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# Project Summary

# Annual Report on Establishment and Operation of the Eastern Fine Particle and Visibility Network

Albert Hendler, Lisa Collins and James Howes

**The Eastern Fine Particle and Visibility Monitoring Network (EFPVN) was established to obtain long term, regionally scaled measurements of visibility and related fine particle characteristics throughout the eastern United States. The overall goal of the EFPVN is to provide data through which a quantitative assessment can be made regarding trends and causes of visibility impairment in the East. This goal will be achieved through continuous monitoring of atmospheric light scattering coefficient, 24-hour integrated measurements of fine particle mass, elemental composition and optical absorption coefficient, and photographic measurements of visual range taken three times each day. The program is expected to run for five years.**

**During the first year of the EFPVN, five monitoring stations were established. Three of the stations are located in the southeastern U.S., where airport observations indicate as much as 60 percent reduction in visual range during the past 40 years. The remaining stations are located in the Northeast, where long term trends are less evident.**

**Data collected and processed through July, 1988 are summarized. Light scattering data consists of measurements made with both conventional and insulated integrating nephelometers. The insulated nephelometers maintained the sample temperature typically to within 2.5°C above ambient.**

**A limited number of fine particle filter samples were collected and processed through July, 1988. These consist of fifty-two 12-hour integrated samples collected at the Horton Station field site, near Blacksburg, Virginia. During the sampling period, May 3 through May 31, sulfate ion typically comprised about half of the fine particle mass (FPM). FPM and light scattering coefficient ($B_{sp}$) were related according to $B_{sp} \times 10^4 = 0.032(FPM) + 0.11$, where $B_{sp}$ is in $m^{-1}$ and FPM is in $\mu g/m^3$. The regression coefficient compares well with similar measurements conducted during other field studies. The average particle scattering and absorption coefficients were $0.67 \times 10^{-4}$ $m^{-1}$ and $0.04 \times 10^{-4}$ $m^{-1}$, respectively.**

***This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Ordering information at back).***

## Introduction

Visibility impairment is one of the most obvious effects of air pollution. This is particularly true in the eastern U.S. where episodes of widespread regional haze are known to occur. Recent studies have shown that the average visibility in most areas east of the Mississippi River is less than 15 miles. In contrast, average visual range in most of the western U.S. exceeds 25 miles and approaches 100 miles in some pristine areas of the desert Southwest. Historical records indicate that the intensity of haziness in the eastern U.S. has increased over the past 40 years, although the magnitude of this trend varies from place to place and in some areas has leveled during the past decade. The visibility reduction in the East is usually attributed to the concentration of people and industrial activities and the concomitant consumption of energy, especially derived from coal. However, the extent, trends, and specific causes of visibility impairment are not well characterized since much of the previous data, obtained primarily by human observations made at airports, are limited and primarily qualitative in nature.

One of the predominant causes of visibility reduction is the extinction (scattering and absorption) of light by fine particles (<2.5 µm diameter). Results from several field studies show that extinction of light due to scattering increases proportionally to increases in fine particle mass concentrations, although the scattering efficiency of fine particles varies from place to place and exhibits seasonal differences. The relative contributions of light scattering and absorption to total extinction are also known to vary. These variations may be attributed to differences in fine particle characteristics such as size, elemental composition, and state of hydration.

Under the auspices of the U.S. Environmental Protection Agency's, Atmospheric Research and Exposure Assessment Laboratory (AREAL), the Eastern Fine Particle and Visibility Monitoring Network (EFPVN) was established to provide data through which a quantitative assessment can be made regarding trends and causes of visibility reduction in the eastern U.S. Specifically, the monitoring network was designed to provide long term, regionally scaled visibility and fine particle monitoring data to accomplish the following objectives:

- Determine spatial and temporal variations in the ambient air quality parameters associated with visibility impairment.
- Improve the understanding of visibility - fine particle relationships, especially with regard to fine particle characteristics such as organic and elemental carbon, nitrate, sulfate, and liquid water content.
- Support modeling efforts to identify the sources of visibility degradation (receptor modeling) and to predict visibility impairment (e.g.,pollutant dispersion modeling).
- Elucidate the links between visibility impairment, climate modification and acid deposition caused by anthropogenic air pollutants.
- Provide support for decisions regarding ambient fine particle regulation.

