Jeffery C. Camplin, CSP 1-708-284-4563
1681 Verde Lane, Mundelein, IL 60060 Fax: 1-847-837-1852

April 24, 2008

Information Quality Guidelines Staff (Mail Code 2811R)
U.S. EPA
1200 Pennsylvania Ave., NW
Washington, DC 20460

Attention: Information Quality Office

Re: Information Quality Challenge: EPA/600/R-08/046 - April 2008

- **Misrepresentation of Study Scope and Findings**
- **Use of the Term "Asbestos" is Inaccurate and Unclear**
- **Publication Biased by Implication it Addresses Amphiboles**
- **Authors Acknowledge Study Limited to Chrysotile**
- **Lack of Objectivity Violates Information Quality Requirements of OMB and USEPA**
- **Report Harms Amphibole Exposure Assessment Validity**
- **Corrections Requested for Information Quality Compliance**

Dear Information Quality Office:

The new EPA publication entitled, "*Sampling and Analysis of Asbestos Fibers on Filter Media to Support Exposure Assessments: Bench-Scale Testing*" referenced above does not comply with the Office of Management and Budget (OMB) "*Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies; Republication*" dated February 22, 2002. The publication also does not comply with the "*USEPA Information Quality Guidelines, EPA/260R-02-008,*" dated October 2002.

EPA Document is not "Objective" or "Unbiased" as Defined by OMB Guidance Which Must be Complied With for Scientific Publications

Section V "Definitions" of the OMB guidelines state:

3. ''Objectivity'' involves two distinct elements: presentation and substance.

a. ''Objectivity'' includes whether disseminated information is being presented in an accurate, clear, complete, and unbiased manner. This involves whether the information is presented within a proper context.

b. In addition, ''objectivity'' involves a focus on ensuring accurate, reliable, and unbiased information.

EPA Document Doesn't Adhere to EPA's Quality Guidelines by Taking Liberties to Over-Extending Its Applicability to Unstudied Minerals

Page 5 of the USEPA Information Quality Guidelines state:

> **2.2 Information Management in EPA**
> **The collection, use, and dissemination of information of known and appropriate quality are integral to ensuring that EPA achieves its mission. Information about human health and the environment -- environmental characteristics; physical, chemical, and biological processes; and chemical and other pollutants -- underlies all environmental management and health protection decisions. The availability of, and access to, information and the analytical tools to understand it are essential for assessing environmental and human health risks, designing appropriate and cost-effective policies and response strategies, and measuring environmental improvements.**

The guide goes on to state:

> **5 Guidelines Scope and Applicability**
> **5.1 What is "Quality" According to the Guidelines?**
> **Consistent with the OMB guidelines, EPA is issuing these Guidelines to ensure and maximize the quality, including objectivity, utility and integrity, of disseminated information. Objectivity, integrity, and utility are defined here, consistent with the OMB guidelines. "Objectivity" focuses on whether the disseminated information is being presented in an accurate, clear, complete, and unbiased manner, and as a matter of substance, is accurate, reliable, and unbiased. "Integrity" refers to security, such as the protection of information from unauthorized access or revision, to ensure that the information is not compromised through corruption or falsification. "Utility" refers to the usefulness of the information to the intended users.**

EPA Document Misstates Study: Objectivity and Integrity of Document Compromised by Omitting Specific Chrysotile Reference

The USEPA document "EPA/600/R-08/046 - April 2008" misrepresents a study specific to chrysotile asbestos as being applicable to all forms of asbestos. The current federal definition of asbestos is the asbestiform varieties of: chrysotile (serpentine); crocidolite (riebeckite); amosite (cummingtonite/grunerite); anthophyllite; tremolite; and actinolite. The EPA document purposefully and inappropriately expands the limited term chrysotile

asbestos in the study design by omitting the word chrysotile to solely use the broader term "asbestos." The use of the broader term "asbestos" in place of "chrysotile asbestos" leaves the public and scientific community with the impression that the study findings are applicable to all forms of asbestos including regulated and non-regulated amphibole fibers. This omission by the study's authors and/or reviewers misinforms the public and professional community about the applicability of significant modifications to an important exposure evaluation tool used to determine health risks from asbestos and other amphibole minerals.

The EPA document being challenged states in the Abstract on page ii:

> **Sampling efficiency is essential in exposure assessments of contaminants in air, as well as other matrices. In the measurement of airborne contaminants, it is critical to collect a sample of air containing representative contaminants in the air of concern, that is, contaminant concentration and size distribution in the sampled air must be the same as that of the air of concern.**

This document evaluated the sampling efficiency of collecting chrysotile asbestos using two different sampling media. However, the title of the document and much of the discussion found in the document omit the word "chrysotile" from the original study and refer to the contaminant of concern as merely "asbestos." The science used to support this document only examined the collection efficiency of filter media on chrysotile asbestos. Therefore, the document should only refer to "chrysotile asbestos," specifically when the broader term "asbestos" is used alone. There is no evidence provided in the referenced studies to indicate that amphibole asbestos or other amphibole fibers will behave the same as chrysotile asbestos for collection efficiency. Therefore, the USEPA should be prohibited from being able to use the broader term "asbestos," which was inserted by the USEPA after the authors published their *original* paper, in place of the more accurate term "chrysotile asbestos" in the challenged document.

Broad and Misleading Use of the Term Asbestos Must Specifically Address Chrysotile to Improve Amphibole Exposure Assessments

The bottom of page 5 of the EPA document being challenged states:

> **Therefore, U.S. EPA's National Exposure Research Laboratory (NERL) conducted a study in which *chrysotile* asbestos (fibers**

both shorter and longer than 5 µm) were generated in an aerosol chamber and sampled by 25-mm diameter MCE filter media to compare the efficiency of 0.45 µm pore size versus 0.8 µm pore size filter media. In addition, the effect of plasma etching times on fiber densities was evaluated.

The NERL study did not include any regulated amphibole or other amphibole fibers in their study. Yet, page 6 of the challenged document defines the project objectives as:

> **1.1 Project Objectives**
> **The goal of this research study was to determine the effect of mixed cellulose ester membrane filter pore size on collection efficiency of *asbestos fiber aerosols*.**

Therefore, the NERL study, which serves as the scientific foundation of the challenged document, fails to meet the information quality guides of OMB and USEPA for two reasons:

1. **The study was deficient in meeting the project objective by limiting their study to chrysotile asbestos mineral fibers, and;**
2. **The report significantly mischaracterized the limited study scope of chrysotile asbestos mineral filter collection efficiency as representing collection efficiencies for all asbestos minerals.**

The failure to include amphibole asbestos in the NERL study has diminished the quality of the EPA/600/R-08/046 publication including its objectivity, utility and integrity of disseminated information. References to "asbestos" must be clarified.

NERL Authors Correctly Cite Their Study Only Addresses Chrysotile in Peer Presentation, Yet Inexplicitly Makes Changes in EPA Report

The authors of the NERL study will be presenting their findings at the ASTM 2008 Johnson Conference: *Critical Issues in Monitoring Asbestos*. The ASTM's Committee D22 sponsors the Johnson Conference to provide a special forum for presenting current research and fostering open discussion. For more than two decades, these conferences have served as international benchmarks for developing and refining asbestos monitoring methods and have made major contributions to understanding and advancing asbestos monitoring technology. This conference is attended by the top asbestos experts throughout the world. The ASTM website promotes this conference as providing, "current monitoring strategies, methods, data, results interpretation, and quality assurance associated with asbestos monitoring programs and research

frontiers. National and international experts in asbestos monitoring research will present their latest findings."

At this year's conference, the four authors of the NERL study and document I am challenging, will present their findings in front of the prestigious conference attendees. In a peer review environment, the study's authors titled the presentation of their study: *"Comparison of Chrysotile Asbestos Relative Collection Efficiencies on Mixed-Cellulose Ester Filters."* The conference program lists the presenters as John R. Kominsky, EQM, Inc., Cincinnati, OH; Daniel A. Vallero, USEPA, Research Triangle Park, NC; Michael E. Beard and Owen Crankshaw, RTI International, Research Triangle Park, NC. I have personally confirmed with Mike Beard and the ASTM D-22 member Andy Oberta that this is a discussion of the NERL study used to support the EPA/600/R-08/046 publication.

I am recommending that the EPA/600/R-08/046 document also specifically limit the scope and conclusions of the fiber collection efficiency report to chrysotile asbestos only. This reference to chrysotile should distinctively appear in the front cover/title page, as well as in all "asbestos" references found in the conclusion and recommendation sections of the EPA/600/R-08/046 publication. It is clear from the initial ASTM presentation submission by the authors of both the NERL study and EPA/600/R-08/046 publication that they intended to properly communicate the study conclusions to only apply to chrysotile asbestos. Yet, the EPA's version EPA/600/R-08/046 does not make this clarification that was intended by the authors.

Correction/Clarification in EPA/600/R-08/046 Document Necessary for Proper Design of Amphibole Risk Assessment Air Testing Studies

The clarification of the challenged EPA/600/R-08/046 document's misuse of the broad term "asbestos" to discuss only chrysotile asbestos findings, will significantly improve the quality of the EPA/600/R-08/046 publication to the OMB and USEPA required levels. Specifically, the quality of the document will be improved by limiting the conclusions and recommendations to the contaminant of concern (chrysotile asbestos) utilized in the NERL study. These changes will not affect the study's findings or conclusions for chrysotile asbestos. In fact, the requested changes will make the EPA/600/R-08/046 publication more accurate.

The requested changes to the publication will also have an effect on amphibole asbestos and other amphibole fiber exposure assessments currently being performed by USEPA and others. The

requested changes will inform the public, just as the authors will do at the Johnson conference, that chrysotile asbestos has varying collection efficiencies on different filter media. However, the findings and conclusions of the EPA/600/R-08/046 publication are not applicable to amphibole asbestos, specifically for use in selecting air sampling filter media for the purpose of amphibole exposure assessment air sampling strategies. The requested changes will improve risk assessment data obtained during airborne sampling events because sample media with unknown collection efficiencies such as amphiboles, will not be allowed to be utilized for exposure assessments. This improves the reliability of sampling data which in turn improves the risk assessment process for amphiboles.

In conclusion, the requested changes significantly improve the quality of the EPA/600/R-08/046 publications. The requested changes will improve the public's understanding of the uncertainty and limitations associated with the USEPA's current practice of swapping amphibole air sampling filter media whose collection efficiency differences (between the use of 0.45 and 0.8 µm pore size filter media) are unknown. However, the requested changes will not affect the EPA/600/R-08/046 publication's conclusions and recommendations as they apply to chrysotile asbestos air testing. The requested changes will bring the challenged document into compliance with quality guidelines of OMB and USEPA by significantly improving its accuracy, clarity, and completeness. The requested changes also remove the bias of the challenged document by removing amphiboles from consideration in the study's findings and recommendations.

Thank you for your prompt attention to this information quality challenge. Please contact me with any questions.

