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THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**BLACK CARBON MONITORS**
APPLICATION:	**MEASUREMENT OF BLACK CARBON IN AMBIENT AIR**
TECHNOLOGY NAME:	**Model AE33 Aethalometer**
COMPANY:	**Magee Scientific Corporation (Manufactured by Aerosol d.o.o., Ljubljana, Slovenia)**
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The U.S. Environmental Protection Agency (EPA) has established the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies. Information and ETV documents are available at www.epa.gov/etv.

ETV works in partnership with recognized standards and testing organizations, with stakeholder groups (consisting of buyers, vendor organizations, and permitters), and with individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Advanced Monitoring Systems (AMS) Center, one of six verification centers under ETV, is operated by Battelle in cooperation with EPA's National Risk Management Research Laboratory. The AMS Center evaluated the performance of monitors for determining black carbon concentrations in ambient air. This verification statement provides a summary of the test results for the Magee Scientific Corporation Model AE33 Aethalometer.

VERIFICATION TEST DESCRIPTION

The verification test was conducted over a period of approximately 30 days (April 5 to May 7, 2013) and involved the continuous operation of duplicate Model AE33 Aethalometer at the Battelle Columbus Operations Special Support Site (BCS3) in Columbus, Ohio. Duplicate reference samples were collected over 12-hour sampling intervals throughout the testing period, from approximately 7:00 am to 7:00 pm and from approximately 7:00 pm to 7:00 am daily. The reference samples were collected and analyzed by Desert Research Institute for organic carbon (OC) and elemental carbon (EC) using the Interagency Monitoring of PROtected Visual Environments (IMPROVE) thermal/optical reflectance (TOR) and thermal/optical transmittance (TOT) protocols. Note that in this report the filter samples will be referred to as "reference samples." However, it should be noted that the IMPROVE method is not a true Reference Method in that it is not recognized as an absolute standard. Nonetheless, it is used within the IMPROVE network as the standard method for EC analysis. Thus the method was used in this test as an analytical technique used for comparison to the BC monitors. Other thermal/optical reference methods such as the NIOSH 5040 method may result in different results. The comparability and correlation of the monitoring technology was determined through comparisons to the collocated reference method samples. The precision of the Model AE33 Aethalometers was determined from comparisons of paired data from the duplicate units (identified as "SN089" and "SN090"). Other performance parameters such as data completeness, maintenance requirements, ease of use, and consumable use were assessed from observations by the Battelle field testing staff. This test was not intended to simulate long-term performance of analyzers at a monitoring site.

QA oversight of verification testing was provided by Battelle and EPA. Battelle technical staff conducted a performance evaluation audit and Battelle QA staff conducted a technical systems audit and a data quality audit of 10% of the test data. This verification statement, the full report on which it is based, and the test/QA plan for this verification test are all available at www.epa.gov/etv/centers/center1.html.

TECHNOLOGY DESCRIPTION

The following description of the Model AE33 Aethalometer is based on information provided by the vendor. This technology description was not verified in this test.

The Aethalometer™ is used for the real-time measurement of optically-absorbing 'Black' or 'Elemental' carbon aerosol particles. The name "Aethalometer" is derived from the classical Greek verb 'aethaloun' (αεθαλουν), meaning 'to blacken with soot'. It was conceptualized in 1979, commercialized in 1986, and has been under continuous development since that date. The Aethalometer Model AE31 was tested by the ETV Program in 2001. The Model AE33 Aethalometer was released in 2012, and incorporates many scientific and technical improvements relative to earlier models.

The Aethalometer uses a continuous filtration and optical measurement method to provide a continuous readout of real-time data for the concentration of 'BC', which is fundamentally defined by 'blackness', an optical measurement. The optical analysis for BC is designed to be consistent and reproducible, and may be validated by the use of Neutral Density optical standards.

