Reconstructing historical exposures to elongated mineral particles (EMP) on Minnesota's Iron Range for 1955-2010

Jooyeon Hwang [1], Gurumurthy Ramachandran [1], Peter C. Raynor [1], Bruce H. Alexander [1], Richard F. MacLehose [2], Andrew D. Ryan [1], and Jeffrey H. Mandel [1]

Division of Environmental Health Sciences[1], Division of Epidemiology & Community Health[2], School of Public Health, University of Minnesota, Minneapolis, Minnesota

Introduction

Historical exposure data for mining jobs in the Mesabi Iron Range are sparse. By combining comprehensive present-day exposure levels with the minimal historical data, we generated exposure matrices that provide estimates of exposure levels. The goal of this study is to estimate cumulative total and amphibole elongated mineral particles (EMP) exposure levels to examine the relationship between exposure and mesothelioma.

Methods

Historical EMP measurements (n=682) were extracted from three mining companies and Mine Safety and Health Administration databases. Present-day EMP concentrations (n=1280) were monitored and analyzed using NIOSH 7400 for total EMP and NIOSH 7402 for amphibole EMP. Using present-day and historical data and a quantile regression time-varying exposure model, we reconstructed the exposure for each similar exposure group (SEG) by mine between 1955-2010. The resulting exposure matrix was combined with employment history to estimate a cumulative exposure for each worker.

Table 1. Number of EMP observations by mine in present-day and historical databases

Zone	Mine	Total	Present-day	Historical *
East	A	487	266	190 MSHA/ 31 Company
	G	70	0	70 MSHA
West	B	237	197	40 MSHA
	C	307	218	89 MSHA
	D	233	203	30 MSHA
	E	422	267	90 MSHA/ 65 Company
	F	206	129	77 MSHA
Total N=	7	1962	1280	682

* MSHA: Mine Safety and Health Administration/ Company: Currently operating companies in Mesabi Iron Range

For each mine, $$\log(X)_{ij} = \beta_0^{(p)} + \beta_1^{(p)} year_i + \beta_{ij}^{(p)} SEG_{ij} + \varepsilon_{ij}$$

- $\log(X)_{ij}$: Log concentration of total EMP for the i^{th} year of the j^{th} SEG
- $\beta_0^{(p)}$: Intercept of p^{th} quantile
- $\beta_1^{(p)} year_i$: Slope of p^{th} quantile at the i^{th} year
- $\beta_{ij}^{(p)} SEG_{ij}$: Slope of p^{th} quantile at the i^{th} year of the j^{th} SEG
- ε_{ij} : Random error effects at the i^{th} year of the j^{th} SEG

Results

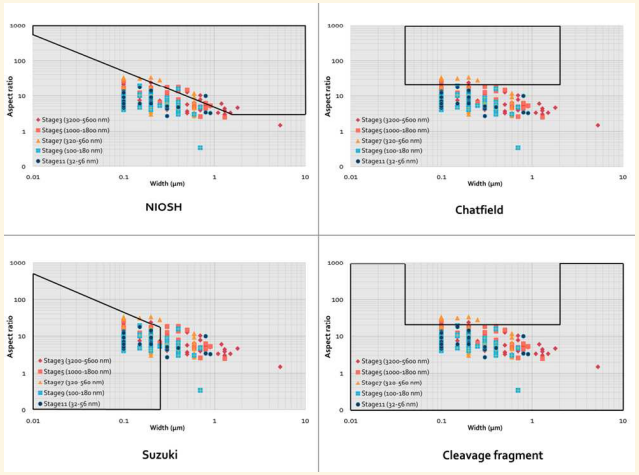

Fig 1. Illustration of the effect of different definitions of EMP on measured EMP concentrations. The black boxes indicates the dimension-based EMP exposure metrics based on the NIOSH, Chatfield, Suzuki, and cleavage fragment definitions.

