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
5. Lung cancer case-control

(SPH-Bruce Alexander, Ph.D.)

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

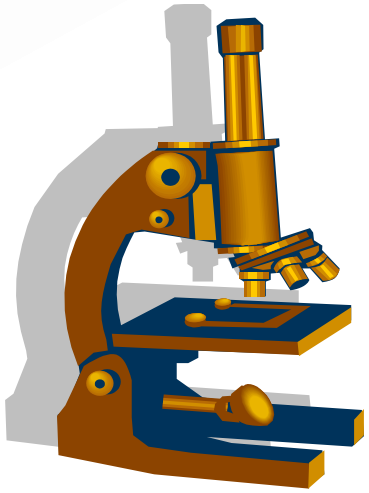
Assessed current and past exposures to Long EMPs in the taconite industry

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

Personal

↓

Poly carbonate cassettes

↓

NIOSH Method 7400 PCM [a] & 7402 TEM [b]

PCM [a] : Phase Contrast Microscopy

TEM [b] : Transmission Electron Microscopy – identification of amphibole EMPs

Elongate Mineral Particles (EMPs)[a]

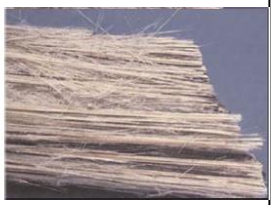
Amphibole EMPs

- Amosite (Cummingtonite-grunerite)
- Actinolite
- Anthophyllite
- Tremolite
- Crocidolite (Riebeckite)

Non-amphibole EMPs

Asbestiform EMPs

Amosite



Actinolite asbestiform

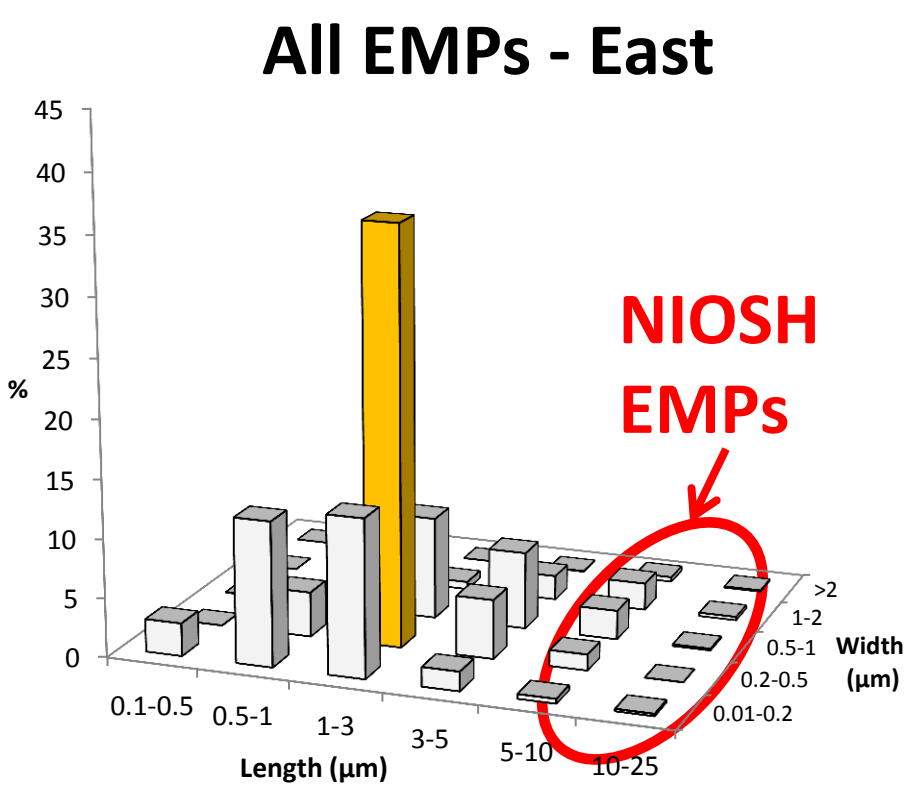
Non-asbestiform EMPs

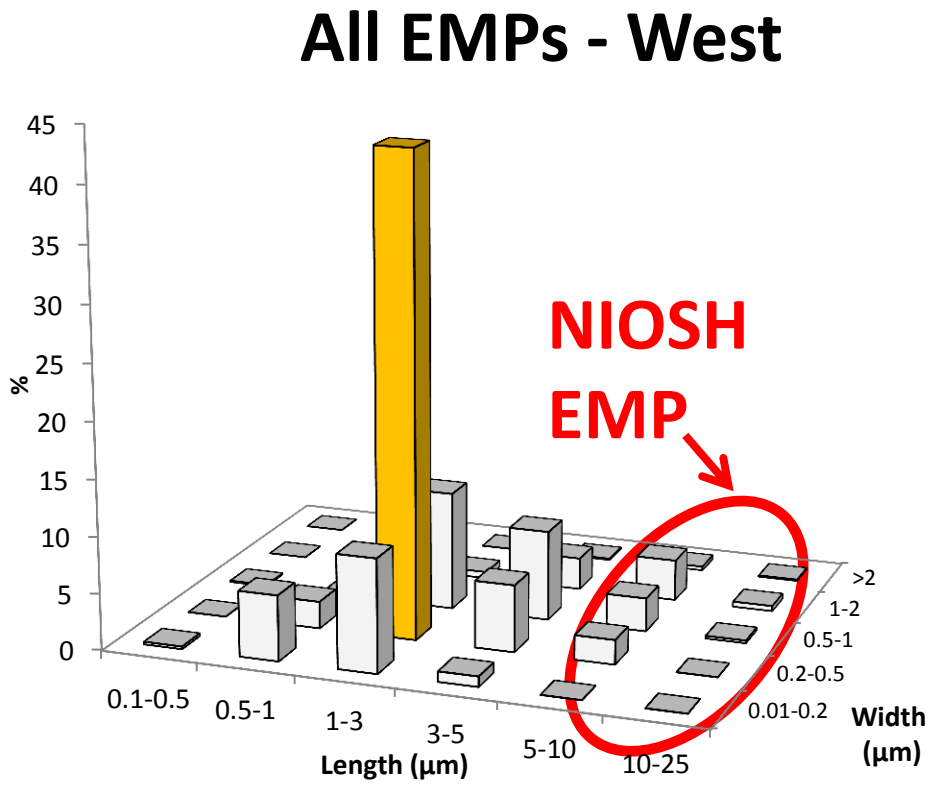
Cummingtonite -grunerite

Actinolite

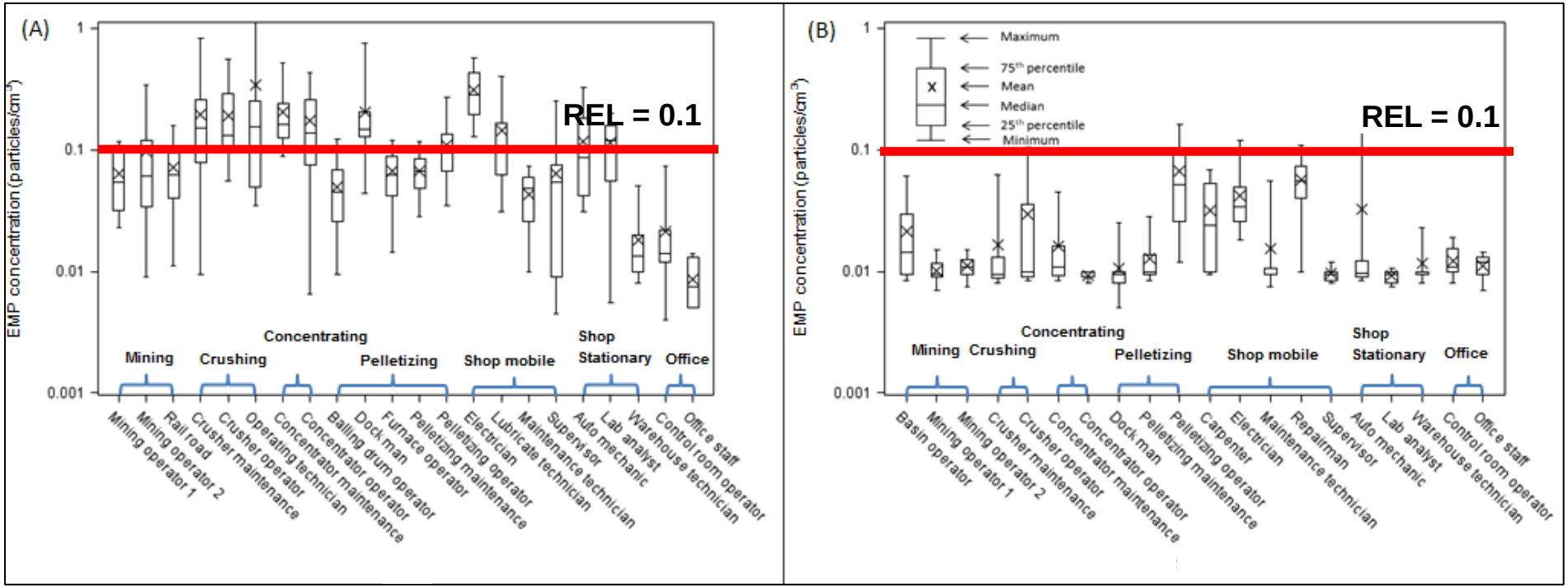
Cleavage Fragments

NIOSH 7400 does not measure short EMPs that are more numerous

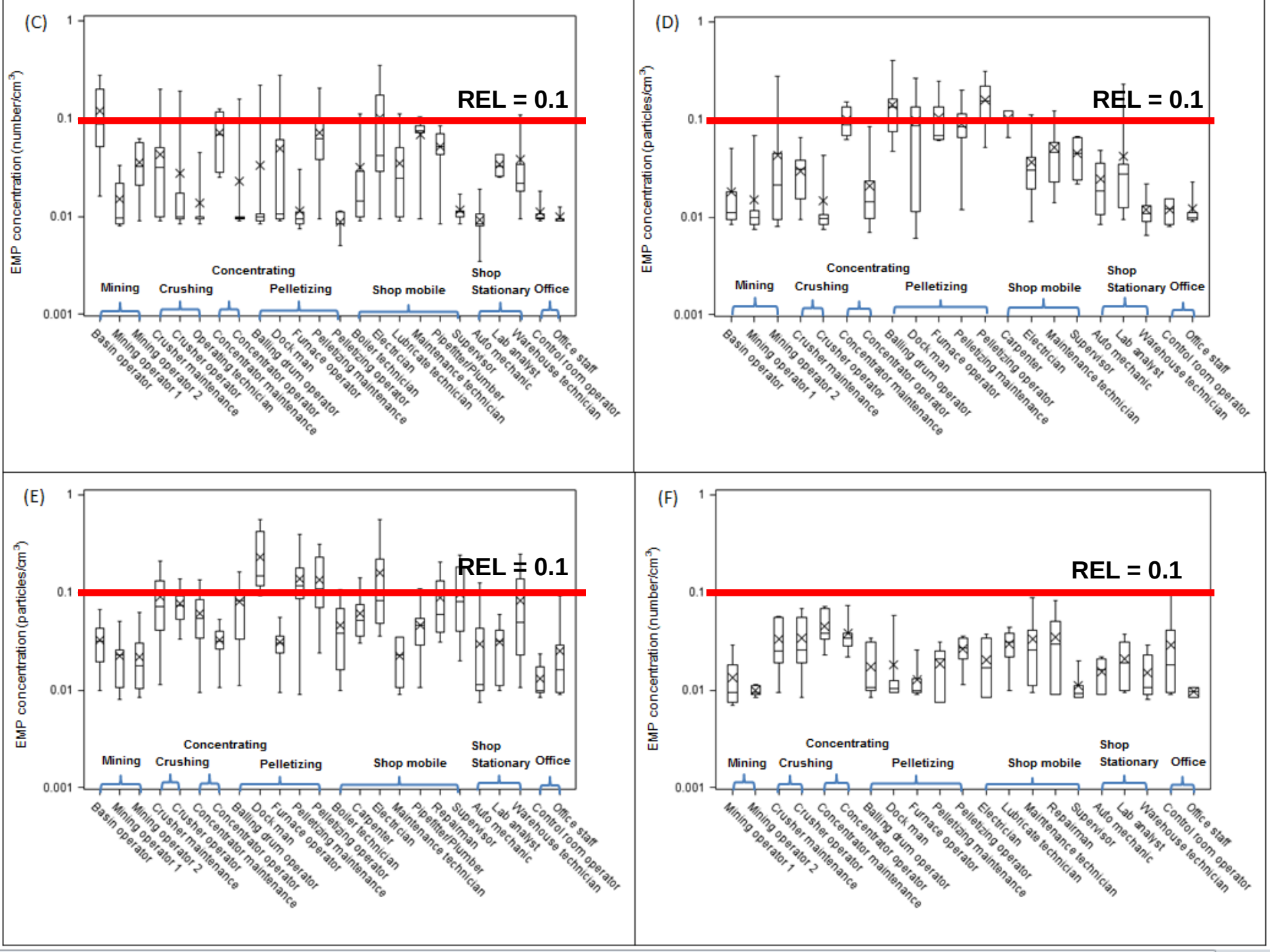




- Exposures in some job groups in some mines are above the NIOSH Recommended Exposure Limit of 0.1 particles/cm^3
- Most job groups have exposures below this limit



