Minnesota Taconite Workers Health Study

University of Minnesota

Final Presentation to Lung Health Partnership

December 1, 2014
Hibbing, Minnesota
Minnesota Taconite Workers Health Study

What we’ll do today:

1. Overview
   Jeff Mandel, M.D.
   University of Minnesota School of Public Health

2. Review study components-investigators

3. Summary and recommendations

4. Q&A-all
Original Issue

In 2007 the Minnesota Department of Health showed that there were 51 cases of mesothelioma in taconite miners. Since mesothelioma is a rare cancer, that number appeared to be in excess.
Key Facts

Mesothelioma is a form of lung cancer caused primarily by exposure to asbestos fibers.

The disease takes decades to develop in an exposed person (often 30 years+)

Mesothelioma is a “sentinel disease”
Key Facts

Previous research shows that people in certain occupations are at greater risk of asbestos exposure and mesothelioma:

- Shipyards, construction, demolition trades
- Insulators, cement workers where asbestos added
- Electrical workers (motors)
- Some textile, tile manufacturing where asbestos is used in products
Minnesota Taconite Workers Health Study

- Brings together all the stakeholders:
  - Iron Range Legislative Delegation
  - Unions, Contractors, Industry
  - Federal, State, County, Local Agencies
  - Iron Range Health Sector
  - Retirees, Families, the Public

  Co-chairs: Ron Dicklich, J. Finnegan
Minnesota Taconite Workers Health Study

• 2 Science Advisory Boards (SAB)
  – Guiding UMN-Twin Cites Researchers
  – Guiding UM-Duluth Researchers

• Ongoing peer review of study questions, methods and results by independent experts
Minnesota Taconite Workers Health Study

Key questions:

1. What is the relationship of working in the taconite industry to the excess number of cases of mesothelioma?

2. Are other diseases, respiratory and non-respiratory, associated with work in the taconite industry?

3. Are spouses at risk for lung diseases as a result of their partners working in the taconite industry?
Minnesota Taconite Workers Health Study

Study Components:

1. Occupational exposure assessment (SPH-G. Ramachandran, Ph.D.)
2. Causes of death
3. Cancer incidence
4. Mesothelioma case-control (SPH-Bruce Alexander, Ph.D.)
5. Lung cancer case-control
6. Respiratory Health Survey (Medical School-David Perlman, M.D.)
7. Environmental exposure characterization (NRRI)
Occupational Exposure Assessment

Gurumurthy Ramachandran, Ph.D.
School of Public Health
Occupational Exposure Assessment

Assessed current and past exposures to Long EMPs in the taconite industry

Evaluated existing practices and methods to reduce workers exposures
Measuring Long EMPs

NIOSH 7400 (PCM) method

- Most often used
- Easiest
- Good estimate
- Doesn’t look at mineralogy

EMP : Elongate Mineral Particles
PCM : Phase Contrast Microscopy
Sampling method for current EMPs exposures

PCM\textsuperscript{a}: Phase Contrast Microscopy

TEM\textsuperscript{b}: Transmission Electron Microscopy – identification of amphibole EMPs
Elongate Mineral Particles (EMPs)\textsuperscript{a}

**Amphibole EMPs**
- Amosite (Cummingtonite-grunerite)
- Actinolite
- Anthophyllite
- Tremolite
- Crocidolite (Riebeckite)

**Non-amphibole EMPs**

**Asbestiform EMPs**
- Amosite
- Actinolite

**Non-asbestiform EMPs**
- Cummingtonite-grunerite
- Actinolite

**Cleavage Fragments**
NIOSH 7400 does not measure short EMPs that are more numerous.

All EMPs - East

NIOSH EMPs

All EMPs - West

NIOSH EMP

University of Minnesota
Driven to Discover™
• Exposures in some job groups in some mines are above the NIOSH Recommended Exposure Limit of 0.1 particles/cm³
• Most job groups have exposures below this limit

*NIOSH Recommended Exposure Limit (REL)
• Almost all amphibole EMPs exposures are below the NIOSH REL of 0.1 particles/cm³
• Amphibole EMPs exposures are an order of magnitude lower than 0.1 particles/cm³

*NIOSH Recommended Exposure Limit (REL)
Reconstruction of Past Exposures

- Historical data were obtained from three sources:
  - MSHA – Mine data retrieval system
  - Three companies’ internal IH databases
  - Previous UMN study from the mid 1980s

Example of exposure history for one job code – **Crusher Operator**.
EMPs Conclusions

