, so that comparisons between exposure pathways and levels (dose-response) could be made in follow-up studies for health outcomes.

Current residents living in the community who did not speak English or Spanish and did not have someone in the family who could serve as an interpreter were not able to participate in the interviews and are not represented in the study. There were 15 residential properties and 53 additional households that were excluded due to a language barrier.

Another limitation is that most exposure information is based on participant recall during the interview. Participants were asked to recall events that occurred up to 60 years in the past. Residential histories and previous home addresses were difficult for most people to recall with accuracy. Occupational histories (years worked, job titles, etc.) were particularly difficult for next-of-kin proxies who were often children or elderly spouses of the deceased workers. Media coverage of the EPA and MDH activities in the community was frequent and may have influenced recall for some and raised concerns about health, biasing interview responses. Some residents with publicly reported health outcomes were represented by attorneys and refused to participate in the MDH interviews. Early news reports were based on information provided by families and their attorneys, the accuracy of which could not be verified.

Throughout the study, health education materials were available to participants, and all persons with health concerns were encouraged to speak with a health care provider. Approximately 11% of the study population reported that they had no health insurance and another 8 % were covered by public medical assistance (Medicaid/Minnesota Care). Therefore, a lack of access to or use of health care may have prevented some participants with symptoms from getting a physician's diagnosis and appropriate care for respiratory disease. Based on discussions with physicians, asbestos-related disease among persons with no history of working in an occupation with known exposure to asbestos may not be recognized, particularly among women whose only exposure may be non-occupational.

In response to community concerns about cancer, a review of cancer occurrence from the Minnesota Cancer Surveillance System (MCSS) examined incident cancer cases from 1988 to 2002 in the two zip code areas, which encompass the NMCVI study area (MDH, 2004). A total of 322 lung cancers were observed in men when 250 were expected. A total of 14 mesotheliomas were found, 6 of them in women, when only 2 cases were expected in women. While the excess of lung cancers among men is not unusual given their higher prevalence of occupational asbestos exposure and past smoking, the unexpected excess of mesothelioma in women suggests the possibility that cumulative, lower level domestic exposures to asbestos may also increase risk. Further study of domestic exposures to asbestos and health outcomes among women in this population are needed to explain this observation.

VIII. Recommendations for Follow-up

Given the excesses of pleural abnormalities observed in the Libby studies and the similarity of the exposure pathways, it seems likely that similar asbestos-related pleural changes and other asbestos–related lung diseases have occurred in the Northeast Minneapolis cohort or that these effects will become clinically apparent in the years ahead. Numerous anecdotal reports from community members and workers regarding diseases in this community have been made in recent years, including reports of excess lung cancer, asbestosis, and mesothelioma. No published studies have examined asbestos disease outcomes in a residential population exposed from a vermiculite processing facility outside of Libby.

Cohort follow-up using Minnesota's statewide cancer registry is needed to evaluate cancer incidence in the exposed population. Of particular concern is the large number of middle-aged adults in the community who were exposed frequently as children to the waste material from playing on the piles and/or from household contact with a worker (with 35-50 years latency since first exposure). Relatively little is known about the potential health effects of amphibole asbestos from childhood exposures. A linkage study with the cancer registry should also examine the age at onset to determine whether respiratory cancers are occurring at younger ages in persons exposed as children.

A medical screening study is recommended to determine the prevalence of radiographic lung and pleural abnormalities in a subset of the cohort who were first exposed 20 or more years in the past through one or more community exposure pathways. Confirmation of the Libby community

screening findings in this cohort with similar community exposures would provide further evidence of the heath impacts of Libby asbestos. A medical screening study would also provide an opportunity to examine other determinants of disease occurrence and progression that could not be measured in this study, such as respiratory symptoms, pulmonary function, and biological markers (pre-clinical disease indicators).

Examination of death certificates of workers at the Minneapolis WM/WRG plant indicates that 18 out of 46 worker deaths were from respiratory cancers or non-malignant respiratory disease. The cause-specific mortality and cancer incidence of workers should be further investigated from linkages with Minnesota and national death records, and with the cancer registry.

Finally, due to the widespread contamination of soils in the study area that can be tracked into homes, the elevations in ambient levels that may have occurred in the past, and the use of vermiculite insulation in homes, MDH has proposed a study of asbestos levels in house dust in the Northeast Minneapolis community.

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Tables

Table 1. Residential Properties: Location, Eligibility, Resident Participation and Inspections

	Number	Percent
Target Property Location		
Inside study area	2,313	98
Outside study area[1]	38	2
Property Eligibility for NMCVI Visit		
Non-residential or unoccupied	368	16
Occupied target properties	1,983	84
Total Properties	2,351	100
Occupied Target Properties Participation by One or More Household Residents		
All households ineligible	24	1
Resident refused/unable to interview	138	7
Unable to contact a resident	69	4
Needed foreign language interpreter	15	1
No interview, multiple households, mixed reasons	8	0.4
One or more households participating	1,729	87
Total	1,983	100
Inspections of Properties With One or More Households Participating		
Not inspected by NMCVI[2]	133	8
Inspected, no contamination	1,386	80
Inspected, contamination found/confirmed by EPA[3]	154	9
Inspected, contamination found/not confirmed by EPA	56	3
Total	1,729	100

1. All occupied residential properties with contamination confirmed by EPA and located outside the NMCVI study area were also included as target properties in NMCVI.

2. Sixty-two properties not inspected by NMCVI were inspected by EPA previously and resident declined NMCVI inspection.

3. An additional 105 contaminated properties were discovered by EPA inspectors by the completion of NMCVI fieldwork in October 2003 for a total of 259 contaminated properties identified.

Table 2. Identification and Participation of Target Households

	Number	Percent
Target Households Identified		
Ineligible[1]	140	5
Unable to contact resident	262	8
Interpreter needed	53	2
Contacted and eligible	2,667	85
Total	3,122	100
Contacted and Eligible Households		
Refused interview	318	12
Some adult interviews completed	164	6
All adult interviews completed	2,185	82
Total	2,667	100

1. Moved to property after the end of eligible residence time period (12/31/2001).

Table 3. Identification and Participation of Community Residents

Current Residents Identified by:	Named	Eligibility Unk.[1]	Ineligible	Eligible	Participation: Refused	Participation: Interviewed	% of Eligible Interviewed	% of Named Interviewed
Household Interview	5,430	64	1,332	4,034	100	3,934	98	72
Former Residents Identified by:								
Household Interview	2,782	1,538	240	1,004	44	960	96	35
Referral	1,508	304	111	1,093	9	1,084	99	72
Active Search	4,663	4,139	42	482	27	455	94	10
Total Former	8,953	5,981	393	2,579	80	2,499	97	28
Total Residents	14,383	6,045	1,725	6,613	180	6,433	97	45

1. Eligibility is unknown due to: no contact attempt was made, unable to locate or contact resident, or resident refused contact.