*NIOSH Recommended Exposure Limit (REL)


(C)
EMP concentration (number/cm3)
REL = 0.1
Concentrating
Mining
Crushing
Pelletizing
Shop mobile
Shop Stationary
Office
Basin operator
Mining operator 1
Mining operator 2
Crusher maintenance
Crusher operator
Operating technician
Concentrator maintenance
Concentrator operator
Balling drum operator
Dock man
Furnace operator
Pelletizing maintenance
Pelletizing operator
Boiler technician
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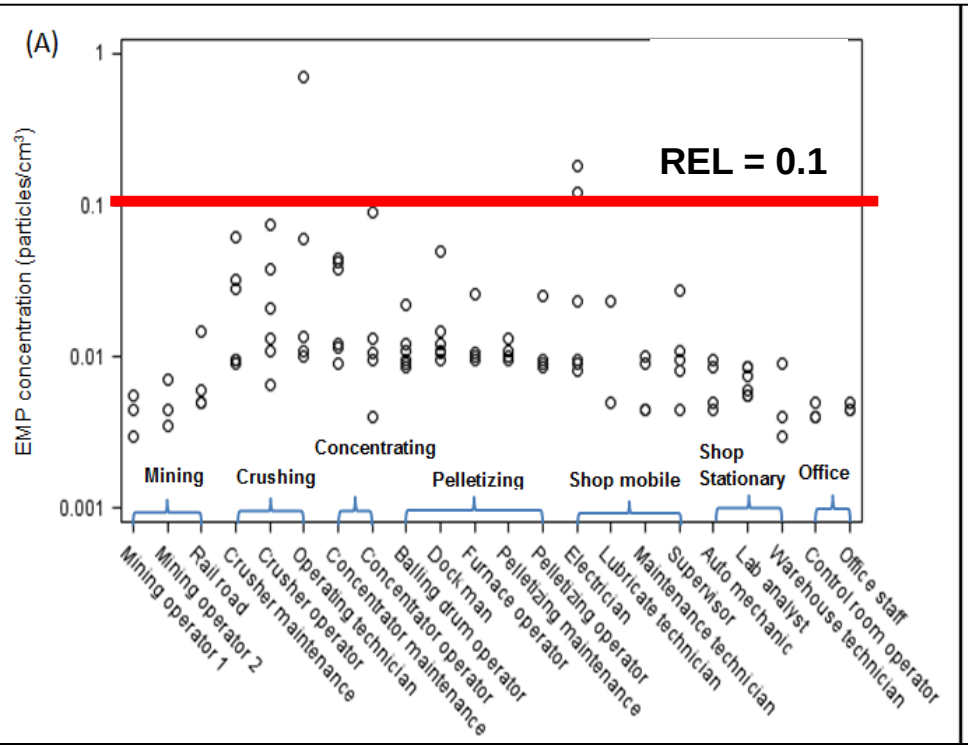
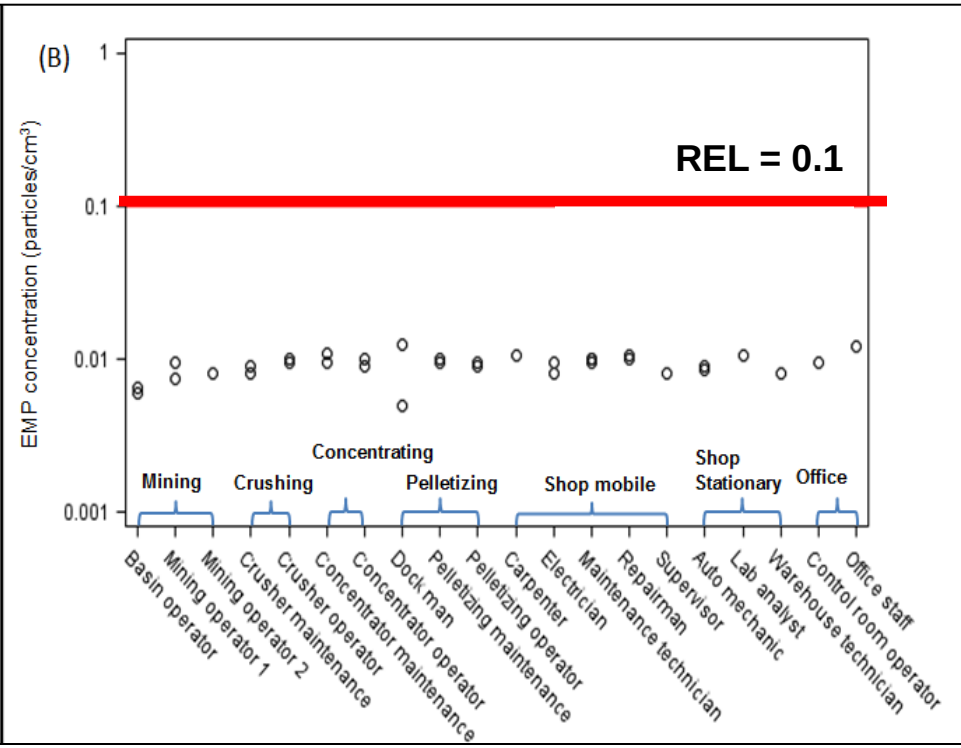
- Almost all amphibole EMPs exposures are below the NIOSH REL of 0.1 particles/cm^3
- Amphibole EMPs exposures are an order of magnitude lower than 0.1 particles/cm^3