Cordially,

Jeffery C. Camplin

Jeffery C. Camplin, CSP, CPEA
Concerned Citizen

cc: Chief Information Officer: Molly A. O'Neill

Attached: 1. Copy of Interim 2008 ASTM Johnson Conference Agenda
2. Copy of USEPA Publication EPA/600/R-08/046

Appendix A

ASTM Johnson Conference Preliminary Agenda

Note the Yellow Highlighted Presentation

2008 JOHNSON CONFERENCE PROGRAM
Preliminary Program
February 8, 2008

MONDAY, JULY 14, 2008

7:30AM **Registration**
Campus Center Theater, University of Vermont

9:00AM
Welcome and Opening Remarks
Michael E. Beard, James S. Webber, and Harry L. Rook, Conference Co-Chairs

Session I: Regulatory Framework versus Risk Assessment

Morning Session Chair: Julie Wroble
USEPA
Seattle, WA

9:15AM
Regulatory Framework for Asbestos Sites in Region 10
Julie Wroble, USEPA, Seattle, WA

9:40AM
Prioritizing Communities for Clean-Up: A Risk Based Approach to South Africa's Environmental Asbestos Contamination
Robert R. Jones, Sustainable Development Consulting Intl., Lebanon, VA

10:05AM Break

10:20AM
Asbestos Presence on the Italian National Territory: Progress Report on Mapping and Remediation Activity
Federica Paglietti*, S. Bellagamba*, Sergio Malinconico**, V. Di Molfetta**, P. De Simone*, Marco Giangrasso***
* Higher Italian Institute for Occupational Health and Safety - Department for Production (ISPESL) Facilities and Human Settlements (DIPIA)
** Research Assignment ISPESL DIPIA
***Italian Ministry of the Environment and Sea

10:45AM
The Challenge of Naturally Occurring Asbestos – Characterization of Amphibole Particles in Mixed Mineral Dust
R.J. Lee, B.R. Strohmeier, K.L. Bunker, and D.R. Van Orden, RJ Lee Group, Inc., Monroeville, PA

11:10AM
Fiber Size Distributions in Naturally Occurring Asbestos: Implications for Health
Presenter: John S. Wheeler and Jill J. Dyken, Agency for Toxic Substances and Disease Registry, Atlanta, GA

11:35AM
Difficulties in Folding Proper Science into Changes in Asbestos Regulations
Peggy J. Forney, USEPA, Denver, CO

12:00N LUNCH (On Your Own)

MONDAY, JULY 14, 2008

Session II: Asbestos in Soils – Occurrence/Assessment

Afternoon Session Chair: James R. Millette
MVA Scientific Consultants
Duluth, GA

1:30PM
The Geographic Distribution of Asbestos Deposits in the Continental U.S.
Bradley S. Van Gosen, U.S. Geological Survey, Denver, CO

1:55PM
Mapping Naturally Occurring Asbestos Using Imaging Spectroscopy
Gregg A. Swayze, US Geological Survey, Denver, CO

2:20PM
Naturally Occurring Asbestos in the State of California
Mark Bailey, Asbestos TEM Labs, Berkeley, CA

2:45PM Break

3:00PM
The Relationship between the Hazard and Risk for Asbestos Contaminated Land –Or What Do I Do about the Big Bits?
Garry Burdett and Delphine Bard, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, UK.

3:25PM
Environmental Exposure to Asbestos and Other Elongated Mineral Particles: The Dilemma of El Dorado County, CA
Gregory P. Meeker, US Geological Survey, Denver, CO

3:50PM
Managing Asbestos in Soil under the Massachusetts Contingency Plan (MCP)
Robert C. Atwood, Resource Control Associates, Inc., Pawtucket, RI; and Steven Grevelis, Groundwater Analytical, Inc., Buzzards Bay, MA / H2O EnviroComp, Harwich, MA

4:15PM
Strategies and Methods for Exposure Assessment from Asbestos Contaminated Land

Garry Burdett, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, UK

4:40PM **ADJOURN**

5:30 -7:00PM **Reception at the Sheraton Hotel – Light hors d'oeuvres and cash bar**

TUESDAY, JULY 15, 2008

8:30AM
Welcome and Opening Remarks
Michael E. Beard, James S. Webber and Harry L. Rook, Conference Co-Chairs

Session III: Asbestos In Soils - Methods For Analysis

Morning Session Chair: Gregory P. Meeker, US Geological Survey, Denver, CO

8:45AM
Asbestos in Soil: Sieving (Modified MA DEP) vs. Milling (CARB 435) - The Application and Performance of These Methods in Various Situations
Edward R. Cahill, EMSL Analytical, Sugar Loaf, NY

9:10AM
A Study of the Asbestos Content of Naturally Occurring Asbestos in Soil Using Sedimentation and Transmission Electron Microscopy
A. Kolk and B. Kolk, EMS Laboratories. Inc, Pasadena, CA

9:35AM
Amphibole Content of Soils by Powder X-Ray Diffraction
Charity Summers and Mickey Gunter, University of Idaho, Moscow, ID; and Matthew Sanchez, RJ Lee Group, Monroeville, PA

10:00AM Break

10:15AM
Measuring Asbestos in Soils
James R. Millette and Whitney B. Hill, MVA Scientific Consultants, Duluth, GA; Brian Schumacher, U.S. EPA, Las Vegas, NV; and John Kominsky, EQM Inc., Cincinnati, OH

10:40AM
Identifying Asbestos and Amphibole Minerals in Sediments, Sands, and Air - A Review of Uncertainty in Testing Protocols, Analytical Techniques, and Risk Screening Methodologies Used on the Illinois Lake Michigan Shoreline
Jeffery C. Camplin, Camplin Environmental Service, Inc., Rosemont, IL

11:05AM
Determining the Releasability of the Asbestos Fiber from Soils and Solid Matrices
Glenn Shaul, USEPA, Cincinnati, OH

11:30AM
Implications of the Proximity Effect as it Relates to Exposure Assessment at Sites with Asbestos Contamination in Environmental Media
Brian E. Brass and William Albrecht, USEPA, Las Vegas, NV; Mark M. Methner, CDC/NIOSH, Cincinnati, OH

12:00 Noon **Poster Session I** Robert G. Lewis, Poster Coordinator

1:00 PM LUNCH (On Your Own)

TUESDAY, JULY 15, 2008

Session IV. Developing Conventions for Distinguishing Asbestos Fibers from Cleavage Fragments

Evening Session Chair: Eric J. Chatfield
Chatfield Technical Consulting, Ltd.
Mississauga, ONT, Canada

7:00PM
Concerning the Particle Size of Airborne Amphibole Reference Materials
Martin Harper, Eun Gyung Lee, NIOSH/HELD, Morgantown, WV; Owen S. Crankshaw, J. Todd Ennis, Stacy S. Doorn, Lisa C. Greene, Wayne G. Winstead, Jr., and Oki Hammond, RTI International, Research Triangle Park, NC; and Thomas W.S. Pang, Ryerson University, Toronto, ONT, Canada

7:25PM
Investigation of Cleavage Fragment / Asbestos Fiber Distinctions
James R. Millette and Bryan Bandli, MVA Scientific Consultants, Duluth, GA

7:50PM
A Procedure for Quantitative Description of Fibrosity in Amphibole Minerals
Eric J. Chatfield, Chatfield Technical Consulting Ltd., Mississauga, Ontario, Canada

8:15PM Break

8:30PM
Extinction Angle of Amphibole Particles
Matt Sanchez, Steve Badger, Richard J. Lee, Drew Van Orden, RJ Lee Group, Inc., Monroeville, PA

8:55PM
The Unique Amphiboles from Biancavilla, Sicily, Italy: Where Morphology Matters
Mickey E. Gunter, University of Idaho, Moscow, ID; Antonio Gianfagna, Simona Mazziotti-Tagliani, Alessandro Pacella, University of Rome, Spaienza, Italy

9:20PM
Concentration and Morphology of Amphibole Minerals Present in Some Sources of Chrysotile
Eric J. Chatfield, Chatfield Technical Consulting Ltd. Mississauga, Ontario, Canada

9:45PM **Discussion**

10:00PM **Adjourn**

WEDNESDAY, JULY 16, 2008

8:30AM
Welcome and Opening Remarks
Michael E. Beard, James S. Webber and Harry L. Rook, Conference Co-Chairs

Session V: Quality Assurance for Analytical Measurements

Morning Session Chair: Bruce W. Harvey
RTI International
Research Triangle Park, NC

8:45AM
Asbestos Analysis Methods of Building Materials in Japan
Naoki Toyama, Tokyo Occupational Safety and Health Center, Tokyo, Japan

9:10AM
Comparison of Chrysotile Asbestos Relative Collection Efficiencies on Mixed-Cellulose Ester Filters

John R. Kominsky, EQM, Inc., Cincinnati, OH; Daniel A. Vallero, USEPA, Research Triangle Park, NC; Michael E. Beard and Owen Crankshaw, RTI International, Research Triangle Park, NC

9:35AM
An Update on the NVLAP Airborne Asbestos Proficiency Testing Program
Stacy S. Doorn, RTI International, Research Triangle Park, NC

10:00AM Break

10:15AM
Quality Assurance Using VDI 3492 or ISO 14966 in Combination with ISO 16000-7
Reiner Koenig, APC, Eschborn, Germany

10:40AM
Non-Friable Organically Bound Bulk Materials: Implications from Proficiency Testing.
Laurie J. Carhart and James S. Webber, New York State Department of Health, Albany, NY

11:05AM
Detection and Quantification of Amphiboles in Vermiculite and Chrysotile Ores
Mickey Gunter and Thomas Williams, University of Idaho, Moscow, ID; Matthew Sanchez, RJ Lee Group, Monroeville, PA

11:30AM
Establishing the Proficiency Test Scheme of Analyzing Airborne Asbestos Fiber in Korea
Ho-Ju Lim, Seong-Ki Jang, National Institute of Environmental Research, Incheon, Korea

11:55AM LUNCH (On Your Own)

No Evening Session

Volleyball tournament this afternoon!

THURSDAY, JULY 17, 2008

8:30AM
Welcome and Opening Remarks
Michael E. Beard, James S. Webber and Harry L. Rook, Conference Co-Chairs

Session VI: Application of Monitoring Techniques to Real-World Projects

Morning Session Chair: Andrew F. Oberta, The Environmental Consultancy, Austin, TX

8:45AM
Rock the Mall
Sean Fitzgerald, Scientific Analytical Institute, Greensboro, NC
Jerome Hairston, ECS Mid-Atlantic, Roanoke, VA

9:15AM
Irish ESB Experience of Remediating Asbestos Contaminated Land
Patrick J. Colman and John Scanlon, Electricity Supply Board, Dublin, Ireland; and Jan Tempelman, TNO Institute of Environmental Sciences and Process Innovation, Apeldoorn, The Netherlands

9:45AM
Laboratory and Initial Field Investigations of Thoracic Samplers for Fibres
A. D. Jones and R. J. Aitken, Institute of Occupational Medicine (IOM), Edinburgh, Scotland; J. F. Fabriès and E. Kauffer, Institut National de Recherche et de Securite', Paris, France; G. Liden and W.l. Sahle, National Institute for Working Life, Stockholm, Sweden; A. Maynard, Health and Safety Laboratory, Sheffield, UK; and G. Riediger, Berafsgenossenschaftliches Institut fur Arbeitssicherheit, Sankt Augustin, Germany

10:15AM Break

10:30AM
ASTM Standard Guide for Evaluating Asbestos in Dust on Surfaces by Comparison between Two Environments
Roger G. Morse, Morse Zehnter Associates, Poestenkill, NY

11:00AM
Studies of Zonolite Attic Insulation Exposure with Less than One Percent Asbestos
W.M. Ewing, Compass Environmental, Inc., Kennesaw, GA

