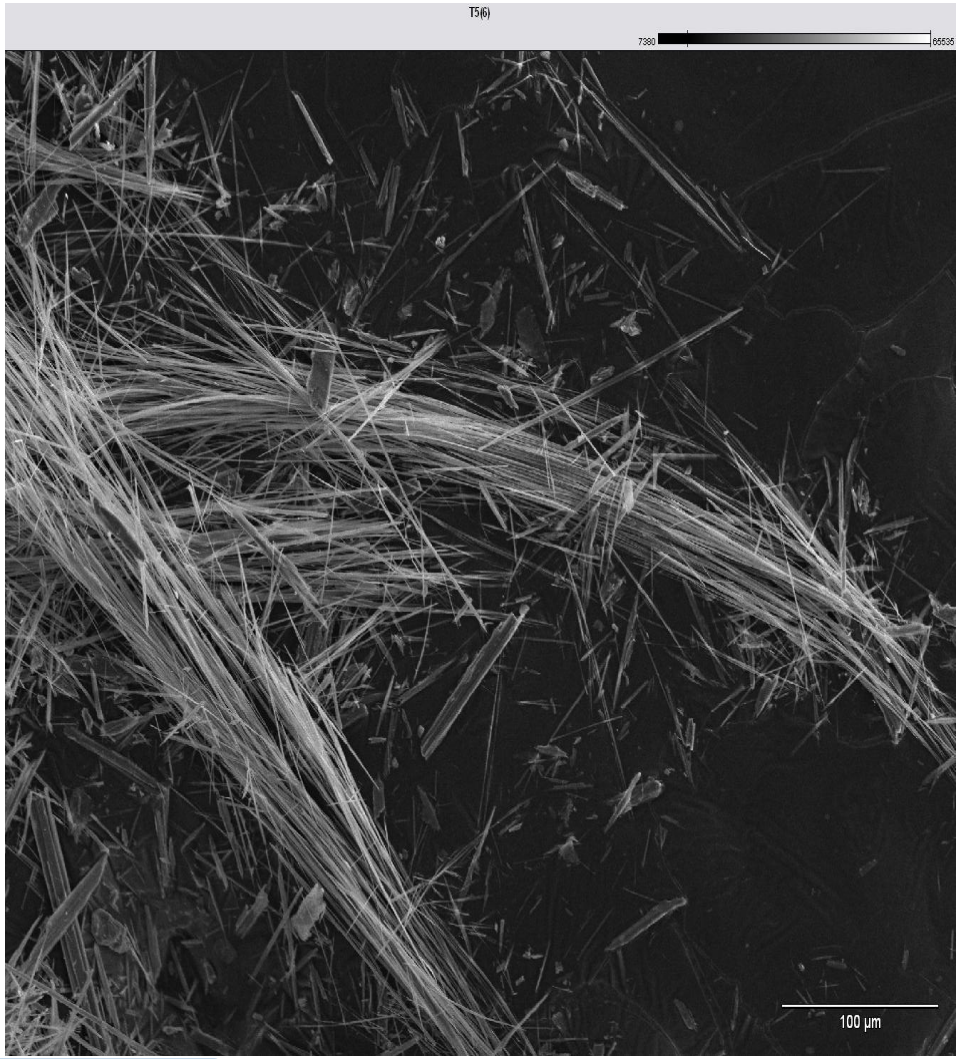
EMP Research at NIOSH: Actualizing the Asbestos/EMP Roadmap



EGU 2020 online

4 May 2020

Presentation Definitions

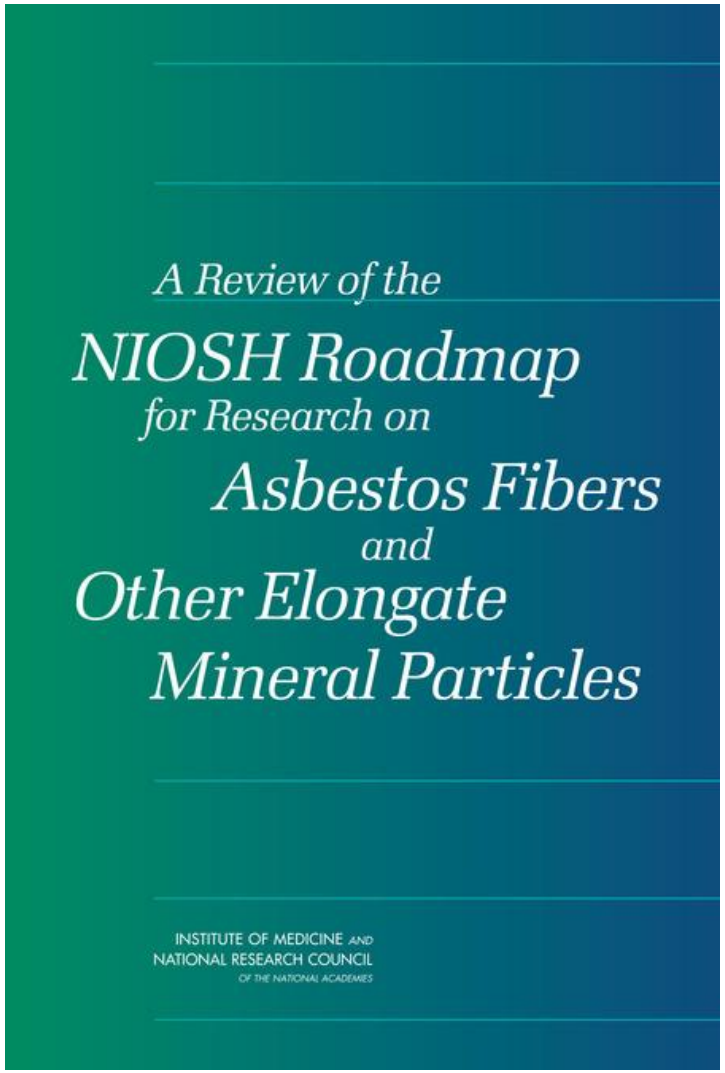
- Asbestos
  - A generic or commercial term given to six naturally occurring silicate minerals with a fibrous crystalline structure including; chrysotile, cummingtonite-grunerite asbestos (amosite), riebeckite asbestos (crocidolite), actinolite asbestos, anthophyllite asbestos and tremolite asbestos.
  - Only one group of a larger class of elongate mineral particles and the subject of most research on these particles.

- Elongate Mineral Particle (EMP)
  - For this research, NIOSH will use the broadest definition of EMP available (chemical composition, fiber dimensions, etc.) comprising all particles meeting any definition of an EMP, including regulated asbestos minerals, amphibole cleavage fragments, erionite, palygorskite, etc.
  - Findings from this research will provide a scientific basis for determining which EMPs should be included in recommendations to protect miners from hazardous occupational exposures.

Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research (2011)

- Purpose: Outline scientific research issues that need addressed to ensure workers are protected from health risks posed by asbestos fibers and other elongate mineral particles (EMPs).

- Asbestos Roadmap Strategic Goals
  - Develop a broader and clearer understanding of the important determinants of toxicity for EMPs.
  - Develop information on occupational exposures to various EMPs and health risks associated with such exposures.
  - Develop improved sampling and analytical methods for asbestos fibers and other EMPs.
- NAS reviewed Roadmap and made several recommendations.



