TÜV RHEINLAND ENERGY GMBH

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ADDENDUM

Addendum to TÜV test report no. 936/21207522/A dated 23 March 2009 on performance testing of the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter $PM_{2.5}$ and PM_{10} manufactured by FAI Instruments s.r.l

TÜV report: 936/21239762/A
Cologne, 22 September 2017

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TÜV Rheinland Energy GmbH and its Ambient Air Quality department in particular
is accredited for the following activities:

- Determination of emissions and ambient air quality affected by air pollutants and odorous substances
- Inspection of correct installation, functionality and calibration of continuous emission monitoring systems including systems for data evaluation and remote monitoring of emissions,
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and air quality as well as electronic data evaluation and remote monitoring systems for emissions
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
- Determination of emissions and ambient air quality affected by noise and vibration, determination of
- sound power levels and noise measurements at wind turbines;

according to EN ISO/IEC 17025.

The accreditation will expire on 22-01-2018. DAkkS registration number: D-PL-11120-02-00.

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1. Summary Overview

FAI Instruments s.r.l commissioned TÜV Rheinland Energy GmbH to carry out performance testing on the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter $PM_{2.5}$ and PM_{10} according to the following Standards.

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002.
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004
- EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 1998
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005
- Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005

Based on the requirements for testing stated above, the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ have already been performance tested and publically announced as such as follows:

- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 03 August 2009 (BAnz. 25 August 2009, no. 125, page 2929, chapter II no. 2.1) – initial publication

- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 15 July 2011 (BAnz. 29 July 2011, no. 113, page 2725, chapter III 7th notification) – notification as required by EN 15267 regarding the manufacturing process and its quality management system

- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 23 February 2012 (BAnz. 2 March 2012, no. 36, page 920, chapter V, 2nd notification) – notification regarding the approval of instrument version SWAM 5a Dual Channel Hourly Mode Monitor with 1h-measurement mode and its OEM version Model 602 BetaPlus offered by Teledyne Advanced Pollution Instrumentation.

- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 23 February 2012 (BAnz. 2 March 2012, no. 36, page 920, chapter V, 3rd notification) – notification regarding the approval of instrument version SWAM 5a Monitor (single channel design)

- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 12 February 2013 (BAnz AT 05.03.2013 B10, chapter V 12th notification) – notification on the new software version for the instrument version SWAM 5a Dual Channel Monitor

- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 25 February 2015 (BAnz AT 02.04.2015 B5, chapter IV 8th notification) – notification regarding the new software version for instrument version SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, optional Ethernet board for the SWAM 5a Dual Channel Hourly Mode Monitor.

- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 22 July 2015 (BAnz AT 26.08.2015 B4, chapter V 44th notification) – notification regarding the availability of standard sample inlets in accordance with annex A of standard EN 12341 (August 2014)

Standard EN 16450 "Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$) has been available since July 2017. This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations (PM_{10} and $PM_{2.5}$) on an European level and will form the basis for the approval of such AMS in the future.

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 (July 2017).

As most of the performance characteristic and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report or tests performed in the context of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor as documented in the corresponding notifications. Entirely new tests were performed only for test items 7.4.4 "7.4.4 Flow rate accuracy", 7.4.8 "7.4.8 Dependence of span on supply voltage" and 7.4.9 "7.4.9 Dependence of reading on water vapour concentration" in Summer 2017.

All tests were performed with instrument version SWAM 5a Dual Channel Monitor. For the purpose of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, additional equivalence tests were performed on the basis of test plans approved by the relevant body on 20 March 2010 (SWAM 5a Dual Channel Hourly Mode Monitor) and on 18 June 2011 (SWAM 5a Monitor). These tests of equivalence are also presented in this addendum.

All test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21207522/A dated 23 March 2009 and will be available at www.qal1.de.

The SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor are automated and sequential measuring systems for the determination of particles on filter membranes. The systems are operated either with two completely independent sampling lines (SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor) or with a single sampling line (SWAM 5a Monitor). As part of the tests reported on in the present addendum, for the dual channel versions, one sampling line was equipped with a PM_{10} sampling head while the other was equipped with a $PM_{2.5}$ sampling head – other configurations are possible. The dual channel versions use pumps to suck in ambient air via the PM_{10} sampling head or via the $PM_{2.5}$ sampling head. Dust-loaded sample air is then precipitated on a filter (1 x PM_{10}, 1 x $PM_{2,5}$). For the single channel version, sampling is performed accordingly for a single PM fraction.

The determination of the mass concentration precipitated on a filer is then performed relying on the principle of beta absorption. The temporal resolution (cycle time) of the measurement was 24h during testing (SWAM 5a Dual Channel Monitor and SWAM 5a Monitor) and 1h (SWAM 5a Dual Channel Hourly Mode Monitor).

There is an option to weigh filters gravimetrically. Moreover, filters are available for further analytical methods (e.g. heavy metal analysis).

The tests were performed in the laboratory and in a several-months long field test.

The field table over a period of several months was performed at the locations specified in Table 1 to Table 3.

Table 1: Description of the measurement sites (SWAM 5a Dual Channel Monitor), see [11]

	Cologne Parking lot	Bonn, Belderberg	Teddington, UK	Brühl
Period	10/2007–02/2008	02/2008–04/2008	07/2008–11/2008	09/2008–12/2008
Number of measurement pairs: Test specimens	100	64	83	55
Description	Urban background	Traffic	Urban background	Gravel plant
Classification of ambient air pollution	average to high	average to high	low to average	average

Table 2: Description of the measurement sites (SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor), see [12]

	Cologne Parking lot
Period	02/2011–05/2011
Number of Measurement pairs SWAM 5a DC:	67 ($PM_{2.5}$) 80 (PM_{10})
Number of Measurement pairs SWAM 5a DC HM:	77
Description	Urban background
Classification of ambient air pollution	average to high

Table 3: Description of the measurement sites (SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, see [13]

	Bornheim
Period	08/2011–10/2011
Number of Measurement pairs SWAM 5a DC:	73
Number of Measurement pairs SWAM 5a $PM_{2,5}$:	47
Number of Measurement pairs SWAM 5a PM_{10}:	71
Description	Rural area + motorway
Classification of ambient air pollution	low

The data from Table 1 to Table 3 for the instrument version SWAM 5a Dual Channel Monitor was consolidated and re-assessed in order to have as comprehensive and robust a data set as possible for the equivalence assessment.

The following table provides an overview of the equivalence tests performed.

Table 4: Results of the equivalence tests (raw data)

Number	Instrument version	PM_x	Slope	Ordinate intercept	All Data sets W_{CM}<25 % Raw data	Calibration yes/no	All Data sets W_{CM}<25% cal. Data
1	SWAM 5a DC	PM_{10}	1.051	-0.271	yes	yes *	yes
2	SWAM 5a DC	$PM_{2,5}$	0.973	0.355	yes	yes *	yes
3	SWAM 5a DC HM**	PM_{10}	0.972	-0.305	yes	no	-
4	SWAM 5a DC HM**	$PM_{2,5}$	0.998	0.685	yes	no	-
5	SWAM 5a**	PM_{10}	1.007	-0.900	yes	no	-
6	SWAM 5a**	$PM_{2,5}$	0.971	0.235	yes	no	-

* Given the significance of the slope or the ordinate intercept, a calibration became necessary.

** The evaluation takes into account a single comparison campaign.

1.1 Summary report on test results

Summary of test results in accordance with standard EN 16450 (July 2017)

Performance criterion	Requirement	Test result	satis-fied	Page
1 Measuring ranges	0 µg/m^3 to 1000 µg/m^3 as a 24-hour average value 0 µg/m^3 to 10,000 µg/m^3 as a 1-hour average value, if applicable	Instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor facilitate monitoring of measuring ranges of more than 2,000 µg/m³ in the 24-h cycle. Instrument version SWAM 5a Dual Channel Hourly Mode Monitor facilitates monitoring of a measuring range of up to 10,000 µg/m³ in the 1-h cycle.	yes	74
2 Negative signals	Shall not be suppressed	Negative signals are directly displayed and correctly output by the measuring system.	yes	75
3 Zero level and detection limit	Zero level: ≤ 2.0 µg/m^3 Detection limit: ≤ 2.0 µg/m³	On the basis of testing both instruments, the zero level was determined at a maximum of 0.39 µg/m³ and the detection limit at a maximum of 0.71 µg/m³.	yes	76
4 Flow rate accuracy (7.4.4)	≤ 2.0%	The relative difference determined for the mean of the measuring results at +5°C and at +40°C did not exceed 1.17%.	yes	78
5 Constancy of sample flow rate (7.4.5)	≤ 2.0% sampling flow (averaged flow) ≤ 5% rated flow (instantaneous flow)	The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%.	yes	80
6 Leak tightness of the sampling system (7.4.6)	≤ 2.0% of sample flow rate	For instrument 1 (SN127), leakage did not exceed 0.24%. For instrument 2 (SN 131), leakage did not exceed 0.30% each at a residual pressure in the system p0. At an air pressure of 102.8kPa, the leakage of instrument 1 (SN 127) did not exceed 0.08%, for instrument 2 (SN 131), it did not exceed 0.06%.	yes	84

Performance criterion	Requirement	Test result	satis-fied	Page
7 Dependence of measured value on surrounding temperature (7.4.7)	≤ 2.0 µg/m³	The tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of 0.64 µg/m³.	yes	86
8 Dependence of measured value (span) on surrounding temperature (7.4.7)	≤ 5% from the value at the nominal test temperature	The tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed 0.1%.	yes	89
9 Dependence of span on supply voltage (7.4.8)	≤ 5% from the value at the nominal test voltage	Voltage variations did not result in deviations > -0.4% compared to the initial value of 230 V.	yes	92
10 Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of main voltage the instrument shall automatically resume functioning.	Buffering protects all instrument parameters against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	94

Performance criterion	Requirement	Test result	satis-fied	Page
11 Dependence of reading on water vapour concentration (7.4.9)	≤ 2.0 µg/m³ in zero air	The maximum difference between measured values determined at 40% and at 90% humidity did not exceed 1.9 µg/m³.	yes	95
12 Zero checks (7.5.3)	Absolute value ≤ 3.0 µg/m³	The maximum measured value determined at zero point was 2.4 µg/m³.	yes	98
13 Recording of operational parameters (7.5.4)	Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters: Flow rate pressure drop over sample filter (if relevant) Sampling time Sampling volume (if relevant); Mass concentration of relevant PM fraction(s) Ambient temperature Ambient pressure Air temperature in measuring section temperature of sampling inlet if heated inlet is used	The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.	yes	105
14 Daily averages (7.5.5)	The AMS shall allow for the formation of daily averages or values.	It is possible to form valid daily averages.	yes	107
15 Availability (7.5.6)	At least 90%.	The availability for instrument 1 (SN 127) was 99.1%, for instrument 2 (SN 131) it was 97.8%, for SN 145 it was 96.7% and for SN 149, it was 100%.	yes	108

Performance criterion	Requirement	Test result	satis-fied	Page
16 Between-AMS uncertainty ubs,AMS (7.5.8.4)	≤ 2.5 µg/m³	At no more than 0.79 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Monitor remains well below the permissible maximum of 2.5 µg/m³. At no more than 0.74 µg/m³ for $PM_{2.5}$ and no more than 0.73 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Hourly Mode Monitor remains well below the permissible maximum of 2.5 µg/m³. Finally, at no more than 0.56 µg/m³ for $PM_{2.5}$ and no more than 0.63 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Monitor also remains below the permissible maximum of 2.5 µg/m³.	yes	112
17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)	≤ 25 % at the level of the relevant limit value related to 24-hour average results (if required, after calibration)	Without the need for any correction factors, the expanded uncertainties WAMS for instrument version SWAM 5a Dual Channel Monitor were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for PM2.5 and PM10 for all data sets observed. This also applies to the uncertainties WAMS determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor.	yes	128
17 Use of correction factors/terms (7.5.8.5–7.5.8.8)	After the calibration: ≤ 25% at the level of the relevant limit value related to the 24-hour average results	Even without the need for any correction factors, the expanded uncertainties W_{AMS} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. After applying correction factors for instrument version SWAM 5a Dual Channel Monitor, the candidate systems continue to meet the requirements for data quality for ambient air monitoring for all data sets. A minor deterioration of the expanded uncertainty for the $PM_{2.5}$ data set was observed. However, a considerable improvement of the expanded uncertainty for the PM_{10} data set was observed at the same time.	yes	161

Performance criterion	Requirement	Test result	satis-fied	Page
18 Maintenance interval (7.5.7)	At least 14 d	The maintenance interval is determined by the necessary maintenance tasks (filter replacement/cleaning the sampling head if necessary). It is 15 days for PM2.5 and 30 days for PM10.	yes	169
19 Automatic diagnostic check (7.5.4)	Shall be possible for the AMS	The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.	yes	170
20 Checks of temperature sensors, pressure and/or humidity sensors	Shall be checked for the AMS to be within the following criteria ± 2 °C ± 1 kPa ± 5 % RH	It is easy to check and adjust the relevant external sensors for determining ambient temperature and ambient pressure on-site. It is also possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement). However, this requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,	yes	171

2. Task Definition

2.1 Nature of the test

FAI Instruments s.r.l commissioned TÜV Rheinland Energy GmbH to carry out performance testing on the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor.

The SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ have already been performance tested and publically announced in the Federal Gazette.

The present addendum assesses the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor in terms of compliance with the requirements for automated measuring systems for the determination of dust concentrations as defined by the new standard EN 16450 (July 2017).

2.2 Objectives

The measuring systems are designed to determine the PM_{10} and $PM_{2.5}$ fractions of dust concentrations in the range between 0 and 200 µg/m3 in ambient air.

The existing performance test had been performed in respect of the requirements applicable at the time of testing while at the same time taking into account the latest developments.

The test was performed on the basis of the following standards:

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002 [1]
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004 [2]
- European standard EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341: 1998, [3]
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005 [4]
- Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005 [5]

Standard

- EN 16450 "Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$), German version EN 16450:2017 [9]

has been available since July 2017.

This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations (PM_{10} and $PM_{2.5}$) on a European level and will form the basis for the approval of such AMS in the future.

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 (July 2017).

As most of the performance characteristic and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report or tests performed in the context of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor as documented in the corresponding notifications. Completely new tests were performed in Summer 2017 only for test items 6.1 4 Flow rate accuracy (7.4.4), 6.1 9 Dependence of span on supply voltage (7.4.8) and 6.1 11 Dependence of reading on water vapour concentration (7.4.9).

All tests were performed with instrument version SWAM 5a Dual Channel Monitor. For the purpose of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, additional equivalence tests were performed on the basis of test plans approved by the relevant body on 20 March 2010 (SWAM 5a Dual Channel Hourly Mode Monitor) and on 18 June 2011 (SWAM 5a Monitor). These tests of equivalence are also presented in this addendum.

All test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21207522/A dated 23 March 2009 and will be available at www.qal1.de.

3. Description of the AMS tested

3.1 Measuring principle

For mass measurement of separated particles, the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor measuring systems rely on the principle of beta attenuation observed on passing through a thin film of material.

The relation between a beta flux attenuated after passing through a thin film of material and the mass density of that material can be described in a relationship.

Mass measurement x_p of particles collected on the filter relies on exact quantification of the relative variation sustained by a flux of β electrons achieving an opposite detector, this film being present or absent.

Overly simplified, the following association generally applies: $m_p=S*x_p$ where

$$x_p = k(z) \cdot \ln \frac{Flux_{blank}}{Flux_{collect}}$$

Where	m_p	is the mass of dust particles
	S	is the deposited surface
	x_p	is the mass density of dust particles
	k(z)	is the mass absorption coefficient function
	$Flux_{blank}$	is the beta flux before sampling
	$Flux_{collect}$	is the beta flux after sampling

Beta fluxes measured may contain systematic fluctuations not attributable to the presence of particulate matter mass accumulated on the filter. These contributions primarily result from:

- the variation of the filtering medium mass thickness (e.g. humidity effects)
- air density fluctuations
- detector response efficiency fluctuations

The SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor instrument versions provide a feature called spy filter to quantify these influences and take them into account for calculations. The spy filters consist of the same filter material as the filters used for measurement and are permanently implemented in the instrument. During measurements, measurement and spy filters are alternated and measured. The beta influence determined with the help of the spy filter potential biases caused by the influences listed above can be taken into account.

The following relationship applies:

$$m_P = S \cdot x_p = S \cdot \overline{k}(z) \cdot Z_{r1}^* \cong S \cdot k_{sh} \cdot \left[\overline{k}(z) \cdot \ln\left(\frac{\overline{\Phi}^i(x_{Fr})}{\overline{\Phi}^j(x_{Fr} + x_p)} \frac{\overline{\Phi}^j(x_{Fs})}{\overline{\Phi}^i(x_{Fs})} \right) + offset \right]$$

where k_{sh} is 1 by definition.

p = particle, F_r = measurement filter, F_s = spy filter and

x_{Fr} = blank and $x_{Fr}+X_p$ = collect

The manufacturer determines the function k(z) with the help of 6 reference aluminium foils and implements it in the measuring system.

This calibration can be verified on every restart of the instrument (or manually at the start of the next measurement cycle) with the help of two reference aluminium foils with known mass density. The values thus obtained are compared to pre-defined values and potential deviations indicated as a percentage. The result of the previous “beta span test” can be recalled at any time.

Note concerning SWAM 5a Monitor:

The SWAM 5a Monitor instrument version does not use spy filters for an additional correction of the radiometric mass measurement. In practice, however, the Geiger counter and its voltage supply prove very stable to drift. Moreover, for the SWAM 5a Monitor, too, performance of the Geiger counter and its voltage supply is constantly monitored as part of internal quality assurance procedures. In the event of deviations from tolerances, the instrument issues warnings and alarms.
The instrument is operated in a temperature-controlled environment (air-conditioned measurement rack or container) in order to avoid temperature fluctuations inside the instrument. Consequently, when properly operating the SWAM 5a Monitor, fluctuations of radiometric measurements caused by influence listed above are highly unlikely, and—should they occur—they will be detected in time given appropriate warnings/alarms. Potential negative effects on mass measurement can be traced at any time.

3.2 Functioning of the measuring system

The SWAM 5a Dual Channel Monitor measuring system is an automated and sequential measuring systems for the determination of particles on filter membranes. The system is operated with two completely independent sampling lines. As part of the tests reported on in the present addendum, one sampling line was equipped with a PM_{10} sampling head while the other was equipped with a $PM_{2.5}$ sampling head – other configurations are possible. Pumps are used to suck in ambient air via the PM_{10} sampling head or via the $PM_{2.5}$ sampling head. Dust-loaded sample air is then precipitated on a filter (1 x PM_{10}, 1 x $PM_{2,5}$). The determination of the mass concentration precipitated on a filer is then performed relying on the principle of beta absorption. A single radiometric mass mass measurement module is used to determine the dust mass deposited on the filters for both sampling lines.

The SWAM 5a Dual Channel Hourly Mode Monitor differs from the SWAM 5a Dual Channel Monitor measuring system in the following way.

1. The collection surface of the filter (filter spot area) is 2.27 cm² and thus is smaller than that of the SWAM 5a Dual Channel Monitor version (5.20 cm² during testing, alternatively: 2.54 cm², 7.07 cm² and 11.95 cm²).
2. During radiometric measurement, the beta source is closer to the filter.
3. In total, 3 filters are inserted 8 times a day per line (time resolution 1h instead of 24h).

The SWAM 5a Monitor differs from the SWAM 5a Dual Channel Monitor measuring system in the following way.

1. Instead of two sampling lines operated in parallel as is the case for the SWAM 5a Dual Channel Monitor, the SWAM 5a Monitor operates a single sampling line.

2. The SWAM 5a does not use spy filters for an additional correction of the radiometric mass measurement.

If not specified otherwise, the following remarks apply to the functioning of all three instrument versions. Additional details are available in the corresponding operation manual.

a) AMS operating modes

The two-channel versions of the measuring system can be operated in one of two modes: Monitor Mode and Reference Mode.

Monitor mode

The Monitor Mode allows the particulate matter sampling and mass measurement on two independent lines (SWAM 5a DC and SWAM 5a DC HM) or on a single line (SWAM 5a). For the dual-channel versions, this mode allows to simultaneously determine two PM fractions (e.g. PM_{10} and $PM_{2.5}$). Moreover, configurations for metrological evaluations such as the following are possible:

- o the evaluation of the volatile material losses thanks to the possibility of heating (cooling) one line and cooling (heating) the other;
- o the evaluation of the performances/comparability of two different sampling inlets.

In the context of this test, the instruments were exclusively operated in the Monitor Mode, two channel versions were configured to determine PM_{10} on one line and $PM_{2.5}$ on the other.

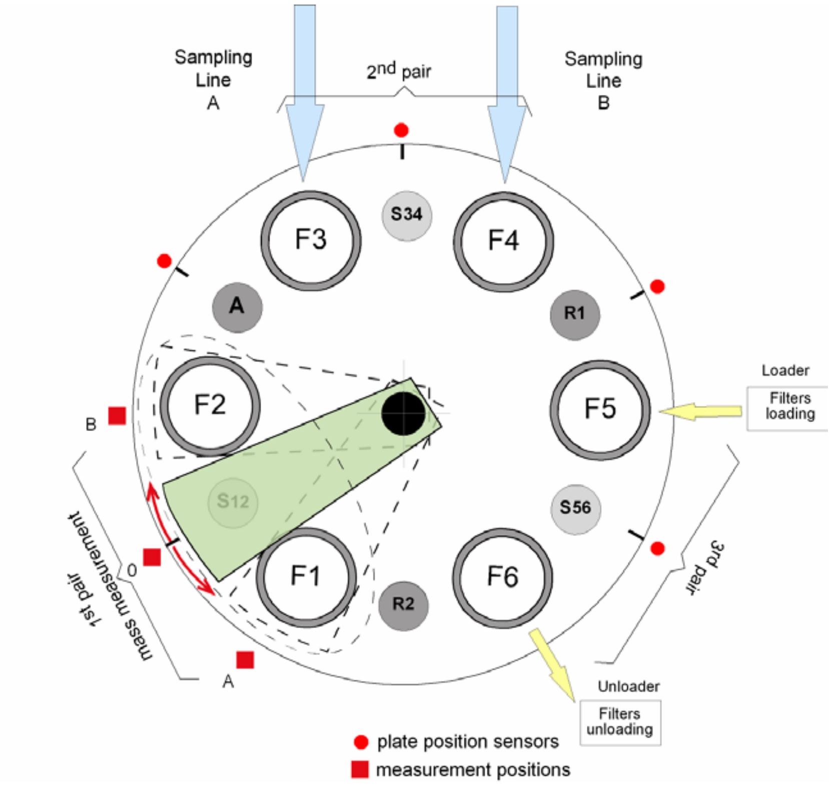
Reference mode (SWAM 5a DC HM and SWAM 5a DC only)

In Reference Mode the instrument is used as improved, high-quality standard reference single-channel monitor. In this mode one sampling line is used for PM sampling as usual, while the other line is equipped with a zero filter that will serve as “field blank”. This configuration provides a field blank for every measured value.

b) Mass measurement

SWAM 5a Dual Channel Hourly Mode Monitor / SWAM 5a Dual Channel Monitor

The module for radiometric mass measurement is mounted to a mechanic swivel arm. The source and the detector are connected to one another and can be moved to the desired position together (see Figure 1).



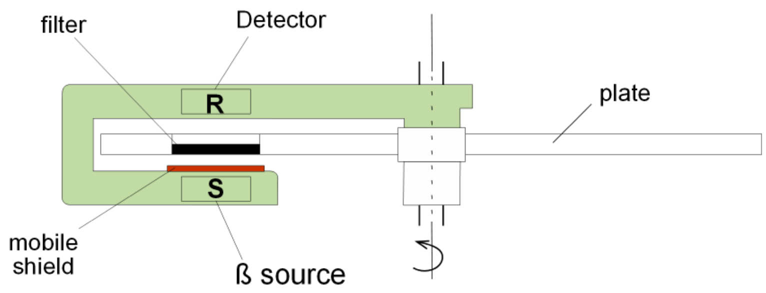


Figure 1: Mass measurement with the SWAM 5a Dual Channel Monitor

SWAM 5a Monitor

There is no need for the radiometric measurement unit to move which is why it is fixed (see Figure 2).