11:30AM
Natural Asbestos Contamination: Biancavilla's Case
Federica Paglietti*, F. Damiani*, P. De Simone* and Sergio Malinconico**,
* Higher Italian Institute for Occupational Health and Safety - Department for Production (ISPESL) Facilities and Human Settlements (DIPIA)
** Research Assignment ISPESL DIPIA

12:00 Noon **Poster Session II** Robert G. Lewis, Poster Coordinator

1:00 LUNCH (On Your Own)

THURSDAY, JULY 17, 2008

Session VII: Application of Monitoring Techniques to Real-World Projects

Evening Session Chair: Thomas G. Laubenthal
The Environmental Institute
Marietta, GA

7:00PM
Trees as reservoirs for amphibole fibers in Libby, Montana
Tony Ward, University of Montana, Missoula, MT

7:30PM
Comparison of the Alternative Asbestos Control Method and the NESHAP Method for Asbestos-Containing Buildings
Glenn Shaul, USEPA, Cincinnati, OH

8:00PM
Environmental Monitorings During Reclamation's Operations: Evaluation of the Monitorings Realized in the Area Ex Sacelit inside the Site of National Interest of Milazzo (Sicily-Italy)
Federica Paglietti*, P. De Simone*, V. Di Molfetta** and Sergio Malinconico**
* Higher Italian Institute for Occupational Health and Safety - Department for Production (ISPESL) Facilities and Human Settlements (DIPIA)
** Research Assignment ISPESL DIPIA

8:30PM Break

8:45PM
Airborne Asbestos Concentrations in System-Built Schools
Garry Burdett, Steve Cotterell and Catherine Taylor, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, UK

9:15PM
The Swift Creek Asbestos Site: A Case Study
Julie Wroble, US EPA, Seattle, WA

9:45PM **Discussion**

10:00PM **Adjourn**

FRIDAY, JULY 18, 2008

8:30AM
Welcome and Opening Remarks
Michael E. Beard, James S. Webber and Harry L. Rook, Conference Co-Chairs

Session VIII: Dose Response

Morning Session Chair: Phillip Cook, USEPA, Duluth, MN

8:45AM
***In vitro* Biosolubility and Cellular Toxicity Testing of Asbestiform, Fibrous, and Cleavage Fragment Mineral Particles from Diverse Geologic Environments**
G.S. Plumlee, S. Morman, H. Lowers, G. Meeker, B. Van Gosen, and T. Ziegler, USGS, Denver, CO

9:15AM
Thin Is In: Libby Fibers Elutriated for Toxicological Studies
James S. Webber, Wadsworth Center, New York State Department of Health, Albany, NY; and Tony Ward, David Blake, and Jean Pfau, Center for Environmental Health Sciences, University of Montana, Missoula, MT

9:45AM
A Mechanistic View of the Determinants of Toxicity of Mineral Fibers for Quantitative Risk Assessment
D. DeVoney, M. Gwinn, T. Bateson, B. Sonawane and K. Guyton, USEPA, Washington, DC; P. Sullivan, NIOSH, Morgantown, WV

10:15AM Break

10:30AM
Application of Rat Organ or Tissue Based Dose-Response Data for Determination of Relative Cancer Potencies of Mineral Fibers.
Phillip M. Cook, USEPA, Duluth, MN

11:00AM
The Stanton Study Revisited: Interpretation of Dose-response Data Based on TEM Analyses of 32 Fiber Samples after Simulated *in vivo* Dissolution.
Phillip M. Cook, USEPA, Duluth, MN

11:30AM
Mesothelioma: What We Know Based on Tissue Analysis for Asbestos
Ronald Dodson, ERI Consulting, Tyler, TX

12:00 Noon LUNCH (On Your Own)

Friday, JULY 18, 2008

Session IX: Health Risks

Afternoon Session Chair: Ronald Dodson
ERI Consulting, Inc.
Tyler, TX

1:30PM
Asbestos and Other Mineral Fibers: A Roadmap for Scientific Research
Paul J. Middendorf, Ralph Zumwalde, and Robert M. Castellan, CDC/NIOSH, Cincinnati, OH

2:00PM
Issues Concerning Mineral Fiber Exposures, Health Effects, and Risk Assessment
Christopher P. Weis and Aubrey K. Miller, USEPA, Denver, CO

2:30PM
Efforts to Improve EPA's Method for Quantification of Cancer Risk from Asbestos
Stiven Foster, William Sette, and Tim Barry, USEPA, Washington, DC; William Brattin, Syracuse Research Corporation, Denver, CO

3:00PM Break

3:15PM
Risk Attributable to Amphibole and Amphibole Asbestos:
A Study to Address the Issues
D. Wayne Berman, Aeolus, Inc., Albany, CA

3:45PM
Risk Assessment Models for Asbestos and Their Applicability for Low Exposures
Garry Burdett, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, UK

4:15PM
Conclusions and Recommendations – Open Discussion by All

5:00PM **CONFERENCE ADJOURNS!!**

Appendix B

"Sampling and Analysis of Asbestos Fibers on Filter Media to Support Exposure Assessments: Bench-Scale Testing"

EPA/600/R-08/046 - April 2008

Note Yellow Highlighted Areas Which Denote Where the Term "Chrysotile" Should Be Added to the Publication

United States Environmental Protection Agency

Sampling and Analysis of Asbestos Fibers on Filter Media to Support Exposure Assessments: Bench-Scale Testing

EPA/600/R-08/046
April 2008
www.epa.gov

Sampling and Analysis of Asbestos Fibers on Filter Media to Support Exposure Assessments: Bench-Scale Testing

Daniel A. Vallero, Ph.D.
U.S. Environmental Protection Agency
National Exposure Research Laboratory
Research Triangle Park, NC 27711

John R. Kominsky
Environmental Quality Management, Inc.
Cincinnati, OH 45240

Michael E. Beard and Owen Crankshaw
RTI International
Research Triangle Park, NC 27709

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

ABSTRACT

Sampling efficiency is essential in exposure assessments of contaminants in air, as well as other matrices. In the measurement of airborne contaminants, it is critical to collect a sample of air containing representative contaminants in the air of concern, that is, contaminant concentration and size distribution in the sampled air must be the same as that of the air of concern. Typically, mixed cellulose ester (MCE, 0.45 or 0.8 μm pore size) and to a much lesser extent, capillary-pore polycarbonate (PC, 0.4 μm pore size) membrane filters are used to collect airborne asbestos for count measurement and fiber size analysis. A literature review did not identify any study that compared the collection efficiencies of 0.45 μm and 0.8 μm pore size MCE or 0.4 μm pore size PC membrane filters for asbestos aerosols. In this research study chrysotile asbestos (fibers both shorter and longer than 5 μm) were generated in an aerosol chamber and sampled by 25-mm diameter MCE filter media to compare the efficiency of a 0.45 μm pore size filters versus 0.8 μ pore size filter media. In addition, the effect of plasma etching times on fiber densities was evaluated. Polycarbonate filters were not tested in this study.

This study demonstrated a significant difference in collection efficiency between 0.45 μm and 0.8 μm pore size MCE filters for asbestos aerosols (structures $\geq$0.5 μm length; s = 0.5 μm). That is, the collection efficiency of a 0.45 μm pore size MCE filter is statistically significantly higher than that of the 0.8 μm pore size MCE filter. However, for asbestos structures > 5μm in length, there is no statistically significant difference between the collection efficiencies of the 0.45 μm and 0.8 μm pore size MCE filters. The mean concentration of asbestos fibers ($\geq$0.5 μm in length) increased with etching time (2, 4, 8, and 16 minutes). Regression analysis of etching time and concentration showed that doubling the etching time adds an average of 180 s/mm^2 to the total asbestos concentration within the concentration range tested. Plasma etching time had no effect on the reported fiber densities of fibers longer than 5 μm.

Many asbestos exposure risk models attribute most of the health effects to fibers longer than 5 μm in length. In these models, both the 0.45 μm and 0.8 μm pore size MCE filter can produce suitable estimates of the airborne asbestos concentrations. However, some models suggest a more significant role for asbestos fibers <5 μm in length. Exposure monitoring for these models should consider only the 0.45 μm pore size MCE filters as recommended by the U.S. EPA AHERA protocol and other methods.

This report is based upon study findings and information submitted in fulfillment of Contract No. 68-C-00-186, Task Order No. 0020 by Environmental Quality Management, Inc. under the sponsorship of the United States Environmental Protection Agency, covering a period from April 28, 2006 to December 24, 2006, and work was completed as of December 31, 2006.

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SECTION 1

INTRODUCTION

Over the years, a number of optical and electron microscopy methods have been developed to detect and quantify asbestos in air, as well as in other matrices. Each method has its own strengths and weaknesses, and they must be carefully evaluated to determine how best to detect and quantify asbestos under a given circumstance.[1-10]

Typically, mixed cellulose ester (0.45 μm or 0.8 μm pore size) and to a lesser extent, capillary-pore polycarbonate (0.4 μm pore size) membrane filters are used to collect airborne asbestos for count measurement and fiber size analysis. It is important to recognize that pore size specification for a membrane filter is an absolute specification only for capillary-pore type filters such as the polycarbonate (PC). The pore size rating for tortuous path filters, such as the mixed-cellulose ester (MCE) filters, is an effective pore size and not a specification that particles exceeding that size are retained by the filter.[11]

The two types of filters differ in their chemical and physical composition. Polycarbonate filters have a smooth filtering surface; the pores are cylindrical, almost uniform in diameter, and essentially perpendicular to the surface (Figure 1). A mixed-cellulose ester filter is a thicker filter with a sponge-like appearance and relies on a tangled maze of cellulose ester strands to trap fibers (Figure 2). For microscopic analysis of asbestos deposited on the filter, it is critical that the fibers be in a single plane to assure they are in focus during the analysis. This requirement is simple to achieve for PC filters because of the smooth filtering surface. Whereas, the MCE filter requires two additional steps in the direct preparation procedure. The MCE filter must be collapsed with an organic solvent and then the top layer of the collapsed filter material must be etched away with a low temperature plasma asher.

The U.S. EPA[1] and the National Institute for Occupational Safety and Health (NIOSH)[5] recommend using 0.45 μm pore size MCE filters when performing transmission electron microscopy (TEM) analysis on the samples because the particles deposit closer to the surface than in larger pore size (e.g., 0.8 μm pore size) MCE filters. However, the higher pressure drop through the 0.45 μm pore size MCE filters normally preclude their use with battery-powered personal sampling pumps.[5] In order to obtain a uniform distribution of collected particulates across the surface of the collecting filter, EPA[1] requires a 5.0 μm pore size MCE backing filter

be placed behind the collecting filter followed by a cellulose support. This tandem filter assembly further increases the pressure drop, which at given velocity is directly proportional to the thickness of the filter. ISO Method 10312:1995 also recommends the tandem filter assembly for 0.45 µm pore size MCE as well as for the 0.4 µm pore size PC filters.[3]

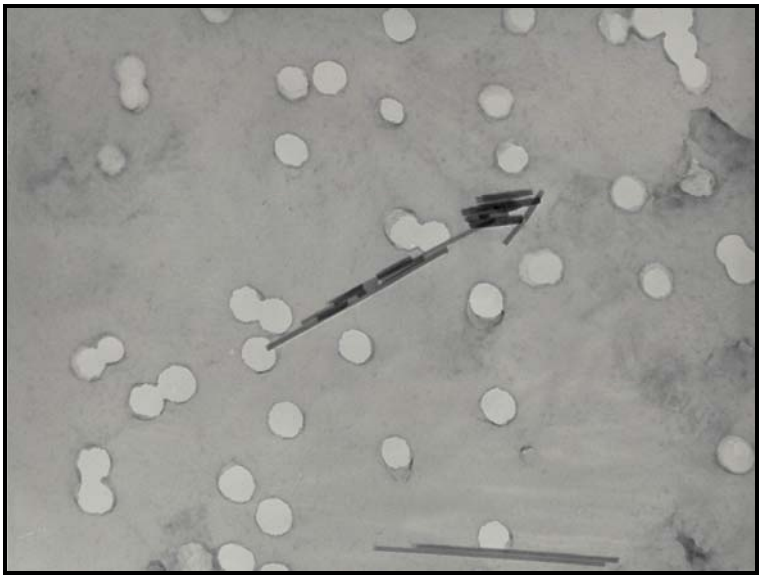

Figure 1. Transmission electron microscope photograph of a 0.4 µm pore size capillary pore polycarbonate membrane filter (16,000X magnification)
(Source RTI International, S. Doorn with permission.)