NAS Recommendations*

1. *Clarify the vision and rationale*
2. *Include key components*
3. ✓ Improve terminology
4. ✓ Strengthen the emphasis on mineralogical research
5. ✓ Develop a reference mineral repository
6. ✓ Emphasize interdisciplinary efforts
7. ✓ Develop a systematic strategy for the toxicological assessment of EMP's
8. ✓ Emphasize additional research areas
    - New exposure assessment tools
    - Toxicological mechanisms of action
    - Epidemiological research (studies of cohorts exposed to EMP's)
    - Statistical methods

*IOM and the National Research Council. 2009. *Review of the NIOSH roadmap for research on asbestos fibers and other elongate mineral particles.* Washington, DC: The National Academies Press

Strategy

- Create a centralized “home” at NIOSH for EMP research
  - Minerals Research Team
  - Mineralogical Research Laboratory
  - NIOSH Minerals Research Coordinating Group (PMRD, SMRD, RHD, HELD, EID, etc.)
- Establish relationships with key research partners
  - Sister Federal agencies (e.g. USGS, EPA, NIEHS, FDA, etc.)
  - Academic Organizations
  - Analytical Laboratories
- Develop an EMP research program
  - “Understanding Elongate Mineral Particle Exposure in Mining” (FY19-FY23)
  - “Developing a Roadmap and Reference Materials for Minerals and Materials Research” (FY18)
  - “Developing a Laboratory for Minerals and Materials Research” (FY17)

Research Objective:

To understand the fundamental nature of EMP exposure in the mining industry and to establish a common measurement and analytical protocol.

Burden	Need	Impact
• Miners have higher than expected burdens of malignant and non-malignant interstitial respiratory diseases. • EPA, OSHA, and MSHA all use different definitions for regulating EMPs. • Mineral fibers have been found in 21 different non-asbestos mineral commodities.	• There is a strong need for research on fundamental mineralogical properties relevant to toxicology, epidemiology and exposure assessment. • Improved analytical methods. • Consistent nomenclature, comprehensive characterization of minerals and reporting in literature.	• Database of mine geologies which could result in EMP exposure • Repository of well-characterized reference samples • Improved monitoring and analysis techniques • Improved miner protection and monitoring efforts

This project will pursue three specific aims designed to improve the basic understanding of miners exposure to EMPs.

- SA 1: To understand miners' potential exposure to asbestos and other EMPs by analyzing bulk material samples previously collected from copper, granite, gold, iron, limestone, and sand and gravel, coal, etc. mines across the country. This analysis will be driven by geological knowledge of the deposits and their host rocks which will enable strategic characterization of EMP bearing strata.

- SA 2: To further elucidate the toxicology of the EMPs by creating new EMP separation methods to allow both in vitro and in vivo toxicity tests on EMP's of specific lengths, widths, mineralogy and other characteristics of concern.

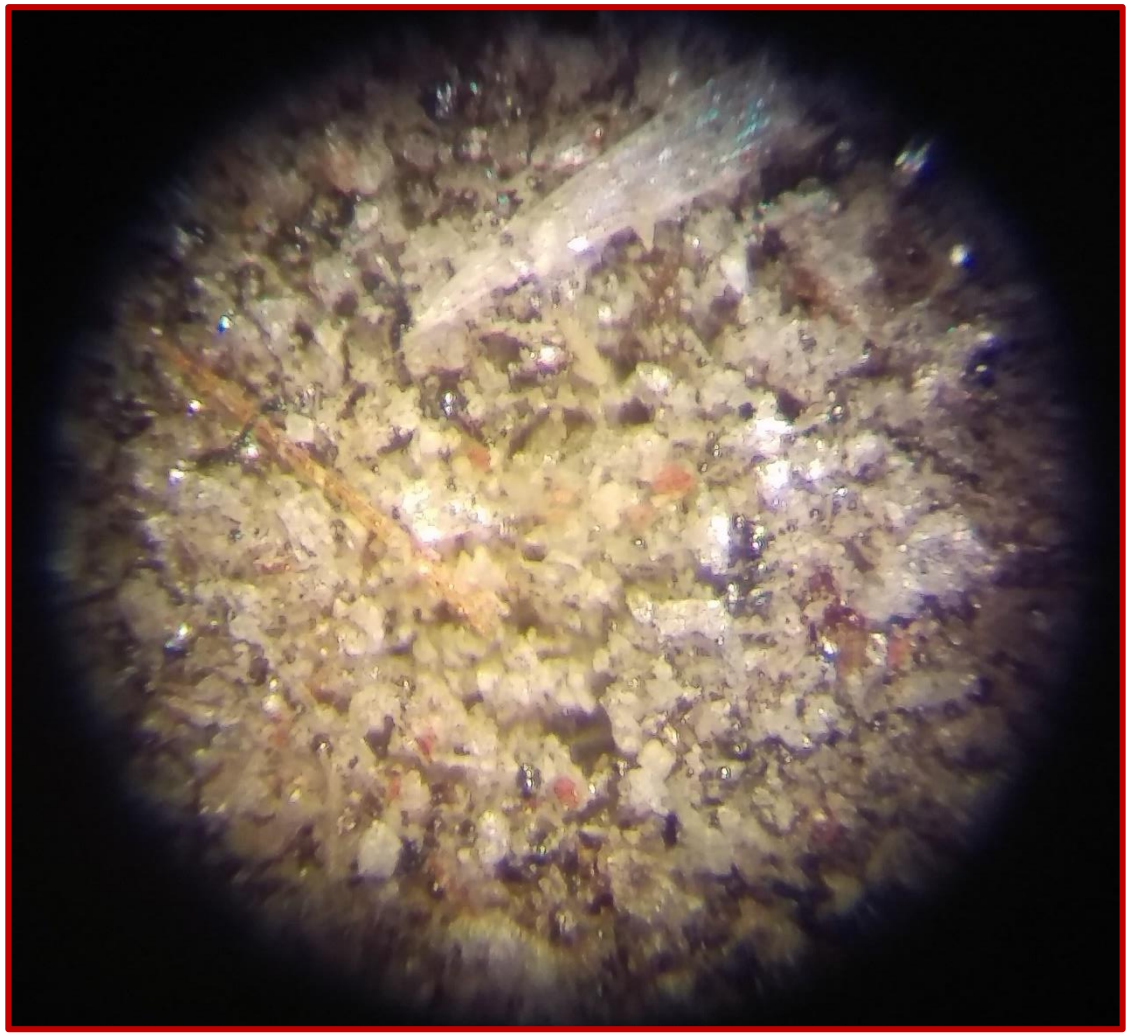
- SA 3: To investigate an application of qualitative and quantitative analysis of EMPs for end-of-shift measurement using newly developed and novel techniques for EMP analysis.

SA 1: To understand miners' potential exposure to asbestos and other EMPs by analyzing approximately 400 bulk material samples previously collected from copper, granite, gold, iron, limestone, and sand & gravel, coal, etc. mines across the country.

- **Milestone Output:** a database of mine geologies which could result in EMP or other potential exposures

- **Approach:**
  - Detailed characterization of previously collected samples (NIOSH or other collaborators)
  - Field collection of samples from missing mine types and/or geologies.