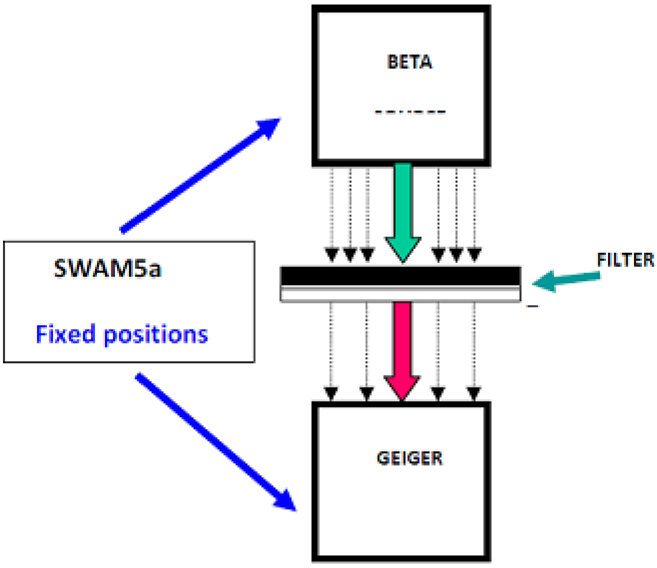


Figure 2: Mass measurement SWAM 5a Monitor

Using the example of the SWAM 5a Dual Channel Monitor, the measurement cycle can be described as follows.

Every measurement session, whether blank or collect measurement, consists of a sequence of beta flux measurement cycles. Every cycle is alternately performed on the operative filtering mediums F_{r1} and F_{r2} and on the spy filter F_s. The matrix describing the sequence of the measurements contained in the n measurement cycles is:

$$\begin{bmatrix} F_s^{11} & F_{r1}^{1} & F_s^{12} & F_{r2}^{1} & F_s^{13} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ F_s^{n1} & F_{r1}^{n} & F_s^{n2} & F_{r2}^{n} & F_s^{n3} \end{bmatrix} \quad \text{with } 4 \le n \le 6$$

Radiometric measurement times Tm relative to the single phases are:

- 10 min for measurement filter F_r
- 5 min for the spy filters

The number of measurement cycles depends on the sampling cycle.

n=4 for 8 h sampling cycles

n = 6 for 12 h or longer sampling cycles

A normal cycle time of 24 h (n=6) results in every measurement filter being measured 6 times per measurement and every spy filter being measured 18 times.

Moreover, for the purpose of quality assurance, every measurement cycle includes a measurement of background noise of the beta measurement (= dark) – with the radiation source shielded – and a measurement of the beta ray influence without the use of filters between the beta source and the detector (= beta flux in the air). The former allows to determine the background noise, while the latter facilitates the stability assessment of the Geiger-Müller detector.

c) Pneumatic system

Two vacuum pumps are used to adjust the flow rate in the range between 0.5–2.5 m³/h (a single vacuum pump for the SWAM 5a Monitor). A regulation valve moved by a step motor serves to control the flow rate.

Two solenoid valves, one placed in each sampling line, allow to switch the pneumatic circuit from the sampling configuration to the span test configuration (automatic check of the flow rate measurement system calibration) and to the leak test configuration (automatic check of the pneumatic circuit seal).

The three possible pneumatic configurations are as follows (see Figure 3):

- Sampling: EV1 open, EV2 closed
- Leakage test: EV1 closed, EV2 closed
- Span test: EV1 closed, EV2 open

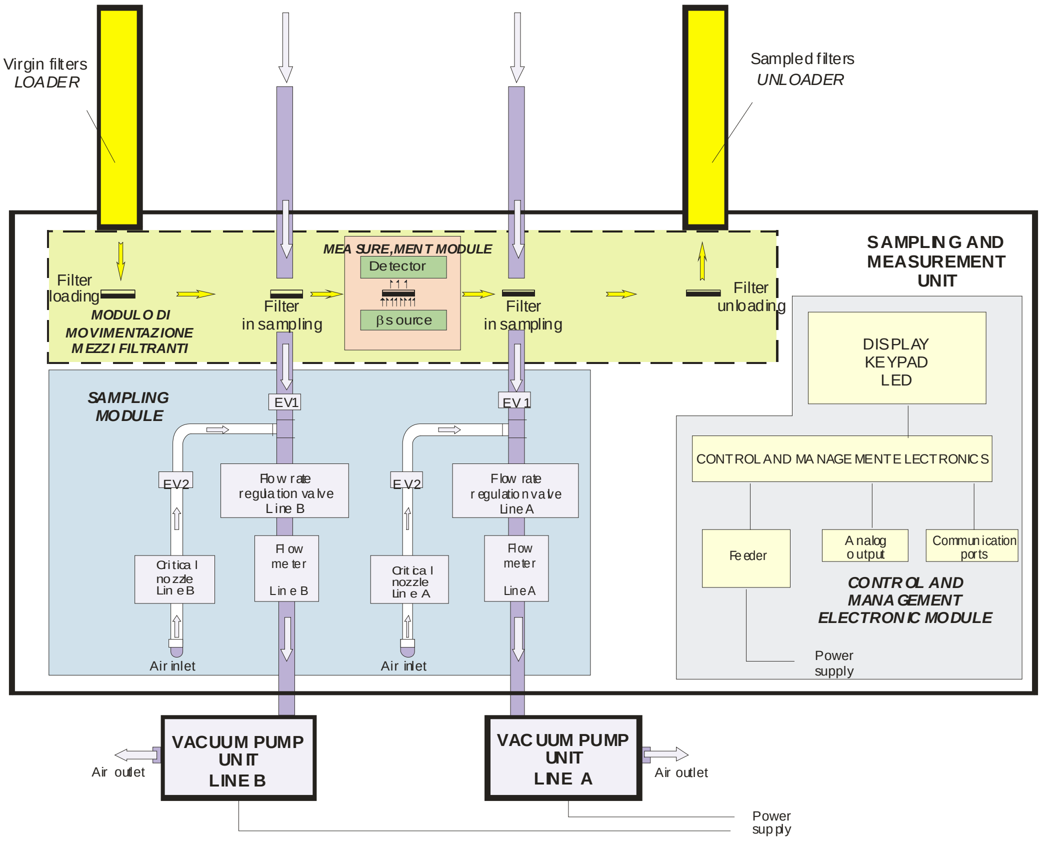


Figure 3: Schematic layout of the sampling unit, dual channel version

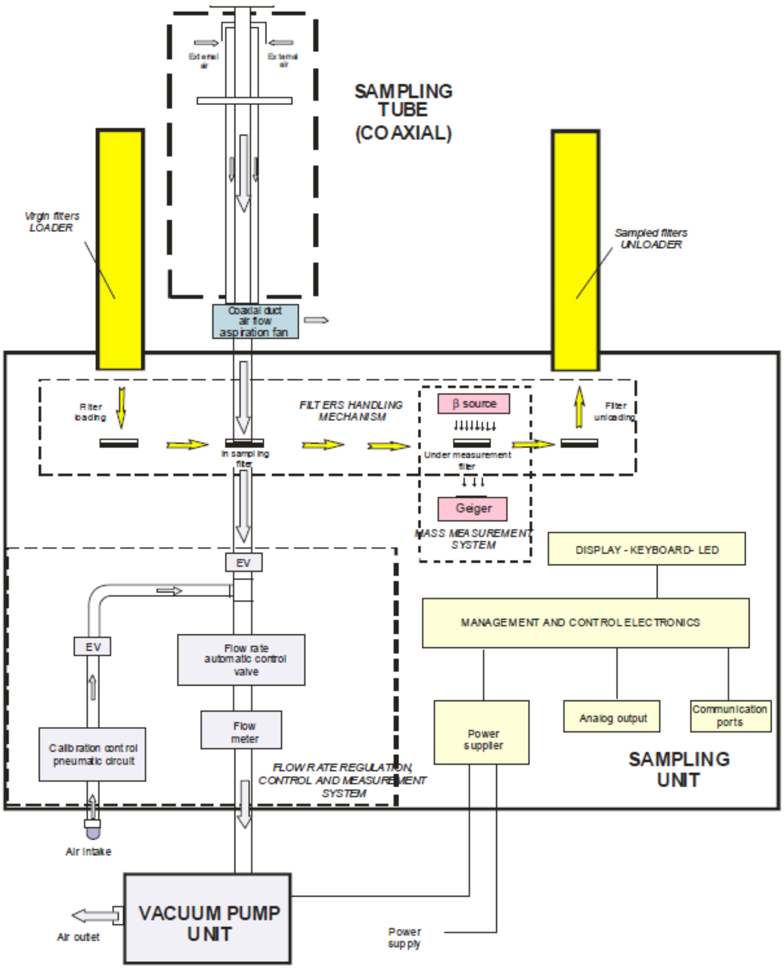


Figure 4: Schematic layout of the sampling unit, single channel version

The sampling flow rate measurement is based on the physical laws controlling the air mass transfer through a nozzle that in the AMS is placed downstream the regulation valve.

By measuring the pressure value P_p, downstream of the nozzle, the nozzle pressure drop ΔP and the air temperature value T_m in the measurement area, it is possible to calculate the standard flow rate value Q_s using the following relation:

Qs = f(z) where $z = \sqrt{\frac{\Delta p \cdot (2P_p - \Delta p)}{T_m}}$

The AMS approximates the form of the function f(z) to a second-order polynomial in z whose coefficients are determined using a multipoint calibration procedure.

d) Filter membrane management

The AMS can handle a maximum of 72 filters. At the end of every sampling and measurement cycle the sampled filters can be removed from the unloader.

The filter membranes management module comprises the following main components:

- Rotating plate for measurement filters F, spy filters S (not for SWAM 5a Monitor) and reference foils R; it has a hole A the measurement of the air beta flux.
- Virgin filter loader
- Virgin filter reserve (inside the instrument)
- Sampled filter unloader
- Electro-pneumatic pistons for filter loading and unloading
- Electro-pneumatic filter-presser pistons for the operative positioning of the filters

Figure 5 provides a design overview of the filter membrane management module using the example of the SWAM 5a Dual Channel Monitor.