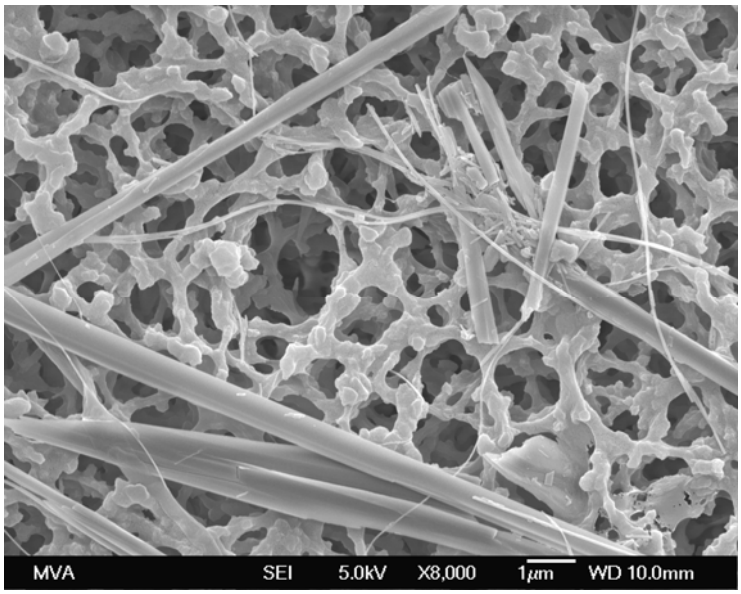

Figure 2. Scanning electron microscope photograph of a 0.8 µm pore size mixed cellulose ester membrane filter (8,000X magnification).
(Source MVA Scientific, J. Millette with permission.)

Studies reporting the collection efficiencies of MCE and PC membrane filters for asbestos aerosols are meager. One study investigated the collection efficiencies of 8 μm pore size MCE filters and 0.2, 0.4, and 0.8 μm pore size PC filters for aerosols of chrysotile asbestos.[13] For MCE filters with 8-μm pores, the collection efficiency at a face velocity of 3.5 cm/s fell from 100% for fibers >5 μm in length to 75% for fibers of 2 μm in length, and to 25% for fibers approximately 0.5 μm in length. For PC filters with pore diameters of 0.2, 0.4, and 0.8 μm, collection efficiencies began to drop for fiber lengths <3 μm and fiber diameters <0.2 μm. For 0.2 μm pores, the efficiencies for fibers >0.5 μm did not drop below approximately 80%, whereas for 0.8 μm pores, the efficiencies dropped to near zero for fiber lengths below 0.5 μm and diameters below 0.05 μm. This study showed that collection efficiencies decrease substantially with fiber length for both MCE and PC pore filters of larger pore size. The orientation of the airborne fibers as they approach the filter pore entrances may have an important effect on their ability to penetrate the filter.

A literature review did not identify any study that compared the collection efficiencies of 0.45 μm and 0.8 μm pore size MCE or 0.4 μm pore size PC membrane filters for asbestos aerosols.[12] Information culled from an informal survey[12] of asbestos analytical laboratories, members of the American Society for Testing and Materials (ASTM) and Environmental Information Association (EIA) revealed that MCE filters were primarily used for airborne asbestos sampling. Accordingly, it was concluded that testing of the PC filters would not be conducted in this study allowing the project to concentrate its efforts and funding on 0.45 μm and 0.8 μm pore size MCE filters that are widely used in asbestos exposure studies today.

Therefore, U.S. EPA's National Exposure Research Laboratory (NERL) conducted a study in which chrysotile asbestos (fibers both shorter and longer than 5 μm) were generated in an aerosol chamber and sampled by 25-mm diameter MCE filter media to compare the efficiency of 0.45 μm pore size versus 0.8 μ pore size filter media. In addition, the effect of plasma etching times on fiber densities was evaluated.

1.1 Project Objectives

The goal of this research study was to determine the effect of mixed cellulose ester membrane filter pore size on collection efficiency of asbestos fiber aerosols. The following are the specific objectives of this study:

- Compare the collection efficiency (structures ≥0.5 µm in length) of asbestos aerosols of 0.45 µm and 0.8 µm pore size mixed cellulose ester filters.
- Compare the collection efficiency (structures >5 µm in length) of asbestos aerosols of 0.45 µm and 0.8 µm pore size mixed cellulose ester filters.
- To evaluate the effect of plasma etching time (2, 4, 6, 8, and 16 minutes) on 0.45 µm pore size mixed cellulose ester filters on total asbestos concentration (structures ≥0.5 µm in length).
- To evaluate the effect of plasma etching time (2, 4, 6, 8, and 16 minutes) on 0.45 µm pore size mixed cellulose ester filters on total asbestos concentration (structures >5 µm in length).

SECTION 2

STUDY DESIGN AND METHODOLOGY

2.1 Preparation of Samples for Analysis

SRI International (SRI) loaded the 25-mm diameter (0.45 μm and 0.8 μm pore size) MCE filters with chrysotile asbestos in an aerosol chamber. The filters were prepared at two fiber loading levels: "low" nominal loading (2-5 fibers per grid opening) and "high" nominal loading (>5 fibers per grid opening). The filters were prepared in four batches of 18 filters each as shown in Table 1.

Table 1. Batch setup for 25-mm MCE filter loading experiment

Batch	Filter Pore Size/Loading and Number of Samples			
	0.45 μm		0.8 μm	
	Low	High	Low	High
1	12	-	6	-
2	-	6	-	12
3	6	-	12	-
4	-	12	-	6
Total	18	18	18	18

2.1.1 SRI Dust Generation and Collection System

Test atmospheres of dusts and fibers are dynamically generated in a dust generation and collection system engineered and built by SRI. The main components are:

- A fluidized bed generator, which delivers a continuous stream of aerosol material;
- A sonic velocity disperser, which disperses, de-agglomerates, and dilutes the aerosol;
- A settling tower, where large particles are removed; and
- Sample collection chambers, where 320 samples can be collected simultaneously.

All of the air streams pass through ionizers to prevent static charge effects. The components are described in detail below.

2.1.1.1. Fluidized Bed Generator

A variety of SRI custom-designed and constructed feeders can be used to introduce particulates and fibers into the collection system. Asbestos fiber atmospheres have been

generated using a two-component fluidized bed consisting of bronze powder and sized asbestos fibers. By proper adjustment of air flow through the bottom and across the top of the bed, a pressure differential is established sufficient to fluidize the bronze powder bed and the asbestos fibers are stripped at a low rate and fed to the sonic velocity disperser. There is a concentration gradient using this system because the asbestos is depleted from the fluidized bed. However, because a homogeneous atmosphere is produced, all 320 sampling ports will still collect an equivalent amount of asbestos. By varying the sampling time, the asbestos loading on the cassettes can be adjusted.

2.1.1.2. Sonic Velocity Disperser and Settling Tower

The air stream from the dust feeder carries the aerosol to the sonic velocity disperser. Dilution air is also delivered to the sonic velocity disperser, where it deagglomerates the aerosol under the action of an on-line static eliminator and high air velocity. The aerosol then enters the settling tower, the linear velocity is reduced, and the larger particles settle out to the base of the settling tower. The diluted aerosol is then divided uniformly among the four collection chambers.

2.1.1.3. Sample Collection Chamber

The base section of the sample collection chamber consists of layers of gaskets and machined aluminum sheets. Eighty sampling ports are situated in an 8 x 10 matrix arrangement. Downstream from each port is a critical flow orifice. The mounting sheet in which the 80 critical flow orifices are embedded forms the upper section of a vacuum chamber, so that a vacuum to this chamber creates the necessary pressure differential to operate the orifices. Aerosol enters the collection chambers through 20 symmetrically located passages. The 320 orifices (80 for each of four sample collection chambers) all have the same diameter and were calibrated at the time the system was constructed to ensure that all the ports sample at the same flow rate. The orifices form a matched set, with a maximum flow rate of 2 L/min through each air monitor in the system.

The collection chambers can be opened from the top by removing a cover. Air monitor cassettes are connected to the sampling port by a Luer fitting. A variety of cassette and filter types and sizes, including 25- and 37-mm-diameter cassettes, mixed cellulose ester filters, and polycarbonate filters, can be accommodated in the collection chambers.

2.1.1.4 Dust Feeder

The asbestos-containing powder was metered into the collection system by a grooved disk, which rotates at a known rate. The powder is pneumatically unloaded from a groove in the disk and then conveyed to a sonic velocity disperser.

Powder is loaded into the top of the powder hopper through the powder feed port. The powder then drops down into the hopper connector, where it is pushed into the groove of the disk by rubber wipers attached to the bottom of the agitator shaft. A spring-loaded guard ring surrounds the hopper connector and scrapes the disk to prevent the disk from carrying away excess powder. The rotation of the disk continuously carries the powder in the groove to the unloading nozzle, where it is removed pneumatically by compressed air. The powder feed rate is determined entirely by the rotation speed of the disk and the size of the groove. The loading of powder on sample filters is further adjusted by varying the collection time.

Asbestos fiber atmospheres are generated using a two-component fluidized bed consisting of bronze powder and sized asbestos fibers. By proper adjustment of air flow through the bottom and across the top of the bed, the bronze powder bed is fluidized and the asbestos fibers are stripped at a low rate and fed to the sonic velocity disperser. There is a concentration gradient using this system because the asbestos is depleted from the fluidized bed. However, because a homogeneous atmosphere is produced, each sampling port still collects an equivalent amount of asbestos. By varying the sampling time, the asbestos loading on the cassettes is adjusted. By using a combination of the fluidized bed and the powder feeder, a variety of fibers and particulates is loaded onto a filter.

2.1.1.5 Sonic Velocity Disperser and Settling Tower

The air stream from the dust feeder carries the aerosol to the sonic velocity disperser. Dilution air is also delivered to the sonic velocity disperser, where it de-agglomerates the aerosol under the action of an on-line static eliminator and high air velocity. The aerosol then enters the

settling tower, the linear velocity is reduced, and the larger particles settle out to the base of the settling tower. The diluted aerosol is then divided uniformly among the four collection chambers.