Analysis of bulk dust materials from mine environments



Objectives:

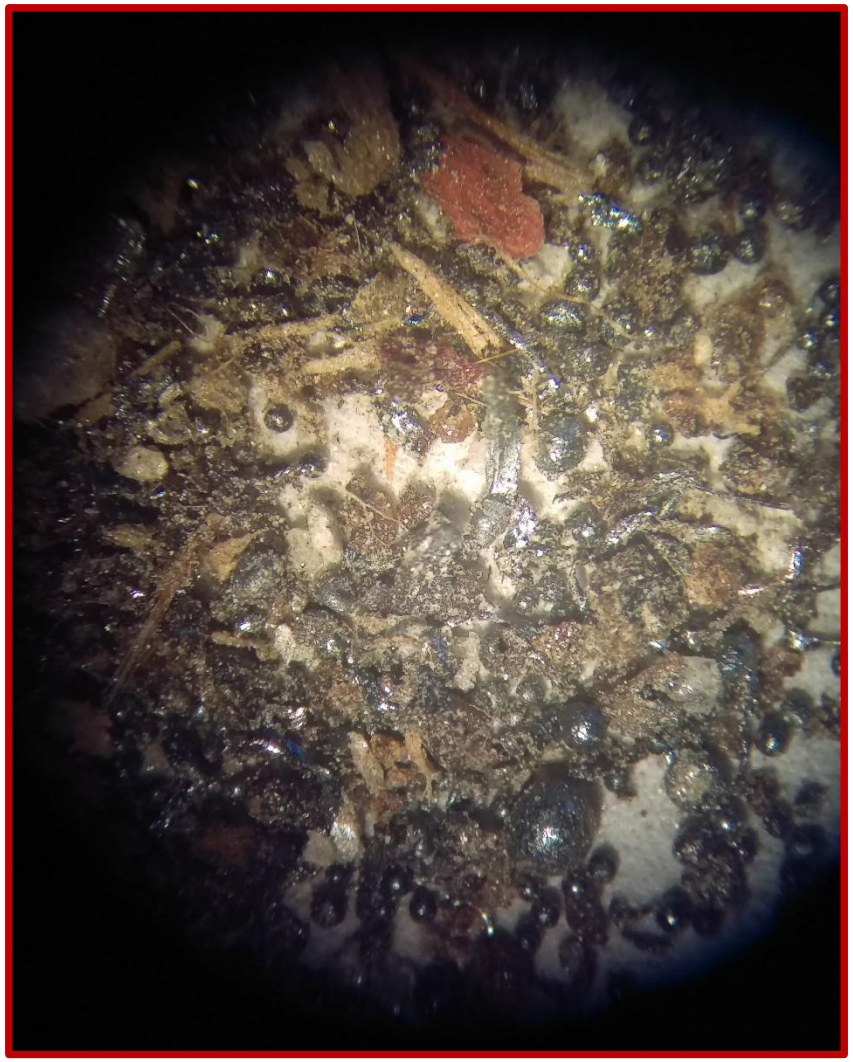
- Characterize the contents of bulk dust samples collected from mine environments (mines, quarries, and operational units);

- Develop a standardized classification for EMPs encountered in mining environments based on geology, geochemistry, mineralogy, and physical characteristics.

Outcomes:

- Produce and publish results, including up-to-date geodatabases, that allow end-users to identify geologies prospective for EMPs and thereby reduce exposure through increased monitoring and control
  - Useful map scale would be 1:24,000

Characterizing the contents of bulk dust samples collected from mine environments (mines, quarries, and operational units)



Samples:

- A collection of bulk dust samples from more than 300 mining facilities, including metal and nonmetal operations.
- Each facility's suite of samples includes between 1 and 81 individual bulk dusts (some duplicates) collected from different locations within the facility. Approximately 130 facilities have been chosen to perform comprehensive analyses.

Rationale:

- Bulk dusts are investigated to (1) determine the presence of EMPs and (2) characterize the mineralogy of dust and associated EMPs, including major, minor, and trace element profiles.

Methods:

- Stereoscopic microscope and polarizing light microscope
- SEM, EPMA, FTIR, XRD, etc.

Develop a standardized classification for EMPs encountered in mining environments based on geology, geochemistry, mineralogy, and physical characteristics.

Terminology:

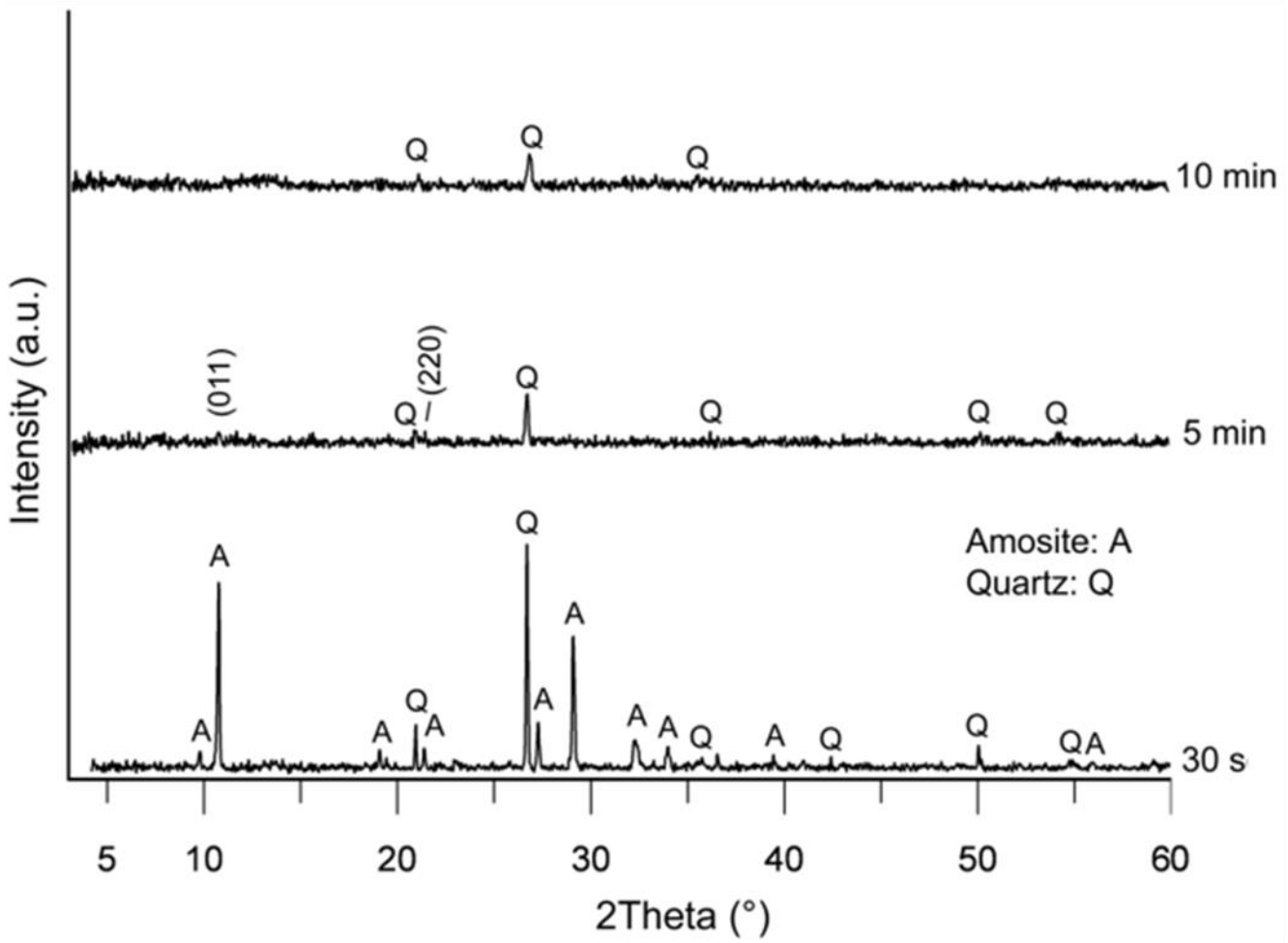
- Resolve imprecise terminology related to asbestos and EMPs that has hindered progress in occupational health and safety research. (i.e. Asbestos, Asbestiform, Cleavage fragment, fiber, etc.)