Table 4. Demographic Characteristics of Community Participants

	Living	Percent	Deceased	Percent	Total	Percent
Gender						
Male	2,772	50	535	61	3,307	51
Female	2,782	50	344	39	3,126	49
Property Resident Status						
Current	3,934	71	0	---	3,934	61
Former	1,557	28	866	99	2,423	38
Never Resident	63	1	13	2	76	1
Age Category						
18 - 44	2,901	52				
45 - 64	1,806	33				
65+	834	15				
unknown	13	<1				
Total	5,554	86	879	14	6,433	100

Table 5. Beneficiated Ore Shipments from Libby, Montana to Minneapolis, MN[1]

Tons per Year and Percent Tremolite by Grade

Year	#0	#1	#2	#3	#4	Total
1958	926	5,503	0	1,359	23	7,811
1959	942	5,743	160	1,861	32	8,738
1960	569	4,902	389	1,726	27	7,613
1961	924	4,042	204	1,482	49	6,701
1962	668	3,663	361	2,085	78	6,855
1963	411	2,958	2,152	1,700	39	7,260
1964	404	1,904	1,735	1,617	0	5,660
1965	324	1,582	1,427	1,509	183	5,025
1966	261	995	1,893	2,020	63	5,232
1967	161	892	1,705	2,301	0	5,059
1968	192	759	1,419	2,652	0	5,022
1969	456	1,061	1,252	1,776	163	4,708
1970	262	1,776	166	3,488	221	5,913
1971		1,621	195	2,445	34	4,295
1972		1,529	226	2,093	0	3,848
1973		2,096	161	2,691	0	4,948
1974		1,784	375	1,308	654	4,121
1975		1,256	343	1,064	1,076	3,739
1976		1,219	190	1,217	1,510	4,136
1977		2,137	254	627	1,816	4,834
1978		191	598	1,910	441	3,140
1979			1,424	2,464		3,888
1980			948	2,186		3,134
1981			759	2,188		2,947
1982			665	2,002		2,667
1983			1,046	2,195		3,241
1984			156	1,550		1,706
1985			162	2,156		2,318
1986			290	1,546		1,836
1987			259	1,581		1,840
1988			225	450		675
Total	6,500	47,613	21,139	57,249	6,409	138,910
Est. % Tremolite[2]	(unk)	4 - 6	4 - 7	2 - 4	0.3 - 1	

Average Tons per Year, 1958-1971 — 6,135

Weighted Percentage of Tremolite in Ore: 4.34

Average Tons per Year, 1972-1988 — 3,119

Weighted Percentage of Tremolite in Ore: 3.52

1. Source: HRO 2000a
2. EPA 2000, data originally from Midwest Research Institute report, 1982. EPA Report Number EPA 0717.

Table 6. Common Uses for Vermiculite Waste Reported by Participants

Individual Uses

- Driveway, yard, and garden fill
- Sand/traction for winter sidewalks and roads
- Foundation fill for cement steps, sidewalks, patios, and buildings
- Potted plants
- Barbeque grill liner
- Bike ramps, sandboxes, and sidewalk chalk
- Kitty litter and pet aquariums

Community Uses

- Local parks and playgrounds
- Neighborhood baseball fields
- School track
- Alleys

Table 7. Identification and Participation of Workers and Household Members

Workers[1]	Named	Eligibility Unk.[2]	Ineligible	Eligible	Participation: Refused	Participation: Interviewed	% of Eligible Interviewed	% of Named Interviewed
Workers previously identified[3]	80	4	20	56	5	51	91	64
Workers newly identified[4]	197	57	49	91	6	85	93	43
Total workers identified	277	61	69	147	11	136	93	49
Household Members[5]								
Household members previously identified[3]	47	3	1	43	2	41	95	87
Household members newly identifed	220	24	5	191	7	184	96	84
Total household members	267	27	6	234	9	225	96	84
Total Worker/Household	544	88	75	381	20	361	95	66

1. Includes contractor employees working at 1720 Madison St. facility.
2. Eligibility is unknown due to worker or household member could not be located or contacted, or refused to respond.
3. Some workers and household members were first identifed during the community study; 49 workers and 31 household members were also interviewed in the community study.
4. Workers were identified from historical company rosters, wage reports, and referrals from other workers or family members.
5. Household members were limited to spouses, ex-spouses or children of a WM/WRG worker who lived with the worker during their employment at the 1720 Madison St. facility.

Table 8. Demographic Characteristics of Worker/Household Interview Participants

	WM/WRG Worker[1]	Percent	Household Contact	Percent	Total	Percent
Gender						
Male	114	84	82	36	196	54
Female	22	16	143	64	165	46
Vital Status						
Living	85	63	197	88	282	78
Deceased	51	38	28	12	79	22
Total	136		225		361	100
Age Category (Living)						
18 - 44	5	6	34	17	39	14
45 - 64	32	38	117	59	149	53
65+	48	57	46	23	94	33
Total Living	85		197		282	100

1. There were 15 workers who were also household contacts for another worker. They are counted only in the worker column.