2.1.1.6 Sample Collection Chamber

The base section of the sample collection chamber consists of layers of gaskets and machined-aluminum sheets. Eighty sampling ports are situated in an 8 x 10 matrix arrangement. Downstream from each port is a critical flow orifice. The mounting sheet in which the 80 critical flow orifices are embedded forms the upper section of a vacuum chamber, so that a vacuum to this chamber creates the necessary pressure differential to operate the orifices. Aerosol enters the collection chambers through 20 symmetrically located passages. The 320 orifices (80 for each of four sample collection chambers) all have the same diameter and were calibrated at the time the system was constructed to ensure that all the ports sample at the same flow rate. The orifices form a matched set, with a maximum flow rate of 2 L/min through each air monitor in the system. SRI collected 100 filters in each batch, and utilized 80 of the primary filter cassettes (e.g., in a 0.45 µm pore size batch the 0.45 µm pore size filters are the primary filter cassettes) and 20 of the secondary filter cassettes (e.g., in a 0.45 µm pore size batch the 0.8 µm pore size filters are the secondary filter cassettes), so that the variable loadings of different batches could be adequately measured and controlled. The 80 primary filter cassettes and 20 secondary filter cassettes were divided evenly between the four quadrants of the chamber. It should be noted that the fiber loading process is trial and error. That is, the asbestos structures per area of filter will be different for two filters in the same loading category.

The collection chambers are opened from the top by removing a cover. Air monitoring filter cassettes are connected to the sampling port using a luer fitting. Quality control activities include checking each orifice flow rate with a digital flow meter before and after sample generation and analyzing for background levels to prevent carryover contamination.

2.2 Sample Analysis Strategy

2.2.1 Collection Efficiency of 0.45 µm and 0.8 µm Pore Size MCE Filters

Seventy-two filter samples were prepared and analyzed to test pore size differences and fiber loading differences between the two MCE filter types (see Table 1). Eighteen filters were

analyzed for each of four batches. Twelve of the primary filters and six of the secondary filters were analyzed for each batch.

2.2.2 Effect of Plasma Etching Time on Asbestos Concentration

Annex A "*Determination of Operating Conditions for Plasma Asher*" of ISO Method 10312:1995 requires etching of collapsed filters for 8 minutes using operating parameters determined for completely ashing uncollapsed filters in 15 minutes. Including the specified 8 minute etching time, three additional etching times were used to etch the 0.45 μm MCE filters (Table 2). Hence, a total of 12 filters were etched for each of four different times (2, 4, 8, and 16-minutes). The filters were loaded at a "high" nominal loading.

Table 2. Plasma etching time for 0.45 μm pore size MCE filters

Filter Loading	Plasma Etching Time (Minutes) and Number of Samples			
	2	**4**	**8**	**16**
High	12	12	12	12

2.3 Analytical Methodology

2.3.1 TEM Specimen Preparation

TEM specimens were prepared from the air filters using the dimethylformamide (DMF) collapsing procedure of ISO 10312:1995, as specified for cellulose ester filters. DMF was used as the solvent for dissolution of the filter in the Jaffe washer. Prior to etching the filters, a March Plasmod asher was calibrated in accordance with ISO 10312:1995 procedures whereby an uncollapsed filter was oxidized under controlled settings in approximately 15 minutes. After asher calibration, the filters were prepared using ISO 10312:1995 procedures and etched for either 2, 4, 8, or 16-minutes. For each filter, an equal number of grid openings were examined on at least two prepared TEM specimen prepared from a one-quarter sector of the filter using 200 mesh-indexed copper grids. The remaining part of the filter was archived in the original cassette in clean and secure storage.

2.3.2 TEM Measurement Strategy

1. The minimum aspect ratio for the analyses was 3:1, as permitted by ISO 10312:1995. As required in the ISO Method, any identified compact clusters and compact matrices

were counted as total asbestos fibers, even if the 3:1 aspect ratio was not met.

2. All fibers larger than or equal to (≥) 0.5 µm in length were quantified with the following breakdown according to ranges by length: a) ≥0.5 to 5.0 µm; b) >5.0 to 10.0 µm; and c) >10.0 µm.

3. The fiber counting data was distributed approximately equally among a minimum of two specimen grids prepared from different parts of the filter sector.

4. The TEM specimen examinations were performed at approximately 20,000 magnification.

5. Phase contrast microscopy-equivalent asbestos structures (PCME) were also determined. PCME asbestos structures, as defined by ISO 10312:1995, are >5 µm in length and from 0.2 to 3.0 µm in diameter with an aspect ration ≥3:1.

2.3.3 Determination of Stopping Point

The analytical sensitivity was ≥ 6 asbestos structures per square millimeter (s/mm^2). In principle, any analytical sensitivity can be achieved by increasing the number of grid openings or fields examined. Likewise, statistical uncertainty around the number of fibers observed can be reduced by counting more fibers. Stopping rules are needed to identify when microscopic examination should stop, both at the low end (zero or very few fibers observed) and at the high end (many fibers observed). The analysis was terminated upon completion of counting ≥25 asbestos structures in a minimum of 10 grid openings or 100 asbestos structures in 4 grid openings. In any case completion of the grid opening being analyzed when the stopping rules have been met was completed.

2.4 Quality Control/Quality Assurance

2.4.1 MCE Filters (0.45 µm and 0.8 µm pore size)

The filter samples generated by SRI were monitored for absolute concentration and for intra-batch uniformity by an independent quality control (QC) laboratory, RTI International (RTI). RTI prepared and analyzed samples and provided feedback to SRI regarding filter concentration so that the batches meet the target concentrations. They also used the data to validate the uniformity of concentration of filters within each batch. For each batch of filters produced, a relative standard deviation (RSD) of fibers per grid opening was developed with 40

grid openings analyzed. Based upon historical RSD levels for SRI filters, each batch was expected to have an RSD at or below 0.50, which was the case for this study.

2.4.2 Lot Blanks

Before filter samples were loaded with chrysotile asbestos two unused filters from each filter lot of 0.45 and 0.8 µm filters were analyzed by the QC laboratory to determine the mean asbestos structure count. The lot blanks were analyzed for asbestos structures by using ISO 10312:1995. In all cases the mean count for all types of asbestos structures was $\leq$ 18 structures/mm^2.

2.4.3 Laboratory Blanks

Laboratory blanks are unused filters that are prepared and analyzed in the same manner as the field samples to verify that reagents and equipment are free of the subject analyte, and that contamination has not occurred during the analysis process. The laboratory analyzed two 0.45 µm and two 0.8 µm pore size MCE filters. Blanks were prepared and analyzed along with the other samples. Asbestos was not present on any of the samples at an analytical sensitivity of 8.9 s/mm^2.

2.4.4 Interlaboratory QA/QC

After analysis by the primary laboratory (Clayton Group Services, Inc.), selected filters and grid preparations were sent to the QC laboratory for analysis as an independent QA/QC check. The QA/QC sample analyses included duplicates and verified counts by TEM.

2.4.4.1 Duplicate Analyses

The duplicate analyses was conducted by repreparing and analyzing the same filter using the same ISO 10312:1995 counting rules. Results of the QC duplicate analysis are presented in Table 3. In Table 3, the third column lists the number of structures analyzed, and the fourth column lists the concentration of asbestos structures per unit area. Note: The primary laboratory used a grid opening size of 0.011 mm^2, and the QC laboratory used a grid opening size of 0.0086 mm^2. Column 5 presents the results of the duplicate sample variability. All four interlaboratory duplicate samples met the acceptance criteria.

Table 3. Interlaboratory duplicates analysis of MCE filters for asbestos by TEM

Sample No.	Laboratory	Analyses		Actual Variability[a]	Accepted Variability
		# Structures	Structures/mm^2		
A0611022-001A	Primary	26	230		
	QC	23	270	1.8	2.24
A0611022-002A	Primary	28	250		
	QC	19	220	1.3	2.24
A0611022-003A	Primary	34	300		
	QC	27	310	0.39	2.24
A0611022-004A	Primary	31	280		
	QC	22	280	0.86	2.24

[a]Analytical Variability = $\frac{|(\text{Analysis A}) - (\text{Analysis B})|}{\sqrt{(\text{Analysis A} + \text{Analysis B})}}$

This variability is the absolute value of the difference of the two analyses, divided by the square root of the sum, which is an estimate of the standard deviation of the difference based on a Poisson counting model. The value 2.24 was selected as targeting false positive rates of 2.5% (1/40) for the Poisson model.

2.4.4.2 Verified Counts

Verification counting involved re-examination of the same grid openings analyzed by the primary laboratory. The verification counting was performed on two of the analyses for each of the filter pore sizes. Verified counting was conducted using the procedure defined in NISTIR 5351, "*Airborne Asbestos Method: Standard Test Method for Verified Analysis of Asbestos by Transmission Electron Microscopy – Version 2.0*."

Results of interlaboratory QC verified counting by TEM are presented in Table 4. In Table 4, the third column gives the total number of asbestos structures counted in the specified grid openings which were determined to be true positives (TP). Column 4 gives the number of

false positives (FP) and Column 5 gives the number of false negatives (FN). The results of all four analyses are combined at the bottom, and ratios of true positives, false positives, and false negatives are developed in the final two rows for both the primary and QC laboratory. Column 6 shows the "pass" (Yes) or "fail" (No) status of the comparison. The acceptable variability is >80% true positives, <20% false negatives, and <20% false positives. All interlaboratory verified count analysis met the acceptance criteria.

Table 4. Interlaboratory verified count analysis of MCE filters for asbestos by TEM

Sample No.	Laboratory	Number of Structures			Pass?
		True Positive	False Positive	False Negative	
A0611024-003A	Primary	24	0	1	
	QC	25	1	0	
A0611024-002A	Primary	35	3	0	
	QC	32	0	3	
A0611024-004A	Primary	5	0	1	
	QC	6	1	0	
A0611024-005A	Primary	8	0	0	
	QC	7	0	1	
Totals	Primary	72	3	2	
	QC	70	2	4	
Percentages	Primary	97%	4%	3%	Yes
	QC	95%	3%	5%	Yes

SECTION 3

RESULTS AND DISCUSSION

3.1 Collection Efficiency (Fibers ≥0.5 µm) of 0.45 and 0.8 µm Pore Size MCE Filters

A total of 72 filters (18 of 0.45 µm pore size and 18 of 0.8 µm pore size) were loaded with asbestos at two filter loadings (low = 2-5 fibers/grid opening; and high = >5 fibers/grid opening). The experiment was conducted in 4 batches of 18 filters each (Table 1).

All asbestos structures ≥0.5 µm in length were quantified and categorized according to three ranges by length: ≥0.5 to 5 µm; >5 to 10 µm; and >10 µm. The asbestos fiber distribution for the low and high filter loadings is presented in Table 5.

Table 5. Mean asbestos concentration (s/mm^2) by batch and fiber length

Batch	Mean concentration (s/mm^2) by length of fibers					
	Filter Low Loading			Filter High Loading		
	≥0.5-5 µm	>5-10 µm	>10 µm	≥0.5-5 µm	>5-10 µm	>10 µm
0.45 µm pore size						
1	237	63	21	-	-	-
2	-	-	-	585	284	89
3	316	71	21	-	-	-
4	-	-	-	1200	235	66
0.8 µm pore size						
1	194	60	19	-	-	-
2	-	-	-	429	225	88
3	287	78	22	-	-	-
4	-	-	-	960	261	71

The mean filter concentration (total asbestos structures per mm^2) for the two filter types in each batch is presented in Table 6. In each batch, the mean concentration on the 0.45 µm filters is higher than on the 0.8 µm filters. In Batch 2, the difference is statistically significant using both the two-sample t-test ($p = 0.008$) and the nonparametric Wilcoxon Rank-Sum test ($p = 0.01$). In the other 3 batches, the difference is not statistically significant.

