



Memorandum

Date: June 13, 2001

From: Roy M. Fleming, Sc.D., Director, Research Grants Program
Office of Extramural Programs, NIOSH, D30 

Subject: Final Report Submitted for Entry into NTIS for Grant 5 R03 OH003774-02.

To: William D. Bennett
Data Systems Team, Information Resources Branch, EID, NIOSH, P03/C18

The attached final report has been received from the principal investigator on the subject NIOSH grant. If this document is forwarded to the National Technical Information Service, please let us know when a document number is known so that we can inform anyone who inquires about this final report.

Any publications that are included with this report are highlighted on the list below.

Attachment

cc: Sherri Diana, EID, P03/C13

List of Publications

Wagner J, Leith D: Passive Aerosol Sampler. Part I: Principle of Operation. Aerosol Sci. Technol 34:186-192, 2001

Wagner J, Leith D: Passive Aerosol Sampler. Part II: Wind Tunnel Experiments. Aerosol Sci. Technol 34:193-201, 2001

Wagner J, Leith: Field Tests of A Passive Aerosol Sampler. J Aerosol Sci. 32:33-48, 2001

NIOSH Extramural Award Final Report Summary

Title: Passive Sampler for Particles
Investigator: David Leith, Sc.D.
Affiliation: University of North Carolina
City & State: Chapel Hill, NC
Telephone: (919) 966-3851
Award Number: 5 R03 OH003774-02
Start & End Date: 9/30/1998–9/29/2000
Total Project Cost: \$72,250
Program Area: Asthma & Chronic Obstructive Pulmonary Disease
Key Words:

Abstract:

A miniature, passive aerosol sampler has been developed. The device can sample periods of hours to weeks, is inexpensive and easy to operate, and has potential utility as a personal sampler. Scanning electron microscopy (SEM) and automated image analysis are used to count and size collected particles with $dp > 0.1$ micrometers. Alternatively, more advanced microscopy techniques can be used for ambient-pressure analysis or elemental characterization. The measured flux and a deposition velocity model are used to estimate the average mass concentration and size distribution over the sampling period. The deposition velocity model consists of a theoretical component and an empirical component. The theoretical component can be approximated by the simple terminal settling velocity in many cases.

Wind tunnel experiments were performed on the passive sampler using a high-output aerosol generator and an eight-stage impactor as a reference sampler. The empirical portion of the deposition velocity model was determined as a function of particle size by minimizing the sum-of-squares difference between impactor and passive sampler across all size bins and experiments. The relatively simple correlation is a function of the particle Reynolds number only. Precision was assessed by running three passive samplers in each experiment, yielding $CV-PM_{2.5}=18.1\%$ and $CV-PM_{10}=32.2\%$. If SEM is used, the passive sampler will exhibit some error when sampling volatile aerosols.

Field tests were conducted in a well-ventilated occupational environment with coarse, high-concentration aerosols. Measured friction velocities were less than 0.4 m/s, a range in which passive sampler performance does not depend on turbulence. Passive sampler results correlated well with those of eight-stage impactors, with $R^2=0.80$ and 0.93 for $PM_{2.5}$ and PM_{10} . Average disagreement between the passive samplers and the impactors was -31% and 41% for $PM_{2.5}$ and PM_{10} . These discrepancies were attributed to the small amount of fine particles present, hygroscopic particles, and particle bounce in the impactors. The average $CV-PM_{10}$ for all samples was 20% . The average $CV-PM_{2.5}$ for hygroscopic samples was higher, 59% ; water losses in these samples created ill-defined particle boundaries which led to imprecision.

Publications

Wagner J, Leith D: Passive Aerosol Sampler. Part I: Principle of Operation. *Aerosol Sci. Technol* 34:186-192, 2001

NIOSH Extramural Award Final Report Summary

Wagner J, Leith D: Passive Aerosol Sampler. Part II: Wind Tunnel Experiments. Aerosol Sci. Technol 34:193-201, 2001

Wagner J, Leith: Field Tests of A Passive Aerosol Sampler. J Aerosol Sci. 32:33-48, 2001

Final Performance Report of

Passive Sampler for Particles
5 R03 OHO3774-01

Project Sponsor:

Centers for Disease Control and Prevention
Grants Management Branch
2920 Brandywine Road, Suite 3000, Mail Stop E-09
Atlanta, GA 30341-4146

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May 4, 2001

ABSTRACT

A miniature, passive aerosol sampler has been developed. The device can sample for periods of hours to weeks, is inexpensive and easy to operate, and has potential utility as a personal sampler. Scanning electron microscopy (SEM) and automated image analysis are used to count and size collected particles with $d_p > 0.1$ micrometers. Alternatively, more advanced microscopy techniques can be used for ambient-pressure analysis or elemental characterization. The measured flux and a deposition velocity model are used to estimate the average mass concentration and size distribution over the sampling period. The deposition velocity model consists of a theoretical component and an empirical component. The theoretical component can be approximated by the simple terminal settling velocity in many cases.