- By correlating detailed characteristics (geochemistry, mineralogy, crystallography, habit, etc.) of the EMPs, to exposure, epidemiology, and toxicology results, a unified classification may be developed.

- A unified classification of EMPs will allow for a reduction of exposure to workers as multiple agencies, industry, and the general public will be able to adopt a consistent working definition into their exposure, monitoring, and control plans.

Evaluating the Effect of Milling on the Crystallinity of Elongate Mineral Particles

- Elongate mineral particles (EMPs) must be processed to prepare them for characterization/toxicology studies.
- In the literature, processing of EMPs has been done using a variety of techniques.
- Depending on the technique used, this processing may result in a lack of crystallinity on the particle surface.
- The objective of this study is to develop a sample comminution protocol which will maintain the integrity of EMP crystalline structure.



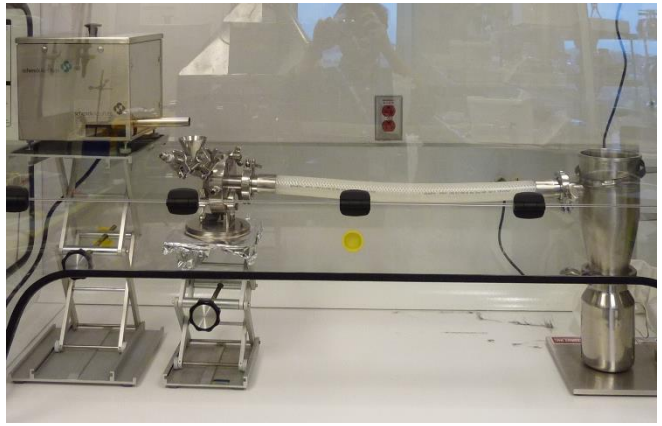
XRPD patterns of amosite recorded after 30 s, 5 min, and 10 min of grinding time [using an eccentric vibration mill]. Bloise, et al., Minerals 2018 Mar 28;8(4):135.