Table 9. Exposure Characteristics of Household Contacts[1]

	Number Reporting	Percent
Relationship to Worker		
Spouse or ex-spouse	77	34
Child	146	65
Both	2	1
Frequency of Laundering Worker's Clothing		
Every week	65	29
> Once per month	14	6
< Once per month	13	6
Never	132	59
Missing	1	<1
Frequency of Visiting/Entering the WM/WRG Plant (reported number of visits)[2]		
0	129	57
1 to 10	40	18
11 to 20	12	5
21 to 30	3	1
31 to 40	2	1
>40	39	17
Number of Years Living With Worker		
< or = 1	16	7
2 to 5	79	35
6 to 10	42	19
11 to 15	32	14
15 to 20	27	12
>20	29	13
Total Household Contacts	225	

1. This table excludes 15 WM/WRG workers who also reported living with a worker as spouse or child.

2. Household contacts estimated the total number of visits inside the 1720 Madison Street facility.

Table 10. Exposure Characteristics of WM/WRG Workers[1]

Workers Primary Work Location	Workers Reporting	Percent
1720 Madison Street	119	93
Perl Tile (Jefferson Street)	3	2
WRG Golden Valley Office	5	4
Other	1	1
Average Hours Worked Per Week at 1720 Madison Street		
>34	83	65
20 to 34	15	12
8 to 19	13	10
1 to 7	14	11
<1	2	2
Don't Know	1	1
Frequency of Using Respiratory Protection While Working at WM/WRG		
Always	5	4
Frequently (greater than half the time)	7	5
Sometimes (less than half the time)	23	18
Never	76	59
Don't Know	16	13
Missing	1	1
Total WM/WRG Workers	128	

1. Table includes 128 WM/WRG employees and excludes 8 contractor employees.

Table 11. Frequency of Reported Work Activities at 1720 Madison Street NE, 1938-1989[1]

Work Activity	Never	Don't know	< 1 day per week	1-4 days per week	>4 days per week	Total Reporting 1 or more days per week
Unloading vermiculite ore from rail cars	63	18	16	16	5	21
Loading or operating expansion furnaces	69	20	4	12	13	25
Entering silos to loosen ore	68	22	24	3	1	4
Moving or dumping waste rock in the pile outside the plant	65	18	7	15	13	28
Bagging vermiculite products from the furnace or stoner	47	11	7	29	24	53
Mixing and bagging Monokote or other products from the mixer	50	23	10	26	9	35
Hauling or loading products in the warehouse, onto trucks or rail cars	51	15	8	20	24	44
Cleaning baghouse filters (after 1972)	93	14	10	1	0	1
Equipment maintenance	80	18	10	5	5	10
Sweeping or cleaning in the plant	36	19	5	16	42	58

1. A total of 118 workers responded to questions about specific work activities at this location.

Table 12. Mortality in Western Minerals/WR Grace Workers and Household Contacts

Cause of Death	ICD 9 or Equivalent Code	Deaths Observed to July 2004 and Percent (%)[1]		Any Fibrosis on Death Certificate[2]
		Workers	Household	
Circulatory Disease	390 - 459	11 (24)	13 (50)	
Respiratory Cancer	160 - 165	11[3] (24)	0 (0)	1
All Other Cancers	140 - 208, 230 - 239; excl. 160-165	8[4] (17)	4[4] (15)	
NMRD[5]	010 - 018, 460 - 519	7 (15)	2 (8)	4
External	800 - 998	3 (7)	0 (0)	
All Other Causes		6 (13)	7 (27)	3
Total All Causes		46 (100)	26 (100)	8

1. Based on hand review of death certificates and excludes 2 deaths in workers that occurred outside Minnesota for which a death certificate was not obtained.
2. Death certificate includes mention of pulmonary fibrosis, asbestosis or pneumoconiosis as underlying or contributing cause of death.
3. Includes 1 mesothelioma (ICD 10, code C45.9).
4. Includes 1 cancer of unspecified site (ICD 9, code 199.1).
5. Non-malignant respiratory diseases (NMRD) include emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, and asbestosis.

Table 13. Years of Residence in the Study Area by Vital Status for Participants Reporting[1]

	Living	(%)	Deceased	(%)	Total	(%)
Ever lived in the study area from 1938-2001						
≤ 5 years	2,450	(46)	132	(16)	2,582	(42)
6 - 15 years	1,396	(26)	168	(20)	1,564	(25)
16 - 25 years	769	(14)	181	(22)	950	(15)
26 - 34 years	331	(6)	117	(14)	448	(7)
35+ years	436	(8)	241	(29)	677	(11)
Total	5,382		839		6,221	
Ever lived in the study area from 1938-1972[2]						
≤ 5 years	556	(31)	134	(18)	690	(27)
6 - 15 years	679	(38)	197	(26)	876	(34)
16 - 25 years	400	(22)	190	(25)	590	(23)
26 - 34 years	176	(10)	245	(32)	421	(16)
Total	1,811		766		2,577	
Ever lived within 1 adjoining block of WM/WRG property from 1938-1989[3]						
≤ 5 years	244	(39)	30	(16)	274	(34)
6 - 15 years	214	(34)	59	(32)	273	(33)
16 - 25 years	124	(20)	50	(27)	174	(21)
26 - 34 years	38	(6)	18	(10)	56	(7)
35+ years	14	(2)	27	(15)	41	(5)
Total	634		184		818	
Ever lived within 1 adjoining block of WM/WRG property from 1938-1972						
≤ 5 years	157	(35)	32	(18)	189	(31)
6 - 15 years	207	(47)	65	(37)	272	(44)
16 - 25 years	70	(16)	54	(31)	124	(20)
26 - 34 years	9	(2)	23	(13)	32	(5)
Total	443		174		617	

1. There were 6,221 participants who reported a residential history in the study area within the study time period.
2. According to the air emissions models, 1938-1972 represents a time period of greater ambient exposure.
3. Ambient exposures were highest within 1-2 blocks of the WM/WRG property.

Table 14. Number and Percent of Participants By Gender and Worker Status Reporting Each Exposure Pathway[1]

Exposure Pathway	Male	(%)	Female	(%)	Worker	(%)	Non-worker	(%)	Total	(%)
1 Ever worked for vermiculite processing facility[2]	121	(4)	23	(1)	136	(100)	8	(<1)	144	(2)
2 Ever lived with a WM/WRG worker	116	(3)	165	(5)	25	(18)	256	(4)	281	(4)
3 Ever moved waste rock from WM/WRG	252	(7)	62	(2)	39	(29)	275	(4)	314	(5)
4 Ever used waste rock from WM/WRG at home on the lawn or in the garden	214	(6)	101	(3)	27	(20)	288	(4)	315	(5)
5 Ever played in or around waste rock piles at WM/WRG	486	(14)	204	(6)	8	(6)	682	(10)	690	(10)
6 Ever installed or removed vermiculite insulation	350	(10)	76	(2)	34	(25)	392	(6)	426	(6)
7 Ever lived on a contaminated property from 1938-2001	912	(26)	834	(26)	17	(13)	1,729	(26)	1,746	(26)
8 Ever lived within 1 adjoining block of WM/WRG from 1938-1989	422	(12)	398	(12)	19	(14)	801	(12)	820	(12)
Total Participants	3,457		3,257		136		6,578		6,714	

1. Note that participants may have answered yes to more than one pathway.
2. Includes 8 community members whose reported work at WM/WRG was not confirmed or refused to participate in worker interview.