To achieve these goals, a network of 10 Tier 1 stations and up to 20 Tier 2 stations has been proposed. However, current funding has limited the network to only five Tier 1 stations and no Tier 2 stations. At Tier 1 stations, color photography and nephelometry are used to measure visibility parameters. Fine particle samples (0-2.5 µm diameter) are collected on filters and analyzed for mass, light absorption, elemental composition, sulfate, nitrate, and organic and elemental carbon. Only color photographic measurements were proposed at Tier 2 stations.

During March - June, 1988, five Tier 1 monitoring stations were established. This document reports the accomplishments achieved in initiating the field program and to develop the data management system required to support the network. Site descriptions and initial data summaries are also presented.

## Experimental Procedures

### *Site Selection*

Five Tier 1 monitoring stations were established during the first year of the EFPVN program. The locations of the stations are shown in Figure 1. The general location of each site was chosen to be representative of a multi-state region with similar visibility trends.[1] One station, Look Rock, Tennessee, is collocated with an Interagency Monitoring for Protection of Visual Environments (IMPROVE) network station. This arrangement will provide a basis for merging data from the two networks to assess visibility trends throughout the entire U.S. Of the remaining stations, three are collocated with stations in the EPA Dry Deposition Network (DDN) and one is collocated with the Massachusetts State Acid Deposition and NAMS station at Quabbin Reservoir. Collocation with these other programs is designed to benefit the EFPVN by providing supporting pollutant and meteorological data to interpret the results of the visibility and fine particle measurements. Some cost benefits have also been achieved by sharing existing facili services and trained operators addition, all sites, except for Look R are either collocated with or within 1Ę of stations in the EPA Acid-MOI network. The proximity to Acid-MO monitoring sites will facilitate examin of possible linkage between visib impairing aerosols and acid depositio

Candidate locations for EFPVN stat were identified by the EPA. geographical distribution of th locations was chosen so that each of stations would represent a regior unique visibility trends as determi from airport observations.[1] Each ca date site was surveyed to assess con ance with the following criteria:

- The site is representative in cli tology, meteorology, and topogra of the region under study.
- An unobstructed vista is avail that contains a target (or targets) the proper inherent color (prefer dark) and the appropriate obse tion angle(s) and distance(s) photographic visibility meas ments. (Ideally, the camera-to get distance is approximately 25 the average local visual range. camera-target angle should be more than 3 degrees from horizontal plane.)
- The site is not impacted by l pollution sources.
- The area surrounding the site paved or has year-around gro cover to minimize fugitive c emissions.
- There are no anticipated land- changes in the vicinity of the during the projected lifetime of EFPVN.
- The site is easily accessible operating personnel and secu from encroachment by unauthori persons.
- Electrical power is available operate the monitoring equipment
- Adequate shelter space exists house the monitoring equipment.

### *Light Scattering Measurement*

Two types of nephelometers were u in the EFPVN. Initially, data w collected at Horton Station, Perryv and Look Rock using conventio MRI/Belfort Model 1597 nephelomet The conventional nephelometer, howe may not always monitor accurately light scattering properties of the amb air. This is because the sample temperature is not preserved from ambient into the nephelometer's opt chamber. Inadvertent sample heating, light source. The sample volume may also be either heated or cooled from ambient temperature by conduction to the interior environment of an air conditioned or heated shelter. Departures from the ambient temperature alter the light scattering properties of the air sample by modulating the amount of liquid water content of the particles as well as altering the phase equilibrium of volatile atmospheric components such as nitric acid and ammonia. Consequently, modifications designed to limit temperature changes were incorporated in nephelometers which were later deployed.

## Fine Particle Characterization

Aerosol sampling was performed using modified Andersen Model 245 particle samplers. The sampler has an automatic sample changer that accommodates 20 pairs of 37mm filters held in circular, polypropylene holders. Electronic circuitry associated with the sample changer permits programming filter change times, sample duration and sampling frequency. Conventionally, this unit operates as a dichotomous sampler. However, to provide two identical sampling channels, the conventional virtual impactor inlet was replaced with two identical inlets, each equipped with a cyclone with a D50 cut point at 2.5 µm when operated at 28 liters/minute.

Sampling was performed using Teflon filters (Gelman R2PJ037)* in one channel and quartz fiber filters (Pallflex 2500 QAO-UP) in the other. Teflon filters were analyzed for mass concentration, elemental composition and light absorption coefficient of particulate deposit. Quartz fiber filters were analyzed for elemental and organic carbon.