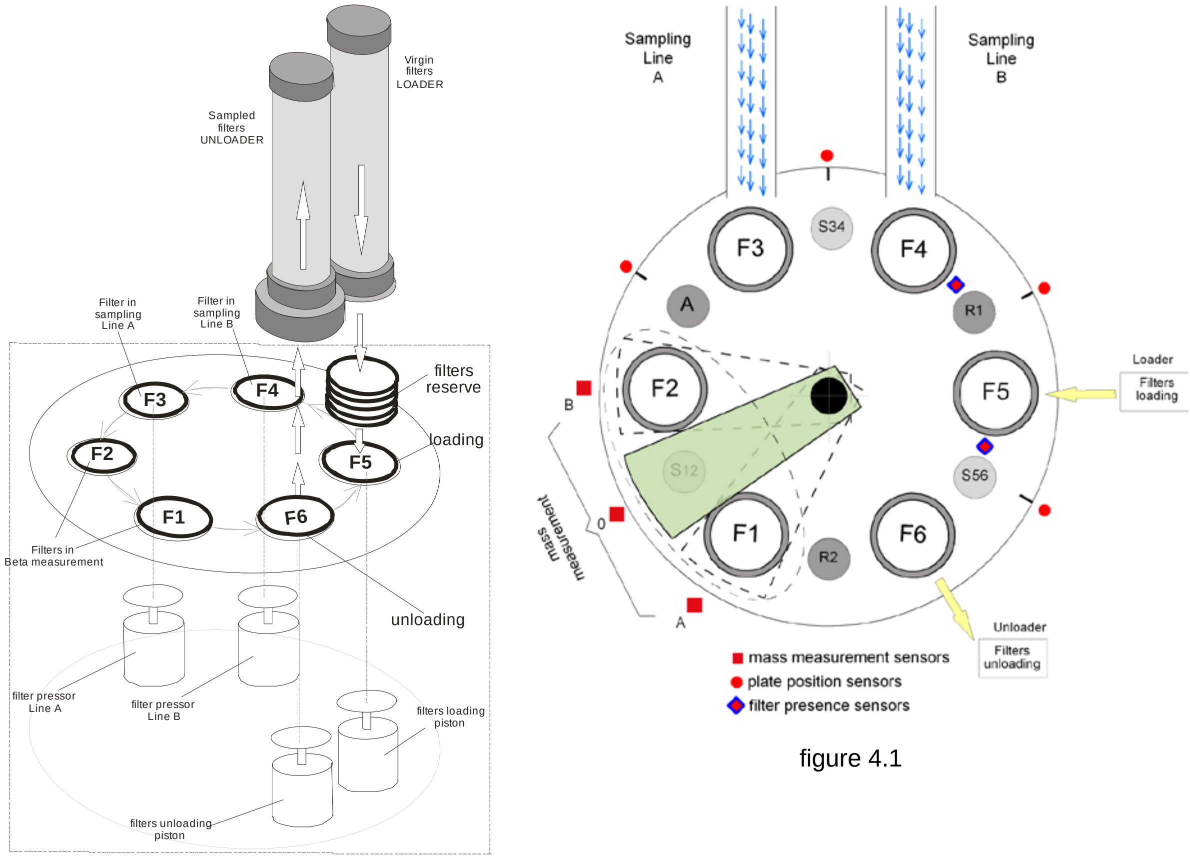


Figure 5: Filter membrane management system

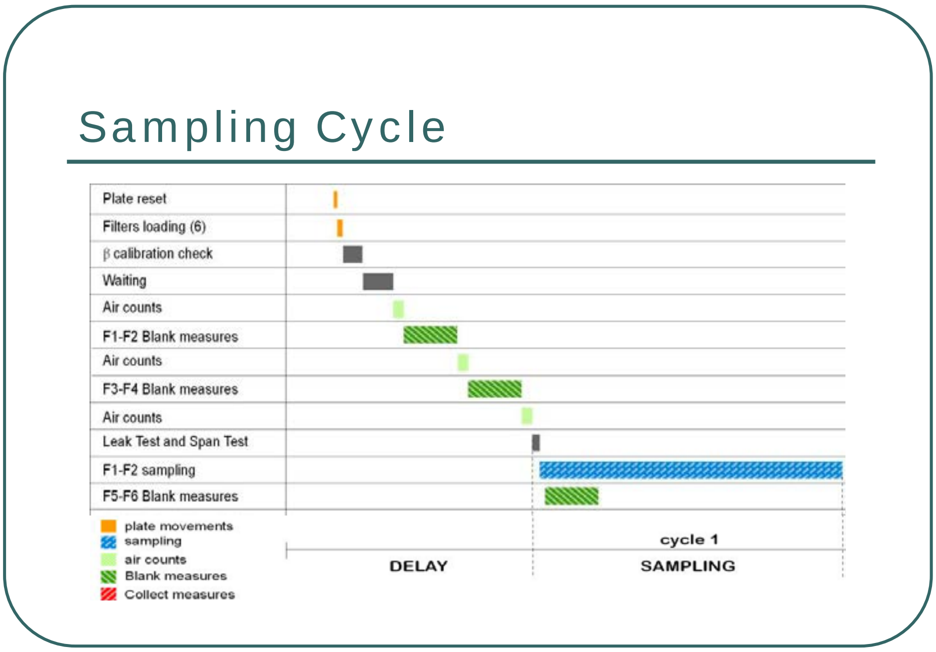
Measurement filters (∅ 47 mm) are inserted into specific filter cartridges. Depending on the dust load to be expected, filter cartridges may contain filters with smaller or larger spot areas (starting from 2.54 cm² for low dust concentrations up to 11.95 cm² for higher concentrations in the SWAM 5a Dual Channel Monitor/SWAM 5a Monitor and 2.25 cm² for the SWAM 5a Dual Channel Hourly Mode Monitor). The size of the spot area needs to be taken into account for parameterisation.

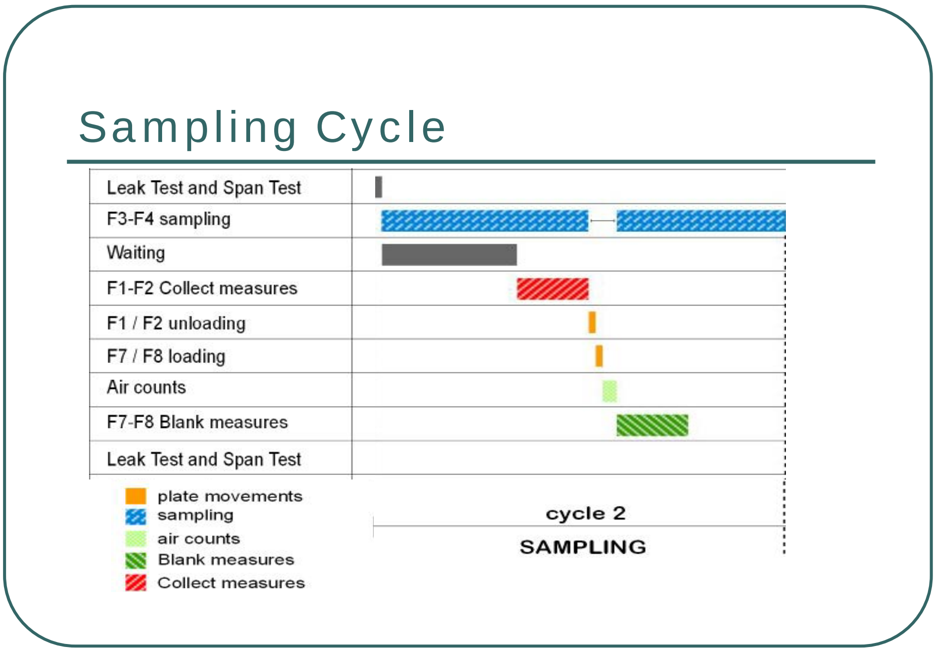
During the performance test of the SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, filter cartridges with a 5.20 cm² spot area were used; for the SWAM 5a Dual Channel Hourly Mode Monitor 2.27 cm² spot areas were used.

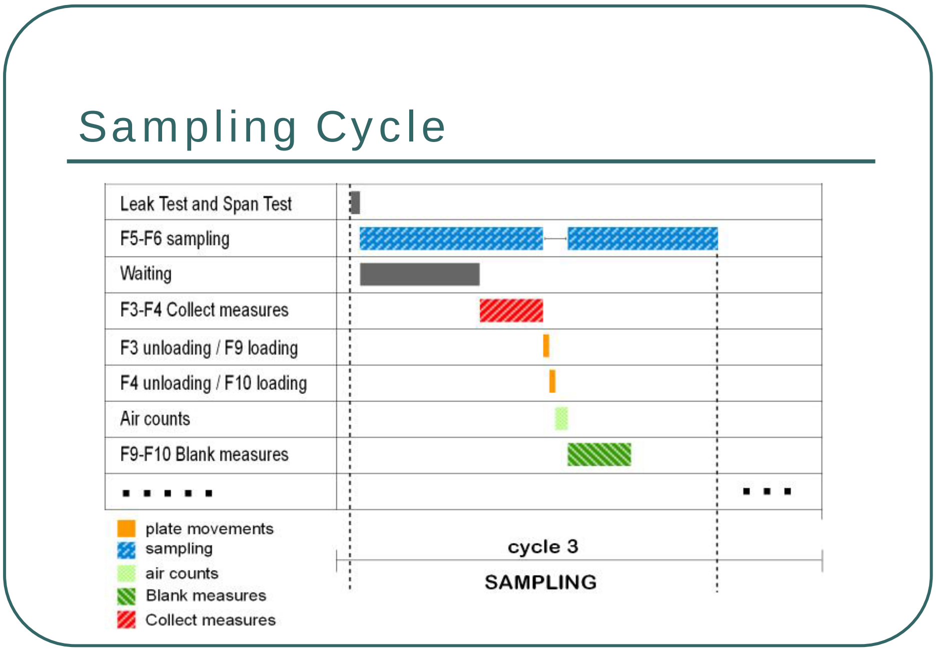
Filter cartridges with virgin filters are inserted into the loader. As part of performance testing, 36-filter cartridges were inserted into the filter loader. When operating two lines in parallel and at a cycle time of 24 h, the measuring system can then be operated for 18 days without the need to stock up filters. Stocking up filters can take place at any time without having to interrupt AMS operation.

e) Overview of the sequence of steps followed for three consecutive sampling cycles

The following figure illustrates the sequence of steps followed during three consecutive sampling cycles and, in doing so, the functioning of the measuring system as well as the filter positions inside the instrument.






Sampling Cycle
Leak Test and Span Test
F5-F6 sampling
Waiting
F3-F4 Collect measures
F3 unloading / F9 loading
F4 unloading / F10 loading
Air counts
F9-F10 Blank measures
plate movements
sampling
air counts
Blank measures
Collect measures
cycle 3
SAMPLING

f) Quality assurance

The measuring system provides for a number of internal tests for quality checks in order to verify and ensure correct operation.

The results of these quality checks can be reviewed in the data stored for each measurement. For some of the parameters monitored, warnings or alarms are issued when certain, specified limits are exceeded.

The annexes to the relevant operation manuals provide an overview of warnings and alarms issued.

Among others, the following parameters are being monitored:

- Leak tightness of the pneumatic system (before every measurement cycle)
- Test of the flow rate calibration (before every measurement cycle)
- Flow rate stability (continually during every measurement cycle)
- Pressure drop at the measurement filter (continually during every measurement cycle)
- Monitoring of pressure and temperature sensors (continually during every measurement cycle)
- Background noise of the beta flux (before every measurement cycle)
- Stability test of the Geiger counter (continually during every measurement cycle)
- Test of the mass calibration (before every restart or manually initiated at the beginning of the upcoming measurement cycle)
- Use of sensors to establish proper mechanical functioning

3.3 AMS scope and set-up

SWAM 5a Dual Channel Hourly Mode Monitor / SWAM 5a Dual Channel Monitor:

The measuring system consists of two sampling heads (PM_{10} and $PM_{2.5}$), two sampling lines, two vacuum pumps, the instrument, the compressor for generating compressed air and the two filter cartridges for virgin and sampled filters.

SWAM 5a Monitor

The measuring system consists of one sampling head (PM_{10} or $PM_{2.5}$), one sampling line, one vacuum pump, the instrument, the compressor for generating compressed air and the two filter cartridges for virgin and sampled filters.

The individual components are described below:

Measuring system/sampling unit

The sampling unit contains all the servo mechanics, the pneumatic and beta measurement component as well as all electronic parts and microprocessors for operation, control and monitoring of the measuring system. The control panel with display is located at the front of the system; pneumatic and electronic connections as well as communication interfaces are located at the back of the system. Filter loader/unloader housings and sampling lines are located on the upper instrument surface.

Figure 6: SWAM 5a Dual Channel Monitor measuring system

Figure 7: SWAM 5a Monitor measuring system

Vacuum Pump

Ambient air is taken in through the sampling inlets, the two sampling lines and the two filters with the help of the vacuum pump (1 pump and 1 filter for the SWAM 5a Monitor). They consist of a piston pump with with an upstream silencer filter to balance out pressure fluctuations. Automatic flow rate control takes place for each sampling line independently.

In principle, it is possible to use a different pump type (e.g. graphite rotary vane pump) as long as the required pump performance is ensured at any given time.

Figure 8: Vacuum pump

Service air compressor unit

The instrument is equipped with a service air compressor able to supply compressed air (200–300 kPa) used for the servomechanisms movements (e.g. for loading/unloading filters into the relevant housing). A compressor generates the necessary compressed air.

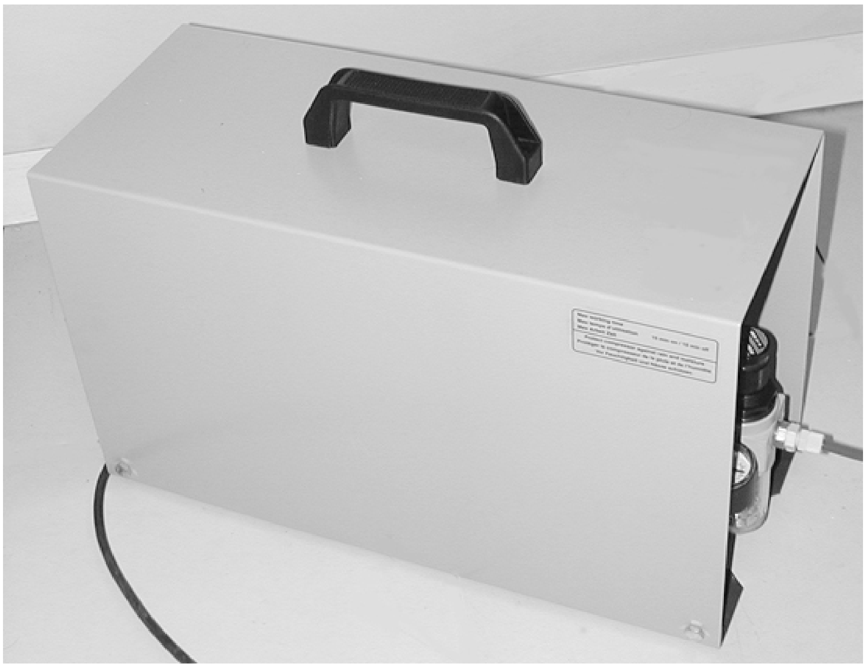


Figure 9: Compressor for generating compressed air

Sampling inlets

The measuring system is equipped with two sampling inlets for PM_{10} and $PM_{2.5}$. The sampling inlets are manufactured by the instrument manufacturer and are available for various flow rates (2.3 m³/h or 1 m³/h).