Commonly Used Grinding and Milling Techniques for EMP/Asbestos samples

1. Hand Grinding using Agate Mortar/Pestle (With DI water)

2. Impact Milling using a Ball Mill (Wig-L-Bug amalgamator)

3. Impact Milling using a Ball Mill and LN_2 (Retsch CryoMill)



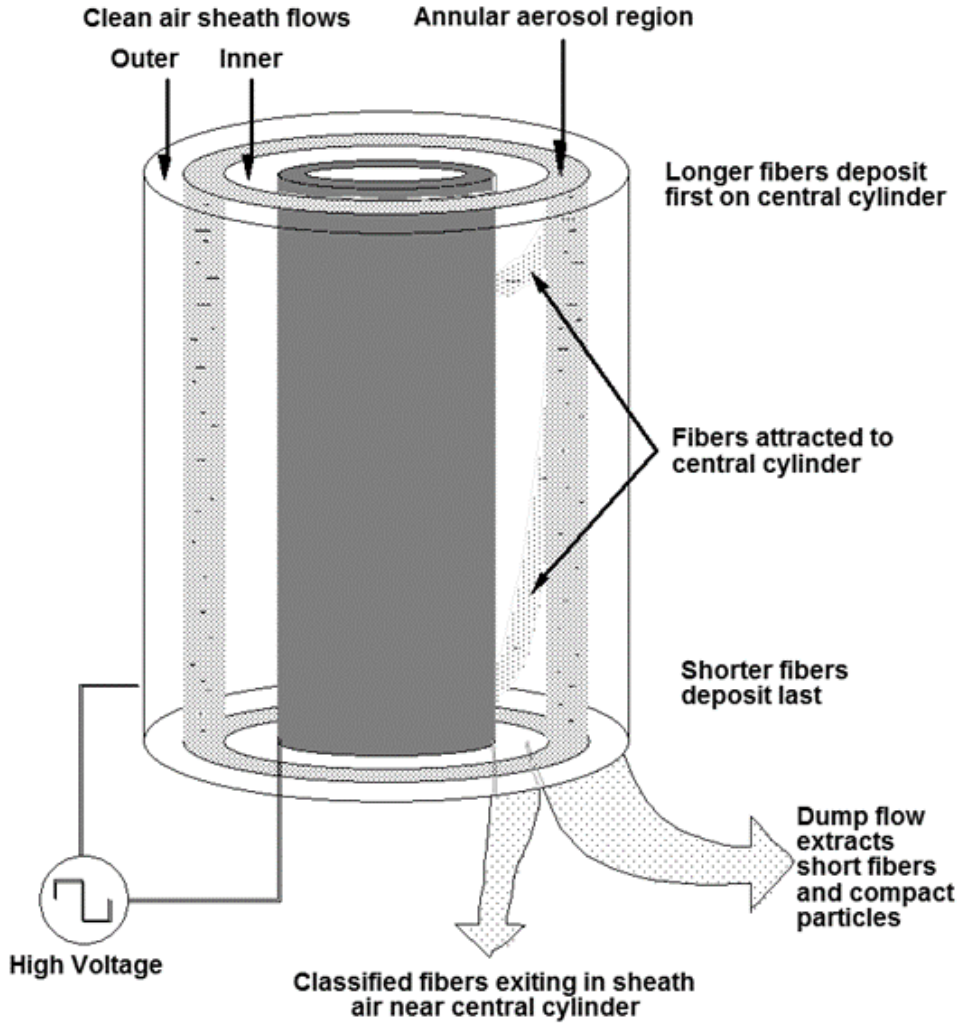
4. Impact Milling using a Jet Mill

5. Addison-Davies Milling using an Electric Coffee Grinder

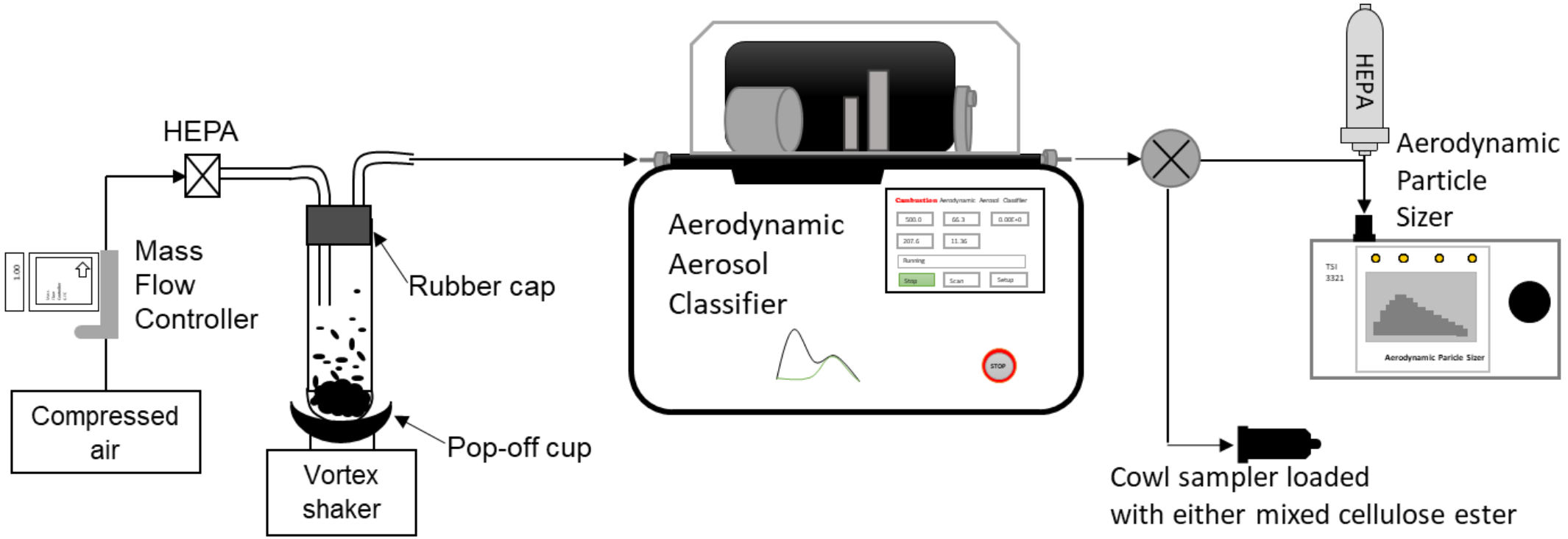
6. Retsch Ultra Centrifugal Mill ZM 200

SA 2: To further elucidate the toxicology of the EMPs, NIOSH will work on creating new EMP separation methods to allow both in vitro and in vivo toxicity tests on EMP's of specific lengths, widths, mineralogy and other characteristics of concern.

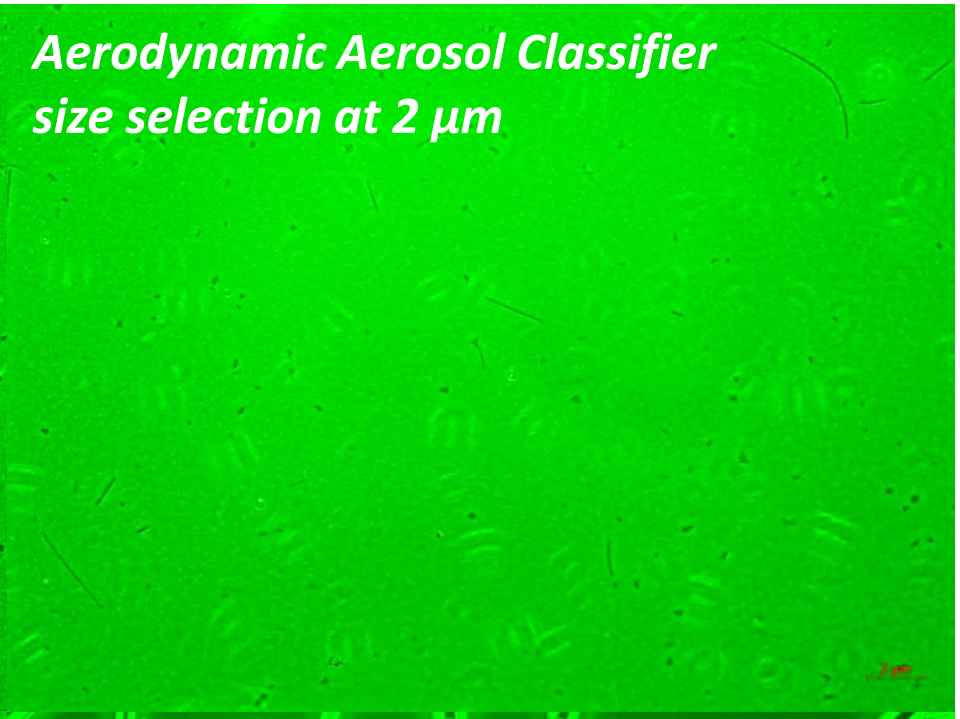
- **Milestone Output**: EMP separation methods suitable for toxicological evaluations
- **Approach**:
  - Laboratory testing of novel separation techniques using previously characterized EMP material
  - Toxicological testing using well characterized samples to further understand disease drivers and endpoints

