Chapter 10

AIR QUALITY MONITORING

Air Quality Monitoring for Smoke

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Introduction

There are several reasons why wildland fire managers may want to conduct an ambient air quality-monitoring program. These include:

- smoke management program evaluation purposes,
- to fulfill a public information need,
- to verify assumptions used in Environmental Assessments,
- to assess potential human health affects in communities impacted by smoke,
- and to evaluate wildland burning smoke impacts on State and Federal air quality laws and regulations.

Both visibility data and $PM_{10}/PM_{2.5}$ concentration data are useful to smoke management program coordinators for assessing air quality conditions if the information is provided in real-time. Fire managers may also be interested in monitoring impacts on visibility in Class I areas. Whatever the objective may be, care must be taken to match monitoring objectives to the right monitoring method. Monitoring locations, sampling schedules, quality assurance, and monitoring costs are elements that must also be considered.

Particulate Monitoring Techniques

Particulate monitoring instruments generally use one of two particle concentration measurement techniques: gravimetric or optical. Gravimetric or filter-based instruments collect particulates on ventilated filters. The filters are later weighed at special laboratory facilities to determine the mass concentration of particulate collected. Gravimetric monitoring techniques have been used for years to quantify mass concentration levels of airborne particulate matter. Filter-based sampling is labor intensive. Filters must be conditioned, weighed before sampling, installed and removed from the instrument, and reconditioned and weighed again at a special facility. Results may not be available for days or weeks. Also, airflow rates and elapsed sampling time must be carefully monitored and recorded to ensure accurate results. Filter-based techniques integrate samples over a long period of time, usually 24-hours, to obtain the required minimum mass for analysis. Gravimetric monitoring is best for projects where high-accuracy is needed and the time delay in receiving the data is not a problem. State monitoring networks designed to detect violations of air quality standards rely largely on gravimetric monitors. Specific monitoring devices must be approved by EPA for this task and are called Federal Reference Monitors (FRM's).

Optical instruments measure light-scattering (nephelometers) or light-absorbing (aethalometers) characteristics of the atmosphere. This measurement can then be converted to obtain an estimate of the concentration of airborne particulates. Optical instruments offer several advantages over gravimetric methods, including real-time readings, portability, low power consumption, and relatively low cost. Optical instruments have the disadvantage of being generally less accurate than gravimetric instruments at estimating particulate mass concentration. Optical instruments are best for projects where real-time or near-real time data is needed, where a high degree of accuracy is not a requirement, and if instrument portability and ruggedness is desirable.

Proper conversion of the light scattering measurement collected by nephelometers to an estimate of particle concentration requires development of customized conversion equations. The light scattering value measured depends on particle size distribution and optical properties of the specific aerosol mix in the area of interest. The light scattering value measured varies as a function of the relative proportions of fine particles (including smoke) and coarse particles (such as soil dust). As a result, optical instruments should be calibrated against a co-located FRM in the same area, and pollutant mix, in which they will eventually operate. A formula is then developed to properly convert scattering to a particulate mass per unit volume ($\mu g/m^3$) estimate.

In a recent monitoring instrument evaluation study, sixty-six laboratory measurements were made with the MIE DataRam, the Radiance Research nephelometer, and an EPA FRM sampler where the instruments were exposed to pine needle smoke (Trent and others 1999). Results from these tests concluded that both nephelometers overestimated mass concentrations of smoke when using the scattering to mass conversion factors provided by the manufacturer. A follow-up study (Trent and others 2000) compared optical instruments from various manufacturers (Radiance, MIE, Met One, Optec, and Andersen) to FRM instruments both in the field and laboratory and developed preliminary custom calibration equations (figure 10.1). The report provides an estimate of a conversion equation for each instrument tested

Figure 10.1. Three of the nephelometers tested during the Trent and others (2000) study include the MIE DataRam, the Radiance Research nephelometer, and the Met One GT-640.

but also recommends that optical instruments be field calibrated for a type of fire event, and that meteorological conditions and existing levels of ambient particles be included. Specific conditions to consider during calibration are age of the smoke, type of fire (flaming or smoldering), fuel moisture, relative humidity, and background particle concentration without smoke from the fire. Figure 10.2 shows the correlation found between $PM_{2.5}$ measurements made with an EPA FRM gravimetric instrument vs. results from an MIE DataRam nephelometer (Trent and others 2000).

