Method to Convert Fiber Counts Asbestos and Non-asbestos Based on NIOSH 7400/7402 into Counts Based on Other Fiber Definitions

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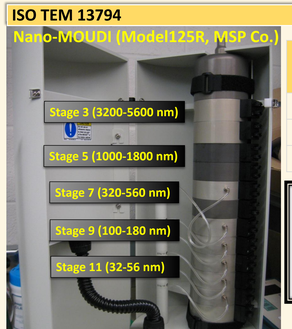
Introduction

Different definitions of asbestos fibers have been proposed as most relevant to respiratory health end-points such as mesothelioma and lung cancer. We demonstrate a methodology to convert personal exposures to asbestos fibers using NIOSH 7400/7402 methods into exposures based on different ranges of fiber length and width.

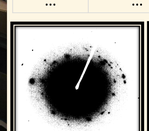
Methods

ISO TEM 13794

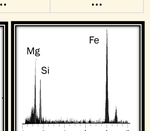
Nano-MOUDI (Model125R, MSP Co.)



Fiber	Dimension (µm)	
	Length	Width
Fiber 1	0.35	0.01
Fiber 2	0.70	0.25
...	...	...



Electron diffraction (ED)



Energy disperse x-ray analysis

NIOSH 7400 PCM

Definition: > 5 µm in length and ≥ 3 µm in aspect ratio

Counting: fiber dimension and fiber shape

NIOSH 7402 TEM

Identification: asbestos fibers and non-asbestos fibers

Counting: PCM + ISO TEM

Figure 1. Asbestos fiber area size fraction sampler and sampling analysis (above) and personal sampler (below).

Table 1. Number of area & personal asbestos fiber samples per mine

Zone *	Mine	SEGs	Workers	Fiber samples /worker	Personal sample	Area sample
Eastern	Northshore	22	56	6	332	110
Western	Keetac	21	34	6	220	105
	Minntac	24	46	6	325	120
	ArcelarMittal	22	22	6	159	110
	Hibbtac **	22	34	6	239	110
	Utac **	27	38	6	285	135
Total		**230**			**1560**	**690**

* Amphiboles which are regulated as asbestos are prevalent in eastern zone while phyllosilicates which are regulated as non-asbestos are prevalent in western zone.

** Sampling analysis is in progress.

$$\text{Conversion factor}_{ijzy} = \frac{F_{ijzy}}{FNIOSH_{iy}}$$

- Conversion factor $_{ijzy}$ = Each fiber definition to NIOSH conversion factor for SEG_i, fiber diameter $category_j$, length $category_z$, and $zone_y$
- F_{ijzy} = Proportion of all PCM fibers that are equivalent to TEM fibers in SEG_i and $zone_y$ and that fall into fiber diameter $category_j$ and length $category_z$ by each fiber definition
- $FNIOSH_{iy}$ = Proportion of all PCM fibers that are equivalent to TEM fibers that are counted using the NIOSH definition for SEG_i and $zone_y$

Results

Results show that the conversion factors (CF) varied by the geologically different eastern (CF=0.43-5.21, p <0.05) and western (CF=0.13-1.74, p <0.05) zones of the Iron Range. Using the variance components of exposure, we were able to calculate the contrast between the 27 similar exposure groups (SEGs) into which the workers in the taconite industry were classified. A high contrast (Ɛ) in fiber exposures was observed between the SEGs based on all fiber definitions (Ɛ=0.84-0.94).

Table 2. Conversion factor from the regression model (SAS 9.2)

Authors	Asbestos		Non-asbestos	
	Eastern	Western	Eastern	Western
Suzuki	5.21	1.74(0.27) *	0.43	0.13
Stanton	NA	NA	1.06	1.01
Chatfield	0.45	NA	0.98	1.01
Lippmann	NA	NA	1.07	1.01
Pott	1.58	0.94	0.91	0.97
Stayner	NA	NA	1.07	1.01

* ( ) is the intercept and all conversion factors are based on p < 0.5.
Both slope and intercept were zero by Quinn asbestos fiber definition.

Table 3. Different asbestos fiber definitions

Authors	Year	Width	Length	Aspect ratio	Analysis methods
Suzuki et al.	2005	≤0.25	≤5	NA	Electron microscopy
Stanton et al.	1981	≤0.25	>8	NA	Electron, light
Chatfield	2007	0.04< W < 1.5	NA	20< AR< 1000	TEM
Quinn et al.	2000	<6	>5	≥3	SEM, TEM
Lippmann*	1988	<0.1	>5	NA	NA
Pott et al.	1974	<1	>3	>5	NA
NIOSH A rule	1994	NA	>5	≥3	PCM
Stayner et al.	2008	<0.25	10<L<20	NA	PCM, TEM

*This fiber dimension is indices of mesothelioma.

$$\varepsilon = \frac{S^2_{BG}}{S^2_{BG} + S^2_{WG}} \qquad \pi = \frac{1}{\sqrt{S^2_{WG}/k + S^2_{WJ}/kn}}$$

Assumptions : $\alpha_i \sim N(0, \sigma^2_{BG})$, $\beta_{ij} \sim N(0, \sigma^2_{WG})$, $\varepsilon_{ijk} \sim (0, \sigma^2_{WW})$

$\sigma^2_{BG} \approx S^2_{BG}$, $\sigma^2_{WG} \approx S^2_{WG}$, $\sigma^2_{WW} \approx S^2_{WJ}$

$\sqrt{S^2_{BG}} = GSD_{BG}$, $\sqrt{S^2_{WG}} = GSD_{WG}$, $\sqrt{S^2_{WW}} = GSD_{WW}$

Hans Kromhout and Dick Heederik, Occupational epidemiology in the rubber industry: Implications of exposure variability, AJIM 27: 171-185

The original formation of SEGs was focused on exposure to asbestos fibers. Therefore, new SEGs based on the mean of non-asbestos fiber concentration in the western zone were created for non-asbestos fiber exposures. Three different sets of SEGs (n=27, 12, and 6) were created to compare the contrast (0.06, 0.09, 0.20, respectively)

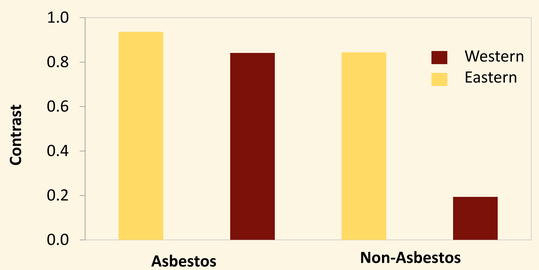


Figure 2. Contrast by asbestos and non-asbestos fiber definitions for each zone

Conclusion

- Analysis demonstrated the importance of well-defined SEGs when inferences are made regarding exposures based on different fiber definitions.
- The conversion factor for asbestos fibers has a larger range of values in the eastern zone.
- The conversion factor for non-asbestos fibers has a larger range of values in the western zone.
- Contrasts between SEGs were higher in the eastern zone than in the western zone for asbestos and non-asbestos fibers.
- The high contrast between SEGs indicated that exposure misclassification will be minimized in epidemiology studies based on them.

Acknowledgements

State of Minnesota and Minnesota Department of Health

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