During performance testing, sampling inlets with a throughput of 2.3 m³/h were used which, in terms of design, comply with the reference standards applicable at the time of testing, namely EN 12341:1998 (PM_{10}) and EN 14907:2005 ($PM_{2.5}$).

Standards EN 12341: 1998 and EN 14907:2005 have been revised in the meantime and consolidated in the new standard EN 12341 (August 2014) version. Annex A to the new standard provides normative requirements for instrument design of standard sampling inlets for PM_{10} and $PM_{2.5}$ for a flow rate of 2.3 m³/h. For PM_{10} in particular, requirements for standard sampling inlets in the new standard have been revised and slightly modified. This is why, FAI Instruments s.r.l have included sampling inlets in compliance with the new standard EN 12341 (August 2014 version) in their range of products, which may be used alternatively with the measuring system.

The new sampling inlets are clearly labelled as PM_{10}-EN12341-2014 and $PM_{2.5}$-EN12341-2014 respectively and are manufactured in compliance with Annex A to standard EN 12341 (August 2014 version).

Figure 10: Sampling inlets FAI

Sampling line

Ambient air containing particles is taken in through the sampling inlet, it passes through the sampling line and finally reaches the filter.

In situations with high amounts of volatile dust components it is possible to have the sampling line purged co-axially with ambient air (it may alternatively heated or cooled).

As part of the test at hand, neither purging with ambient air, nor active heating or cooling took place. Inside the measuring rack, the sampling line was isolated by wrapping foamed material around it.

For the field test, the measuring systems were installed in an outdoor rack specifically designed and distributed by the manufacturer. The measuring rack consists of a minimum of three modules:

Module 1 for housing the measuring system

Module 2 for housing the rack's temperature control

Module 3 for housing pumps and the compressor

Of course, the measuring system can be installed in any conventional measuring rack. In that case it should be noted that the SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Monitor require two roof ducts for the two sampling lines.

Figure 11: Outdoor measurement racks at the field test site in Bonn, Belderberg

Figure 12: SWAM 5a Dual Channel Monitor inside the outdoor measurement rack

The measuring system is operated via a membrane keypad combined with a display at the front of the instrument. This is where all necessary parameters can be adjusted (e.g. sampling time). Moreover, information regarding the current instrument status (on-going sampling), data saved on completed measurements and numerous parameters for quality assurance can be accessed here.

In addition to direct communication via the control panel/display, the system can be fully operated, controlled and parameterised via the RS-232 serial interfaces and a standard terminal programme (e.g. Hyperterminal) or the software component Dr. FAI Manager (version 0.6.6.0 used during performance testing), either directly or indirectly via a GSM modem. This provides a convenient possibility to read stored data as a text file and use them for further processing. Figure 13 to Figure 19 provide an overview of information provided and available monitoring and control features offered by the Dr. FAI Manager.

An analogue output provides measured values and status signals if this is desired.

Moreover, the measuring system provides a feature which informs its user about the instrument status and the latest measured values via SMS.

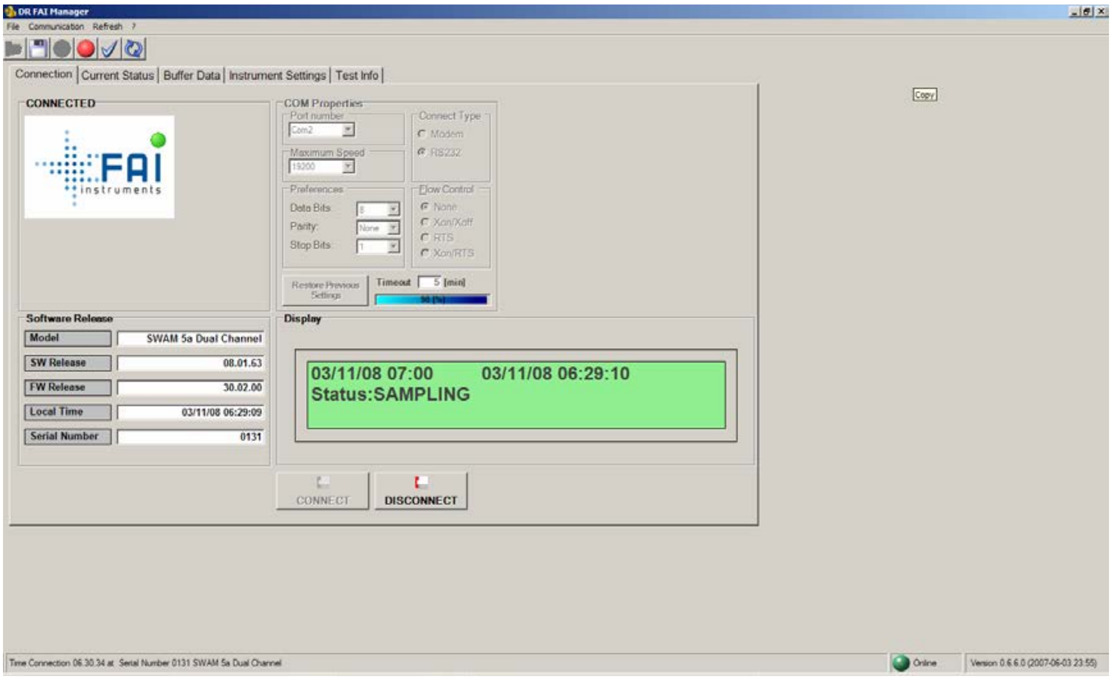


Figure 13: Dr. FAI Manager operating software

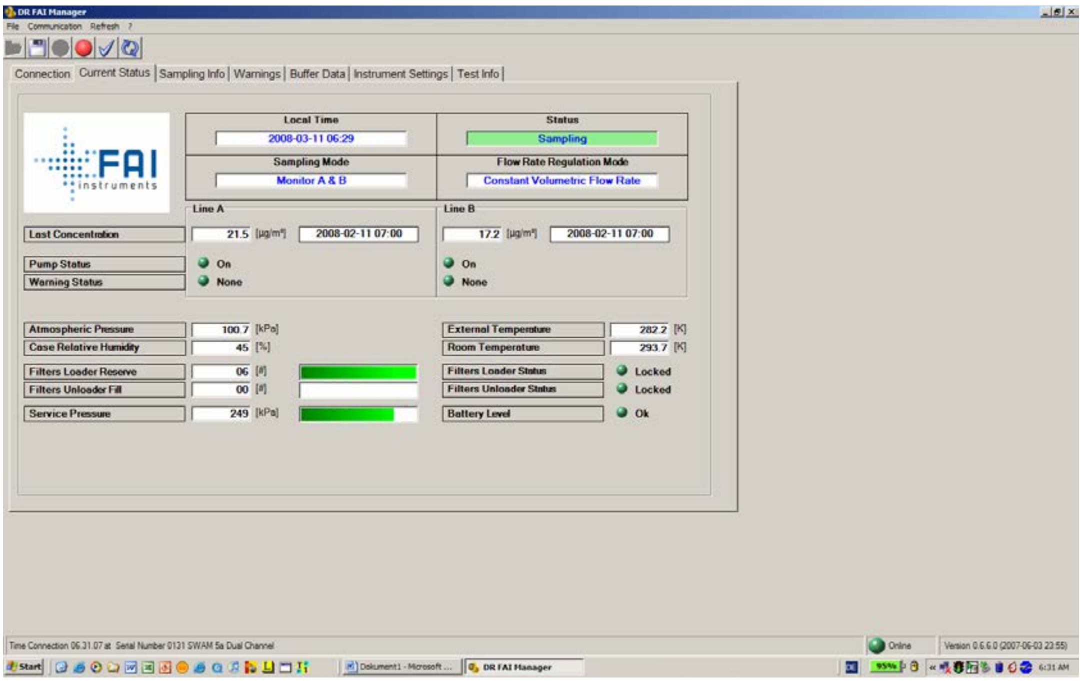


Figure 14: Dr. FAI Manager operating software (sampling information)

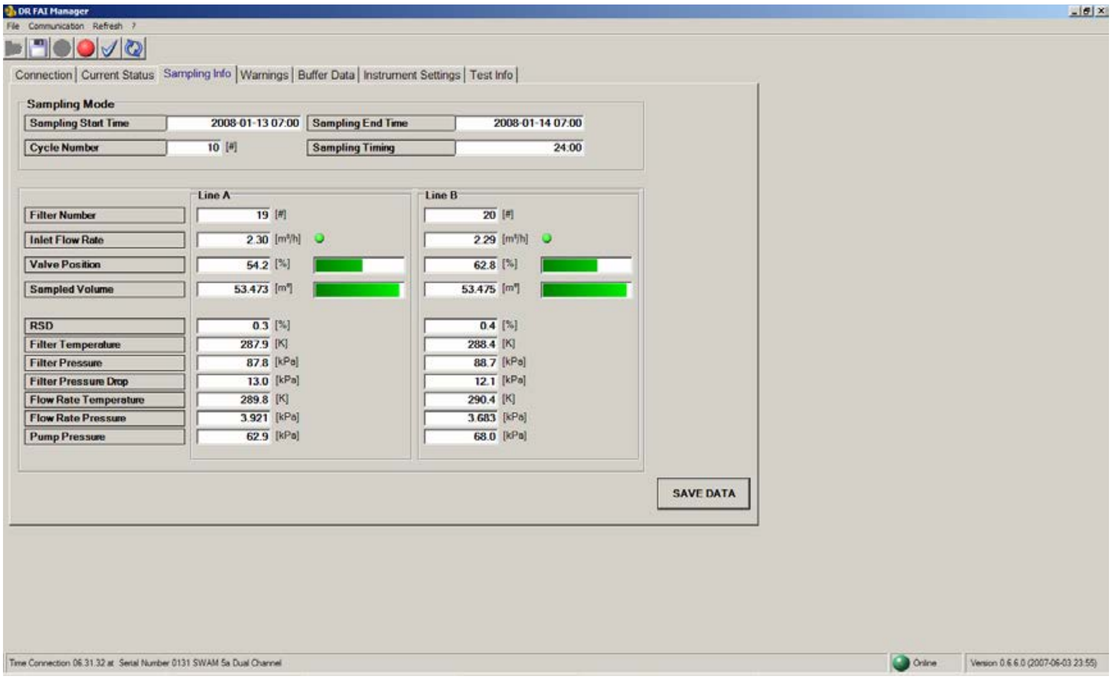


Figure 15: Dr. FAI Manager operating software

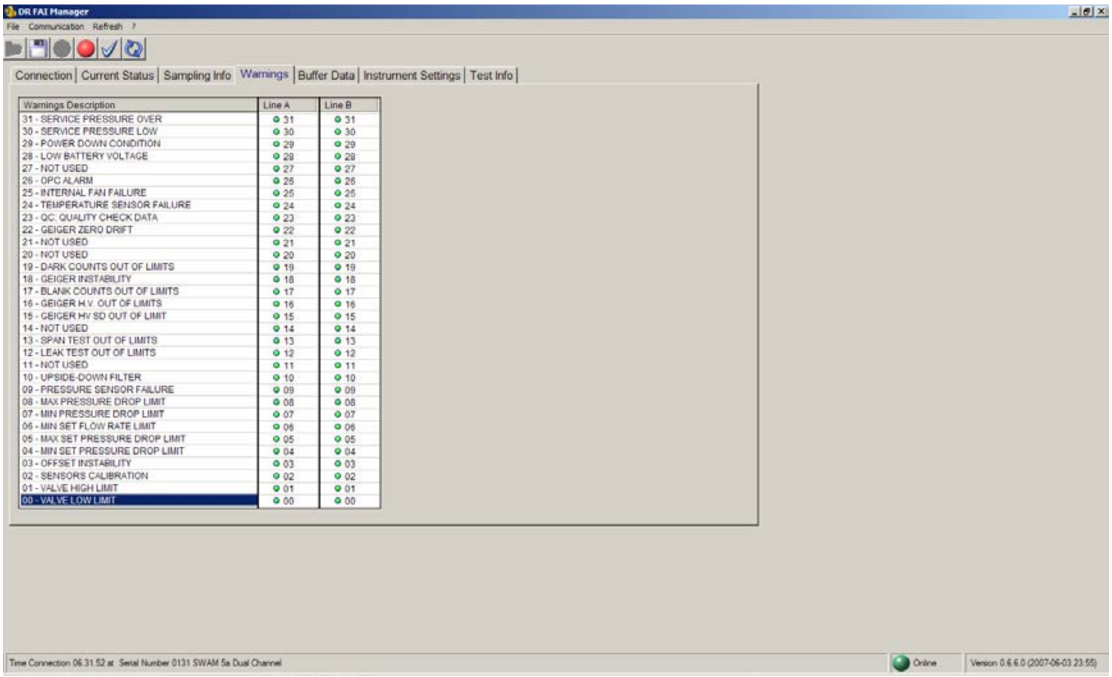


Figure 16: Dr. FAI Manager operating software (warnings)