Wildland Fire Smoke Monitoring Objectives

Gathering PM_{10}/$PM_{2.5}$ air quality data downwind from a prescribed burn or wildfire is an important fire manager goal in some areas. This data may be used as an input to smoke management decision-making, and may or may not involve immediate public release of estimated pollutant levels and health warnings. This monitoring can be conducted at a few sensitive locations within a relatively small area during specific events such as a planned large-scale understory burn, or used as a permanent part of smoke management effectiveness monitoring. Real-time data access, ease of use, and ruggedness are all generally required so optical instruments are most appropriate (table 10.1). Monitors are often equipped with data loggers and modems to permit downloading of the data over a telephone line or via radio modem. In the near future, technology will be available to make air quality monitoring data from remote sites accessible over the Internet. The USDA Forest Service, Missoula Technology and Development Program with Applied Digital Security, Inc have developed a satellite-based data retrieval system. Appropriately outfitted

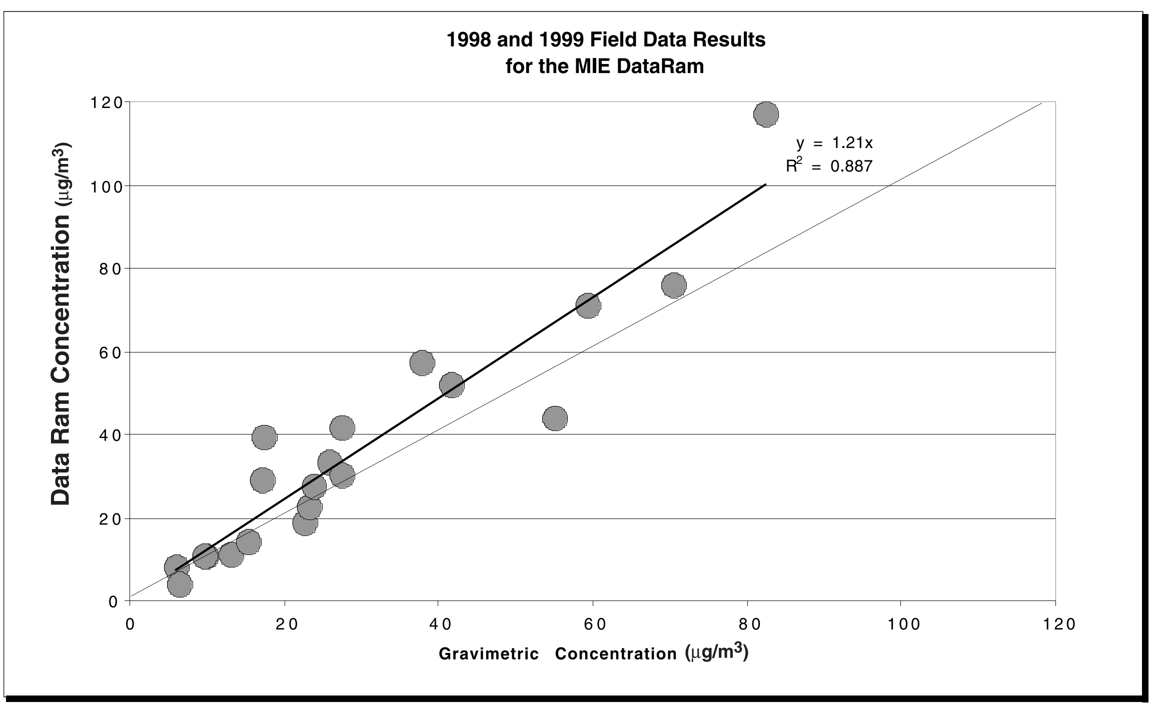

Figure 10.2. Comparison of $PM_{2.5}$ measurements made with a gravimetric Federal Reference Monitor vs. an MIE DataRam nephelometer (Trent and others 2000).

Table 10.1. Equipment appropriate for smoke monitoring differs by program objective.