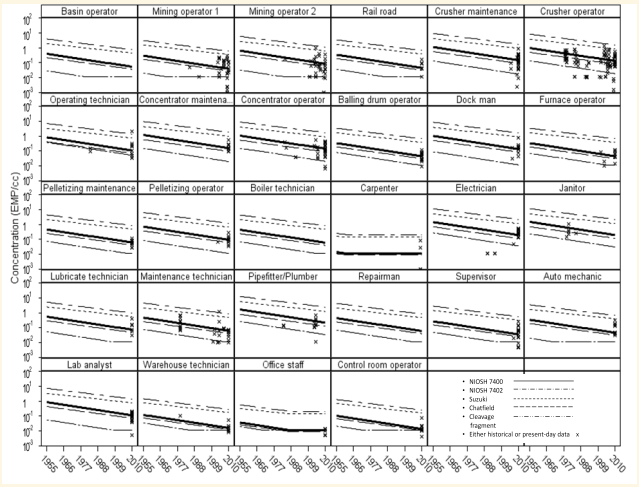

Fig 2. Model-based exposure panel matrix for total EMP (NIOSH 7400, Suzuki, Chatfield, and Cleavage fragments) and amphibole EMP (NIOSH 7402) by SEG for mine A. Scatterplot displays actual NIOSH 7400.

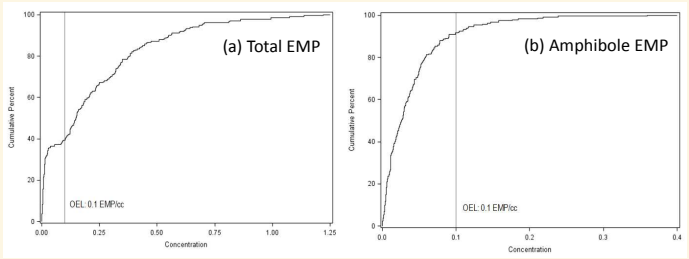

Fig 3. Cumulative distribution function for the average exposure concentration using time-varying exposure models for combined cases and controls (n=241) for (a) NIOSH 7400 and (b) NIOSH 7402

Conclusions

- Exposure matrices for total and amphibole EMP were developed using historical and present-day data for each SEG by mine between 1955-2010. The matrix contains 10976 estimates (28 SEGs and 7 mines for 56 years) using a quantile regression time-varying exposure model.
- Exposures were reconstructed for four size-based EMP definitions for the epidemiological study. There are no overlapping areas between the NIOSH and Suzuki or Chatfield and Cleavage fragment definitions. Very few EMP were identified by the NIOSH and Chatfield definitions, while many were identified by the Suzuki and Cleavage fragment definitions (**Fig 1**).
- Across all mines, the exposure levels for total cleavage fragment EMP and total Suzuki EMP were similar over the years, as were the levels for total Chatfield EMP and NIOSH 7400. In addition, exposure estimates calculated using the Cleavage fragments and Suzuki definitions were higher than those calculated using Chatfield and NIOSH 7400. This observation is consistent with measurements from area sampling using a MOUDI cascade impactor, in which the total EMP were found to be primarily short with a small aspect ratio. Because the amphibole EMP measured using NIOSH 7402 are a fraction of the total EMP measured using NIOSH 7400, the level of exposure estimates for amphibole EMP are lower than for all the other definitions as shown in the exposure panel plots (**Fig 2**).
- Using the time-varying exposure model for the average exposure for total EMP, a majority of historical EMP levels exceeded the OEL. Based on the cumulative distribution for average total and amphibole EMP exposure concentrations, ~60% of the workers in the mesothelioma case control study had lifetime average total EMP exposure levels greater than the occupational exposure limit (OEL: 0.1 EMP/cc) and ~8.3% of the workers had amphibole EMP levels exceeding the OEL (**Fig 3**).

Acknowledgements

State of Minnesota, Minnesota Department of Health, and Taconite mining companies (U.S. Steel, Cliffs Natural Resources, and Arcelor Mittal)