Table 6. Mean total asbestos concentration (s/mm^2) by batch and filter type

Batch	Mean Concentration (s/mm^2) by Filter Pore Size and Nominal Loading			
	0.45 µm		0.8 µm	
	Low Loading	High Loading	Low Loading	High Loading
1	321	-	274	-
2	-	958	-	743
3	413	-	388	-
4	-	1512	-	1304

It is apparent from Table 6 that the two "Low Loading" batches differ substantially, as do the two "High Loading" batches. For example, the 0.8 µm concentration in Batch 3 is higher than the 0.45 µm concentration in Batch 1, even though both batches were loaded at the same nominal level. Likewise, the 0.8 µm concentration in Batch 4 is higher than the 0.45 µm concentration in Batch 2. In fact, the between-batch differences (at the same nominal loading) are greater than the differences between the two filter types. Thus, it is not appropriate to combine the 4 batches into a single dataset for purposes of an overall comparison between the two filter types (Primary Objective 1).

To make the overall comparison, the sum of the Wilcoxon statistics for the 4 separate batches was used. In each batch, the Wilcoxon statistic is the rank-sum for the 0.45 µm concentrations in the 18 samples comprising the batch. Under the null hypothesis that the two filter types have the same collection efficiency, this statistic has (approximately) a normal distribution with mean 57 (Batches 2 and 3) or 114 (Batches 1 and 4), and variance 114 (all batches). Thus, under the null hypothesis, the sum of the 4 Wilcoxon statistics is approximately normal with mean 342 and variance 456. The observed value of the sum is 395.5, resulting in a test statistic z = (395.5-342)/21.4 = 2.50, with a p-value of 0.01. Thus, the null hypothesis is rejected, and we conclude that the collection efficiency of the 0.45 µm pore size filter for fibers ≥0.5 µm in length is significantly higher than that of the 0.8 µm pore size filter. However, for fibers >5 µm in length there is no difference in the two filter pore sizes (see Figures 5 and 6, Section 3.2).

3.2 Effect of Plasma Etching Time on Total Asbestos Concentration (Fibers ≥0.5 µm)

Four different etching times were used to etch 0.45 µm filters. A total of 12 filters were etched for each of the 4 times (2, 4, 8 and 16 minutes). The filters were loaded in at the "High" nominal loading. Table 7 shows the mean total asbestos concentration (s/mm^2) for fibers ≥0.5 µm in length for each etching time.

Table 7. Mean total asbestos (fibers >0.5 µm) concentration (s/mm^2) for variable etching times

Filter Loading	Plasma Etching Time for 0.45 µm MCE Filters (Minutes)			
	2	4	8	16
High	1123	1251	1512	1635

The mean concentration increases with etching time. To examine the relationship between etching time and concentration, two regression models were fit to the data. The first model assumes a linear relationship between etching time (t) and concentration (TA):

$$TA = a + b*t \quad (1)$$

The fitted equation was

$$TA\ (s/mm^2) = 1113 + 35.7*t \qquad (R^2 = 0.24)$$

The relatively low value of R^2 is due to the considerable variability in concentrations observed at each etching time. However, the coefficient of t is highly significant (SE = 9.27). This regression indicates that each additional minute of etching time adds an average of 35.7 s/mm^2 to the total asbestos concentration within the range tested.

The second regression model assumes a logarithmic relationship between concentration and etching time, of the form

$$TA = a + b*\log(t) \quad (2)$$

Here, "log" denotes the natural logarithm (ln). The fitted equation was

$$TA\ (s/cm^2) = 931 + 259*\ln(t) \qquad (R^2 = 0.27)$$

R^2 is slightly higher than for the linear model. Again, the regression is highly significant (SE of coefficient = 63). This model estimates that a doubling of the etching time adds an average of 180 s/cm^2 to the total asbestos concentration within the range tested.

On physical grounds, it would appear that a point of diminishing returns for increased etching time would be reached, i.e., there is a level of etching time beyond which no increase in concentration is expected (Figures 3 and 4). The data from this experiment do not appear to shed light on what this level might be. For example, the increase in concentration from 8 to 16 minutes is comparable to that from 2 to 4 minutes. However, the increase in concentration with etching time does not appear to be the case for fibers >5 µm in length (Figures 5 and 6). These data suggest that the etching time of 8 minutes that is specified in ISO 10312:1995 is adequate for fibers >5 µm in length. If fibers <5 µm in length are of interest, additional research may be needed to determine the optimum etching time.

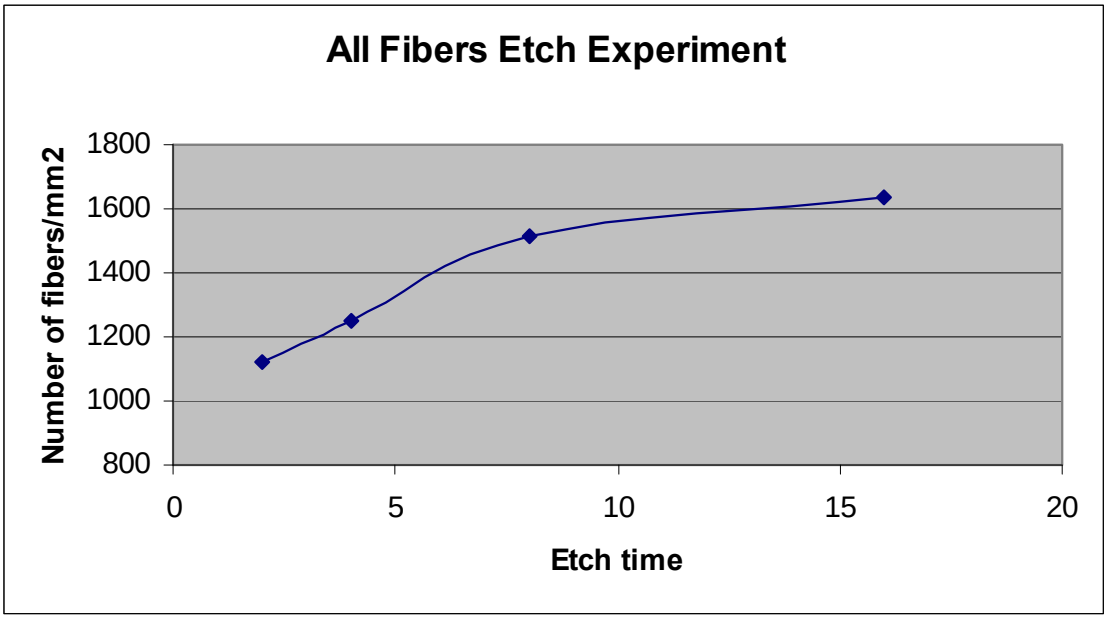

Figure 3. Fiber densities (fibers ≥ 0.5 µm in length) observed on 0.45 µm pore size MCE Filter.

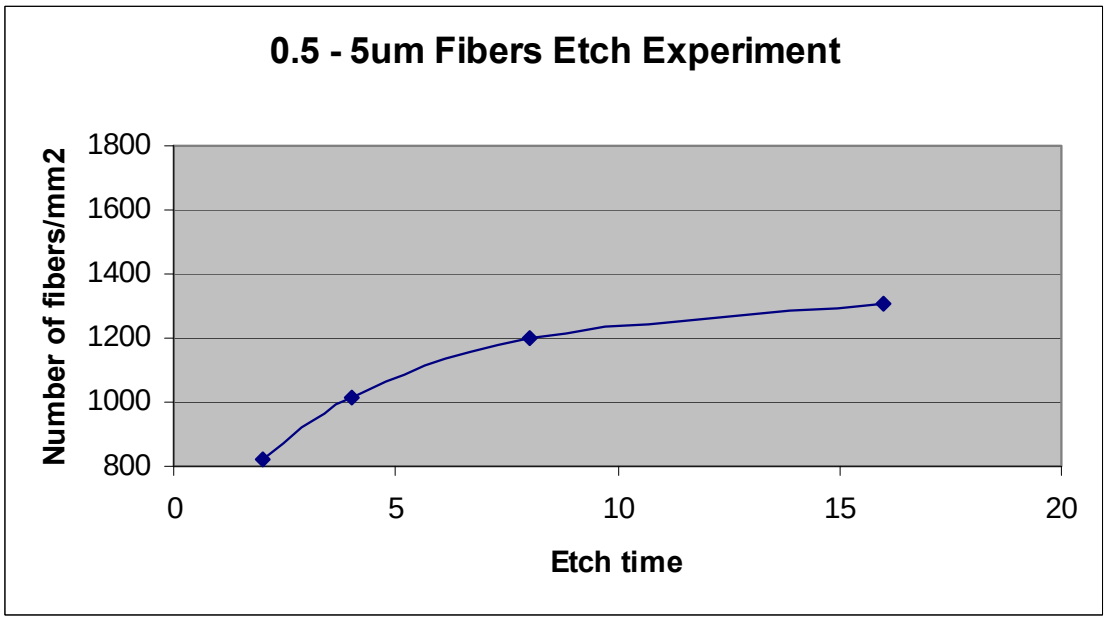

Figure 4. Fiber densities (fibers ≥ 0.5 to 5 µm in length) observed on 0.45 µm pore size MCE Filter.

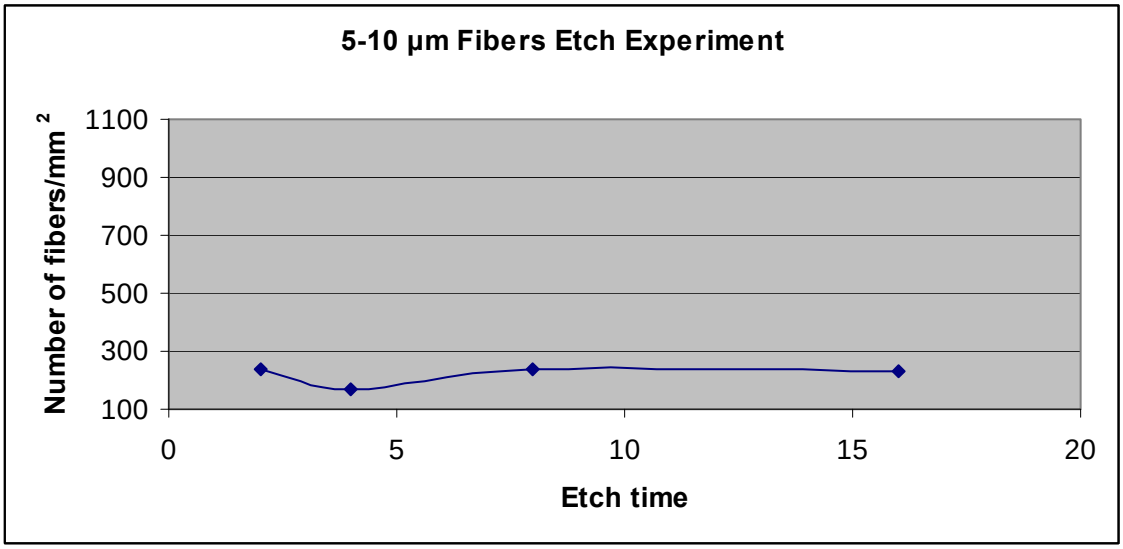

Figure 5. Fiber densities (fibers 5 to 10 µm in length) observed on 0.45 µm pore size MCE filter.