Exposures to total EMPs are low but are above 0.1 EMP/cc* for some jobs

Almost all the amphibole EMPs are below the REL

Total EMPs measures have been decreasing through time

*NIOSH Recommended Exposure Limit (REL)
Sampling strategy for present-day RD/RS exposure

Personal sampling

Respirable dust (RD)
- NIOSH Method 0600

Respirable silica (RS)
- NIOSH Method 7500

Note: NIOSH Method 0600 – Gravimetric (filter weight)
NIOSH Method 7500 – X-ray powder Diffraction
• No single RD exposure concentration was higher than the ACGIH TLV in any of the mines.
• The RD concentrations in the milling processes (crushing, concentration, and pelletizing) tended to be higher than those in the non-milling processes.
Except for a few exceptions, the concentrations of RS in the crushing and/or concentration processes were higher than 0.025 mg/m$^3$, as well as higher than the rest of the taconite processes.
Assessment of exposure controls

Engineering controls are appropriate for normal operations
Miners may be exposed to elevated dust levels when making repairs or performing maintenance
Atypical conditions may lead to significant exposures
Plants should continue efforts to minimize exposures

*Mine Safety and Health Administration (MSHA) Permissible Exposure Limit (PEL)
Mortality Study

Bruce Alexander, Ph.D.
University of Minnesota
School of Public Health
Purpose

• Compare rates of death in iron mining workers to the general population of Minnesota
• Evaluate all causes of death combined and deaths from specific causes
• Characterize overall health of population
Approach

• Workers born after 1920
  – Focus on people with majority of work in taconite
• Nationwide follow-up
• Determine who is still alive and the cause of death for those who died
• Compare mortality rates in workers to rates in Minnesota for people of similar age, sex, and year of birth
• Calculate Standardized Mortality Ratios (SMR)
  – SMR = Observed Deaths/Expected Deaths
Study Population and All Causes of Death of Iron Mining Workers Born 1920 or Later

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>44,161</td>
</tr>
<tr>
<td>Deaths Identified</td>
<td>13,318</td>
</tr>
<tr>
<td>Expected Deaths</td>
<td>12,720</td>
</tr>
</tbody>
</table>

Standardized Mortality Ratio = 1.05
(95% Confidence Interval=1.03-1.06)
Oberved and Expected Mesothelioma Deaths

SMR = 2.8 (95% CI = 2.1-3.9)
Observed and Expected Deaths from Lung Cancer, Heart Disease and Other Respiratory Diseases

- **Lung Cancer**
  - Observed: 1400
  - Expected: 1168
  - SMR: 1.2

- **Heart Disease**
  - Observed: 3871
  - Expected: 3483
  - SMR: 1.1

- **Respiratory**
  - Observed: 883
  - Expected: 888
  - SMR: 0.99
Observed and Expected Deaths from Mesothelioma, Lung Cancer, Heart Disease and Other Respiratory Diseases

45
1400
3871
883

15.5
1168
3483
888

388 excess deaths
Summary

• Taconite workers have higher rates of death for
  – All causes combined
  – All cancers combined
  – Mesothelioma
  – Lung cancer
  – Heart disease
  – Other causes generally at or below rates of Minnesota

• Lifestyle as well as occupational factors likely important

• Mesothelioma is an indicator of an occupational exposure to asbestos
Cancer Incidence Study

Bruce Alexander, Ph.D.
University of Minnesota
School of Public Health
Purpose

• Compare rates of cancer diagnoses in iron mining workers to the general population of Minnesota
• Includes cancers that are not included in the death records
• Compare rates of specific cancer subtypes
• Focus on cancers potentially related to taconite exposures
Approach

• Workers born after 1920 (same as mortality study)
• Diagnosed with a cancer in Minnesota since 1988
  – Minnesota Cancer Surveillance System (MCSS)
• Compare rates of cancer rates in workers to rates in Minnesota
• Calculate Standardized Incidence Ratios (SIR)
  – SIR= Observed cancers/Expected cancers
• Adjust for estimated rates of smoking in population.
## SIRs for Selected Cancers