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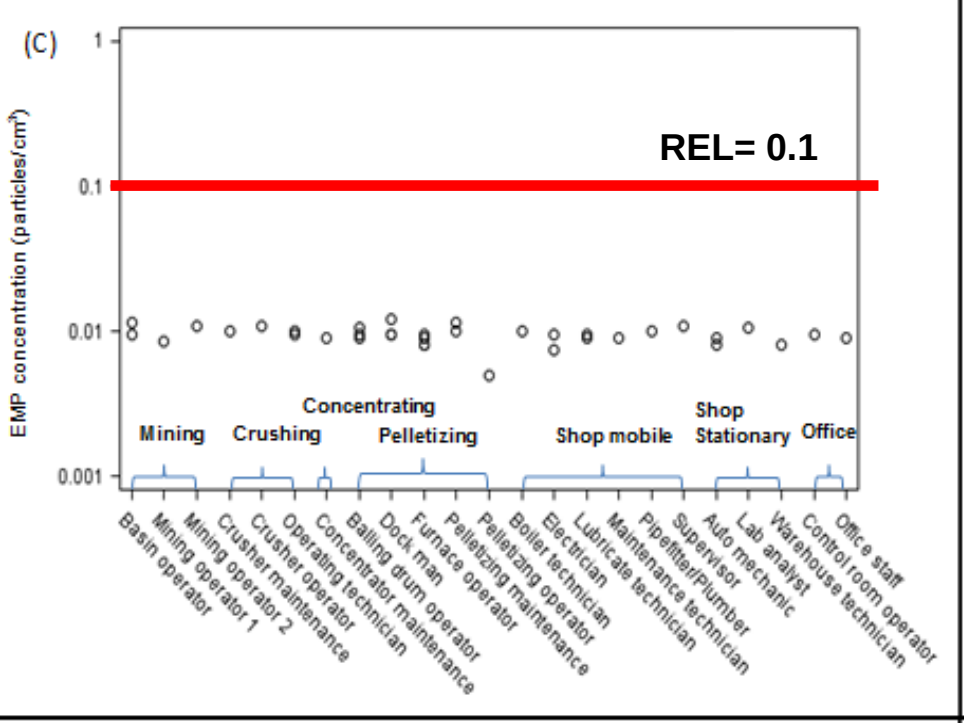
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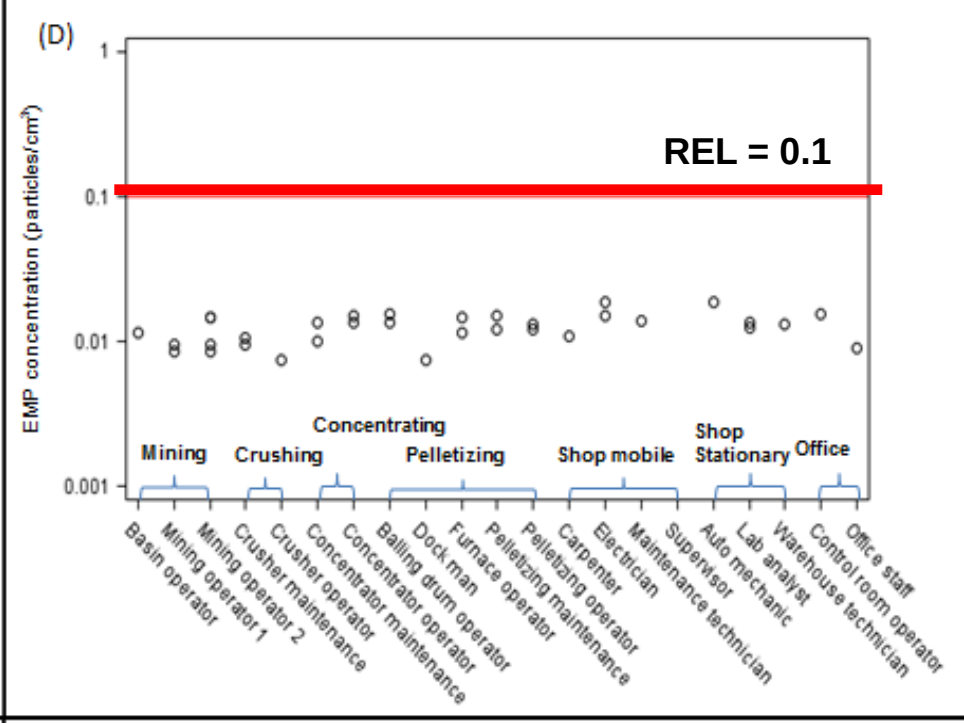
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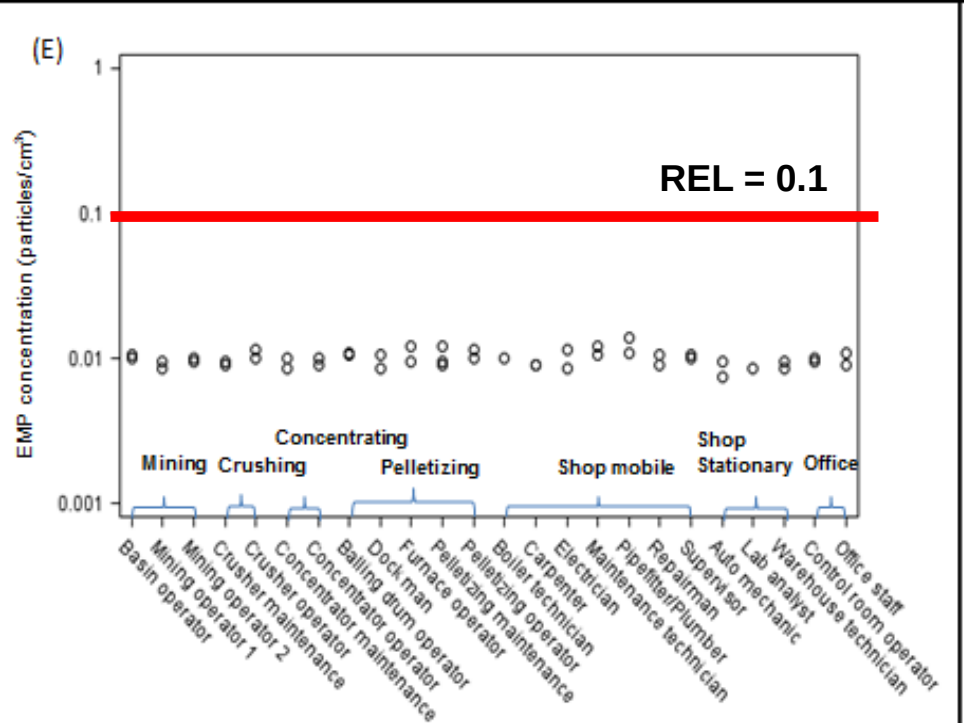
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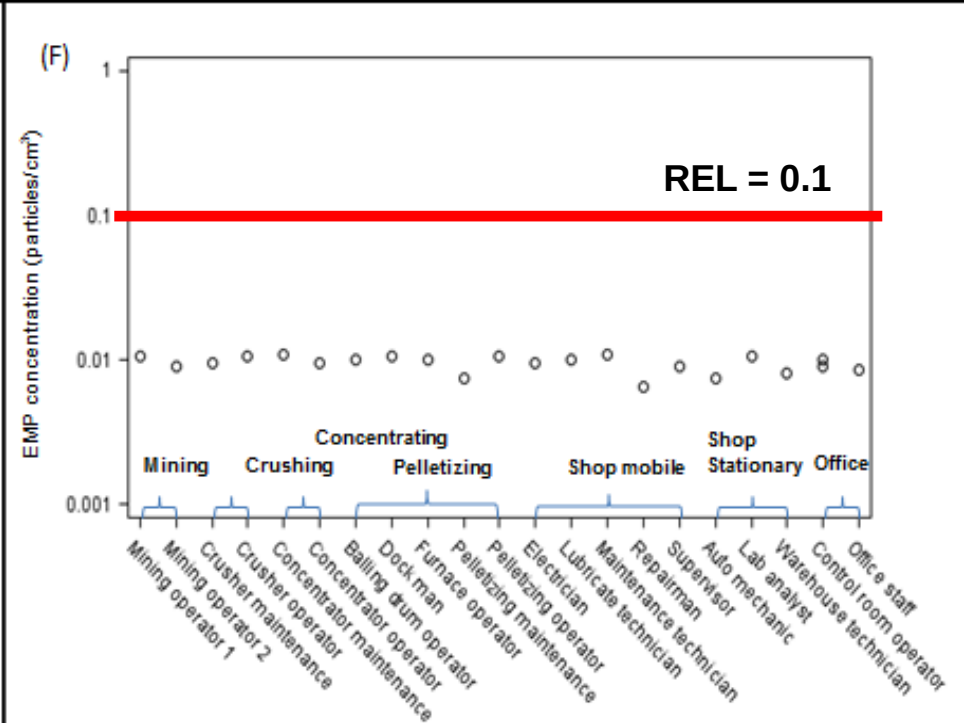
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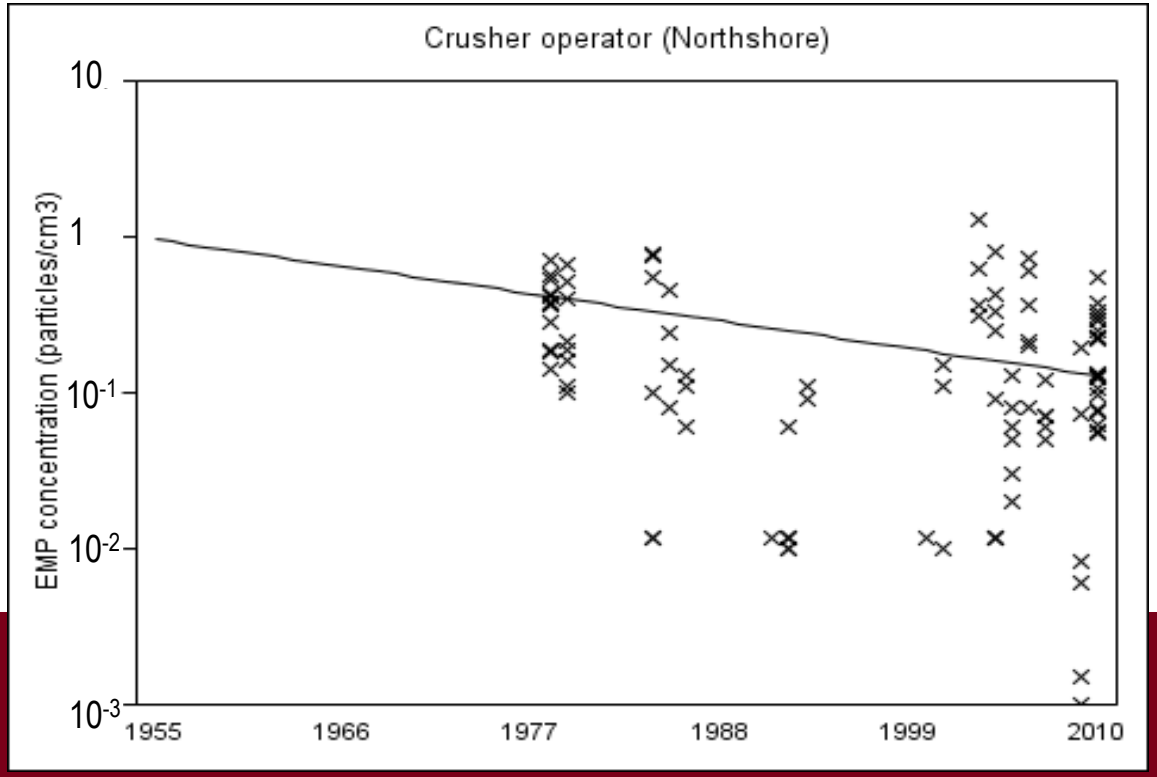
Reconstruction of Past Exposures

- 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

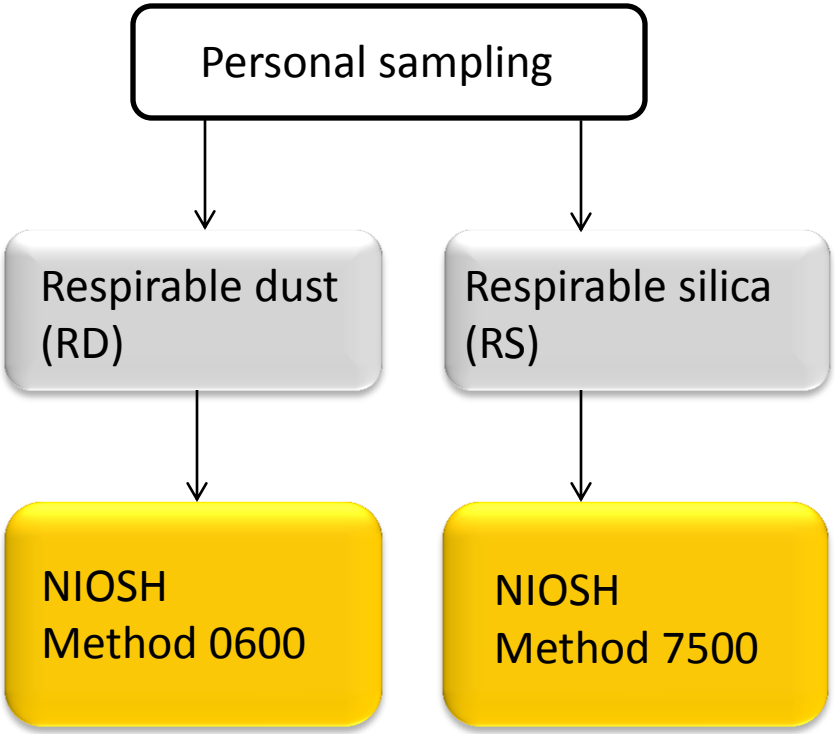
Exposures to total EMPs are low but are above 0.1 EMP/cc* for some jobs

Almost all the amphibole EMPs are below the REL

Total EMPs measures have been decreasing through time

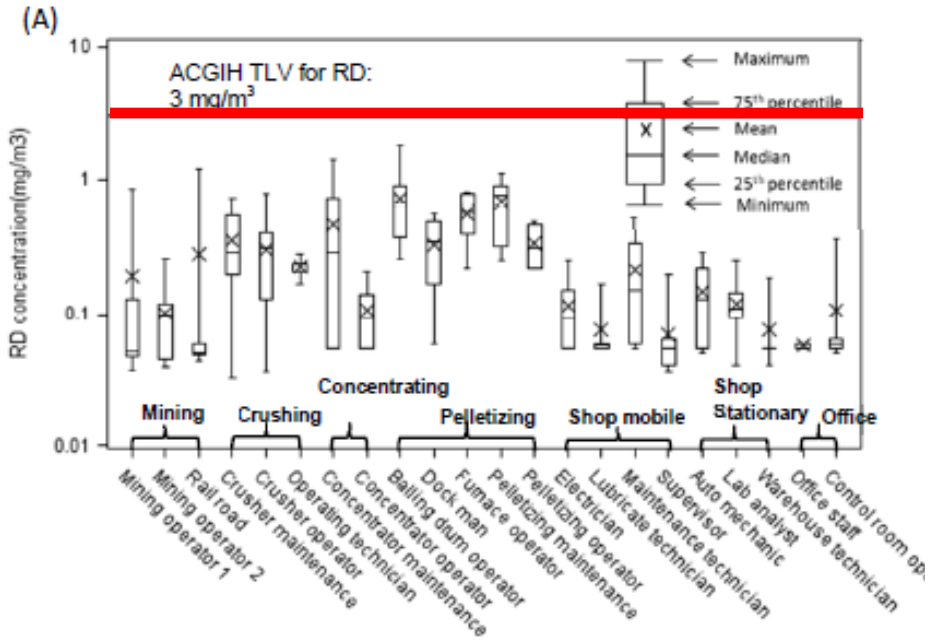
*NIOSH Recommended Exposure Limit (REL)