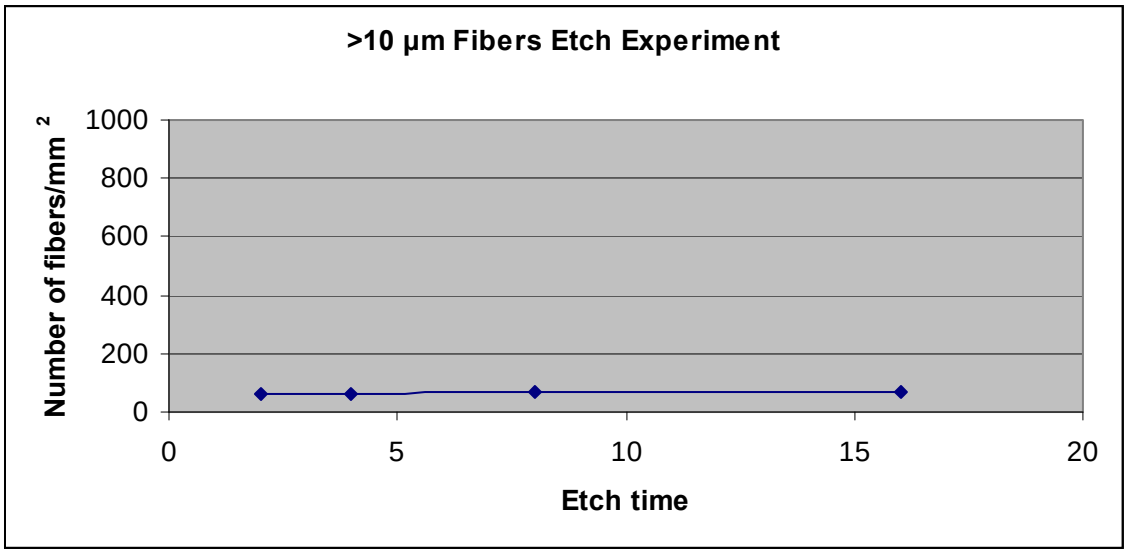

Figure 6. Fiber densities (fibers >10 µm in length) observed on 0.45 µm pore size MCE filter.

3.3 Comparison of Collection Efficiency of 0.45 µm and 0.8 µm Pore Size Filters for Fibers > 5 µm in Length

The mean filter concentration (total asbestos structures, > 5 µm, per mm^2) for the two filter types in each batch is shown in Table 8.

Table 8. Mean asbestos concentration (s/mm^2) for fibers ≥5 µm in length by batch and filter type

Batch	Mean Concentration (s/mm^2) by Filter Pore Size and Nominal Loading			
	0.45 µm		0.8 µm	
	Low Loading	High Loading	Low Loading	High Loading
1	84	-	80	-
2	-	373	-	313
3	92	-	100	-
4	-	301	-	333

In Batches 1 (Low loading) and 2 (High loading), the mean concentration on the 0.45 µm filters is higher than on the 0.8 µm filters. In Batches 3 (Low loading) and 4 (High loading), the reverse is true; i.e., the 0.8 µm filters are higher. None of the differences are statistically significant using both the two-sample t-test. When Batches 1 and 3 (Low loading), and Batches 2 and 4 (High loading), are combined, the differences between the filter types are even smaller. We conclude that, for fibers > 5 µm, there is no difference between the collection efficiencies of the 0.45 µm and 0.8 µm filters.

3.4 Effect of Plasma Etching Time on Asbestos Fibers >5 µm

Table 9 shows the mean total asbestos concentration for fibers > 5 µm (s/mm^2) for each etching time. The mean concentrations for the 2, 8 and 16 minute etching times are virtually identical. The mean concentration for the 4 minute etching time is a little lower.

Table 9. Mean asbestos concentration for fibers > 5 µm (s/mm^2) for variable etching times

Filter Loading	Plasma Etching Time for 0.45 µm MCE Filters (Minutes)			
	2	4	8	16
High	301	232	301	303

To examine the relationship between etching time and concentration, two regression models were fit to the data. The first model assumes a linear relationship between etching time (t) and concentration (TA):

$$TA = a + b*t \quad (3)$$

The fitted equation was

$$TA\ (s/mm^2) = 267 + 2.2*t \qquad (R^2 = 0.016)$$

The regression is not statistically significant.

The second regression model assumes a logarithmic relationship between concentration and etching time, of the form

$$TA = a + b*\log(t) \tag{4}$$

Here, "log" denotes the natural logarithm. The fitted equation was

$$TA\ (s/mm^2) = 266 + 10.5*\log(t) \qquad (R^2 = 0.007)$$

Again, the regression is not statistically significant. The fact that neither regression is statistically significant indicates that, for 0.45 µm filters**,** there is no statistically significant relationship between etching time and concentration of fibers > 5 µm.

This is consistent with a study conducted by Chatifield.[11] The study showed that fiber densities for fibers longer 5 µm are similar for 0.2 µm pore size PC filters and various etching schedules for 0.22 µm pore size MCE filters. In particular, plasma etching had no effect on the reported fiber densities of fibers longer than 5 µm. At the 1% significance level, there was no statistically significant differences between the mean fiber densities for any of the etching preparations evaluated.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 Collection Efficiency of 0.45 and 0.8 µm Pore Size MCE Filters

Conclusion—The null hypothesis was that the two mixed-cellulose ester (MCE) filter types (0.45 µm and 0.8 µm pore size) have the same collection efficiency for asbestos aerosol (structures ≥0.5 µm length). The null hypothesis was rejected, and it is concluded the collection efficiency of the 0.45 µm pore size MCE filter is statistically significantly higher than that of the 0.8 µm pore size MCE filter ($p=0.01$) for fibers ≥ 0.5 µm in length. However, for asbestos structures >5 µm in length, there is no statistically significant difference between the collection efficiencies of 0.45 µm and 0.8 µm pore size MCE filters ($p>0.05$).

Recommendation—This research study demonstrates that the collection efficiency of a 0.45 µm pore size MCE filter for aerosols of asbestos fibers (structures ≥0.5 µm) is greater than that for a 0.8 µm pore size MCE filter. However, there is no difference in collection efficiency between these pore sizes for structures longer than 5.0 µm. If the exposure study is focused on fibers less than 5.0 µm, the investigator should use filters with 0.45 µm pore size. If the exposure study is only interested in structures longer than 5.0 µm, then either filter pore size may be used.

4.2 Effect of Etching Time for 0.45 µm MCE Filters

Conclusion—There is a significant difference in the effect of etching times for fibers < 5.0 µm and fibers > 5.0 µm in length. The mean concentration of asbestos fibers ≥0.5 µm in length increases with etching time (2, 4, 8, and 16-minutes) of 0.45 µm pore size MCE filters. Regression analysis of etching time and concentrations showed that doubling the etching time adds an average of 180 s/mm^2 to the total asbestos concentration within the range tested. This increase is a diminishing percentage of the total fiber count as the etching time increases; *e.g.*, 20% at 2 minutes, and 12% at 8 minutes. There is likely an etching time beyond which no increase in concentration is expected and in fact would decrease; the data from this experiment did not identify this etching time. However, etching the filter for longer periods may remove too much filter so that a specimen for TEM analysis cannot be prepared.

For fibers > 5.0 µm in length, there is no significant difference in numbers of structures counted at the etching times used in these tests.

Recommendation—Since most asbestos exposure risk models include fibers > 5.0 µm in length, the 8 minute etching time specified in ISO 10312:1995 is adequate. However, if an exposure study is focused on fibers < 5.0 µm in length, the etching time of 8-minutes should be reviewed. A study should be conducted to determine the etching time beyond which no significant increase in asbestos concentration of fibers < 5.0 µm in length is expected.

4.3 Additional Recommendations

- NIOSH Method 7402 notes that a 0.45 μm pore size filter may be difficult to use with some personal sampling pumps due to the pressure drop across this filter. The tandem MCE filter assembly (0.45 μm pore size collection filter and 5 μm pore size diffusing filter) recommended by AHERA (40 CFR §761), ISO Method 10312:1995, and ASTM Method D 6281-04 may preclude the use of some battery-powered personal sampling pumps due to the resultant high pressure drop. Analysis of filters by TEM require the use of the 5 μm pore size diffusing filter to assure uniform deposition on the primary collection filter. A study should be conducted to evaluate the difference between asbestos aerosols collected on 0.45 μm and 0.8 μm pore size MCE filters with and without the 5 μm pore size MCE diffusing filter. Also, specifications for personal pumps should be investigated to determine optimum requirements for sampling using the 0.45 μm pore size collection filter and 5 μm pore size diffusing filter combination.

- This study has focused on MCE filters since this filter type is the primary choice for air monitoring. Exposure to asbestos through inhalation is considered the most likely route for asbestos exposure. Polycarbonate (PC) filters are used in monitoring asbestos in water and possibly by some studies of inhalation. Since no data has been found comparing the relative effectiveness of MCE and PC filters, research should be considered to compare the retention of asbestos fibers on 0.45 μm pore size MCE filters to 0.4 μm pore size polycarbonate filters.

SECTION 5

ACKNOWLEDGMENTS

This report is the result of recommendations and insights from numerous scientists interested in advancing the state-of-the-science of airborne fiber measurements. In particular, the experts in the EPA Regional Offices, most notably Julie Wroble, Mark Maddaloni, Aubrey Miller, Phil King and Mary Goldade, provided reviews and recommendations from the onset.

SECTION 6

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Appendix – Asbestos Data Listing

Batch	Loading	Sample ID	Grid Openings Counted	Grid Opening Size (mm)	Filter Type (MCE = mixed cellulose ester)	Size (mm)	Effective Filter Area (mm^2)	Total Asbestos Structures (s/mm^2)
1	Low	A0611022-002A	10	0.01122	MCE Filter, 0.45 µm	25	385	249.6
1	Low	A0611022-003A	10	0.01122	MCE Filter, 0.45µm	25	385	303.0
1	Low	A0611022-006A	10	0.01122	MCE Filter, 0.45µm	25	385	249.6
1	Low	A0611022-008A	10	0.01122	MCE Filter, 0.45µm	25	385	606.1
1	Low	A0611022-010A	10	0.01122	MCE Filter, .45µm	25	385	267.4
1	Low	A0611022-012A	10	0.01122	MCE Filter, 0.45µm	25	385	311.9
1	Low	A0611022-013A	10	0.01122	MCE Filter, 0.45µm	25	385	294.1
1	Low	A0611022-014A	10	0.01122	MCE Filter, 0.45µm	25	385	267.4
1	Low	A0611022-015A	12	0.01122	MCE Filter, 0.45µm	25	385	185.7
1	Low	A0611022-016A	10	0.01122	MCE Filter, 0.45µm	25	385	481.3
1	Low	A0611022-017A	10	0.01122	MCE Filter, 0.45µm	25	385	338.7
1	Low	A0611022-018A	10	0.01122	MCE Filter, 0.45µm	25	385	294.1
1	Low	A0611022-001A	10	0.01122	MCE Filter, 0.8µm	25	385	231.7
1	Low	A0611022-004A	10	0.01122	MCE Filter, 0.8µm	25	385	276.3
1	Low	A0611022-005A	10	0.01122	MCE Filter, 0.8µm	25	385	267.4
1	Low	A0611022-007A	11	0.01122	MCE Filter, 0.8µm	25	385	210.7
1	Low	A0611022-009A	10	0.01122	MCE Filter, 0.8µm	25	385	285.2
1	Low	A0611022-011A	10	0.01122	MCE Filter, 0.8µm	25	385	374.3
2	High	A0611023-001A	8	0.01122	MCE Filter, 0.45µm	25	385	1114.1
2	High	A0611023-002A	8	0.01122	MCE Filter, 0.45µm	25	385	1192.1
2	High	A0611023-004A	10	0.01122	MCE Filter, 0.45µm	25	385	748.7
2	High	A0611023-005A	10	0.01122	MCE Filter, 0.45µm	25	385	944.7
2	High	A0611023-009A	10	0.01122	MCE Filter, 0.45µm	25	385	935.8
2	High	A0611023-010A	10	0.01122	MCE Filter, 0.45µm	25	385	811.1
2	High	A0611023-	10	0.01122	MCE Filter,	25	385	748.7