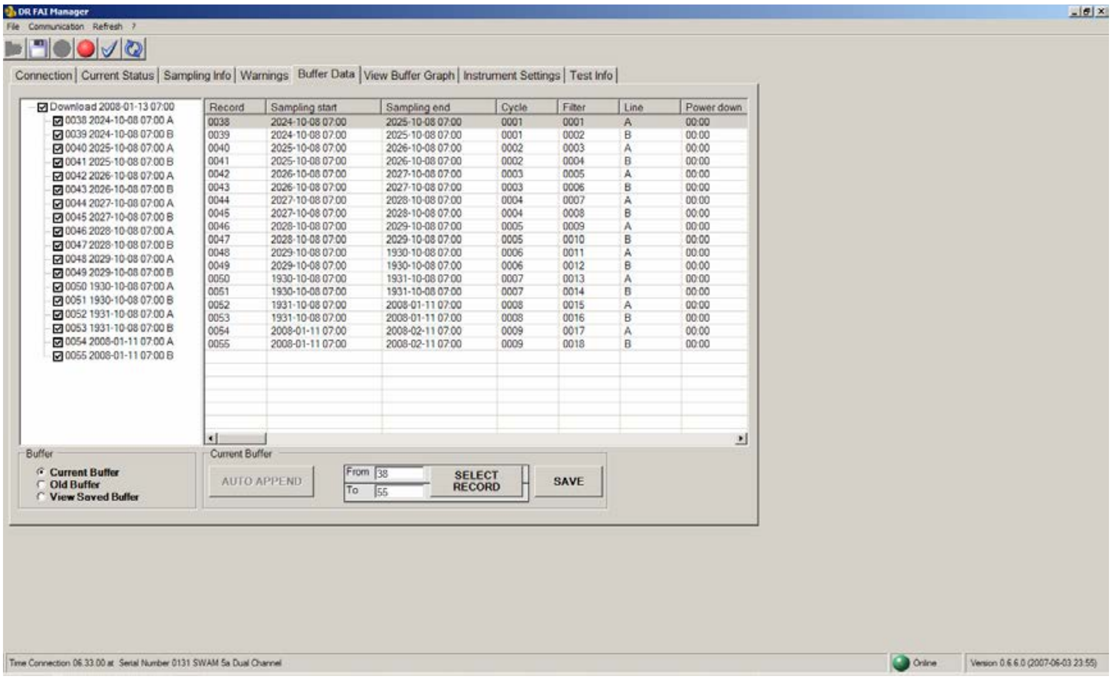


Figure 17: Dr. FAI Manager operating software (saving data)

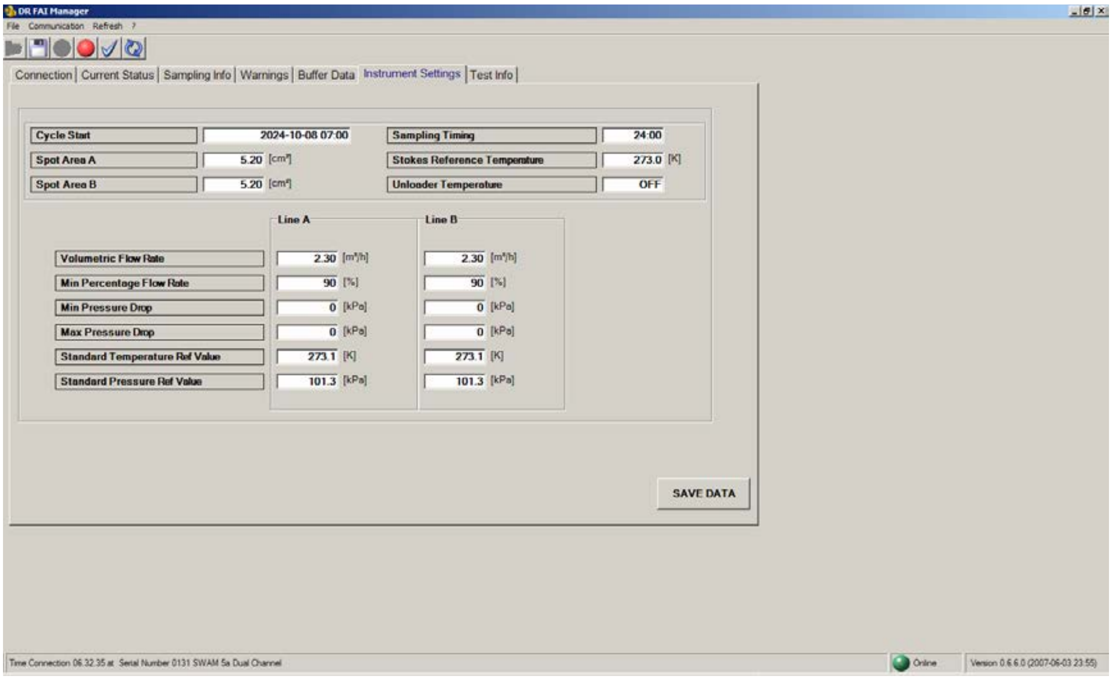


Figure 18: Dr. FAI Manager operating software (system parameterisation)

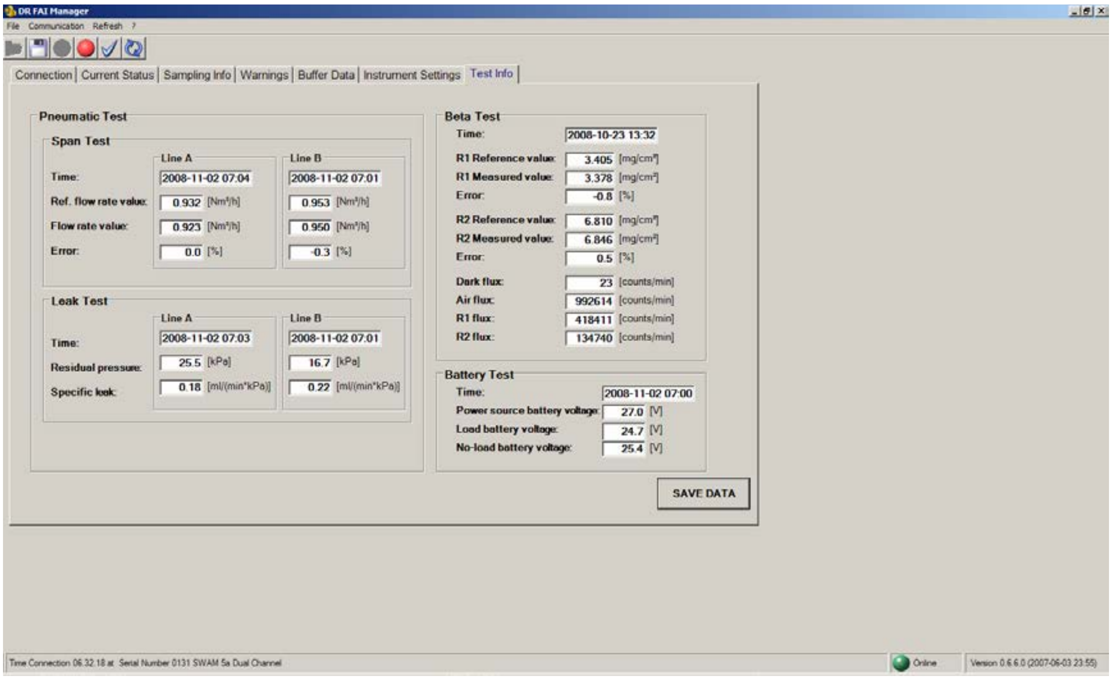


Figure 19: Dr. FAI Manager operating software (results of internal tests)

Instead of a sampling inlet, a zero filter placed at the instrument inlet is used for the purpose of zero checks and the determination of the offset. The use of this filter allows the provision of PM-free air.

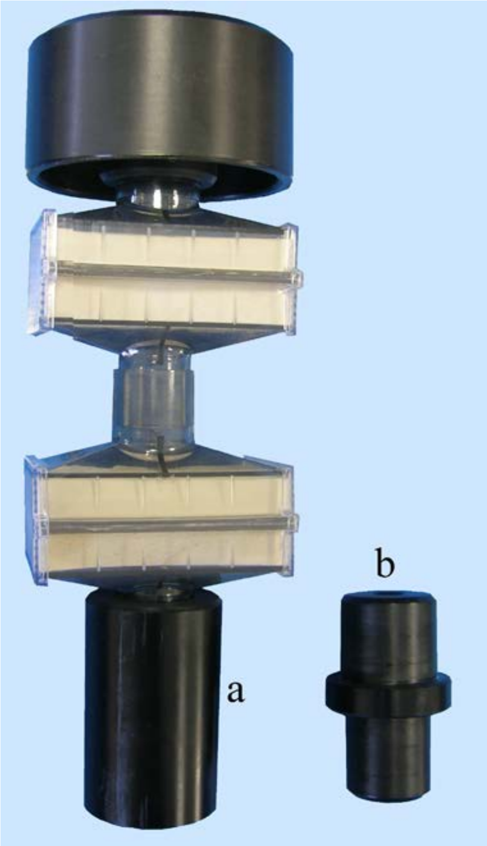


Figure 20: Zero filter (a = zero filter, b = adapter connecting to the sampling line)

The radiometric calibration can be verified on every restart of the instrument (or manually at the start of the next measurement cycle) with the help of two reference aluminium foils with a known mass density. The values thus obtained are compared to pre-defined values and potential deviations indicated as a percentage. The result of the previous “beta span test” can be recalled at any time.

In addition, the manufacturer provides a set of reference aluminium foils for checking and, if necessary, recalibrating the radiometric measurement. There are 6 foils in this set. The necessary procedure is described in detail in the operation manual.

Table 5 lists the most important instrument characteristics of the SWAM 5a measuring system.

Table 5: SWAM 5a instrument characteristics (manufacturer specifications)

Dimensions / weight	**SWAM 5a**
Measuring device	430 x 540 x 370 mm / 36 kg (SWAM 5a DC/DC HM) 430 x 540 x 240 mm / 33 kg (SWAM 5a)
Vacuum pump	200 x 320 x 200 mm / 10 kg
Compressor	180 x 320 x 200 mm / 18 kg
Sampling tube	1.5 m
Sampling inlet	FAI, 2.3 m³/h, PM_{10} & $PM_{2.5}$
Outdoor measuring cabinet	700 x 700 x 1950 mm / 95 kg
Power supply	230 V±10 %, 50 Hz
Power requirement	max. 1.200 W / 1000 W (SWAM 5a)
Ambient conditions	
Temperature	+5 - +40 °C during performance testing
Moisture	not condensing (<85%)
Sample flow rate	0.8–2.5 m³/h, adjustable 2.3 m³/h = 38.33 l/min during performance testing
Radiometric source	^{14}C, 3.7 MBq (100 µCi)
Detector	Geiger-Müller
Mass measurement	
Measuring range mass density	10 mg/cm²
Reproducibility of the mass density determination	±2 µg/cm²

Spot area (β equivalent spot area) in cm², depends on the filter material, flow rate and concentration level	2.54 / 5.20 / 7.07 / 11.95 (SWAM 5a DC / SWAM 5a) 2.27 (SWAM 5a DC HM)
Reproducibility of the mass measurement	±10 µg at a spot area of 5.2 cm²
Sampling	
Filter replacement interval (cycle time)	adjustable, 8–12–24–48–72–96–120–144–168 h 1h for SWAM 5a DC HM
Maximum permissible flow rate at filter	40 kPa at 2.3 m³/h
Data storage capacity (internal)	1 500 data sets
Data saved for each measurement	see operation manual
Analogue output	0–5 V – parameterisable, 200 µg/m³ by default, others selectable
Digital output	2 x RS 232 (for PC and for Modem) – interface for (remote) data transmission
Status signals/error messages	available, consult operation manual for overview

4. Test programme

4.1. General

The original performance test [11] was carried out with two identical instruments, type SWAM 5a Dual Channel Monitor, serial numbers 127 and 131.SWAM 5aSWAM 5a Tests in the context of the scheduled test programme "Combined MCERTS and TÜV PM Equivalence Testing Programme" were performed simultaneously at the sites in Teddington and in German and with two identical instruments, serial numbers 145 and 149.