The AE-33 performs optical analysis at seven discrete wavelengths from 370 nm to 950 nm. These data can be interpreted in terms of source apportionment, due to the different spectral characteristics of diesel particulates versus biomass-burning smoke. Aethalometers provide fully automatic, unattended operation. The sample is collected and analyzed as a spot on a roll of filter tape: depending on location, one roll of tape may last from months to years. No other consumables are required. The instrument requires no calibration other than periodic checks of the air flow sensor response.

In recent years, it became apparent that under certain conditions, at certain locations, filter-based optical measurement techniques can be influenced by a saturation effect (also known as the "loading effect") of variable magnitude. This effect, when present, can change the reported data by up to a factor of 2 or more, depending on the nature of the aerosol and the settings of the instrument. At other locations, or at the same location under conditions of different aerosol climatology, the effect may be reduced or completely absent. The fact that the "loading effect" is variable and clearly dependent on some attribute of the aerosol indicates that it is a combination of some aspect of the instrumental method, together with an actual chemical or microphysical aspect of the aerosol. However, the "loading effect" is always found to be linear with respect to the light attenuation measured on the filter spot. The Model AE33 Aethalometer corrects for the "loading effect" by collecting two aerosol spots in parallel, but at rates of accumulation that differ by a factor of two. Mathematical combination of the data from the two parallel analyses permits reconstruction of the "ideal" result, together with a report of the "loading compensation parameter" which may be informative of aerosol properties in its own right.

VERIFICATION RESULTS

Comparability- Regression analysis comparison to reference samples	Analyzer	TOR		TOT	
		Slope	Intercept	Slope	Intercept
	SN089	1.277 (0.064)	0.286 (0.041)	1.701 (0.072)	0.305 (0.034)
	SN090	1.350 (0.066)	0.309 (0.042)	1.795 (0.076)	0.330 (0.036)

Comparability- Calculation of Relative Percent Difference (RPD) between Aethalometer results and reference method results	Analyzer	RPD[a]	
		TOR	TOT
	SN089	95.6% (N=39)	149.7% (N=26)
	SN090	105.9% (N=39)	163.7% (N=26)

Correlation - Regression analysis comparison to reference samples	Analyzer	r^2	
		TOR	TOT
	SN089	0.875	0.906
	SN090	0.880	0.908

Precision - Comparison of results from duplicate monitoring systems[a]		RPD (# of Observations)
	1-hour	8.5% (N=756)
	12-hour	7.1% (N=63)

Precision – Regression analysis of results from duplicate monitoring systems	Period	Slope	Intercept (μg/m^3)	r^2
	1-hour	1.063 (0.004)	-0.000 (0.005)	0.990
	12-hour	1.051 (0.012)	0.010 (0.012)	0.992

Data Completeness	Analyzer	Period	Total Periods	Valid Measurements	% Complete
	SN089	1-minute	45,360	45,157	99.6%
		12-hour	63	63	100%
	SN090	1-minute	45,360	45,149	99.5%
		12-hour	63	63	100%

Maintenance	• Default instrument settings restored from internal memory card twice during testing. • No routine maintenance performed during testing.
Consumables/waste generated	• Filter tape required.
Ease of use	• Installation of two units without inlets completed in ~5 minutes. • Installation of inlets and sampling lines completed in ~10 minutes • Calibration of flow rates completed in less than30 minutes, after allowing the units to operate overnight. • Routine operation required no effort other than brief daily instrument checks and approximately weekly data downloads. • Data exported as csv files and processed using Microsoft Excel.

[a] For these calculations, reference method results below twice the method detection limit were excluded. For perfect agreement between the Aethalometers and the reference method results, the RPD would be zero. In general, the measured concentrations from the Aethalometers were approximately twice as high as those from the reference method resulting in positive RPD values. It should be noted that only about two thirds of the TOR reference method results and fewer than half the TOT reference method results were above twice the detection limit.

Signed by Spencer Pugh 2/28/14
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