Batch	Loading	Sample ID	Grid Openings Counted	Grid Opening Size (mm)	Filter Type (MCE = mixed cellulose ester)	Size (mm)	Effective Filter Area (mm^2)	Total Asbestos Structures (s/mm^2)
		003A			0.8µm			
2	High	A0611023-006A	10	0.01122	MCE Filter, 0.8µm	25	385	713.0
2	High	A0611023-007A	10	0.01122	MCE Filter, 0.8µm	25	385	641.7
2	High	A0611023-008A	10	0.01122	MCE Filter, 0.8µm	25	385	606.1
2	High	A0611023-011A	10	0.01122	MCE Filter, 0.8µm	25	385	980.4
2	High	A0611023-012A	10	0.01122	MCE Filter, 0.8µm	25	385	891.3
2	High	A0611023-013A	10	0.01122	MCE Filter, 0.8µm	25	385	641.7
2	High	A0611023-014A	10	0.01122	MCE Filter, 0.8µm	25	385	730.8
2	High	A0611023-015A	10	0.01122	MCE Filter, 0.8µm	25	385	935.8
2	High	A0611023-016A	10	0.01122	MCE Filter, 0.8µm	25	385	650.6
2	High	A0611023-017A	10	0.01122	MCE Filter, 0.8µm	25	385	730.8
2	High	A0611023-018A	10	0.01122	MCE Filter, 0.8µm	25	385	650.6
3	Low	A0611025-001A	10	0.01122	MCE Filter, 0.45µm	25	385	463.5
3	Low	A0611025-002A	10	0.01122	MCE Filter, 0.45µm	25	385	436.7
3	Low	A0611025-003A	10	0.01122	MCE Filter, 0.45µm	25	385	392.2
3	Low	A0611025-004A	10	0.01122	MCE Filter, 0.45µm	25	385	436.7
3	Low	A0611025-005A	10	0.01122	MCE Filter, 0.45µm	25	385	311.9
3	Low	A0611025-007A	10	0.01122	MCE Filter, 0.45µm	25	385	436.7
3	Low	A0611025-006A	10	0.01122	MCE Filter, 0.8µm	25	385	267.4
3	Low	A0611025-008A	10	0.01122	MCE Filter, 0.8µm	25	385	445.6
3	Low	A0611025-009A	10	0.01122	MCE Filter, 0.8µm	25	385	472.4
3	Low	A0611025-010A	10	0.01122	MCE Filter, 0.8µm	25	385	499.1
3	Low	A0611025-011A	10	0.01122	MCE Filter, 0.8µm	25	385	383.2
3	Low	A0611025-012A	10	0.01122	MCE Filter, 0.8µm	25	385	383.2
3	Low	A0611025-013A	10	0.01122	MCE Filter, 0.8µm	25	385	267.4
3	Low	A0611025-014A	10	0.01122	MCE Filter, 0.8µm	25	385	508.0

Batch	Loading	Sample ID	Grid Openings Counted	Grid Opening Size (mm)	Filter Type (MCE = mixed cellulose ester)	Size (mm)	Effective Filter Area (mm^2)	Total Asbestos Structures (s/mm^2)
3	Low	A0611025-015A	10	0.01122	MCE Filter, 0.8µm	25	385	463.5
3	Low	A0611025-016A	10	0.01122	MCE Filter, 0.8µm	25	385	356.5
3	Low	A0611025-017A	10	0.01122	MCE Filter, 0.8µm	25	385	303.0
3	Low	A0611025-018A	10	0.01122	MCE Filter, 0.8µm	25	385	303.0
4	High	A0611028-001A	9	0.01122	MCE Filter, 0.45µm	25	385	1029.9
4	High	A0611028-002A	5	0.01122	MCE Filter, 0.45µm	25	385	1836.0
4	High	A0611028-003A	7	0.01122	MCE Filter, 0.45µm	25	385	1311.4
4	High	A0611028-007A	9	0.01122	MCE Filter, 0.45µm	25	385	1029.9
4	High	A0611028-008A	8	0.01122	MCE Filter, 0.45µm	25	385	1225.5
4	High	A0611028-010A	9	0.01122	MCE Filter, 0.45µm	25	385	1099.2
4	High	A0611028-011A	5	0.01122	MCE Filter, 0.45µm	25	385	1978.6
4	High	A0611028-012A	5	0.01122	MCE Filter, 0.45µm	25	385	2014.3
4	High	A0611028-014A	5	0.01122	MCE Filter, 0.45µm	25	385	1853.8
4	High	A0611028-015A	6	0.01122	MCE Filter, 0.45µm	25	385	1738.0
4	High	A0611028-016A	6	0.01122	MCE Filter, 0.45µm	25	385	1515.2
4	High	A0611028-017A	7	0.01122	MCE Filter, 0.45µm	25	385	1515.2
4	High	A0611028-004A	8	0.01122	MCE Filter, 0.8µm	25	385	1214.3
4	High	A0611028-005A	7	0.01122	MCE Filter, 0.8µm	25	385	1286.0
4	High	A0611028-006A	6	0.01122	MCE Filter, 0.8µm	25	385	1515.2
4	High	A0611028-009A	10	0.01122	MCE Filter, 0.8µm	25	385	873.4
4	High	A0611028-013A	9	0.01122	MCE Filter, 0.8µm	25	385	1099.2
4	High	A0611028-018A	5	0.01122	MCE Filter, 0.8µm	25	385	1836.0

Batch	Sample ID	Grid Openings Counted	Grid Opening Size (mm)	Filter Type (MCE = mixed cellulose ester)	Size (mm)	Effective Filter Area (mm^2)	Total Asbestos Structures (s/mm^2)
16	A0611024-001A	6	0.0112	MCE Filter, 0.45µm	25	385	1723
16	A0611024-002A	6	0.0112	MCE Filter, 0.45µm	25	385	1738
16	A0611024-003A	7	0.0112	MCE Filter, 0.45µm	25	385	1757
16	A0611024-004A	5	0.0112	MCE Filter, 0.45µm	25	385	1800
16	A0611024-005A	5	0.0112	MCE Filter, 0.45µm	25	385	1783
16	A0611024-006A	6	0.0112	MCE Filter, 0.45µm	25	385	1485
16	A0611024-007A	5	0.0112	MCE Filter, 0.45µm	25	385	1872
16	A0611024-008A	6	0.0112	MCE Filter, 0.45µm	25	385	1619
16	A0611024-009A	6	0.0112	MCE Filter, 0.45µm	25	385	1753
16	A0611024-010A	6	0.0112	MCE Filter, 0.45µm	25	385	1485
16	A0611024-011A	6	0.0112	MCE Filter, 0.45µm	25	385	1619
16	A0611024-012A	9	0.0112	MCE Filter, 0.45µm	25	385	990
4	A0611026-001A	8	0.0112	MCE Filter, 0.45µm	25	385	1125
4	A0611026-002A	10	0.0112	MCE Filter, 0.45µm	25	385	900
4	A0611026-003A	10	0.0112	MCE Filter, 0.45µm	25	385	633
4	A0611026-004A	5	0.0112	MCE Filter, 0.45µm	25	385	1854
4	A0611026-005A	6	0.0112	MCE Filter, 0.45µm	25	385	1575
4	A0611026-006A	6	0.0112	MCE Filter, 0.45µm	25	385	1515
4	A0611026-007A	7	0.0112	MCE Filter, 0.45µm	25	385	1439
4	A0611026-008A	6	0.0112	MCE Filter, 0.45µm	25	385	1515
4	A0611026-009A	5	0.0112	MCE Filter, 0.45µm	25	385	1836
4	A0611026-010A	10	0.0112	MCE Filter, 0.45µm	25	385	499
4	A0611026-011A	9	0.0112	MCE Filter, 0.45µm	25	385	1000
4	A0611026-012A	8	0.0112	MCE Filter, 0.45µm	25	385	1125
2	A0611027-	10	0.0112	MCE Filter,	25	385	535

Batch	Sample ID	Grid Openings Counted	Grid Opening Size (mm)	Filter Type (MCE = mixed cellulose ester)	Size (mm)	Effective Filter Area (mm^2)	Total Asbestos Structures (s/mm^2)
	001A			0.45µm			
2	A0611027-002A	10	0.0112	MCE Filter, 0.45µm	25	385	856
2	A0611027-003A	7	0.0112	MCE Filter, 0.45µm	25	385	1426
2	A0611027-004A	7	0.0112	MCE Filter, 0.45µm	25	385	1286
2	A0611027-005A	9	0.0112	MCE Filter, 0.45µm	25	385	1188
2	A0611027-006A	8	0.0112	MCE Filter, 0.45µm	25	385	1114
2	A0611027-007A	10	0.0112	MCE Filter, 0.45µm	25	385	811
2	A0611027-008A	8	0.0112	MCE Filter, 0.45µm	25	385	1136
2	A0611027-009A	9	0.0112	MCE Filter, 0.45µm	25	385	1030
2	A0611027-010A	7	0.0112	MCE Filter, 0.45µm	25	385	1350
2	A0611027-011A	6	0.0112	MCE Filter, 0.45µm	25	385	1634
2	A0611027-012A	9	0.0112	MCE Filter, 0.45µm	25	385	1109
8	A0611028-001A	9	0.0112	MCE Filter, 0.45µm	25	385	1030
8	A0611028-002A	5	0.0112	MCE Filter, 0.45µm	25	385	1836
8	A0611028-003A	7	0.0112	MCE Filter, 0.45µm	25	385	1311
8	A0611028-007A	9	0.0112	MCE Filter, 0.45µm	25	385	1030
8	A0611028-008A	8	0.0112	MCE Filter, 0.45µm	25	385	1225
8	A0611028-010A	9	0.0112	MCE Filter, 0.45µm	25	385	1099
8	A0611028-011A	5	0.0112	MCE Filter, 0.45µm	25	385	1979
8	A0611028-012A	5	0.0112	MCE Filter, 0.45µm	25	385	2014
8	A0611028-014A	5	0.0112	MCE Filter, 0.45µm	25	385	1854
8	A0611028-015A	6	0.0112	MCE Filter, 0.45µm	25	385	1738
8	A0611028-016A	6	0.0112	MCE Filter, 0.45µm	25	385	1515
8	A0611028-017A	7	0.0112	MCE Filter, 0.45µm	25	385	1515

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