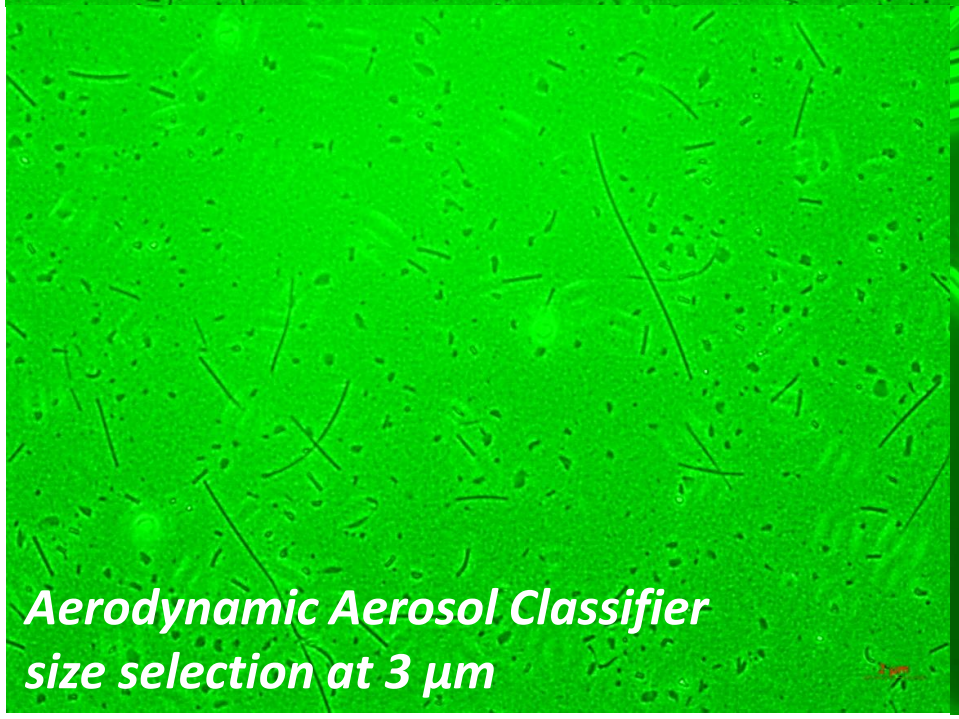


Classification of Glass Fiber Aerosols with Aerodynamic Aerosol Classifier



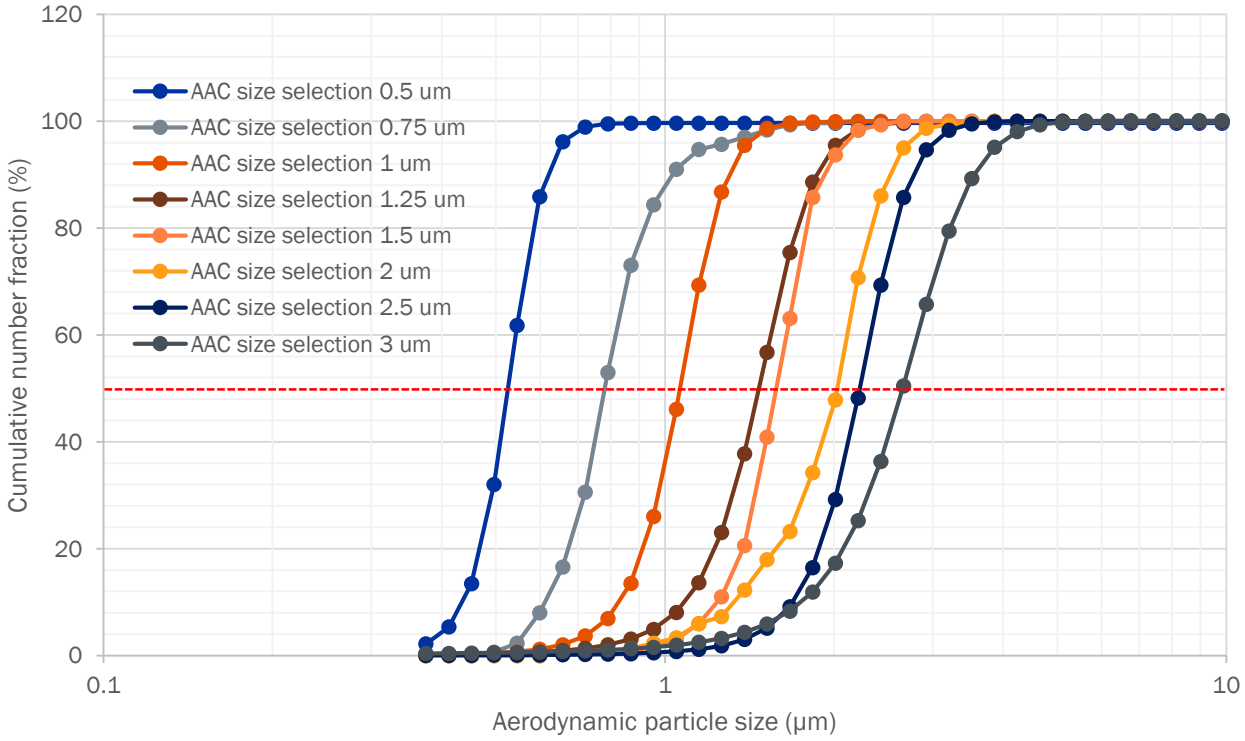
Phase contrast microscope images (400x magnification) of glass fiber aerosols



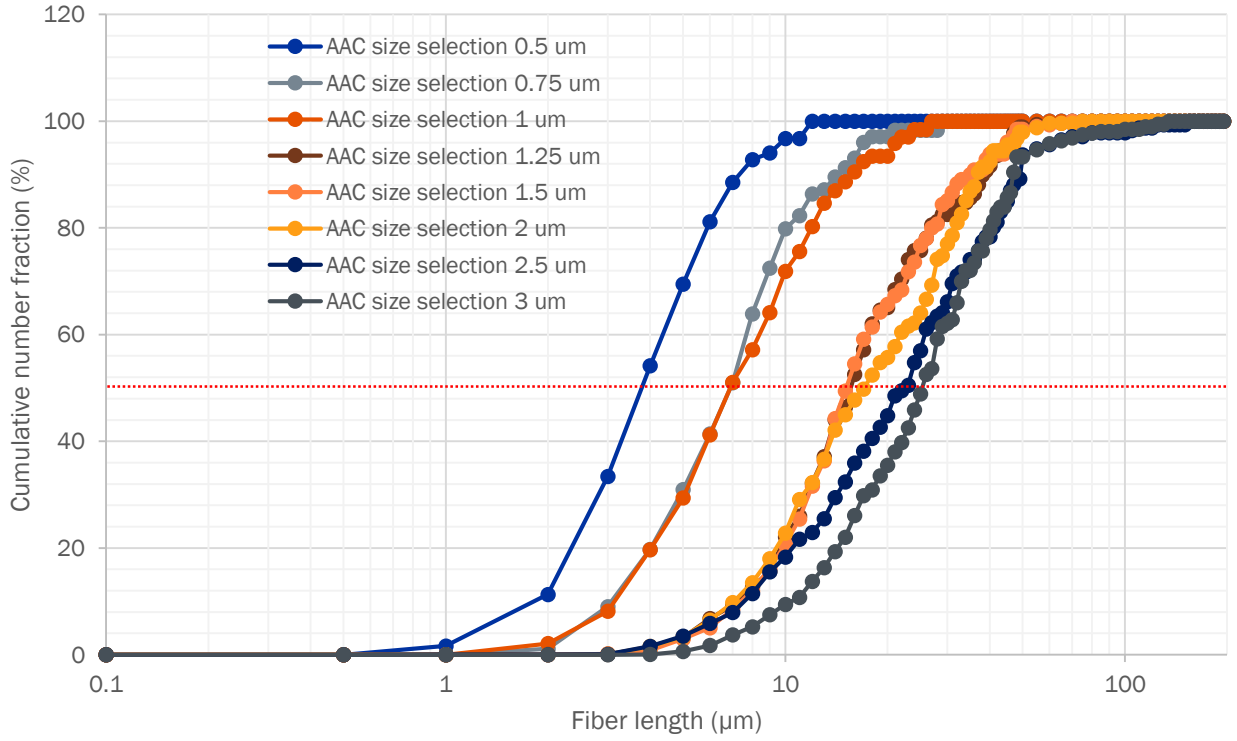


Classification of Glass Fiber Aerosols with Aerodynamic Aerosol Classifier

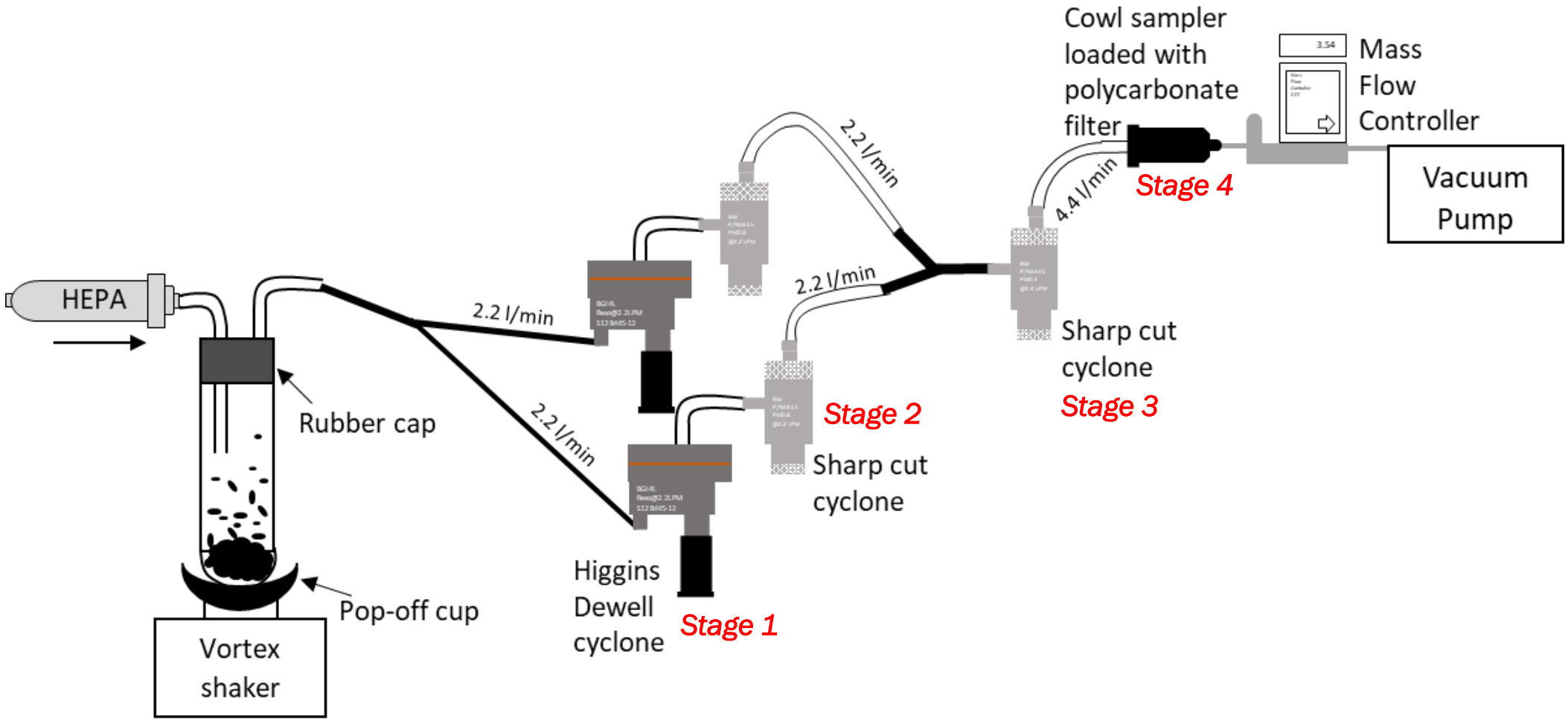
Cumulative number distribution for **aerodynamic diameter** of glass fiber aerosols