Wind tunnel experiments were performed on the passive sampler using a high-output aerosol generator and an eight-stage impactor as a reference sampler. The empirical portion of the deposition velocity model was determined as a function of particle size by minimizing the sum-of-squares difference between impactor and passive sampler across all size bins and experiments. The relatively simple correlation is a function of the particle Reynolds number only. Precision was assessed by running three passive samplers in each experiment, yielding $CV_{PM_{2.5}} = 18.1\%$ and $CV_{PM_{10}} = 32.2\%$. If SEM is used, the passive sampler will exhibit some error when sampling volatile aerosols.

Field tests were conducted in a well-ventilated occupational environment with coarse, high-concentration aerosols. Measured friction velocities were less than 0.4 m/s, a range in which passive sampler performance does not depend on turbulence. Passive sampler results correlated well with those of eight-stage impactors, with $R^2 = 0.80$ and 0.93 for $PM_{2.5}$ and PM_{10} . Average disagreement between the passive samplers and the impactors was -31% and 41% for $PM_{2.5}$ and PM_{10} . These discrepancies were attributed to the small amount of fine particles present, hygroscopic particles, and particle bounce in the impactors. The average $CV_{PM_{10}}$ for all samples was 20% . The average $CV_{PM_{2.5}}$ for hygroscopic samples was higher, 59% ; water losses in these samples created ill-defined particle boundaries which led to imprecision.

SIGNIFICANT FINDINGS

This work has led to the development of a miniature, passive aerosol sampler that will reliably estimate both the long-term average concentrations and size distributions. This sampler is about the size of a dime, costs only a few dollars, and collects particles by gravity, diffusion, and convection. These passive aerosol samples are examined with scanning electron microscopy (SEM) and analyzed using a refined deposition velocity model and the measured particle flux to the sampler to obtain estimates of average concentrations and size distributions. The accuracy and precision of the passive sampler are not dependent on relative humidity, wind speed, or aerosol concentration. Field tests in an occupational environment confirmed that the size distribution and concentration data for the passive sampler correlated well with those from a conventional sampler.

A patent application for the passive aerosol sampler has been filed through the University of North Carolina at Chapel Hill.

USEFULNESS OF FINDINGS

Epidemiological studies have shown a relationship between particle exposure and community health effects, but the mechanisms in this relationship are not clear due to the uncertainties in exposure assessment. Current methods to assess aerosol exposures are limited by their expense, obtrusiveness, and maintenance requirements.

The aerosol sampler designed and tested in this project has a simple, passive design. This sampler is small, lightweight (1.7 g), inexpensive, easy to operate, so that a large number of passive samplers can be deployed. Additionally, it can sample unattended for hours to weeks and has potential for use as a personal sampler. Because the passive sampler is much lighter, smaller, quieter, and far less inconvenient than pump-operated personal samplers, it may yield more representative measurements and would be a more feasible sampler for children or elderly people to wear. Hence, this passive aerosol sampler should improve assessments of long-term mean exposures for chronic health studies and address the quantitative relationship between personal and regional exposures. These concerns have been deemed top priorities by the National Academy of Sciences as stated in the National Research Council Report on research priorities in assessing the health effects of particulate matter.

PUBLICATIONS

1. Wagner, J. and Leith, D. (2001). Passive aerosol sampler. Part I: Principle of operation, *Aerosol Sci. Technol.* 34: 186-192.

This manuscript addresses aims, one, two, three, and nine of the project: (1) The development and refinement of the deposition model including the theoretical basis of the deposition velocity model; (2) the development of an analytical procedure with protocols for using scanning electron microscopy (SEM) and image analysis software; (3) the refinement of the passive sampler design using computational fluid dynamics (CFD) and various practical improvements, and (9) the writing and submission of the manuscript.

2. Wagner, J. and Leith, D. (2001). Passive aerosol sampler. Part II: Wind tunnel experiments, *Aerosol Sci. Technol.* 34: 193-201.

This manuscript addresses aims four, five, six, and nine of the project: (4) The design, construction, and characterization of a specially-designed wind tunnel to refine the empirical portion of the deposition velocity model under different wind conditions; (5) the testing of the passive aerosol sampler in the wind tunnel at different wind speeds to determine precision; other tests were performed to determine dependency on relative humidity and aerosol concentration; (6) the analysis of the data using the appropriate statistics, and (9) writing and submission of a manuscript for publication.

3. Wagner, J. and Leith, D. (2001). Field tests of a passive aerosol sampler, *J. Aerosol Sci.* 32: 33-48.

In this manuscript, the authors address aims seven, eight, and nine: (7) Field tests of the passive aerosol sampler were conducted under real-world turbulence and aerosol conditions and compared to a conventional sampler, the eight-stage Andersen impactor. (8) data from these tests were analyzed, and (9) the appropriate paper was written.

4. Wagner, J., PhD Thesis, "Passive aerosol sampler", The University of North Carolina at Chapel Hill, Department of Environmental Sciences and Engineering, (2000).

This doctoral thesis encompasses the three publications listed above as well as the data and Standard Operating Procedures from all tests.

FINANCIAL STATUS REPORT

Please refer to separate document

EQUIPMENT INVENTORY

No equipment having a unit acquisition cost of \$1000.00 or more was acquired under this contract.

FINAL INVENTION STATEMENT

Please refer to separate document