Table 15. Number and Percent of Participants By Gender and Worker Status Reporting Multiple Exposure Pathways

Number of Pathways Reported	Male	(%)	Female	(%)	Workers[1]	(%)	Non-workers[1]	(%)	Total	(%)
0	1,798	(52)	1,994	(61)	0	(0)	3,792	(58)	3,792	(56)
1	948	(27)	841	(26)	53	(39)	1,736	(26)	1,789	(27)
2	407	(12)	294	(9)	35	(26)	666	(10)	701	(10)
3	167	(5)	89	(3)	21	(15)	235	(4)	256	(4)
4	83	(2)	28	(1)	19	(14)	92	(1)	111	(2)
5	47	(1)	11	(0)	6	(4)	52	(1)	58	(1)
6	6	(0)	0	(0)	1	(1)	5	(0)	6	(0)
7	1	(0)	0	(0)	1	(1)	0	(0)	1	(0)
8	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Total Participants	3,457		3,257		136		6,578		6,714	

1. Workers refer only to the 136 who participated in the worker study and excludes 8 community members whose reported work at WM/WRG was not confirmed or refused to participate in the worker interview. All other participants are "non-workers".

Table 16. Playing on Processing Waste Piles: Frequency, Years and Age at First Exposure

Reported Frequency of Pile Playing[1]	Living	(%)	Deceased	(%)	Total	(%)
1 - 10 times	111	(17)	1	(2)	112	(16)
11 - 50 times	156	(24)	4	(10)	160	(23)
51 - 100 times	89	(14)	2	(5)	91	(13)
101 - 500 times	180	(28)	8	(19)	188	(27)
>500 times	87	(13)	1	(2)	88	(13)
Unknown	25	(4)	26	(62)	51	(7)
Total	648		42		690	
Year of First Exposure[2]						
<1938	3	(1)	0	(0)	3	(1)
1938 - 1949	68	(19)	4	(11)	72	(18)
1950 - 1959	90	(25)	5	(13)	95	(24)
1960 - 1969	129	(35)	9	(24)	138	(34)
1970 - 1979	56	(15)	7	(18)	63	(16)
1980 - 1989	15	(4)	0	(0)	15	(4)
>1989	1	(<1)	0	(0)	1	(<1)
Unknown	3	(1)	13	(34)	16	(4)
Total	365		38		403	
Age at First Exposure[3]						
0 - 5 yrs	74	(20)	5	(13)	79	(20)
6 - 10 yrs	226	(62)	15	(40)	241	(60)
11 - 15 yrs	51	(14)	4	(11)	55	(14)
16 - 20	6	(2)	1	(3)	7	(2)
21 - 29	3	(1)	0	(0)	3	(1)
30 - 39	2	(1)	0	(0)	2	(1)
Unknown	3	(1)	13	(34)	16	(4)
Total	365		38		403	

1. All participants who reported ever playing on piles (n=690) were asked how many times they had played on the piles. Responses ranged from 1 to 6,570 times with a mean response of 248 times.

2. Among pile players interviewed by telephone (n=403), respondents were asked during what year they first played on the piles at WM/WRG. The plant operated from 1938-1989.

3. Pile players interviewed by telephone (n=403) were asked at what age they first played on the piles. Responses ranged from age 1 to 37.

Table 17. Prevalence of Other Respiratory Health Risk Factors Reported On Interview

Reported Respiratory Health Risk Factor	Male	(%)	Female	(%)	Workers[1]	(%)	Non-workers[1]	(%)	Total	(%)
Report 1 or more occupations with asbestos exposure (not WM/WRG)	1,507	(44)	216	(7)	79	(58)	1,644	(25)	1,723	(26)
Ever regular cigarette smoker	2,153	(62)	1,632	(50)	100	(74)	3,685	(56)	3,785	(56)
Ever regular pipe or cigar smoker	357	(10)	20	(0.6)	24	(18)	353	(5)	377	(6)
Total Full Interview Respondents:	3,452		3,252		136		6,568		6,704	
Current regular cigarette smoker	944	(33)	823	(28)	10	(13)	1,757	(31)	1,767	(31)
Ever had a chest x-ray	1,832	(64)	1,881	(65)	79	(93)	3,634	(64)	3,713	(64)
If yes, ever told of any lung changes on x-ray[2]	213	(12)	154	(8)	29	(37)	338	(9)	367	(10)
If yes, ever told of pleural changes/plaques on x-ray[2]	41	(2)	26	(1)	9	(11)	58	(2)	67	(2)
Total Living Full Interview Respondents:	2,875		2,891		85		5,681		5,766	

1. Workers refer only to the 136 who participated in the worker study and excludes 8 community members whose reported work at WM/WRG was not confirmed or refused to participate in the worker interview. All other participants are "non-workers".
2. Percents are calculated from people who reported having chest x-rays.

Table 18. Prevalence of Self-Reported Respiratory Disease Ever Diagnosed by a Physician[1]

Lung Disease	Workers[2]	Non-workers[2]	Total	% Reporting
Asthma	10	481	491	7.32
Pneumonia	22	400	422	6.29
Bronchitis[3]	6	284	290	4.33
Emphysema	12	138	150	2.24
Lung Cancer	9	102	111	1.66
Pleurisy	1	87	88	1.31
Chronic Obstructive Pulmonary Disease	4	40	44	0.66
Asbestosis	10	22	32	0.48
Tuberculosis	0	28	28	0.42
Lung Infections[4]	0	14	14	0.21
Fibrosis of the Lung (Pulmonary Fibrosis)	1	11	12	0.18
Collapsed Lung/pneumothorax	0	11	11	0.16
Mesothelioma	4	3	7	0.10
Sleep Apnea	0	7	7	0.10
Asbestos Related - Unspecified	3	4	7	0.10
Bronchiectasis	0	6	6	0.09
Sarcoidosis	0	5	5	0.07
Pleural Plaques/thickening	0	4	4	0.06
Reactive Airway Disorder	0	3	3	0.04

1. Out of 6,704 respondents (including 136 workers and 6,568 non-workers from the combined community and worker/household cohorts), 1,442 self-reported diagnoses of a lung disease or condition. This table excludes reports of allergies, influenza, heart/circulatory conditions, symptoms only, and non-specific clinical findings only (e.g. spots on lung.) Also excluded are conditions reported by fewer than 3 individuals. Note that these self-reported conditions have not been confirmed or validated through medical record reviews and respondents may have reported more than one disease.