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Observed</th>
<th>Expected</th>
<th>SIR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesothelioma</td>
<td>51</td>
<td>21.1</td>
<td>2.4 (1.8, 3.2)</td>
</tr>
<tr>
<td>Lung</td>
<td>931</td>
<td>726.5</td>
<td>1.3 (1.2, 1.4)</td>
</tr>
<tr>
<td>Larynx</td>
<td>93</td>
<td>68.5</td>
<td>1.4 (1.2, 1.7)</td>
</tr>
<tr>
<td>Oral</td>
<td>165</td>
<td>159.9</td>
<td>1.0 (0.8, 1.0)</td>
</tr>
<tr>
<td>Bladder</td>
<td>359</td>
<td>336.7</td>
<td>1.2 (1.0, 1.2)</td>
</tr>
<tr>
<td>Esophagus</td>
<td>87</td>
<td>76.7</td>
<td>1.1 (0.9, 1.4)</td>
</tr>
<tr>
<td>Kidney</td>
<td>165</td>
<td>174.3</td>
<td>0.9 (0.8, 1.0)</td>
</tr>
<tr>
<td>Liver</td>
<td>50</td>
<td>48.6</td>
<td>1.0 (0.7, 1.3)</td>
</tr>
<tr>
<td>Pancreas</td>
<td>110</td>
<td>101.8</td>
<td>1.1 (0.9, 1.3)</td>
</tr>
<tr>
<td>Stomach</td>
<td>103</td>
<td>76.4</td>
<td>1.3 (1.1, 1.6)</td>
</tr>
</tbody>
</table>
### SIRs Adjusted for Estimated Smoking Rates

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Smoking Adjusted SIR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>1.2 (1.1, 1.2)</td>
</tr>
<tr>
<td>Larynx</td>
<td>1.2 (1.0, 1.5)</td>
</tr>
<tr>
<td>Oral</td>
<td>0.9 (0.8, 1.1)</td>
</tr>
<tr>
<td>Bladder</td>
<td>1.0 (0.9, 1.1)</td>
</tr>
</tbody>
</table>

- **Smoking Adjusted SIR**
- **Unadjusted SIR**
Summary

• Taconite workers have higher rates of some cancers compared to the Minnesota population
• Smoking may not explain elevated rates of lung and laryngeal cancer
• Results similar for subtypes of lung cancer
Mesothelioma Case Control Study

Bruce Alexander, Ph.D.
University of Minnesota
School of Public Health
Purpose

- To determine if the risk of mesothelioma in iron mining workers is related to:
  - Length of employment in taconite industry
  - Exposure to the EMPs generated by taconite operations
Approach

- Compare workers with mesothelioma (cases) to workers of similar age who have not developed mesothelioma (controls)
- Years worked in taconite industry
- Exposure to EMPs
  - Based on time working in exposure job groups
- Control for time working in hematite and potential exposure to commercial asbestos
Relative Risk of Mesothelioma from Working in Taconite Industry (All Exposures)

Years of Employment in Taconite Industry
RR=1.03  (95% CI=1.00-1.06)

Averaged across the population a 3% increase per year of employment

Control for the effects of age and employment in hematite mining
Relative Risk of Mesothelioma from Exposure to EMPs in Taconite Industry

Cumulative EMP exposure: EMP/cc × year
RR = 1.10 (95% CI = 0.97-1.24)
- Averaged across the population, a 10% increased risk of mesothelioma per 1 EMP/cc × year

High vs. Low Exposure
RR = 1.93 (95% CI = 1.00-3.72)
- (High = above median of 1.15 EMP/cc × years)

Control for any effects of age, hematite mining, and potential for exposure to commercial asbestos
Estimated Cases of Mesothelioma in 10,000 Men Living to Age 80 Working in Taconite up to 30 Years and the Expected Cases in 10,000 Men in the General Population

*Lifetime risk for white males at age 80 is 0.144 percent.
Surveillance Epidemiology and End Results Program of the National Cancer Institute.
Estimated lifetime risk at age 80 for white male taconite workers who worked for 30 years is 0.333 percent.
Summary

- Mesothelioma cases were more likely to work for a longer time in the taconite industry than non-cases

- Mesothelioma cases had slightly higher estimated cumulative exposure to long EMPs
  - Risk is increased, but estimate is imprecise

- Cannot entirely rule out impact of commercial asbestos exposure used in taconite industry or exposure from other jobs.
Lung Cancer Case Control Study

Bruce Alexander, Ph.D.
University of Minnesota
School of Public Health
Purpose

• To determine if the risk of lung cancer in iron mining workers is related to:
  • Length of employment in taconite industry
  • Exposure to the EMPs generated by taconite operations
  • Exposure to silica generated by taconite operations
Approach

- Compare workers with lung cancer (cases) to workers of similar age who have not developed lung cancer (controls)
- Timeworked in taconite industry
- Exposure to EMPs and Silica
  - Based on time working in exposure job groups
- Control for time working in hematite and potential exposure to commercial asbestos
# Demographics