## Photographic Visibility Measurements

An automatic camera system, consisting of a 35 mm single lens reflex camera, a 135 mm lens with a UV filter, automatic timing mechanism and a databack to record the time and date of each exposure, was used at each site to obtain photographic visibility measurements. Distant, natural features were photographed at 0900, 1200, and 1500 hours (local time) each day. The resulting color slides were analyzed using a scanning densiometer to determine the film density (at 550 nm wavelength) of the selected target and adjacent sky areas. The target/sky contrast was used to estimate the standard visual range (SVR). Qualitative visibility information, such as general sky conditions and types of haze conditions (e.g., uniform or layered haze), were also derived from the photographic measurements.

## Data Acquisition and Management

Continuous field measurements were recorded at each site using an Environmental Systems Corporation (ESC) model AQM-8000B data logger. Each data logger was programmed to receive up to 16 channels of double-ended analog signal inputs, scale and process the data into hourly and 5-minute averages, calculate standard deviations based on 1-minute averages, store data in memory and on RAM cartridges and transmit over dial-up telephone lines to the central computer. In addition, the data logger is equipped with up to 16 output control lines and input status and calibration detection lines which were used to automatically actuate nephelometer dark signal, zero, and span checks and flag the data accordingly. Custom-designed software enabled automatic calibration checks to be performed several times each day.

Each data logger is interfaced with a bar-code reader which can be used to facilitate sample tracking by digitally linking each pre-coded filter with a coded slot in the fine particle sampler carousel.

The central data management system (DMS) was designed to receive and process hourly and 5-minute data from the site data loggers, 12-hour and 24-hour integrated fine particle data from the analytical labs, and instantaneous, discrete quantitative and qualitative visibility measurements obtained from color slide photography. The system receives these measurements; processes and screens the measurements to apply data quality flags; loads the data into the EFPVN data base; archives the data; and retrieves the data for subsequent analysis and report generation.

## Results and Discussion

The nephelometers deployed in the EFPVN were custom-modified to limit inadvertent sample heating, typically caused by high thermal output of the instrument's light source. Initial testing of a modified nephelometer indicated a reduction in inadvertent sample heating by as much as 10.7°C, when compared to a conventional unit. The modified nephelometers were each equipped to continuously monitor the sample temperature near the exit from the optical chamber. During the summer months, sample heating was contained typically to within 2.5°C above ambient. Later in the year, as ambient temperatures cooled, heat conduction to the heated shelter environment made it increasingly difficult to maintain near-ambient conditions. Summary statistics for the light scattering measurements are presented in Table 1.

Andersen model 245 dichotomous aerosol samplers were modified to (1) provide two separate sample streams with particle cut-off diameters of 2.5 µm; (2) continuously monitor and electronically record flow rates; (3) continuously monitor and record the filter carousel position, thus indicating the precise start and stop time for each filter exposure; and (4) weatherproof the samplers to increase operating reliability under all weather conditions. As the latter three modifications were being performed, a sampler modified only to yield the required particle diameter cut point was deployed at the Horton Station, Virginia field site. Results from these measurements, conducted during May, 1988, indicate the following:

- Fine particle mass concentrations (PPM) ranged from 0.11 to 43.96 $\mu g/m^3$, with a mean of 17.55 $\mu g/m^3$.
- On the average, sulfate comprised 53% of the total fine particle mass. This fraction is almost identical to that measured during the Shenandoah Valley field study[2,3], conducted during Summer, 1980.
- Particulate carbon accounted for 11% of the FPM, nearly two times the 6% measured during the Shenandoah Study.
- Fine particle mass concentration and light scattering coefficient ($B_{sp}$) were related according to $B_{sp} \times 10^4$ = 0.032 (FPM) + 0.11, where $B_{sp}$ is in $m^{-1}$ and FPM is in $\mu f/m^3$. The correlation coefficient for FPM and $B_{sp}$ is 0.89. The resulting fine particle scattering efficiency is 3.2 $m^2/g$, which compares well with similar measurements made during previous field studies throughout the U.S.
- Particle light absorption, was typically 8% of the light scattering coefficient, or 7% of the total particle extinction (scattering plus absorption).