2. Workers refer only to the 136 who participated in the worker study and excludes 8 community members whose reported work at WM/WRG was not confirmed or refused to participate in the worker interview. All other participants are "non-workers".

3. Bronchitis includes chronic bronchitis, acute bronchitis, and unspecified.

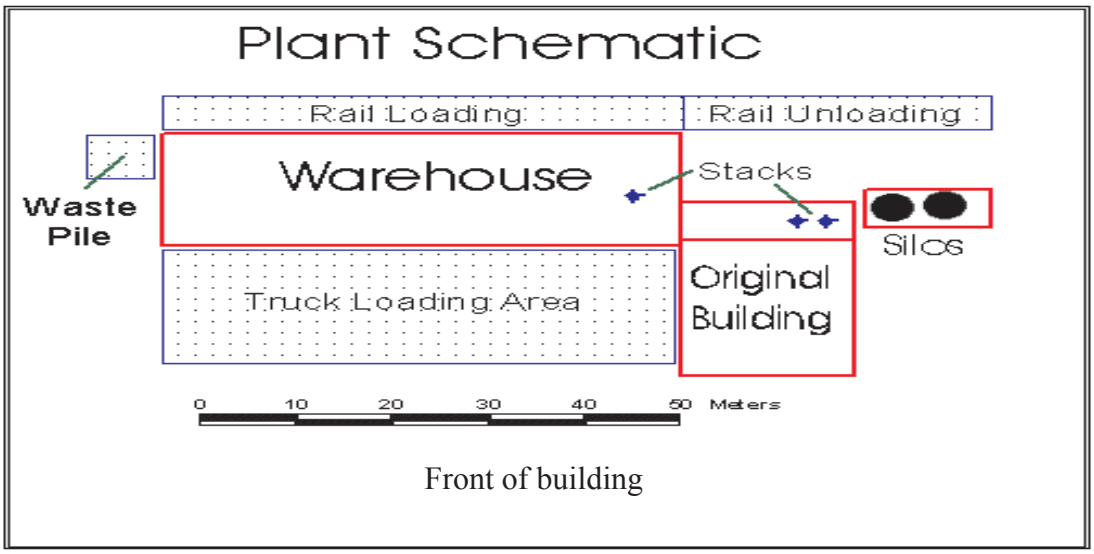
4. Lung infections include psittacosis, pertussis, histoplasmosis, pigeon breeder's disease, pneumonitis, and other unspecified bronchial or lung infections.

Figures

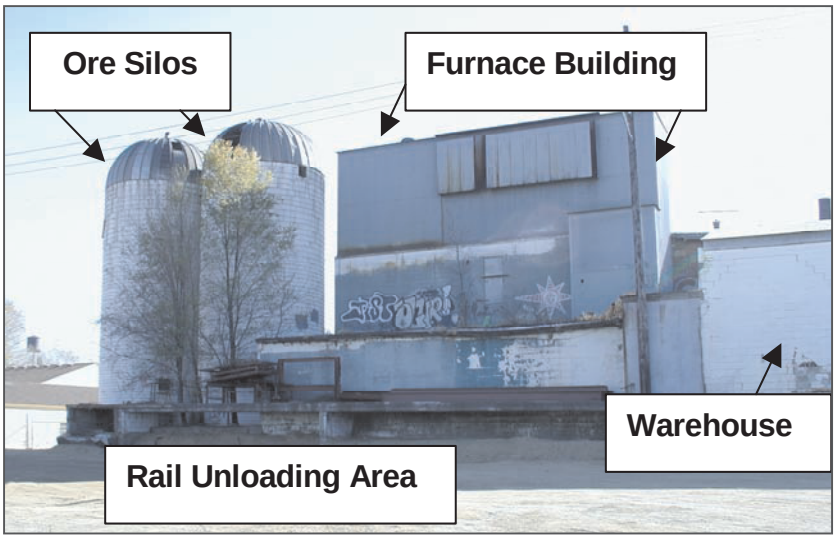
Figure 1. Northeast Minneapolis Community Vermiculite Investigation Study Area