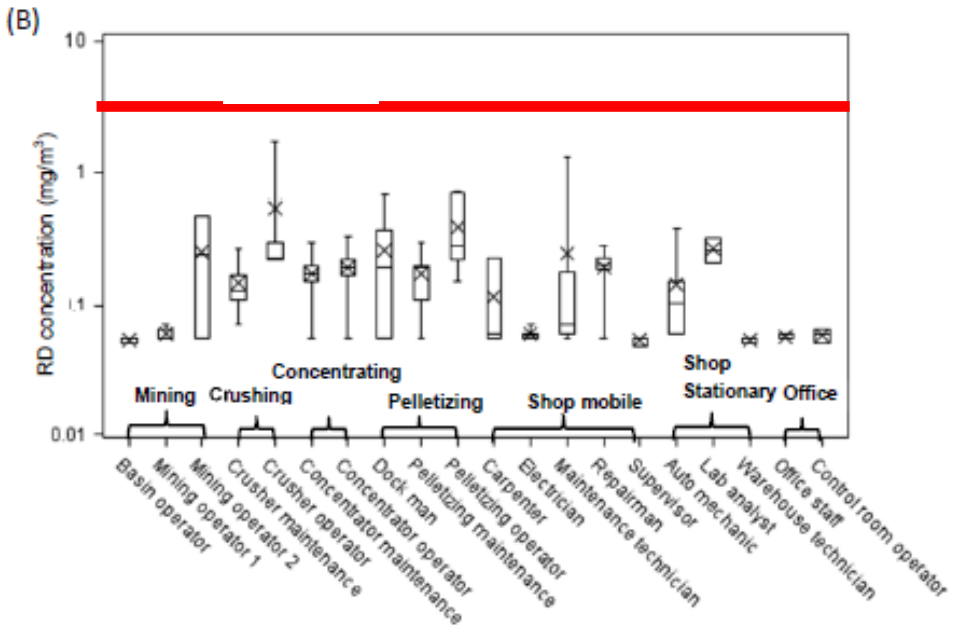
Sampling strategy for present-day RD/RS exposure

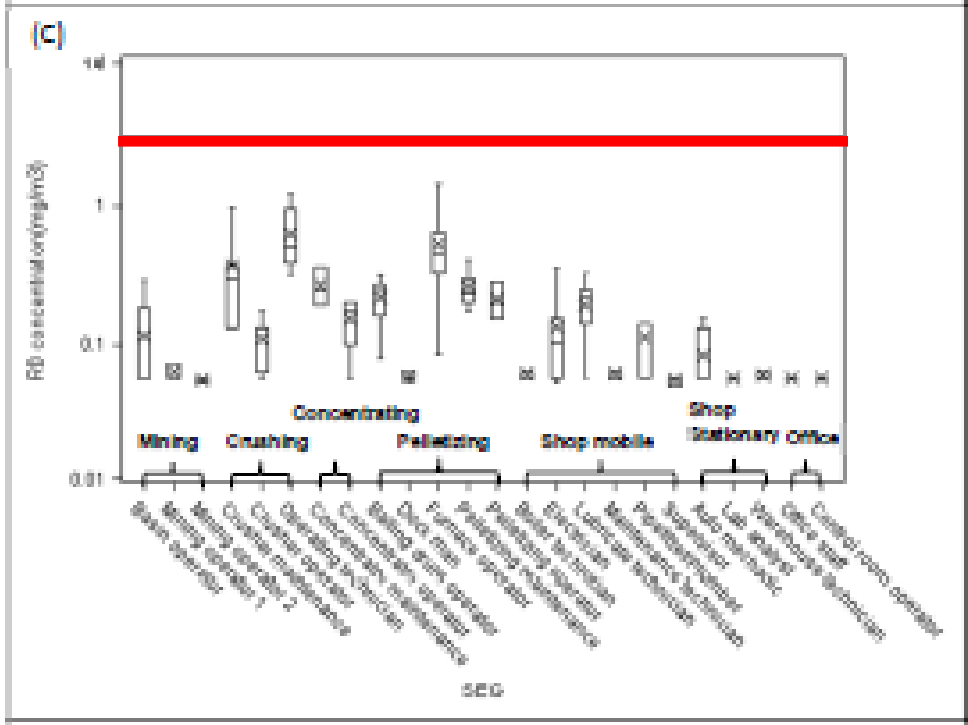


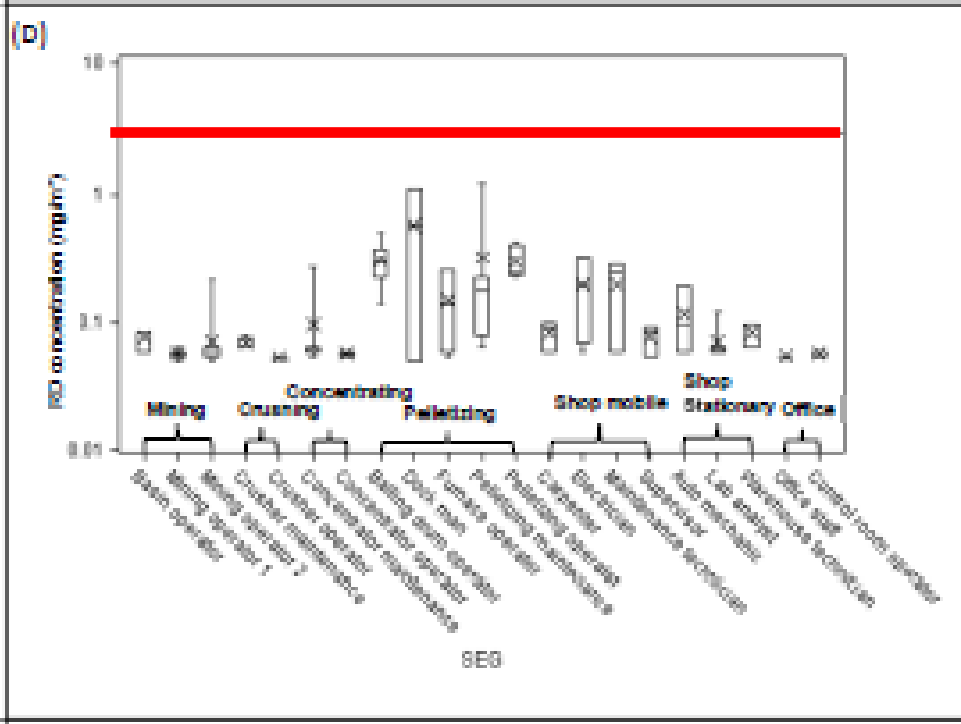
Note: NIOSH Method 0600– Gravimetric (filter weight)
NIOSH Method 7500 – X-ray powder Diffraction

- 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.