At the beginning of the performance test, the candidate systems operated software version Rel 04-08.01.63-30.02.00. In the course of testing, software versions were continually updated to reach version no. Rel 04-08.01.65-30.02.00 in the end.

Changes having led to software version Rel 04-08.01.65-30.02.00 are unlikely to impact instrument performance.

The original test comprised a laboratory test to determine the performance characteristics as well as several field tests over a period of several months at various sites.

Additional tests performed for the purpose of approving instrument version SWAM 5a Dual Channel Hourly Monitor were performed with two identical instruments of that type, serial numbers 111 and 112 as well as with two identical instruments, type SWAM 5a Dual Channel Monitor, serial numbers 127 and 131.

Additional tests performed for the purpose of approving instrument version SWAM 5a Monitor were performed with a total of four instruments identical in design except for the sampling inlets, serial numbers 329 and 330 (PM_{10}) as well as 331 and 333 ($PM_{2.5}$) and with two identical instruments of the approved SWAM 5a Dual Channel Monitor version, serial numbers 248 and 249 [13].

The additional tests for test items 6.1 4 Flow rate accuracy (7.4.4), 6.1 9 Dependence of span on supply voltage (7.4.8) and 6.1 11 Dependence of reading on water vapour concentration (7.4.9) were performed with two identical systems instrument type SWAM 5a Dual Channel Monitor, serial numbers 111 and 395.

During performance testing, each instrument ran the up-to-date, most recently announced software version.

Concentrations are indicated as µg/m³ (operating conditions).

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 [9].

In this report, the heading for each performance criterion cites the requirements according to the relevant standard [9] including its chapter number and wording.

4.2 Laboratory test

The laboratory test was performed in the context of the existing performance test [1]. For the present report, test results were either taken from the previous report or re-assessed.

For the following test items, additional tests had to be performed in 2017.

- Flow rate accuracy
- Influence of mains voltage on measured signal
- Effect of humidity on measured value

The following devices were used to determined the performance characteristics during the laboratory tests.

- Climatic chamber (temperature range –20°C to +50°C, accuracy better than 1°C).
- Isolating transformer,
- 1 reference flow meter, type BIOS Met Lab 500 (manufacturer: Mesa Lab)
- Zero filter (absolute filter) for producing PM-free air
- Reference foils R1&R2 (implemented in the instrument)

Measured values were read with the help of the DR FAI Manager software installed on a notebook.

Chapter 6 summarizes the results of the laboratory tests.

4.3 Field test

The field test for instrument version SWAM 5a Dual Channel Monitor [11] was performed at the field test sites in Cologne (parking lot 2007), Bonn (Belderberg) and Brühl using two identical instruments with the following serial numbers:

AMS 1: No. SN 127 (SWAM 5a Dual Channel Monitor)
AMS 2: No. SN 131 (SWAM 5a Dual Channel Monitor)

Tests in Teddington (UK) were performed as part of the "Combined MCERTS and TUV PM Equivalence Testing" programme" using a second set of instruments identical in design with the following serial numbers:

AMS 1: No. SN 145 (SWAM 5a Dual Channel Monitor)
AMS 2: No. SN 149 (SWAM 5a Dual Channel Monitor)

As part of the supplementary test for the purpose of approving instrument version SWAM 5a Dual Channel Hourly Monitor, a comparison campaign was performed in Cologne (parking lot, 2011) with the following instruments [12]:

AMS 1: No. SN 111 (SWAM 5a Dual Channel Hourly Mode Monitor)
AMS 2: No. SN 112 (SWAM 5a Dual Channel Hourly Mode Monitor)
AMS 3: No. SN 127 (SWAM 5a Dual Channel Monitor)
AMS 4: No. SN 131 (SWAM 5a Dual Channel Monitor)

As part of the supplementary test for the purpose of approving instrument version SWAM 5a Monitor, a comparison campaign was performed in Bornheim with the following instruments [13]:

AMS 1: No. SN 329 (SWAM 5a PM_{10})
AMS 2: No. SN 330 (SWAM 5a PM_{10})
AMS 3: No. SN 331 (SWAM 5a $PM_{2.5}$)
AMS 4: No. SN 333 (SWAM 5a $PM_{2.5}$)
AMS 5: No. SN 248 (SWAM 5a Dual Channel Monitor)
AMS 6: No. SN 249 (SWAM 5a Dual Channel Monitor)

In order to take into consideration the overall dataset for the purpose of equivalence testing of the SWAM 5a Dual Channel Monitor instrument version, the data sets of all six comparison campaigns were combined to provide as comprehensive a data pool as possible.

For the present report, test results were either taken from the previous report or re-assessed. No further testing was required.

The following instruments were used during the field test.

- Outdoor measurement racks for the candidate systems manufactured by FAI Instruments s.r.l
- Measurement container provided by TÜV Rheinland, air-conditioned to about 20 °C and DEFRA measurement station in Teddington
- Weather station (WS 777 manufactured by Conrad Elektronik AG / WS 500 manufactured by ELV Elektronik AG or MK III Series manufactured by Rainwise (US) in UK) for collecting meteorological data such as temperature, air pressure, humidity, wind speed, wind direction and precipitation.
- 2 reference measuring systems, SEQ47/50 or LVS3 for PM_{10} in accordance with item 5 (Germany) and LVS3 (UK)
- 2 reference measuring systems LVS3 for $PM_{2.5}$ in accordance with item 5 (Germany and UK)
- 1 gas meter, dry version
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- Measuring system for power consumption; Metratester 5 (manufacturer: Gossen Metrawatt)
- Zero filter for generating dust-free air
- Reference foils R1&R2 (implemented in the instrument)

During the field test, the candidate systems manufactured by FAI Instruments s.r.l. were operated in parallel with two reference instruments each for PM_{10} and $PM_{2.5}$ and a classification instrument over a period of 24h (Cologne only, parking lot 2007, Bonn, Brühl). The classification instrument and the reference system for $PM_{2.5}$ (all sites) and PM_{10} (Teddington (UK), Cologne, parking lot 2011, Bornheim) operate discontinually, i.e. filters have to be replaced manually after sampling.

Impaction plates of the PM_{10} and $PM_{2.5}$ sampling inlets were cleaned approximately every two weeks and greased with silicone grease in order to ensure reliable separation of particles.

The flow rates of the tested and the reference instruments were checked before and after the field test as well as before and after each change of location using a dry gas meter or a mass flow controller in each case connected to the instrument's air inlet via a hose line.

Sites of measurement and instrument installation

During the field test, the measuring systems were installed in outdoor measurement cabinets. When installing the instruments, care was taken to place the cabinets with candidate system in proximity with the reference measuring systems.

The field test was performed at the following measurement sites:

Table 6: Field test sites

No.	Version	Measurement site	Period	Description
1	SWAM 5a DC	Cologne Parking lot, 2007	10/2007 –02/2008	Urban background
2	SWAM 5a DC	Bonn, Belderberg	02/2008–04/2008	Traffic
3	SWAM 5a DC	Teddington (UK)	07/2008–10/2008	Urban background
4	SWAM 5a DC	Brühl	09/2008–11/2008	Gravel plant
5	SWAM 5a DC SWAM 5a DC HM	Cologne Parking lot, 2011	02/2011 –05/2011	Urban background
6	SWAM 5a DC SWAM 5a	Bornheim	08/2011–10/2011	Rural area + motorway

Figure 21 to Figure 32 show the levels of PM concentrations at the field test sites as determined by the reference measuring systems .

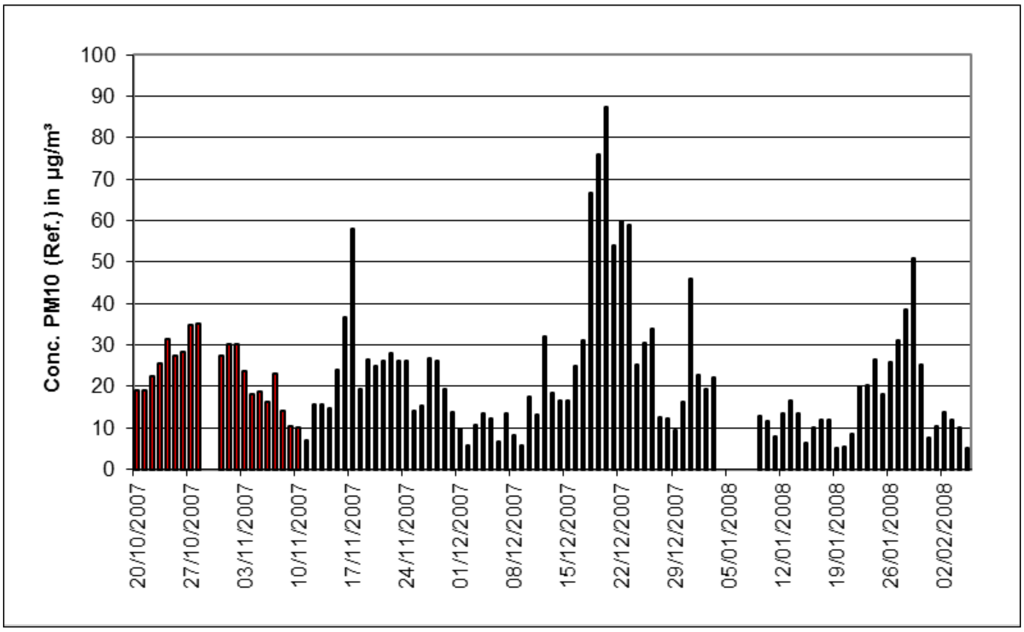


Figure 21: PM_{10} (reference) levels at the site “Cologne, parking lot, 2007”

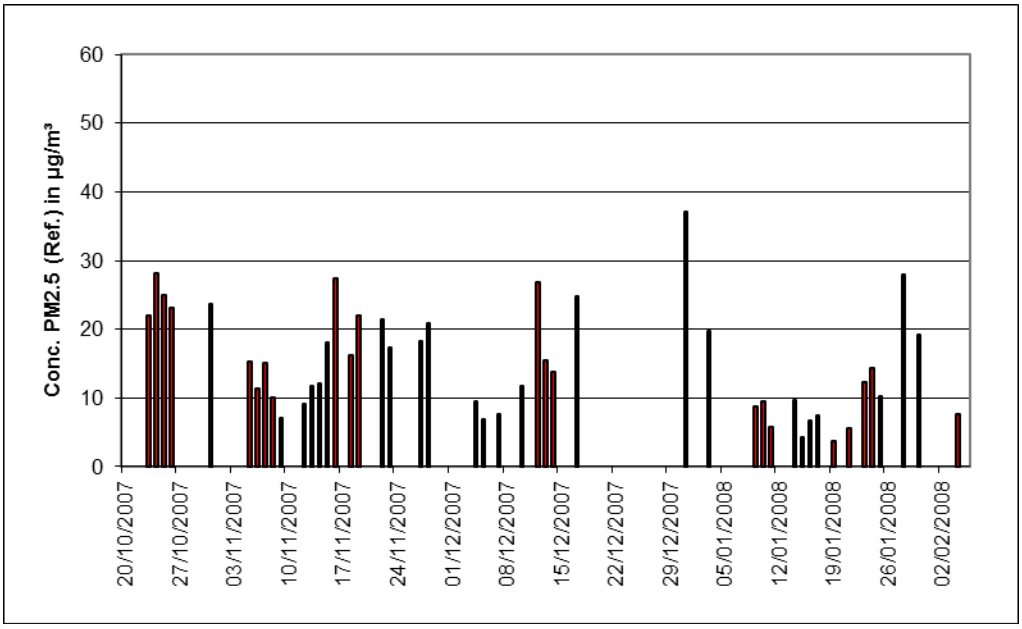


Figure 22: $PM_{2.5}$ (reference) levels at the site “Cologne, parking lot, 2007”