Cumulative number distribution as a function of glass **fiber length**

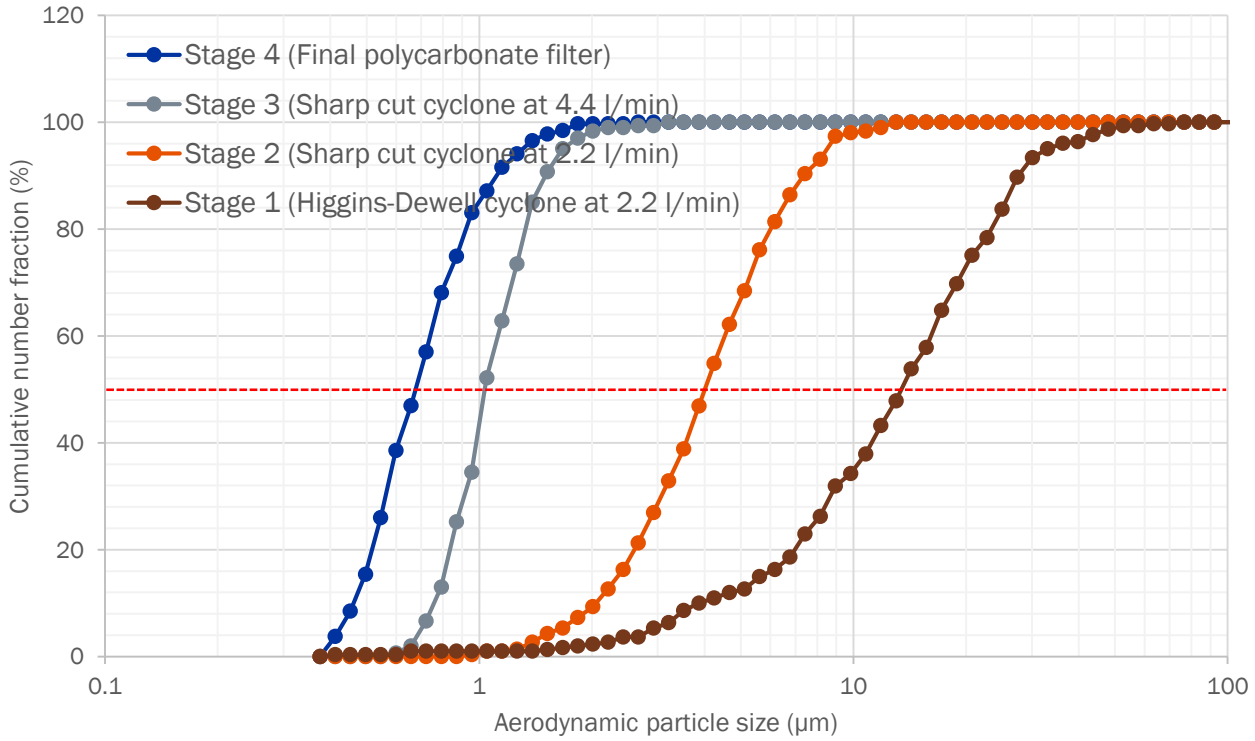


Classification of Glass Fiber Aerosols with Multi-cyclone Sampling Array

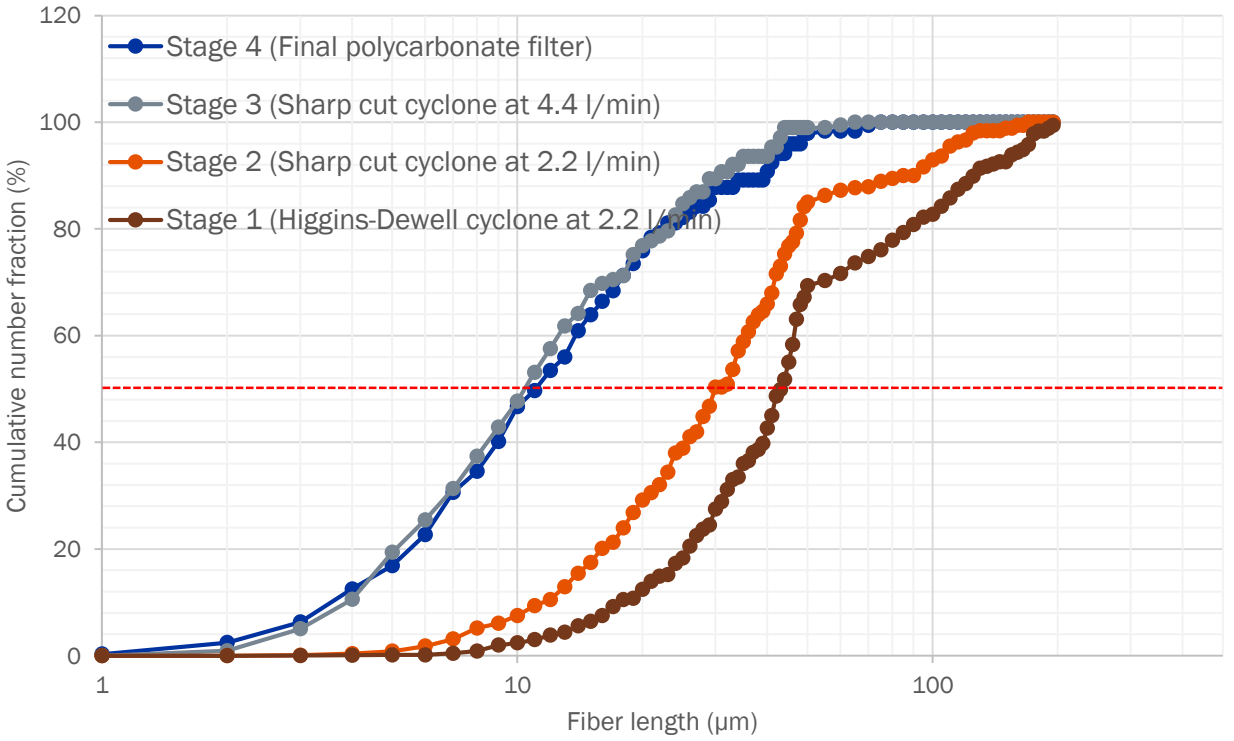


Classification of Glass Fiber Aerosols with Multi-cyclone Sampling Array

Cumulative number distribution for **aerodynamic diameter** of glass fiber aerosols