Program objective	Temporal requirement	Spatial scale or extent	Applicable monitoring equipment
Smoke impact monitoring	Real-time, short-term or event-based	Localized, neighborhood-to-urban scale	▪ Radiance nephelometer[a] ▪ MIE DataRAM nephelometer[b] ▪ Laser photometers[c] ▪ TEOM[d] ▪ BAM[e]
NAAQS monitoring	Long-term	Urban to broad airshed scale	▪ MiniVols[f] ▪ Dichots[g] ▪ Other EPA FRM Monitor[h]
Visibility monitoring	Long-term and real-time	Regional	▪ IMPROVE Sampler[i] ▪ Optec Nephelometer[j] ▪ 35mm Camera[k] ▪ Digital Camera System[l]

[a] A small, lightweight, battery powered integrating nephelometer is manufactured by Radiance Research. Like all light scattering devices, the extinction measurements made by this instrument may be used to estimate PM10/PM2.5 mass by applying an appropriate conversion formula to the light scattering measurements. Units cost about $4,800.

[b] The MIE DataRam nephelometer internally estimates mass concentration via a default or user-specified conversion formula. Units cost about $11,000.

[c] Laser photometers are small, battery powered light scattering devices that provide real-time estimates of light extinction, which can then be converted to PM10/PM2.5 mass given the appropriate conversion formula. Manufacturers include Met One Instruments Inc. and TSI. Units cost about $5,300.

[d] Tapered Element Oscillating Microbalance (TEOM). Manufactured by Rupprecht & Patashnick. The TEOM is an EPA Equivalent Method designated for PM_{10}. Cost is about $17,000.

[e] The Beta Attenuation Monitor (BAM) is also known as a Beta Gauge Monitor. Manufactured by Thermo Environmental, Graseby Andersen, and Dasibi Environmental Corporation. These are EPA Equivalent Methods designated for PM_{10}. Costs range from $14,000 to $20,000.

[f] The MiniVol Portable Air Sampler is a filter-based instrument that utilizes rechargeable batteries, a small air pump, and a programmable timer. Manufactured by Airmetrics, Inc., units cost about $2,300.

[g] The dichotomous sampler (dichot) is a filter-based system manufactured by Graseby Andersen that collects both coarse (2.5-10 µm) and fine particles (<2.5 µm) for speciation analysis. Units cost about $8,500.

[h] EPA federal reference method (FRM) samplers for PM10 and PM2.5 include the Rupprecht & Patashnick Partisol and Partisol-Plus Sequential Sampler; the BGI portable PM10 sampler, the Andersen Instruments RAAS FRM PM2.5 sampler and others. See the EPA AMTIC web page for current information.

[i] The IMPROVE Modular Aerosol Sampler ($35,000) is a filter-based unit manufactured by Air Resource Specialists. It consists of PM10 and PM2.5 sampling heads which capture aerosols on Teflon and quartz filters for chemical analysis (speciation). Costs range from $6,500 to $26,000 depending on configuration.

[j] For true ambient light scattering measurements, the NGN-2 nephelometer manufactured by Optec ($25,000) and used in the IMPROVE network is the standard instrument for visibility monitoring.

[k] A 35mm camera with auto winder, data back and enclosure used for scene monitoring costs about $3,300.

[l] One digital image acquisition system is available from Air Resource Specialists, Inc. and includes a digital camera, weatherproof enclosure, and image capture computer. The system costs approximately $4,800.

instruments will send packets of 5-minute average particulate concentrations each hour by satellite to a stored database to be viewed and retrieved through a Web site.[1]

A second smoke monitoring objective may be to gather data on prescribed fire smoke impacts at sensitive locations over a much longer period for purposes of comparison with ambient air quality standards (NAAQS). In these cases, immediate data access is of secondary importance to gathering data that approximates or is equivalent to the high-accuracy official Federal Reference Method (FRM) instruments used by air regulatory agencies. A popular option is the small, portable, battery powered MiniVol sampler although these are not official EPA FRM designated monitors. The lag-time limitation may be overcome by using one of two EPA-approved continuous air monitoring devices (TEOM or Beta Attenuation Monitors [BAM]) but this equipment is costly and requires a high degree of technical skill to operate (table 10.1).