Figure 2. WM/WRG Building Photos and Plant Schematic

View from the front of the building



Front of building



View from the back of the building

Figure 3. W.R. Grace Worker Monitoring Data 1974-1988, All Jobs

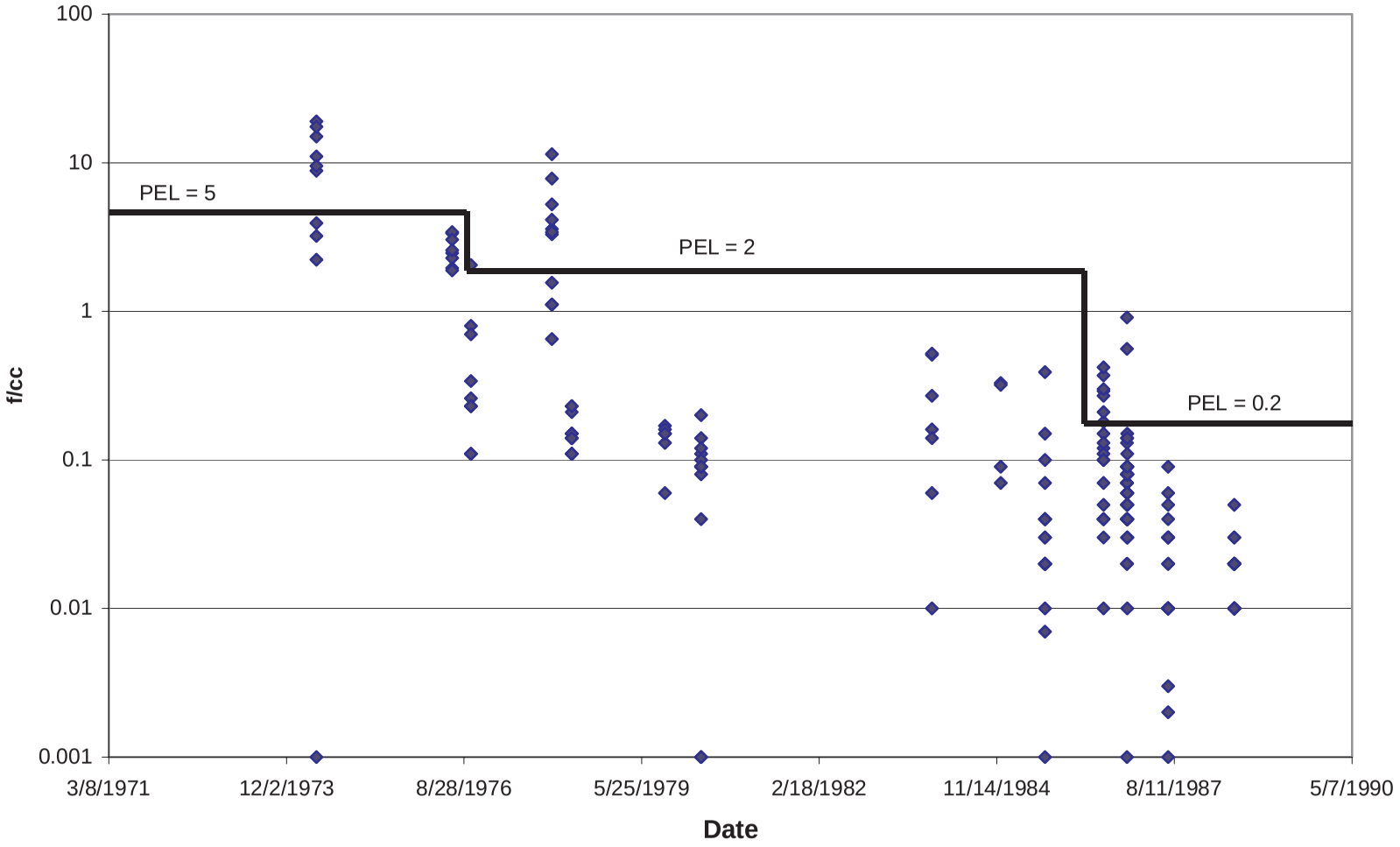


Figure 4. Total Period of Employment for Category 1 Workers, N=70

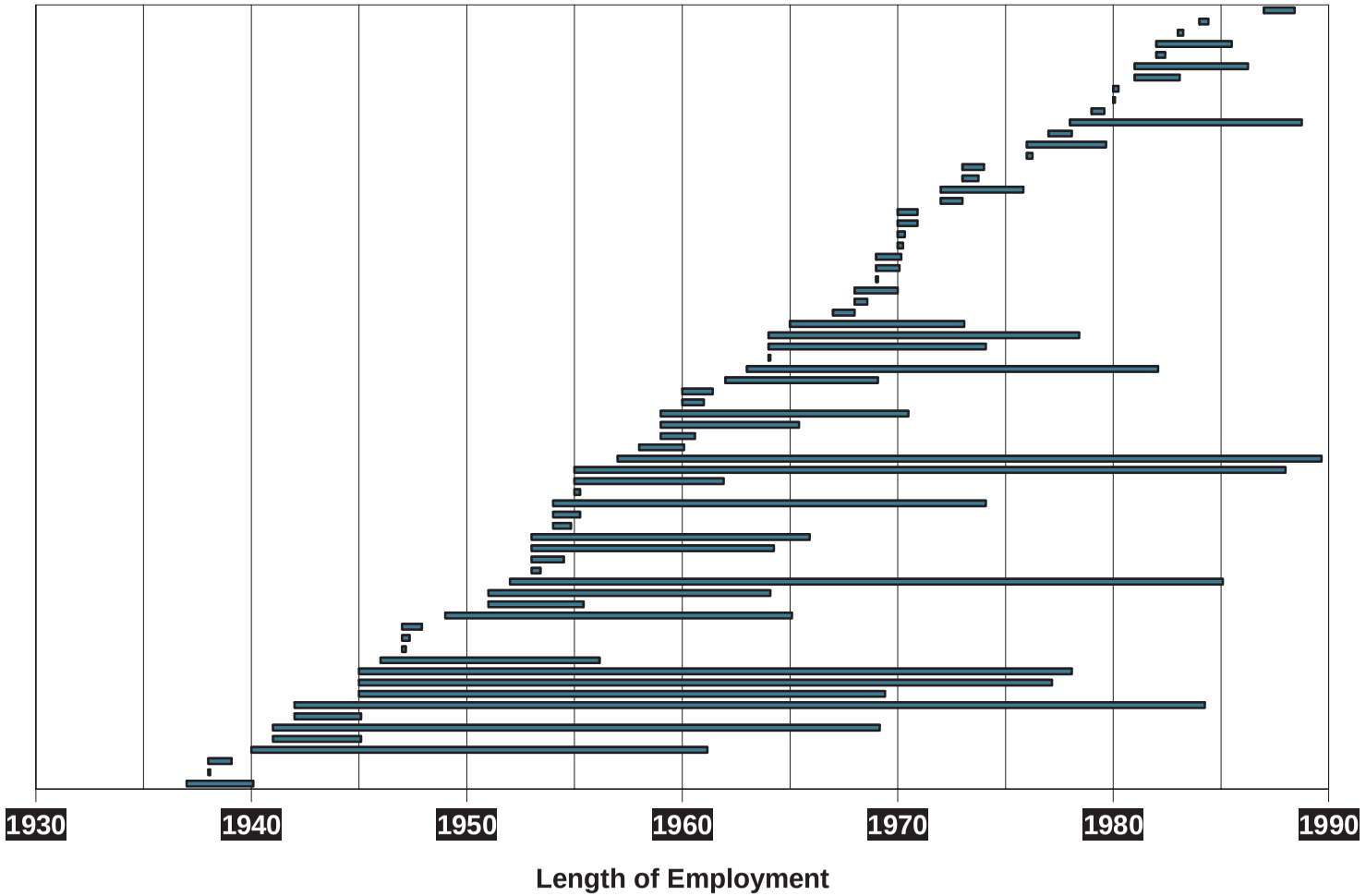
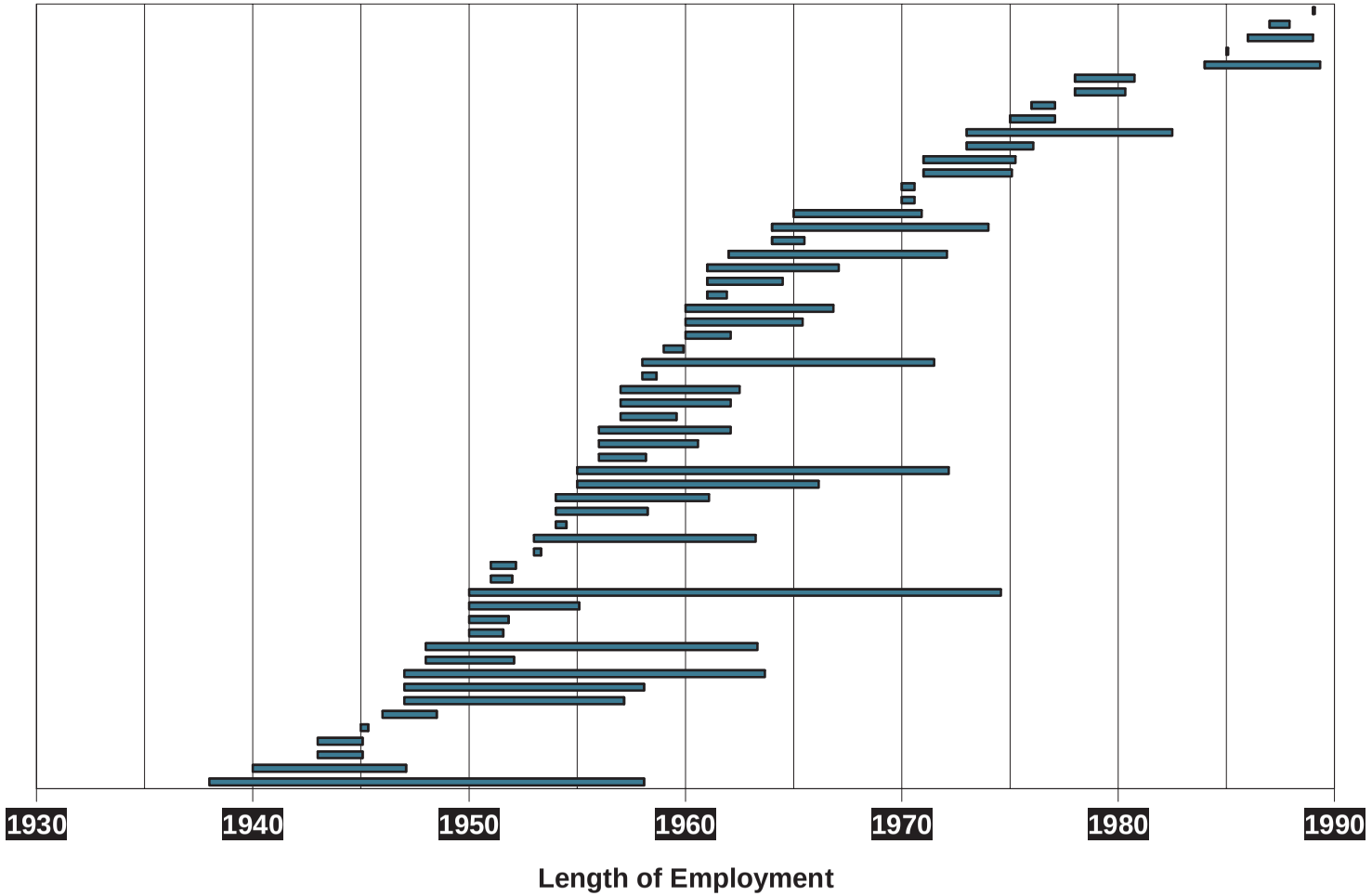