## Conclusions and Recommendations

Five Tier 1 monitoring stations were established during the first year of the EFPVN program. Three of these stations are located in the southeastern U.S., where airport observations indicate as much as 60 percent reduction in visual range during the past 40 years. The remaining stations are located in the Northeast, where long term trends are less evident. In selecting the monitoring sites, emphasis was given to ensure the absence of local pollution sources.

To provide a complete assessment of visibility and fine particle trends and causes in the eastern U.S., the network must be enlarged. Husar[1] has identified 10 regions of unique visibility trends in the eastern U.S. Monitoring stations should be established in each of these regions, especially in the Southeast and Gulf states where visibility impairment has increased most during the past 40 years.

Light scattering due to liquid water undoubtedly contributes substantially to the total light extinction during conditions of high relative humidity. To provide a complete extinction budget, this contribution must be quantified, either through direct measurement or empirical relationship. Direct measurements can be performed via simultaneous operation of two nephelometers, one with the air stream heated and the other operated at ambient temperature.

Measurements of light scattering coefficient using an integrating nephelometer are subject to errors, since the environment inside the instrument's optical chamber is typically of a different temperature and relative humidity from ambient. Efforts to modify the nephelometers used in the EFPVN have succeeded in reducing the artifact; however, it appears that as long as the nephelometer is housed in an environment that is sheltered from the ambient, variations in the difference between sample chamber temperature and ambient temperature will exist. An alternative is to mount the nephelometer outside. However, this would likely cause additional errors due to subjecting the instrument's electronics to variations in temperature and humidity. Continued efforts toward achieving ambient temperature conditions are recommended. Measurements obtained thus far indicate that organic carbon composes nearly 10 percent of the total fine particle mass. Yet, measurement uncertainties, due to loss of volatile matter and collection of gaseous species, limit the accuracy of this estimate. Further study of sampling artifacts, and efforts to limit them are required. The use of a diffusion denuder to remove gaseous organic carbon upstream from the filter should be explored.

In many cases, EFPVN stations are collocated with, or nearby, stations in other EPA monitoring networks where additional meteorological and acid aerosol measurements are being made. These additional measurements may be useful in interpreting EFPVN data and in determining light extinction budgets.

## References


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2. Stevens, R.K., Dzubay, T.G., Lewi C.W., and Shav, R.W. Sourc apportion methods applied to tr origin of ambient aerosols that affe visibility in forested area: *Atmospheric Environment.* 18: 26 1984
3. Ferman, M.A., Wolff, G.T., and Kell N.A. *Journal of the Air Pollutic Control Association.* 31: 1074, 1981


***Table 1.*** *Summary Statisitics for Light Scattering Coefficient Measurements (*$10^{-4}$ $m^{-1}$)*

| Site | Month | No. (Obs.) | Mean | Max | Min | Std | | Fraction Exceeding 2.5 * $10^{-4}$ $m^{-1}$ (equiv. to 15.6 km SVR) |
|---|---|---|---|---|---|---|---|---|
| HORTRC | MARCH | 672 | 0.31 | 1.71 | ------ | 0.327 | | 0.00 |
| | APRIL | 707 | 0.32 | 1.17 | ------ | 0.193 | | 0.00 |
| | MAY | 731 | 0.65 | 2.21 | 0.04 | 0.396 | | 0.00 |
| | JUNE | 572 (341) | 1.26 (1.58) | 3.54 (4.14) | 0.05 (0.08) | 0.759 | (0.878) | 0.09 |
| | JULY | (488) | (2.52) | (6.24) | (0.38) | | (1.28) | 0.43 |
| PERRYV | MAY | 706 | 0.70 | 2.34 | 0.08 | 0.489 | | 0.00 |
| | JUNE | 694 | 1.10 | 4.28 | 0.09 | 0.834 | | 0.07 |
| | JULY | 534 | 1.33 | 3.64 | 0.05 | 0.793 | | 0 09 |
| LOOKRK[1] | MARCH | 320 | 0.40 | 2.35 | ------ | 0.410 | | 0.00 |
| | APRIL | 273 | 0.19 | 1.04 | 0.01 | 0.169 | | 0.00 |
| | MAY | 174 | 0.47 | 1.61 | 0.02 | 0.381 | | 0.00 |
| | JUNE | 579 | 1.39 | 3.95 | 0.08 | 0.813 | | 0.08 |
| | JULY | 469 | 1.10 | 2.93 | 0.03 | 0.757 | | 0.03 |
| ITHACA | JULY | (616) | (1.09) | (4.29) | (------) | | (0.753) | (0.06) |