Visibility protection is another monitoring objective for fire managers when wildland burning smoke may impact nearby Class I areas. For visibility monitoring, information is not only needed on PM_{10}/$PM_{2.5}$ concentrations but aerosol chemical composition and particle light scattering and absorption as well. Since aerosol chemical analysis (speciation) monitoring requires filter-based methods and extinction measurements require in-situ real-time methods, a combination of techniques are used. Monitoring is typically conducted throughout the year over long time periods to establish trends. In as much as data consistency with the national visibility programs is also important, specialized instruments designed and deployed by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Network (Malm

Figure 10.3. A typical IMPROVE monitor installation.

[1] MTDC Air Program News Issue 1. August 2001. Available at: http://fsweb.mtdc.wo.fs.fed.us/programs/wsa/air_news/issue1.htm

2000) should be used whenever possible (figure 10.3). Monitoring the visual quality of a vista, called scene monitoring, is often done at the same time using 35mm cameras. Digital camera systems can be used at sites where real-time web access to the scene is desirable (table 10.1).

Further monitoring guidance is available on the Internet at the EPA Air Monitoring Technology Information Center (AMTIC) web site (http://www.epa.gov/ttn/amtic) and the EPA Visibility Improvement site (http://www.epa.gov/oar/vis/index.html).

Monitoring Locations & Siting

Samplers used for smoke impact monitoring are normally placed at smoke sensitive locations that have the greatest likelihood of impact.[2] This may be a private residence, within a nearby community, or at a county fair. Care must be taken to ensure that the instrument is located in an open, exposed location removed from local pollution sources such as dirt roads, burn barrels, or woodstoves that would influence the data. The sampler should be located two or more meters above ground at a secure location. Power availability and access are often controlling considerations (CH2MHill 1997).

Visibility monitoring sites must be representative of the Class I area of interest and are therefore best located within the area's boundary or, in the case of wilderness areas, as close to the boundary as possible. Since visibility data is used to represent conditions over sub-regional spatial scales, special care is needed in siting to avoid local source influences. The IMPROVE network has recently been expanded with representative monitors for each of the 156 Class I areas in the country. Siting of the instruments was accomplished with state and Federal Land Manager input.

Sampling Schedules

The timing, duration, and frequency of sampling depend on the program objective. Continuous, hourly data is needed to monitor smoke impacts from several days prior to burn ignition to a day or two after the event. In contrast, PM_{10} NAAQS compliance monitoring using filter-based instruments is conducted once every six days in attainment areas. In a nonattainment area, daily sampling is required for cities with more than a million people and every three days otherwise. Filter-based measurements made as part of the IMPROVE visibility monitoring network are made every third day to reduce costs and operational requirements. Continuous monitoring instruments always operate 24 hours per day. Although sampling duration and frequency decisions are often based largely on operating costs and technician time requirements, measurements made as part of the IMPROVE network or for NAAQS compliance determinations must follow the protocols outlined in EPA regulations found on the AMTIC web site.

[2] For NAAQS compliance monitoring, refer to the EPA Monitoring Network Siting Guidance found on the EPA AMTIC web site at: http://www.epa.gov/ttn/amtic.

Quality Assurance

Data integrity is essential in any monitoring program. Every monitoring project should have a documented quality assurance plan. In addition to the maintenance and calibration measures outlined by the manufacturer of the instruments being used, additional quality assurance measures may also be included in the plan if the monitoring data are of an especially important nature. These include auditing procedures conducted by the state/local air quality agency to verify proper instrument siting, calibration and data capture as well as traceability of measurement standards to the National Bureau of Standards (NBS) (EPA 1984). Methods of calculation and data processing should also be audited. Fire managers may wish to confer with their state/local air agency to assure that monitoring results are valid.

Monitoring Costs

Monitoring is expensive. In addition to the capital cost of the instruments, costs for equipment installation, electrical, maintenance, calibration standards, supplies, shipping, data analysis, and reporting must also be considered. In the case of filter-based particulate sampling, laboratory costs for filter weighing and chemical analysis must also be included. On-going annual operating costs for technician time to service the instruments is a major expense that often drives the monitoring system design.

Literature Citations

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