<table>
<thead>
<tr>
<th></th>
<th>CASES (N=1706)</th>
<th>CONTROLS (N=3381)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1637 (95.96)</td>
<td>3183 (94.14)</td>
</tr>
<tr>
<td>Female</td>
<td>69 (4.04)</td>
<td>198 (5.86)</td>
</tr>
<tr>
<td><strong>Ore type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taconite only</td>
<td>668 (39.16)</td>
<td>1239 (36.67)</td>
</tr>
<tr>
<td>Hematite only</td>
<td>738 (43.26)</td>
<td>1530 (45.28)</td>
</tr>
<tr>
<td>Taconite &amp; hematite</td>
<td>300 (17.58)</td>
<td>610 (18.05)</td>
</tr>
</tbody>
</table>
### Lung Cancer Risk by Length of Employment

<table>
<thead>
<tr>
<th>Employment duration</th>
<th>RR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taconite years†</td>
<td>0.99</td>
<td>0.96-1.01</td>
</tr>
<tr>
<td>Hematite years‡</td>
<td>0.99</td>
<td>0.98-1.01</td>
</tr>
</tbody>
</table>

† Adjusted for hematite exposure, silica exposure, asbestos exposure, and sex  
‡ Adjusted for taconite exposure, silica exposure, asbestos exposure, and sex
## Lung Cancer Risk by EMP & Silica Exposure

<table>
<thead>
<tr>
<th>Total Exposure</th>
<th>RR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EMP/cc)-years†</td>
<td>0.95</td>
<td>0.89-1.01</td>
</tr>
<tr>
<td>Silica (mg/m³)-years‡</td>
<td>1.22</td>
<td>0.81-1.83</td>
</tr>
</tbody>
</table>

† Adjusted for hematite exposure, silica exposure, asbestos exposure, and sex
‡ Adjusted for hematite exposure, taconite exposure, asbestos exposure, and sex
* Only exposure in hematite mining
Summary

• No association between lung cancer and length of employment in the taconite industry
• No association between lung cancer and exposure to EMPs
• No association between lung cancer and exposure to silica
• No difference in results by lung cancer subtype
Respiratory Health Survey

Purpose was to identify non-cancerous respiratory diseases

- Silicosis
- Dust related lung disease
- Benign pleural changes (lining of the lung)

Randomly selected workers from company employment rosters were asked to participate
Respiratory Health Survey

Chest X Ray Abnormalities
- **Parenchymal** – changes in the lung, can represent, silicosis, asbestosis, or pulmonary fibrosis
- **Pleural** – changes in the lining of the lung, can be caused by: EMP exposure, silica exposure

Pulmonary Function Tests Abnormalities
- **Obstruction** – caused by smoking, can be seen in silica exposure
- **Restriction** – Many causes, including silica or dust exposure
Other studies of open pit mining have reported rates of 4-11% for parenchymal abnormalities.

Pleural changes were associated with duration of employment and cumulative EMP exposure.

We did not find a correlation between parenchymal abnormalities and duration of employment or exposure.
Respiratory Health Survey
Risk of Pleural Abnormality

<table>
<thead>
<tr>
<th>Exposure Quartile</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; EMP/cc/years &lt; 1.16</td>
<td>1.00</td>
<td>---</td>
</tr>
<tr>
<td>1.16 &lt; EMP/cc/years &lt; 3.29</td>
<td>1.84</td>
<td>1.18-2.94</td>
</tr>
<tr>
<td>3.29 &lt; EMP/cc/years &lt; 5.89</td>
<td>2.22</td>
<td>1.42-3.63</td>
</tr>
<tr>
<td>5.89 + EMP/cc/years</td>
<td>1.78</td>
<td>1.11-2.98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duration of Employment</th>
<th>Relative Risk</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; years &lt; 21</td>
<td>1.00</td>
<td>---</td>
</tr>
<tr>
<td>21 &lt; years &lt; 30</td>
<td>1.39</td>
<td>0.86-2.26</td>
</tr>
<tr>
<td>30 &lt; years &lt; 35</td>
<td>1.65</td>
<td>1.02-2.65</td>
</tr>
<tr>
<td>35+ years</td>
<td>1.84</td>
<td>1.11-3.07</td>
</tr>
</tbody>
</table>
Respiratory Health Survey
Pulmonary Function Test Results

<table>
<thead>
<tr>
<th></th>
<th>Obstruction</th>
<th>Restriction</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
<td>16.8%</td>
<td>4.5%</td>
<td>2.9%</td>
</tr>
<tr>
<td>Spouses</td>
<td>11.6%</td>
<td>4.4%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

• No correlation found between dust exposure and PFT abnormalities
Respiratory Health Survey

• X-ray testing suggests some dust related lung disease similar to what is seen in other open-pit mining operations
• X-ray changes among workers do show an increased amount of pleural abnormalities that are associated with exposure to EMPs and duration of employment.
  • 2% increased risk per year employment
  • 6% increased risk per EMP/cc/year of exposure
• Pulmonary function abnormalities not correlated with dust/silica/EMP exposure
Environmental Study of Airborne Particulate Matter (PM)

George J. Hudak, Ph. D., P. Geo., P. G.
Minerals Division
Natural Resources Research Institute
Environmental Study of Airborne Particulate Matter (PM): What is in the air?