Figure 5. Total Period of Employment for Category 2 Workers, N=58



Appendix

Appendix. Personnel and Area Air Monitoring Data

Personnel Air Monitoring Data

Date	Job Location	Notes	Sample Time (min)	Results (f/cc)
5/20/1974	Bagging concrete aggregate	visible dust during sampling	16	0.00
	Operating lift truck		18	19.00
	Bagging Bar-B-Sorb		15	15.00
	Enter ore storage bin	while ore unloading, drove lift truck	16	17.46
	Bagging con AG		15	11.02
	Mixing and bagging MK-5		16	3.21
	Bag stitching MK-5		18	2.22
	Lead man, sweeping	around stoner	20	8.84
5/21/1974	Mixing and bagging MK-5		16	3.92
	Bag stitching MK-5		18	9.50
6/23/1976	Model A#2 bagger	Libby #3 ore	16	3.42
	Monokote bagger	Libby #3 ore	23	2.58
10/6/1976	Bagger #1 station	attic insulation - Libby #1	15	0.80
	Bagger #2 station	plaster aggregate - Libby #3	15	2.05
	Mixing and bagging MK	Libby #3 ore	15	0.34
1/5/1978	Model A#2 bagger	Libby #2 ore	14	7.82
	Model A#1 bagger	Libby #1 ore	28	3.58
	Bagger MK#4	Libby #3 ore	26	5.26
	Special job cleaning baghouse	very dusty	14	11.40
	Location unknown		32	4.13
4/26/1978	Bagging masonry fill	#2 furnace, Libby #3 ore	30	<0.15
	Mixing and bagging MK-4	Libby #3 ore	22	<0.21
	Mixing and bagging MK-4	Libby #3 ore	20	<0.23
10/3/1979	Bagging station - furnace #1	attic insulation - Libby #2	61	0.15
	Paper bagging MK	Libby #3 ore	55	0.17
	Loading & #2 furnace bagging		56	0.16
4/24/1980	Bagging masonry fill, #2 furnace	Libby #3 ore	56	0.12
	Assorted jobs	hauling and loading product	36	0.14
	Mixing and bagging MK-5	Libby #3 ore	51	0.20