(C)
RD concentration(mg/m3)
Mining
Crushing
Concentrating
Pelletizing
Shop mobile
Shop Stationary
Office
SEG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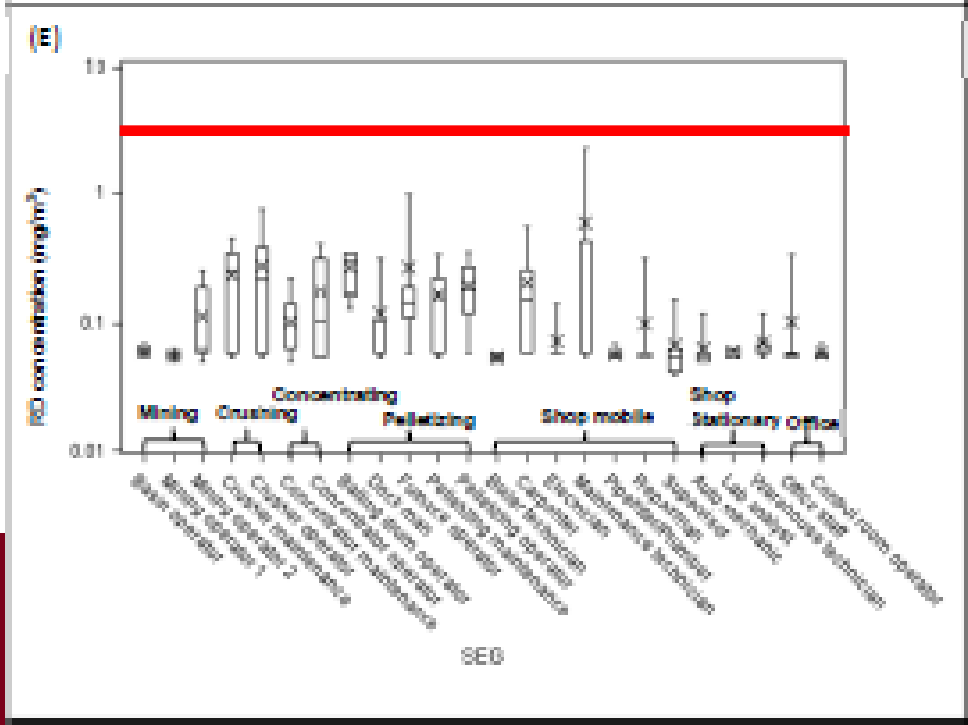
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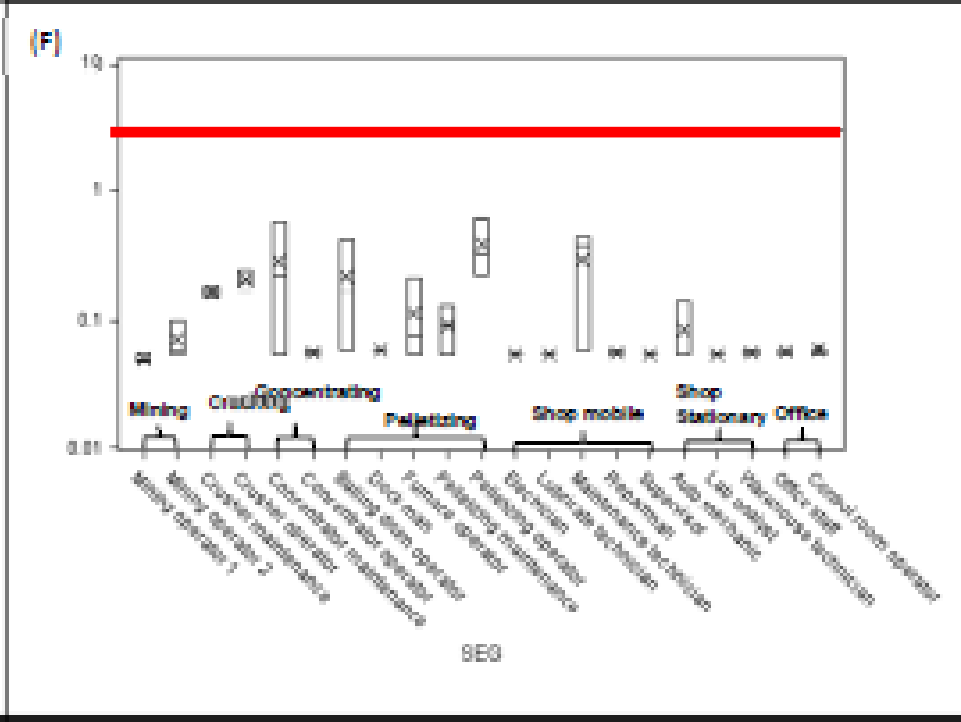
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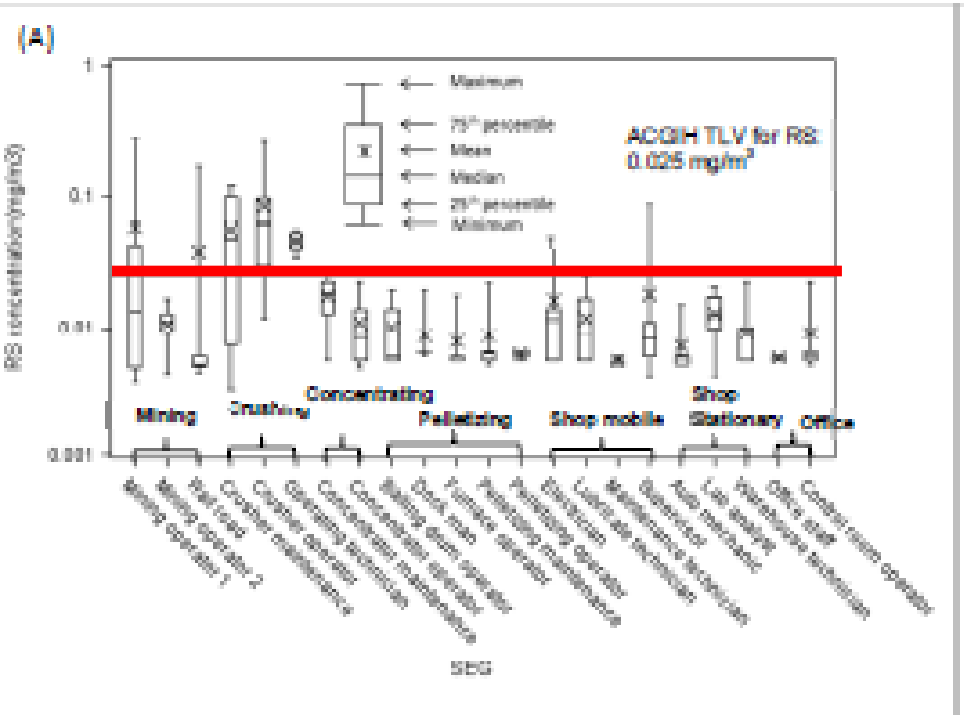
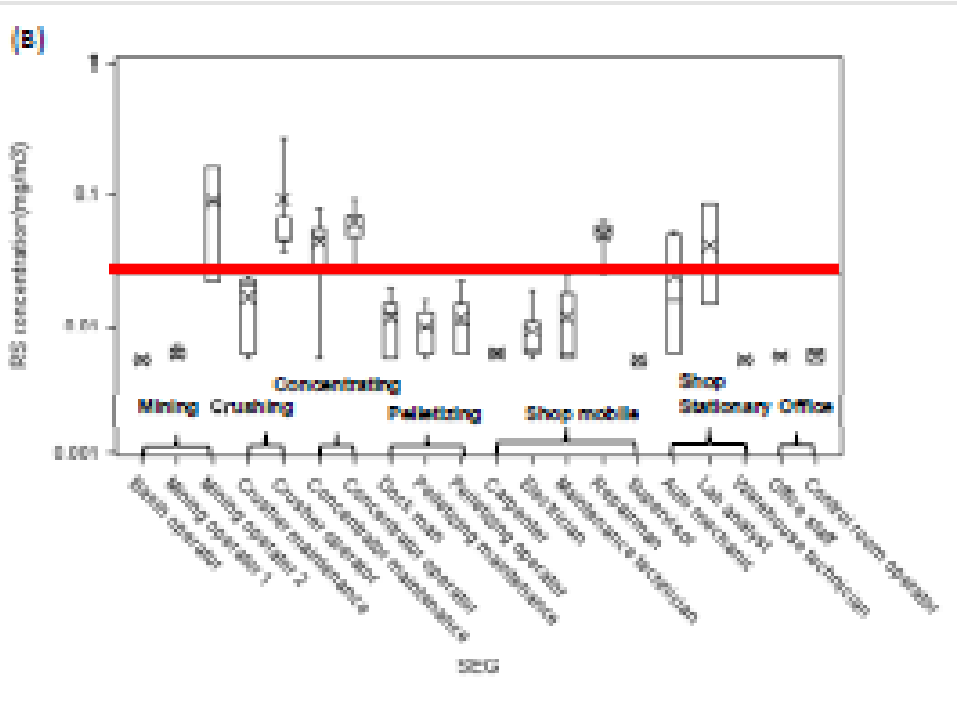
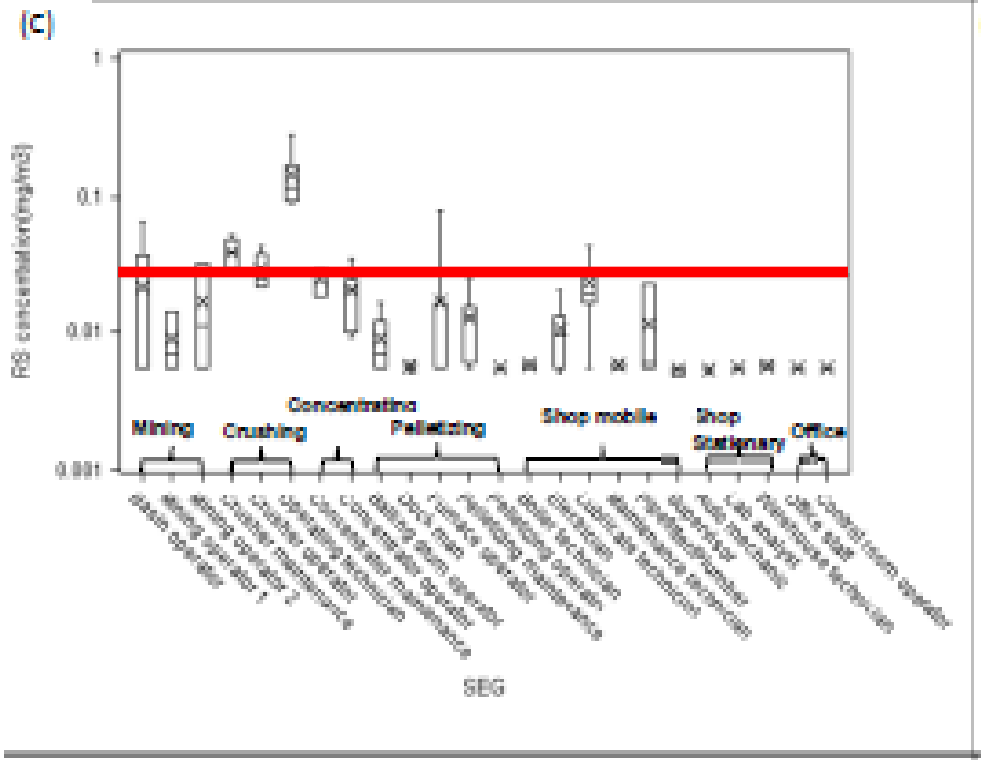
- Except for a few exceptions, the concentrations of RS in the crushing and/or concentration processes were higher than 0.025 mg/m^3, as well as higher than the rest of the taconite processes.



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RS concentration(mg/m3)
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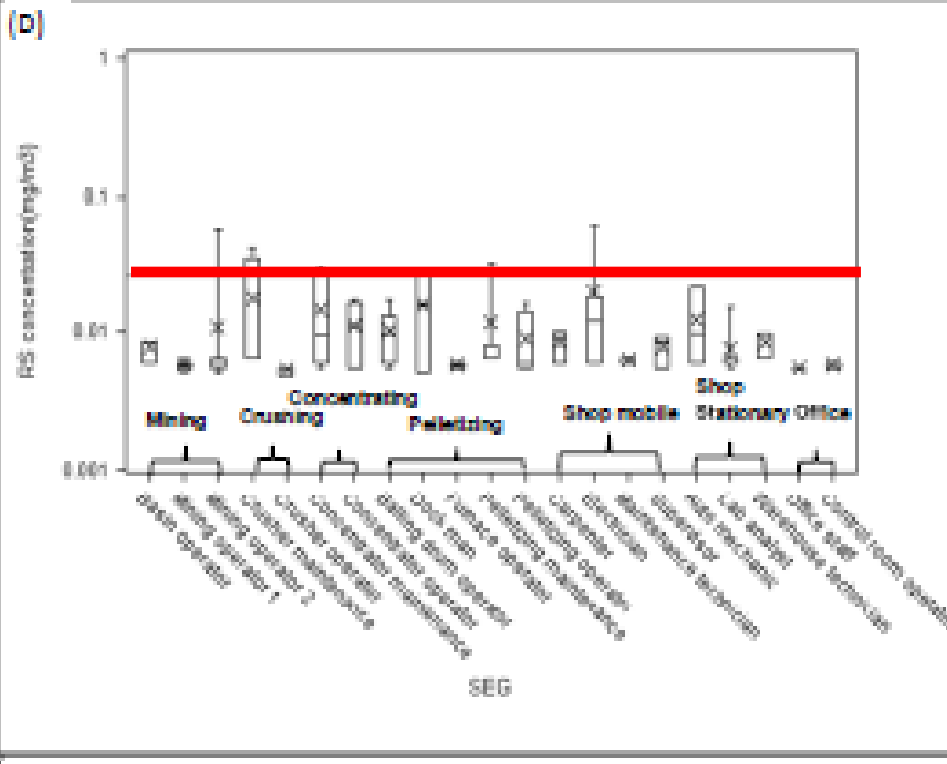
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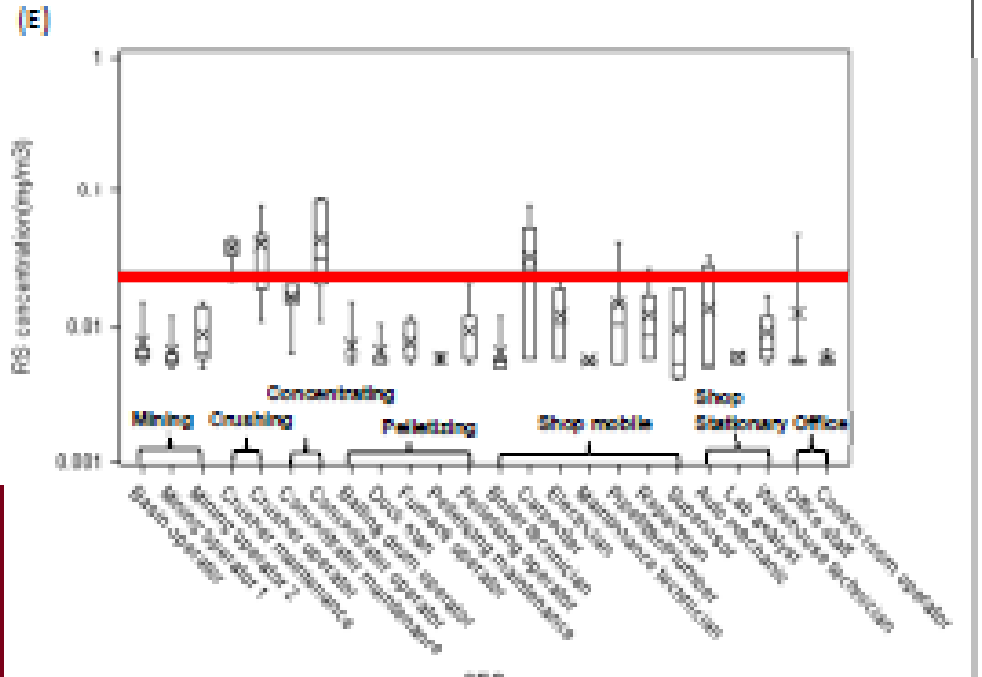
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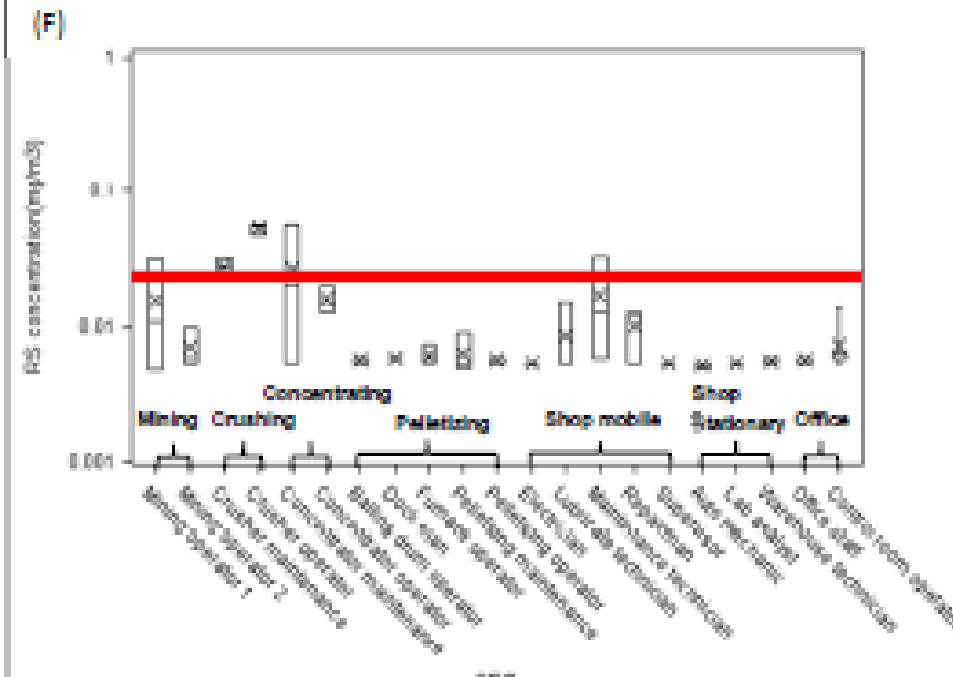
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Assessment of exposure controls