Represents community/environmental component of study

Project Focus: Physically, chemically, and minerallogically characterize mineral dust in 5 Mesabi Iron Range (MIR) communities, 3 background sites, and the 6 taconite plants
MIR Community PM Findings

How much dust is in the communities?

Average mineral dust concentrations are low
No statistical difference in PM compared with the Ely background site
No statistical difference when plants are active/ inactive, suggesting that taconite plant dust mitigation seems to be working well
Are any regulated EMPs found in the communities?

Regulated EMPs were detected in only the east end of the MIR and are rare.

No statistical difference in EMP concentrations when mines/plants are active/inactive.
MIR Plant PM Findings

How much dust is in the plants?

Agglomerator and kiln discharge areas have statistically significant dust levels higher than the crusher and concentrator areas.

There is no statistically significant difference in mineral dust levels by process locations between plants located on the western and eastern MIR.
MIR Plant EMP Findings

Are any regulated EMPs found in the plants?

EMP concentrations were generally not detected in most process areas. When detected in the plants, the concentrations were low. The plant located on the eastern MIR (Zones 3 & 4) had statistically significant higher concentrations of amphibole EMPs in the crusher and concentrator process areas.

<table>
<thead>
<tr>
<th>PROCESS AREA</th>
<th>EMP NOT DETECTED</th>
<th>EMP DETECTED (AVERAGE, EMP/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Crusher</td>
<td>5 Plants</td>
<td>Northshore (0.2)</td>
</tr>
<tr>
<td>Concentrator</td>
<td>4 Plants</td>
<td>Northshore (0.1) Minntac (0.03)</td>
</tr>
<tr>
<td>Agglomerator</td>
<td>6 Plants</td>
<td>No Plants</td>
</tr>
<tr>
<td>Kiln Discharge</td>
<td>6 Plants</td>
<td>No Plants</td>
</tr>
</tbody>
</table>

*Point source samples not to be confused with exposure measurements
EMP = ≥5µm, ≥3:1 aspect ratio, covered minerals
Summary of Component Studies

1. Three occupational exposures of interest:

   Elongate Mineral Particle (EMP)-mostly controlled (at present)

   Non-asbestiform amphibole EMP-controlled (at present)

   Silica-some excursions over TLV (at present)

   Respirable dust-controlled (at present)
Summary of Component Studies

2. Mortality higher than expected for:

Mesothelioma
Lung cancer
Heart disease
Summary of Component Studies

3. Mesothelioma:
   - Is related to time working in the industry
   - Is related to exposure to EMP
     (Twice as many cases in high exposure group)
   - The type of EMP responsible is uncertain
What’s Causing the Mesothelioma Excess?

- Asbestos (asbestiform EMP) most common cause of mesothelioma
- Used in early days of industry
- No exposure information about asbestiform EMP available
- These studies not able to rule out the exposure to asbestiform EMP as a cause of the mesothelioma cases
Mesothelioma

- Non-asbestiform EMP have been much less studied
- It’s possible that they are playing a role in the mesothelioma excess
- Existing information on these EMP from other studies suggests they’re less disease-causing
Summary of Component Studies

4. Lung cancer:

Not related to EMP or silica exposure
Summary of Component Studies

Respiratory Health Survey:

Increased frequency of abnormal chest x-rays in workers (6-7% lung substance; 16.7% lung lining)

Spouses with abnormal chest x-ray comparable to general population (0.5% substance; 4.5% lining)

Pleural disease related to EMP exposure
Summary of Component Studies

Environmental exposure characterization:

• Iron Range communities air safe to breathe (lower particulates than MSP)

• Plants can be dusty but controls appear adequate
Overall Recommendations

(If not being done already):

1. Comprehensive exposure monitoring
2. Electronic data systems for exposure and work status
3. Consider further study of cardiovascular disease
4. Repeat causes of death study in 5 years
5. Update cohort’s mesothelioma status via MCSS
Overall Recommendations

(If not being done already):

6. Exposure avoidance (engineering controls, personal protective equipment, worker education)
7. Comprehensive smoking cessation program
8. Evaluation of existing medical surveillance data
9. Consider post-1982 cohort evaluation
10. Re-evaluate spouses in the future