Personnel Air Monitoring Data

Date	Job Location	Notes	Sample Time (min)	Results (f/cc)
11/14/1983	Bagging masonry fill, #2 furnace		125	0.01
	Bagging Terralite, #1 furnace		60	0.16
	Hauling masonry fill & cleaning		117	0.06
	Bagging Terralite		63	0.14
	Bagging masonry fill		35	0.52
	Hauling masonry fill		121	0.51
	Bagging Terralite		46	0.08
12/6/1984	Bagging masonry insulation	also loading trailers	137	0.09
	Bagging masonry insulation		120	0.07
	Loading trailers		89	0.32
	Bagging masonry insulation		87	0.33
8/13/1985	Furnace #1 bagger/operator		95	0.04
	Furnace #1 bagger/operator		90	0.15
	Furnace #2 bagger/operator		89	0.02
	Furnace #2 bagger/operator		81	0.10
	Foreman		95	0.04
	In furnace chute cleaning it		90	0.39
7/8/1986	Maintenance		78	0.12
	Loading bags	Libby #3 ore	24	0.29
	Bagging station - furnace #2		15	0.42
11/17/1986	#2 bagging station		20	0.56
	Loader		20	0.91
11/18/1986	#2 bagging station	same employees	40	0.08
	Loader		41	0.09
11/19/1986	#2 bagging station	same employees	30	0.15
			35	0.09
7/6/1987	Furnace operator/bagger	Libby #3 ore, masonry fill	40	0.09
	Loading trucks		45	0.06
	Forklift - truck loading		45	0.01
7/12/1988	Furnace operator	Libby #2 ore	45	0.03
	Bagger/warehouse	Libby #2 ore	69	0.02
	Maintenance	Libby #2 ore	40	0.05

Area Air Monitoring Data

Date	Location	Notes	Sample Time (min)	Results (f/cc)
7/25/1972	Masonry fill bagging	Libby #3 ore, furnace #2 only	15	11.40
	Furnace room	upwind of furnace	15	7.60
	Masonry fill bagging		15	11.10
	Furnace room	downwind of furnace		15.20
	Perlite bagging	vacuum pulled dust from vermiculite	15	3.70
	Lunch room			0.40
	3 ft from stoner		25	3.40
	3rd floor storage, general room		16	2.10
	On fence, downwind of outside stoner scrap pile		56	0.30
	2nd floor general room		17	5.40
	Mid RR warehouse		50	0.00
5/21/1974	General air, stoner area		15	4.18
	Just outside open door to ore storage bins, during unloading Libby #3		10	57.57
6/23/1976	Model A#2 3rd floor	stoner rock discharge		2.68
	Stoner waste	next to discharge	25	20.61
1/5/1978	20' in front of furnace #1		152	2.91
	#2 furnace room		29	1.57
	Stoner rock waste hopper	water spray on (wheelbarrow)	30	13.53
1/25/1978	2nd floor - 18' from furnace #2		102	5.30
	3rd floor - 8' from bagging station		84	5.60
	Fan platform - furnace room		73	1.30
	Lunch room	60' from #2 bagger	162	3.00
1/26/1978	2nd floor - 18' from furnace #2	plant not operating	71	0.70
	3rd floor - 8' from bagging station	plant not operating	69	1.20
	Sewing machine #2 bagging	plant not operating	68	0.23
	Lunch room	plant not operating	69	0.87
4/26/1978	No. 2 furnace, stoner rock end	running Libby #3	32	<0.14
	Furnace room, near #2 furnace		30	0.15
	Stoner drop, #2 furnace	fines dropped into wheelbarrow, water spray & exhaust ventilation on	44	6.94
	Lunch room		44	<0.10
	2nd floor, center of bldng		30	<0.15

Area Air Monitoring Data

Date	Location	Notes	Sample Time (min)	Results (f/cc)
10/10/1979	Background sample	on phone books	193	0.14
	#1 furnace waste rock hopper		36	0.06
	#2 furnace waste rock hopper		34	0.13
	#2 furnace stoner prod end		26	0.35
	#2 furnace stoner rock end		33	0.41
9/24/1980	Stoner - rock end	#2 furnace	62	0.06
	Rock hopper (wheelbarrow)	#2 furnace	72	0.14
	Baghouse drop	#2 furnace	76	<0.02
	Background sample	furnace room	65	0.13
	Employees lunch room		54	0.03
	Office		77	<0.02
7/22/1981	Stoner - rock end		72	0.05
	Stoner - product end		72	0.06
	Waste rock hopper - wheelbarrow		79	1.00
	Baghouse #2		76	0.10
	Lunch room		130	0.09
	Background sample	25' south of #1 bagging station	142	0.09
	Base of product elevator	furnace room	46	0.13
	Baghouse #1		36	0.24
7/1/1982	Stoner - rock end		65	0.19
	Stoner - product end		69	0.18
	Background sample - 3rd floor	10' from MK-5 bagger	119	0.04
	Background sample - 2nd floor	18' from baggers	119	0.02
	Baghouse		45	0.25
	Waste rock hopper - #1		48	1.98
	Baghouse drop - corner of room		47	0.10
	Between furnaces		60	0.29
11/14/1983	Furnace #2 waste rock	wheelbarrow	64	0.10
	Stoner rock end	#2 furnace	72	0.11
	Stoner product end	#2 furnace	76	0.38
12/6/1984	Waste rock hopper		120	1.65
	Stoner - rock end		86	0.01
	Stoner - product end		72	0.08

Area Air Monitoring Data

Date	Location	Notes	Sample Time (min)	Results (f/cc)
8/12/1985	Waste rock hopper #1		73	0.02
	Waste rock hopper #2		73	0.04
	Open ore bins	where controls were	75	0.15
	Baghouse drop	#2 furnace	73	0.34
	Stoner - product end	#1 furnace	74	0.06
	Stoner - waste rock end	#1 furnace	49	0.01
	Stoner - product end	#2 furnace	50	0.03
	Stoner - waste rock end	#2 furnace	134	0.02
7/7/1986	One cubic yard hopper		90	0.09
	Stoner - product end		103	0.14
	Stoner - waste rock end		70	0.09
11/17/1986	One cubic yard hopper		80	0.03
	Stoner #2 - product end		65	0.06
	Stoner #2 - waste rock end		65	0.01
	One cubic yard hopper		70	0.01
	Stoner #2 - product end		70	0.06
	Stoner #2 - waste rock end		70	0.06
	#2 bagging station		37	0.10
11/19/1986	One cubic yard hopper		50	<0.01
	Stoner #2 - product end		58	0.04
	Stoner #2 - waste rock end		72	0.13
	Stoner #1 - product end		65	0.08
	Stoner #1 - waste rock end		65	0.05
8/6/1987	Stoner - product end		65	0.02
	Stoner - waste rock end		60	0.03
	2nd floor baghouse flapper valve	common/augers	70	0.01
	2nd floor baghouse flapper valve	furnace room	75	0.03
	1st floor common baghouse	waste drop	60	0.01
	Furnace room		85	0.01