- 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

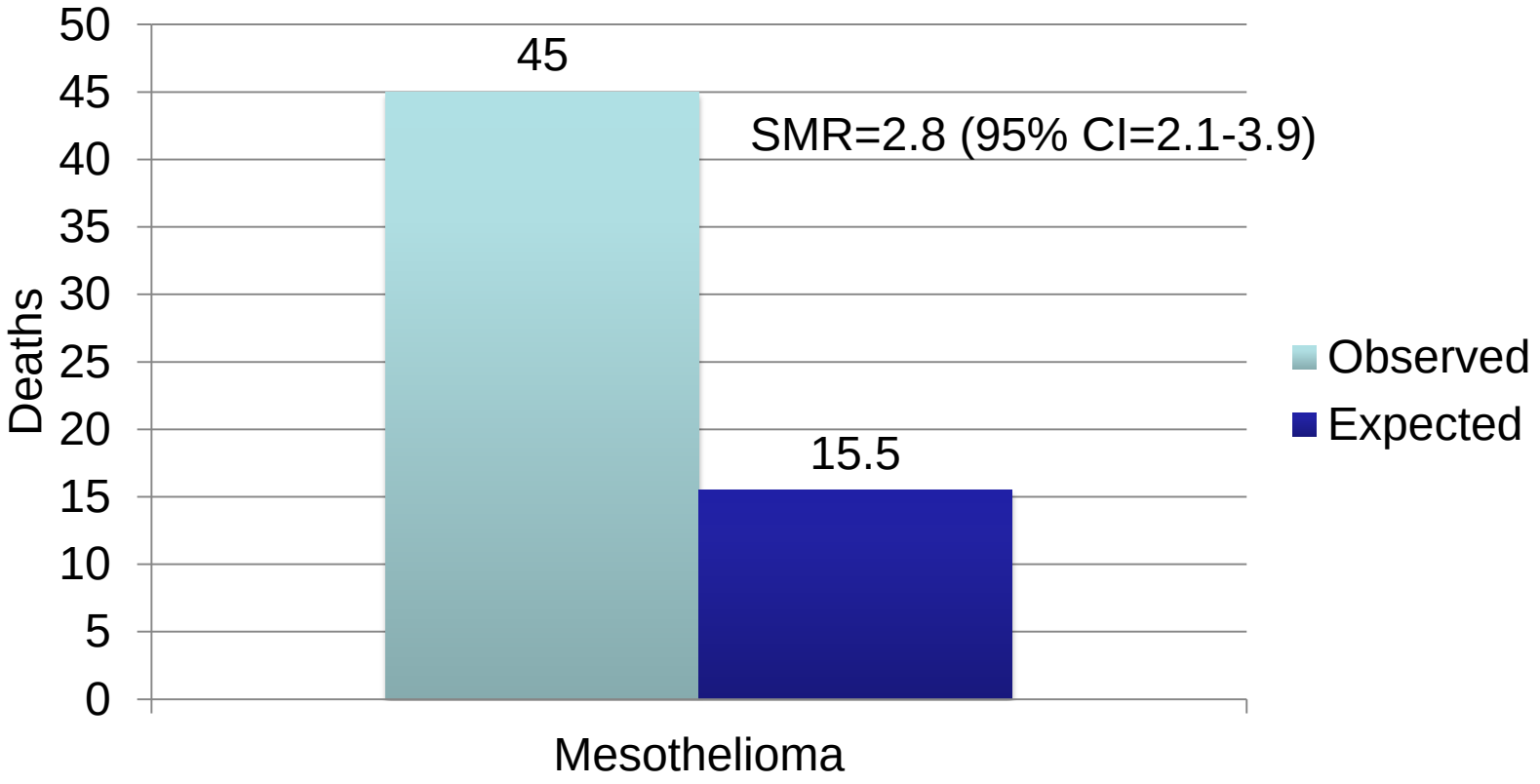
Study Population and All Causes of Death of Iron Mining Workers Born 1920 or Later

Total	44,161
Deaths Identified	13,318
Expected Deaths	12,720

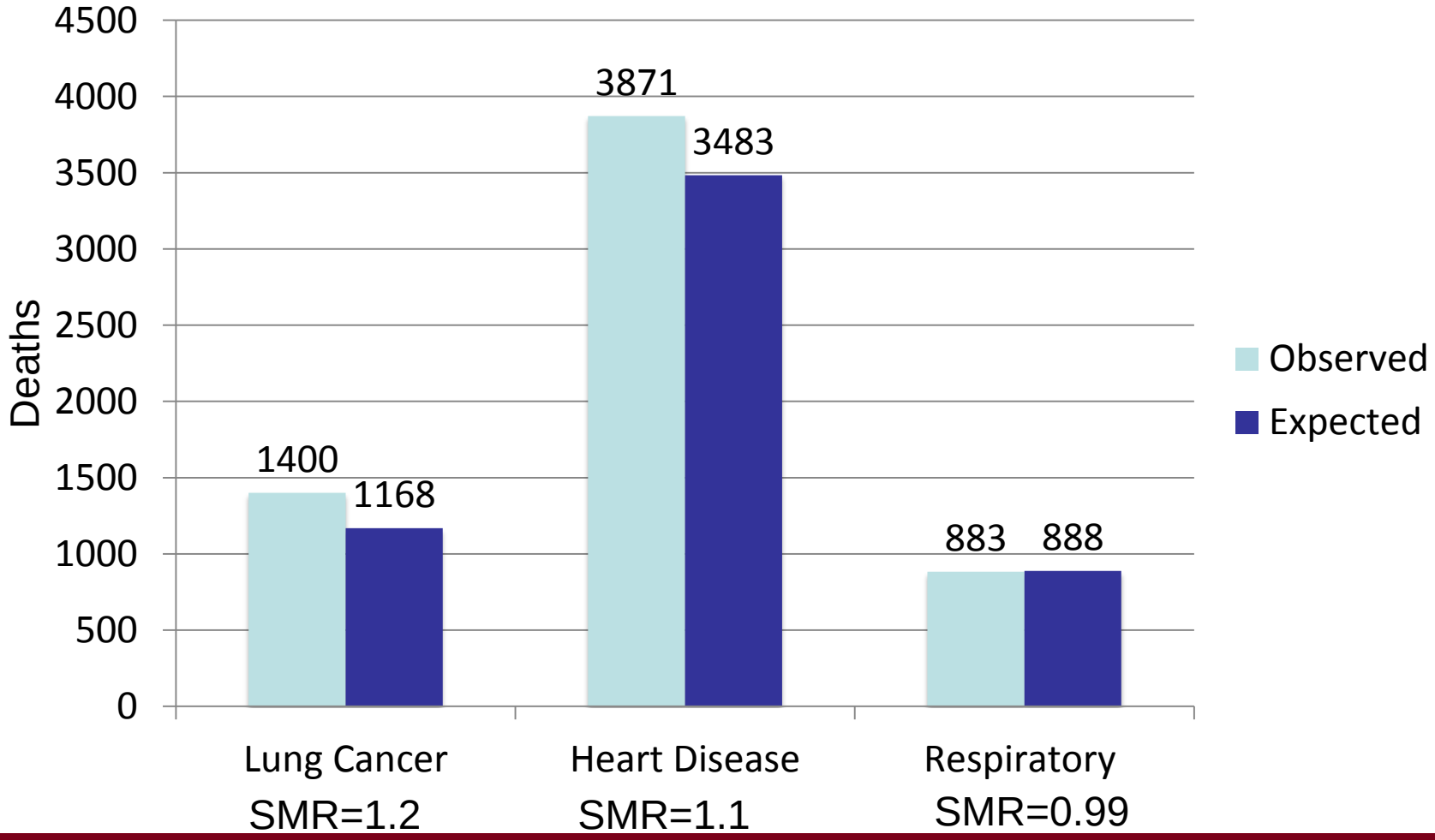
Standardized Mortality Ratio = 1.05

(95% Confidence Interval=1.03-1.06)

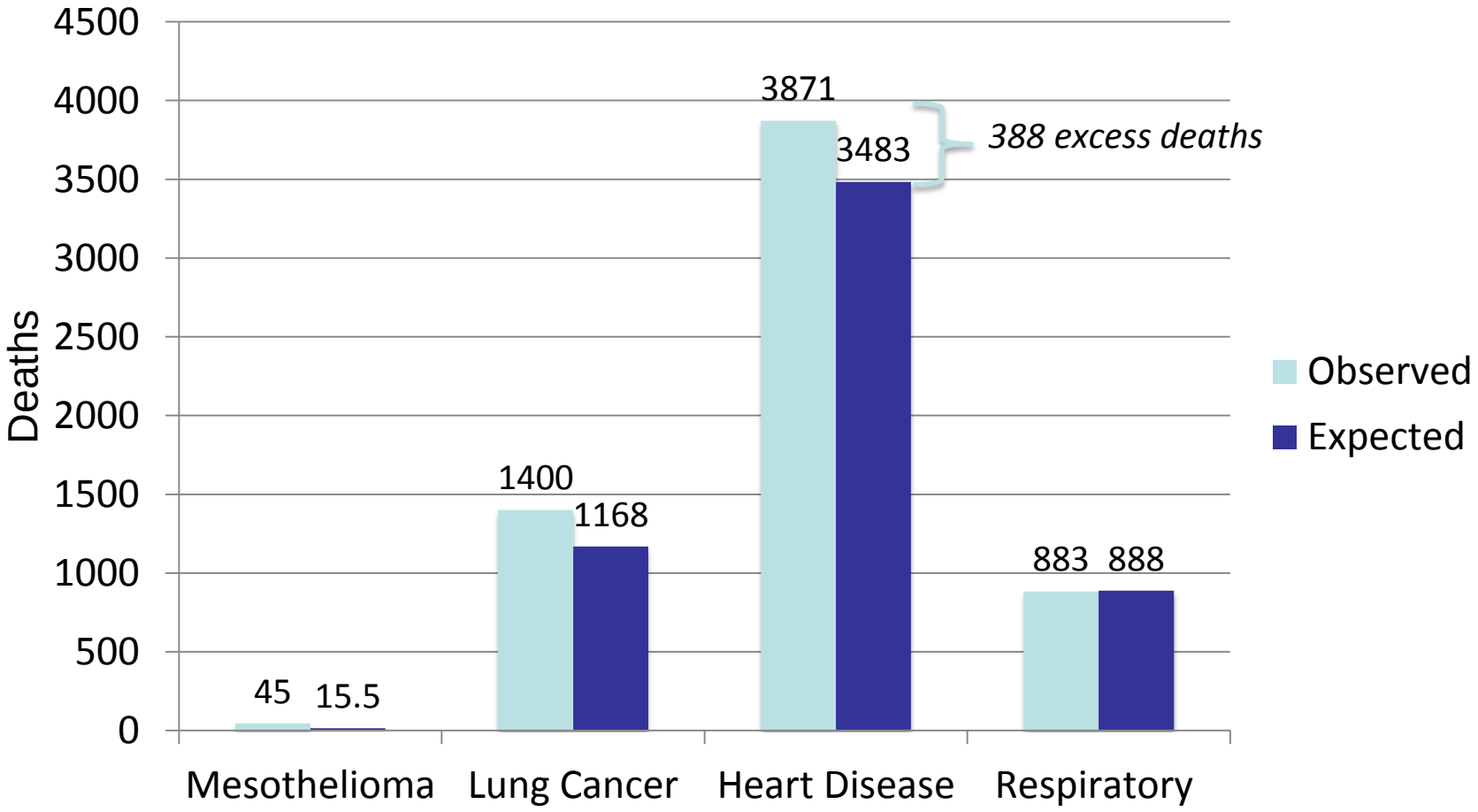
Observed and Expected Mesothelioma Deaths