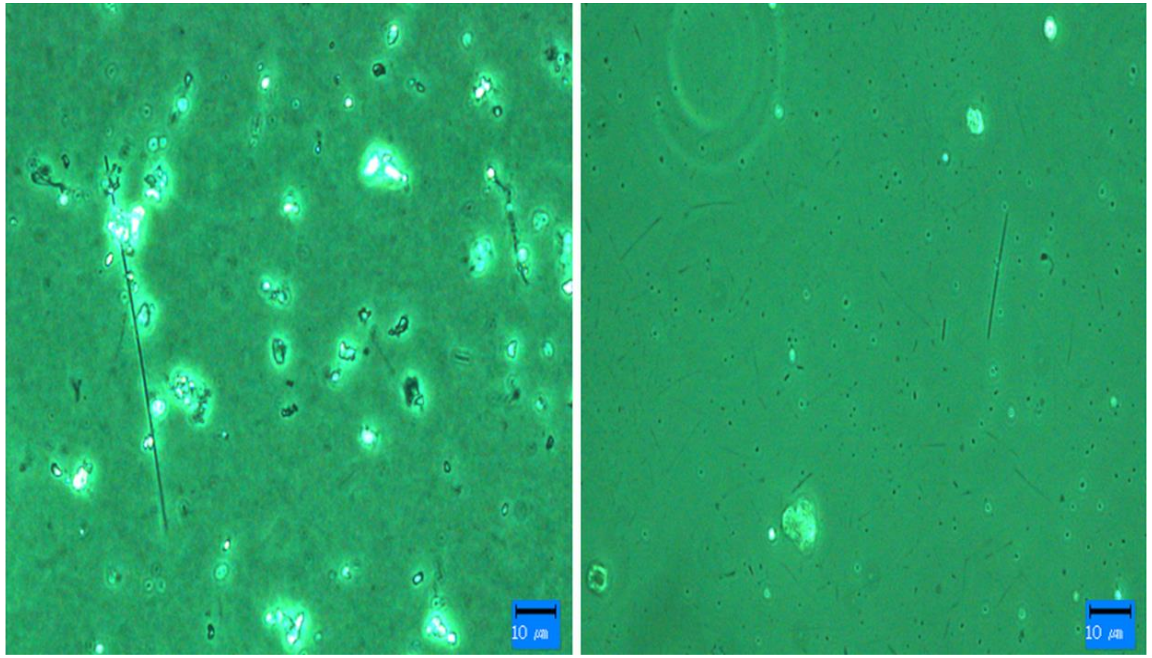


Cumulative number distribution as a function of glass **fiber length**



SA 3: To investigate an application of qualitative and quantitative analysis of regulated asbestos for end-of-shift measurement using newly developed and novel techniques for EMP analysis.

- **Milestone Output**: End-of-shift measurement of EMP exposure
- **Approach**:
  - Laboratory testing of novel identification techniques using previously characterized EMP material
  - FTIR, Fiber staining, etc.



Choi S, Jang K, Park K, Kim H (2017) Real-time measurement of fibers using an HY-differential mobility analyzer with an optical particle counter (KOFAM). PLoS ONE 12(8): e0182119.

NIOSH Research Team

Steven E. Mischler, Ph.D. - Toxicology/Industrial hygiene - smischler@cdc.gov
Elizabeth Ashley – Mechanical Engineer – eashley@cdc.gov
Taekhee Lee, Ph.D. – Industrial hygiene – tlee@cdc.gov
Susan Wacaster – Geologist – swacaster@cdc.gov
Rachel Walker Ph.D. – Chemist – rwalker@cdc.gov

Questions?

Steven E. Mischler, Ph.D.
Senior Research Scientist
Dust Control, Ventilation and Toxic Substances Branch
Pittsburgh Mining Research Division
CDC National Institute for Occupational Safety and Health
626 Cochrans Mill Rd.
Pittsburgh, PA 15236
412 386 6588
smischler@cdc.gov

References

1. Michael E. Beard, T.E., Owen S. Crankshaw, Stacy S. Doorn, Lisa C. Greene, Wayne W. Winstead, Bruce W. Harvey, Preparation of Nonasbestiform Amphibole Minerals for Method Evaluation and Health Studies. 2007, RTI International. Research Triangle Institute.
2. Langer, A., et al., Variation of properties of chrysotile asbestos subjected to milling. 1978. 4(1): p. 173-188.
3. R. L. Perkins, B.W.H., Test Method for the Determination of Asbestos in Bulk Building Materials, EPA, Editor. 1993: Office of Research and Development Washington, DC 20460.
4. Groppo, C., et al., Potential toxicity of nonregulated asbestiform minerals: balangeroite from the western Alps. Part 1: Identification and characterization. J Toxicol Environ Health A, 2005. 68(1): p. 1-19.
5. Lange, B. and J. Haartz, Determination of microgram quantities asbestos by x-ray diffraction: chrysotile in thin dust layers of matrix material. Analytical Chemistry, 1979. 51(4): p. 520-525.
6. Occella, E. and G.J.M.d.L. MADDALAN, X-Ray Diffraction Characteristics of some Types of Asbestos in relation to Differenn Techniques of Comminution. 1963. 54(10): p. 628-36.
7. Pecharsky, V. and P. Zavalij, Fundamentals of powder diffraction and structural characterization of materials. 2008: Springer Science & Business Media.
8. Pott, F., F. Huth, and K.J.Z.f.B. Friedrichs, Parasitenkunde, Infektionskrankheiten und Hygiene. Erste Abteilung Originale. Reihe B: Hygiene, praventive Medizin, Tumors of rats after ip injection of powdered chrysotile and benzo (a) pyrene. 1972. 155(5): p. 463-469.
9. Reeves, A.L., H.E. Puro, and R.G.J.E.r. Smith, Inhalation carcinogenesis from various forms of asbestos. 1974. 8(2): p. 178-202.
10. Stanton, M.F., R. Blackwell, and E.J.A.I.H.A.J. Miller, Experimental pulmonary carcinogenesis with asbestos. 1969. 30(3): p. 236-244.
11. Vorwald, A.J., T.M. Durkan, and P.C. Pratt, Experimental Studies of Asbestosis. Arch. Indust. Hyg. & Occupational Med., 1951. 3(1): p. 1-43.
12. Jolicoeur, C. and D.J.C.J.o.C. Duchesne, Infrared and thermogravimetric studies of the thermal degradation of chrysotile asbestos fibers: evidence for matrix effects. 1981. 59(10): p. 1521-1526.
13. Deng, Y., et al., Effect of structural stress on the intercalation rate of kaolinite. 2002. 250(2): p. 379-393.
14. M.S. Badollet, W.A. Gantt. Preparation of asbestos fibers for experimental use. Ann. N.Y. Acad. Sci., 132 (1965), p. 451
15. Spurny KR, Stober W, Opiela H, Weiss G. On the problem of milling and ultrasonic treatment of asbestos and glass fibers in biological and analytical applications. American Industrial Hygiene Association Journal. 1980 Mar 1;41(3):198-203.
16. Bloise A, Kusiorowski R, Gualtieri A. The effect of grinding on tremolite asbestos and anthophyllite asbestos. Minerals. 2018 Jul;8(7):274.
17. Bloise A, Catalano M, Gualtieri A. Effect of Grinding on Chrysotile, Amosite and Crocidolite and Implications for Thermal Treatment. Minerals [Internet]. MDPI AG; 2018 Mar 28;8(4):135.