*[1] LOOKRK statistics for the following time intervals: March 18-31, April 1-12, May 24-31, June 1-30, and July 1-31.*

*------Indicates minimum hourly average was below the sensitivity level of the nephelometer.*

*( ) Measurements were made with a modified nephelometer.*

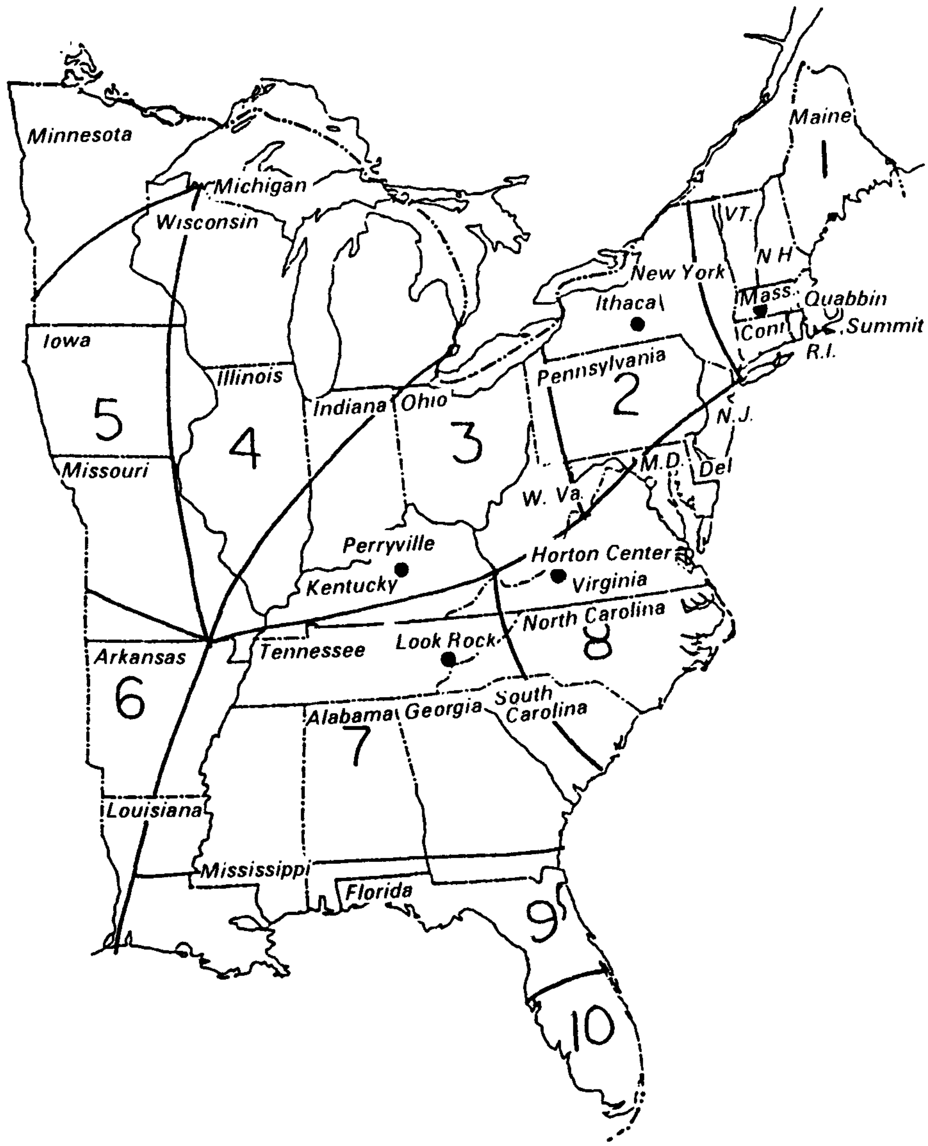


*Figure 1. EFPVN monitoring stations and regions of similar visibility trends as indicated by Husar, et al.*[1]

*Albert Hendler, Lisa Collins and James Howes are with C–E Environmental, Inc., Chapel Hill, NC 27514*
***E. Gardner Evans** is the EPA Project Officer (see below).*
*The complete report, entitled "Annual Report on Establishment and Operation of the Eastern Fine Particle and Visibility Network," (Order No. PB 89-165 948/AS; Cost: $15.95, subject to change) will be available only from:*
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