Observed and Expected Deaths from Lung Cancer, Heart Disease and Other Respiratory Diseases



Observed and Expected Deaths from Mesothelioma, Lung Cancer, Heart Disease and Other Respiratory Diseases



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

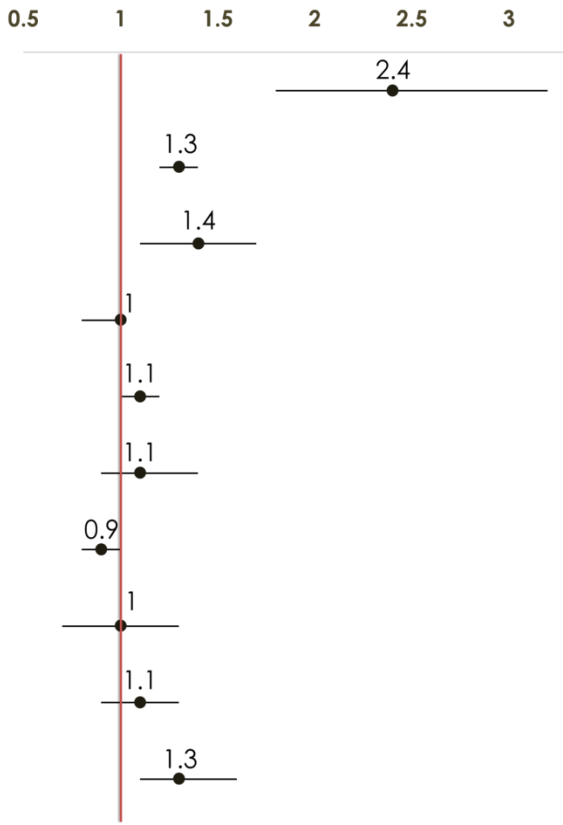
- Compare rates of **cancer diagnoses** in iron mining workers to the general population of Minnesota
- Includes cancers that are not included in the death records
- Compare rates of specific cancer subtypes
- Focus on cancers potentially related to taconite exposures

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.

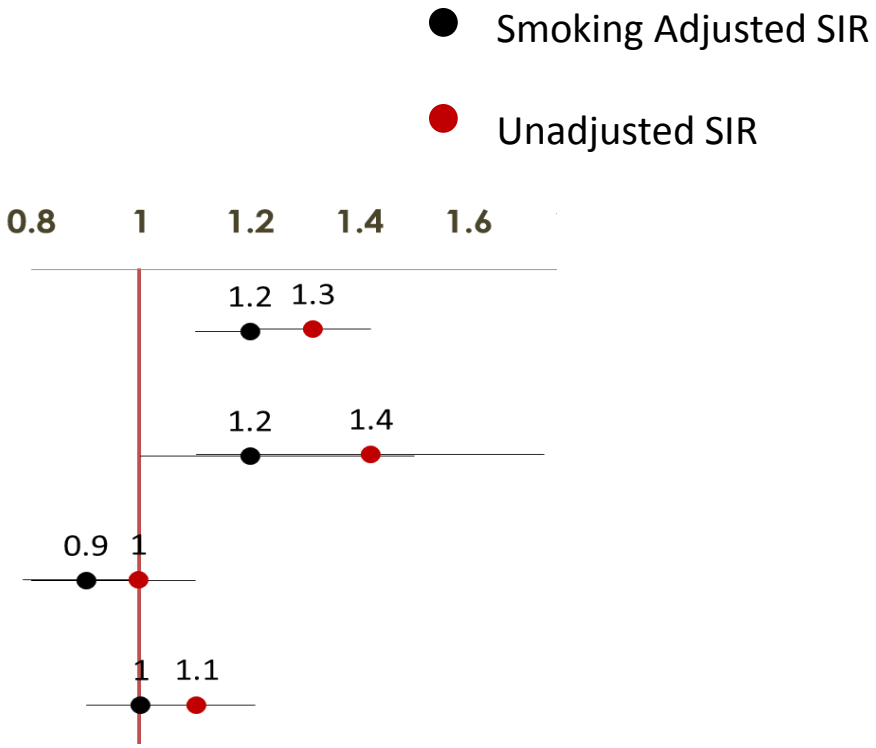
SIRs for Selected Cancers

Cancer	Observed	Expected	SIR (95% CI)
Mesothelioma	51	21.1	2.4 (1.8, 3.2)
Lung	931	726.5	1.3 (1.2, 1.4)
Larynx	93	68.5	1.4 (1.2, 1.7)
Oral	165	159.9	1.0 (0.8, 1.0)
Bladder	359	336.7	1.2 (1.0, 1.2)
Esophagus	87	76.7	1.1 (0.9, 1.4)
Kidney	165	174.3	0.9 (0.8, 1.0)
Liver	50	48.6	1.0 (0.7, 1.3)
Pancreas	110	101.8	1.1 (0.9, 1.3)
Stomach	103	76.4	1.3 (1.1, 1.6)



SIRs Adjusted for Estimated Smoking Rates

Cancer	Smoking Adjusted SIR (95% CI)
Lung	1.2 (1.1, 1.2)
Larynx	1.2 (1.0, 1.5)
Oral	0.9 (0.8, 1.1)
Bladder	1.0 (0.9, 1.1)



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 x year

RR=1.10 (95% CI=0.97-1.24)

- Averaged across the population, a 10% increased risk of mesothelioma per 1 EMP/cc x year

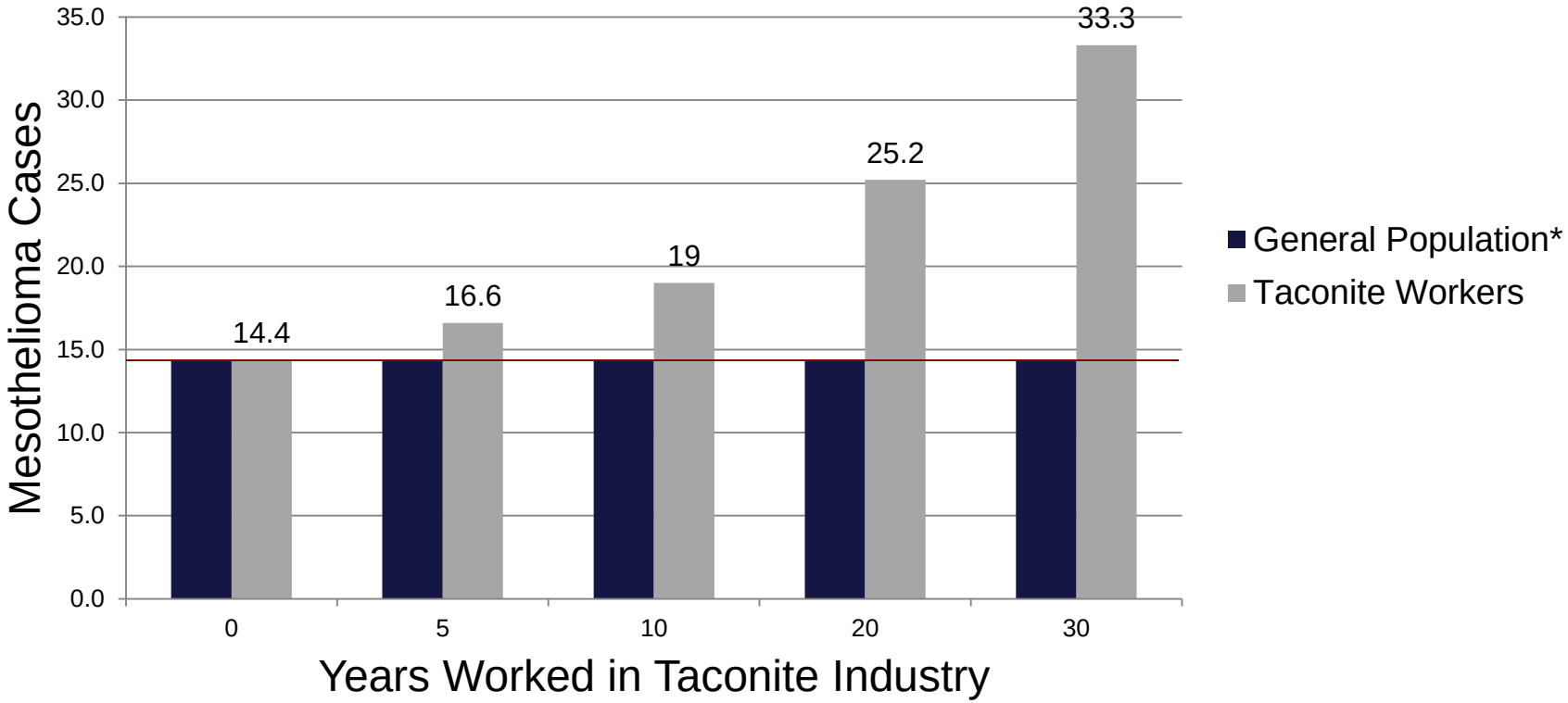
High vs. Low Exposure

RR = 1.93 (95% CI=1.00-3.72)

- (High =above median of 1.15 EMP/cc x 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

	CASES (N=1706) N (%)	CONTROLS (N=3381) N (%)
Sex		
Male	1637 (95.96)	3183 (94.14)
Female	69 (4.04)	198 (5.86)
Ore type		
Taconite only	668 (39.16)	1239 (36.67)
Hematite only	738 (43.26)	1530 (45.28)
Taconite & hematite	300 (17.58)	610 (18.05)

Lung Cancer Risk by Length of Employment

	RR	95% CI
Employment duration		
Taconite years†	0.99	0.96-1.01
Hematite years‡	0.99	0.98-1.01

†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

	RR	95% CI
Total Exposure		
(EMP/cc)-years†	0.95	0.89-1.01
Silica (mg/m^3)-years‡	1.22	0.81-1.83

†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

David Perlman, M.D.
University of Minnesota Medical School

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

Respiratory Health Survey
X-Ray Results

	Parenchymal (Silicosis/Dust)	Pleural (EMPs)
Workers	**5.3%**	**16.7%**
Spouses	**0.6%**	**4.5%**

- 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

Exposure Quartile	Relative Risk	95% Confidence Interval
0 < EMP/cc/years < 1.16	1.00	---
1.16 < EMP/cc/years < 3.29	1.84	1.18-2.94
3.29 < EMP/cc/years < 5.89	2.22	1.42-3.63
5.89 + EMP/cc/years	1.78	1.11-2.98
Duration of Employment	**Relative Risk**	**95% Confidence Interval**
0 < years < 21	1.00	---
21 < years < 30	1.39	0.86-2.26
30 < years < 35	1.65	1.02-2.65
35+ years	1.84	1.11-3.07

Respiratory Health Survey
Pulmonary Function Test Results

	Obstruction	Restriction	Mixed
Workers	**16.8%**	**4.5%**	**2.9%**
Spouses	**11.6%**	**4.4%**	**2.8%**

- 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)

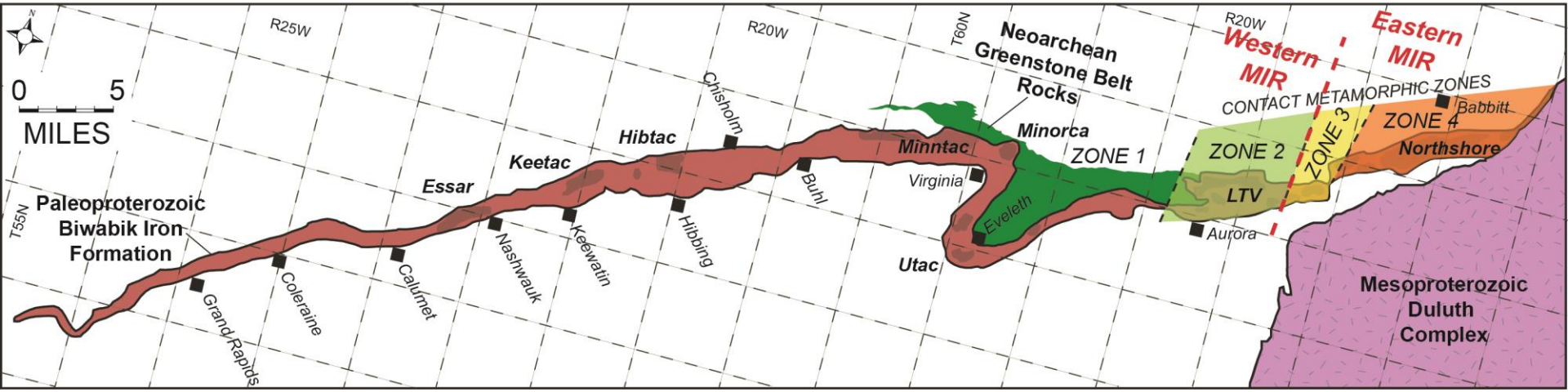
George J. Hudak, Ph. D., P. Geo., P. G.

Minerals Division

Natural Resources Research Institute

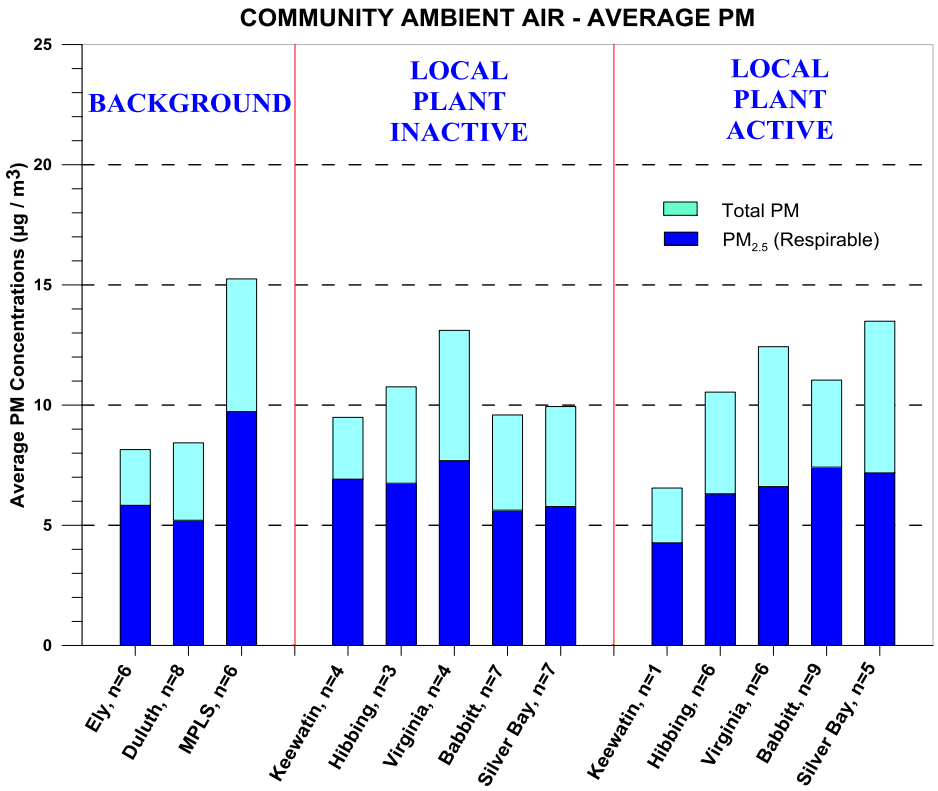
Environmental Study of Airborne Particulate Matter (PM):

What is in the air?



Represents community/environmental component of study
Project Focus: Physically, chemically, and mineralogically characterize mineral dust in 5 Mesabi Iron Range (MIR) communities, 3 background sites, and the 6 taconite plants

MIR Community PM Findings



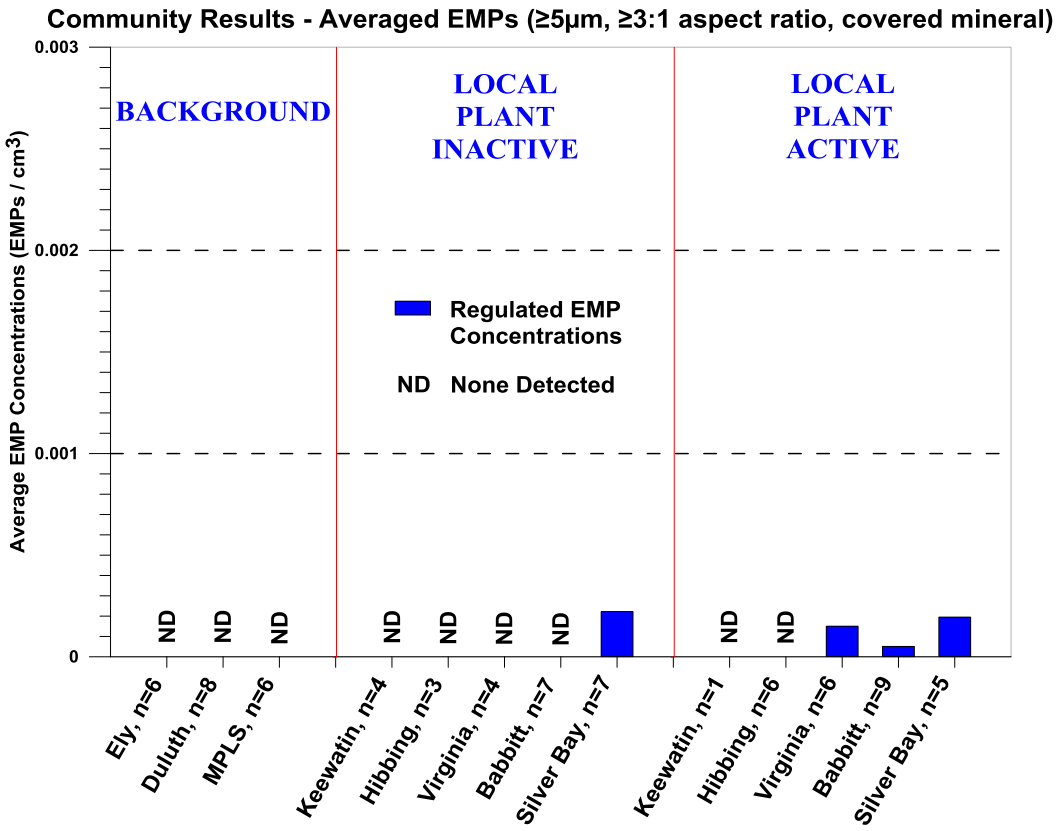
How much dust is in the communities?

- **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**

MIR Community EMP Findings

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**

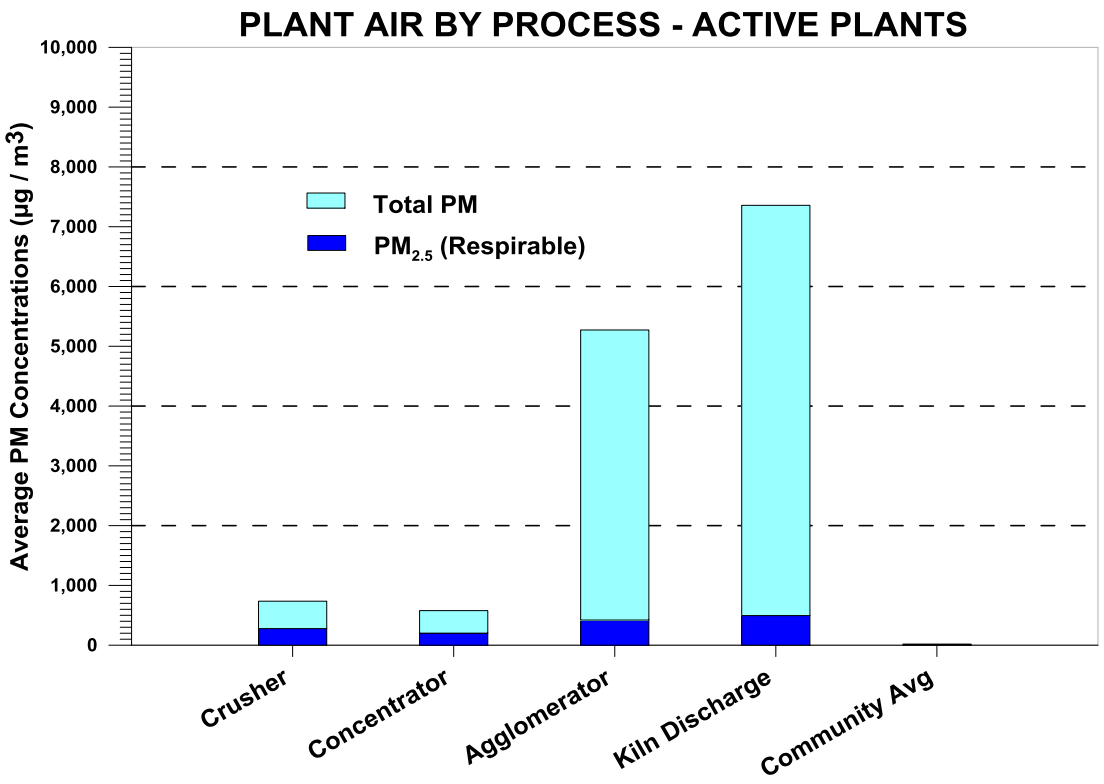


MIR Plant PM Findings

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?

EMPs 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

Plant EMP Concentrations*

PROCESS AREA	EMP NOT DETECTED	EMP DETECTED (AVERAGE, EMP/cm^3)
Secondary Crusher	5 Plants	Northshore (0.2)
Concentrator	4 Plants	Northshore (0.1) Minntac (0.03)
Agglomerator	6 Plants	No Plants
Kiln Discharge	6 Plants	No Plants

*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