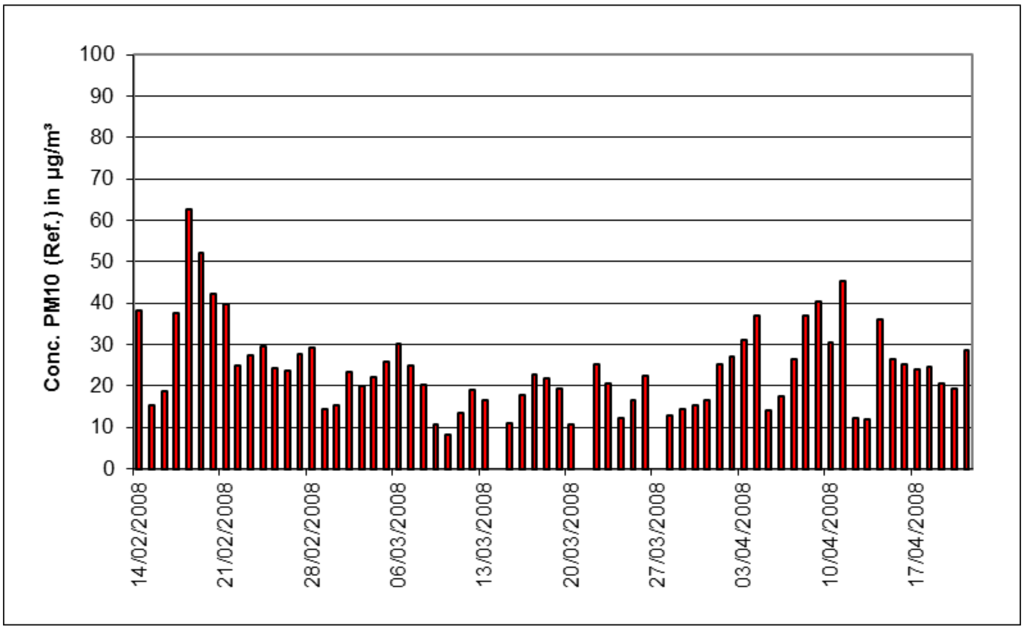


Figure 23: PM_{10} (reference) levels at the site “Bonn, Belderberg”

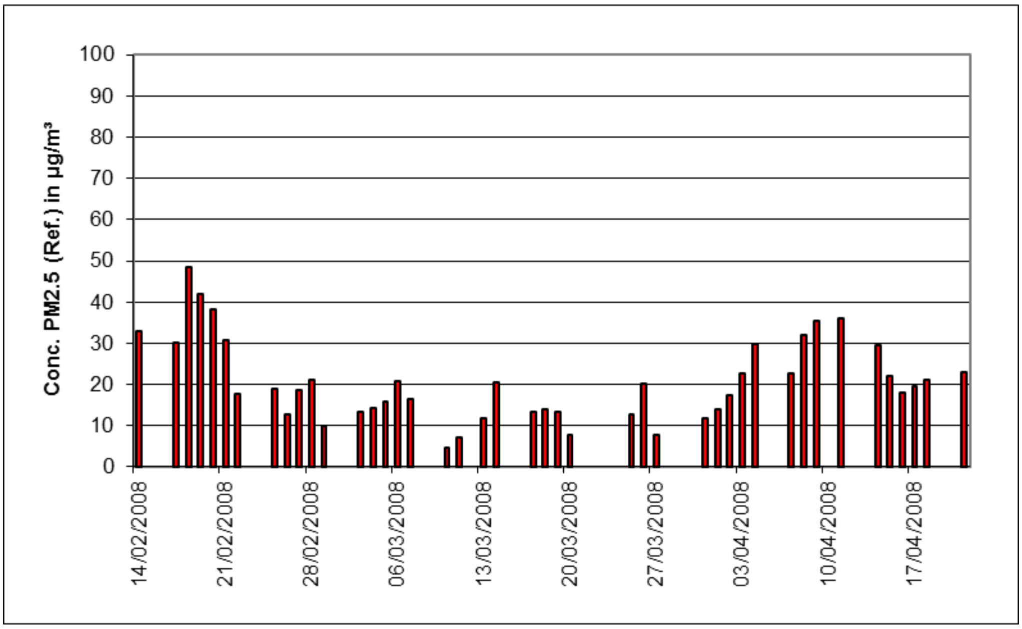


Figure 24: $PM_{2.5}$ (reference) levels at the site “Bonn, Belderberg”

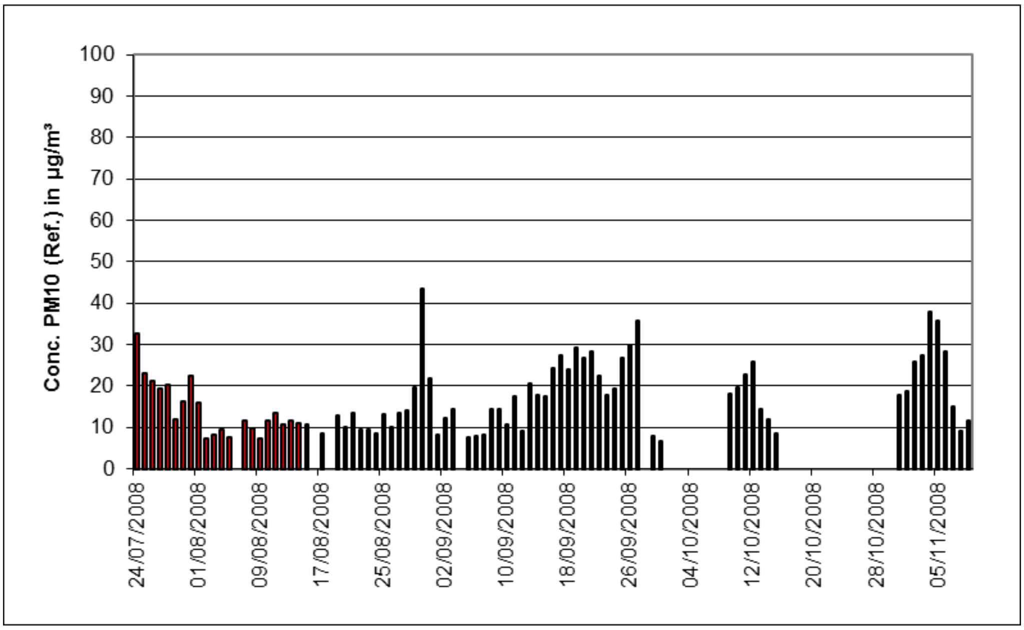


Figure 25: PM$_{10}$ (reference) levels at the site “Teddington (UK)”

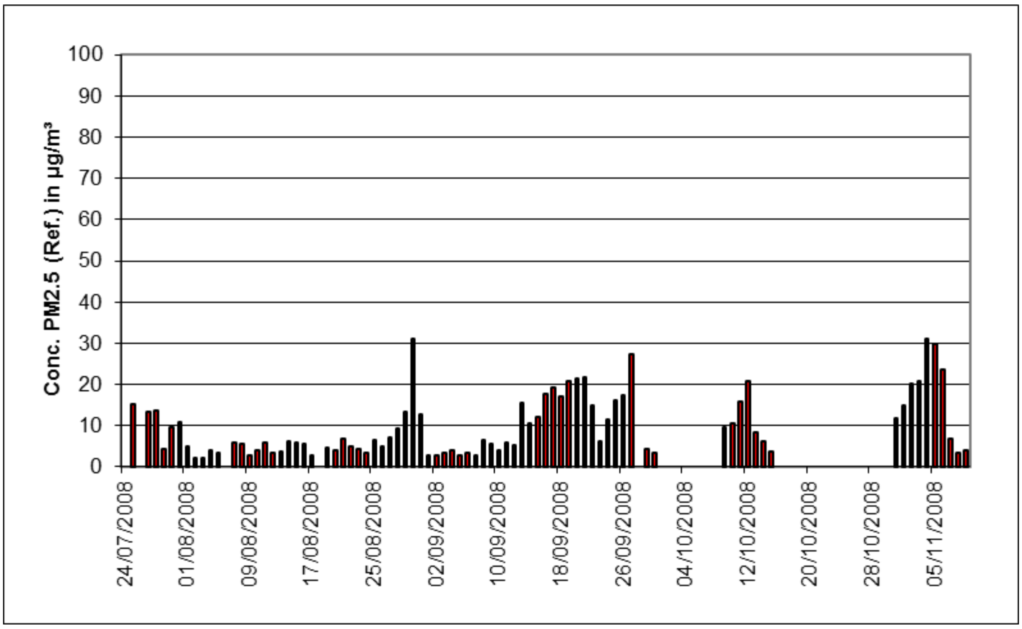


Figure 26: PM$_{2.5}$ (reference) levels at the site “Teddington (UK)”

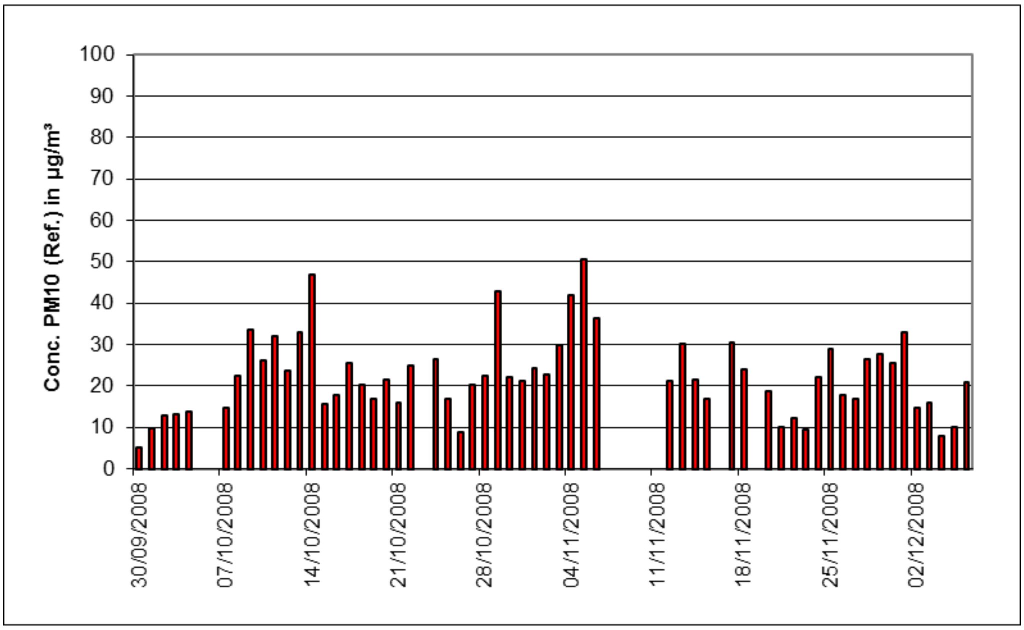


Figure 27: PM$_{10}$ (reference) levels at the site “Brühl”

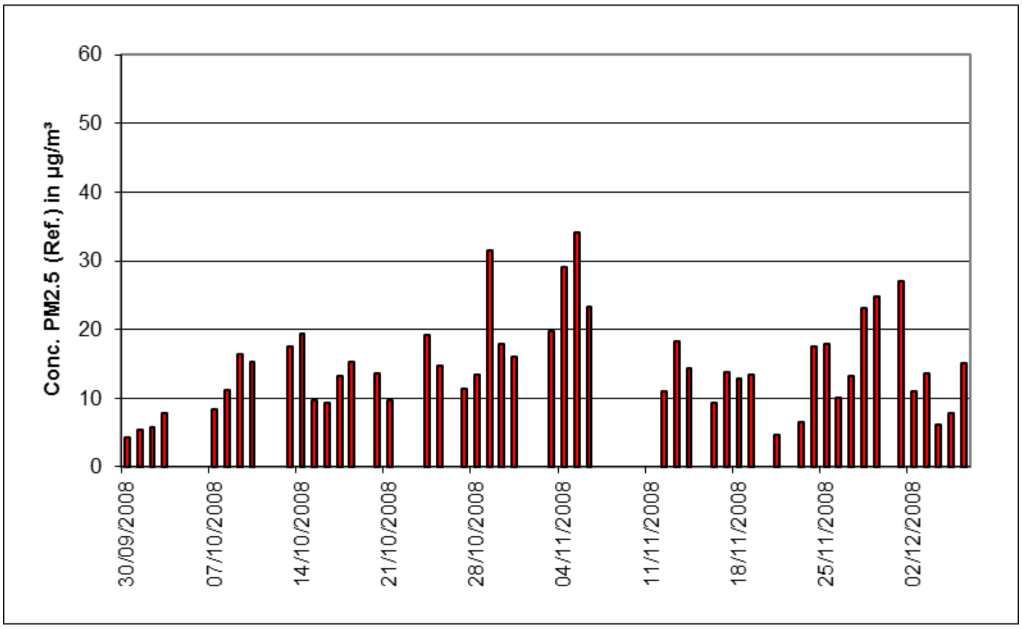


Figure 28: PM$_{2.5}$ (reference) levels at the site “Brühl”

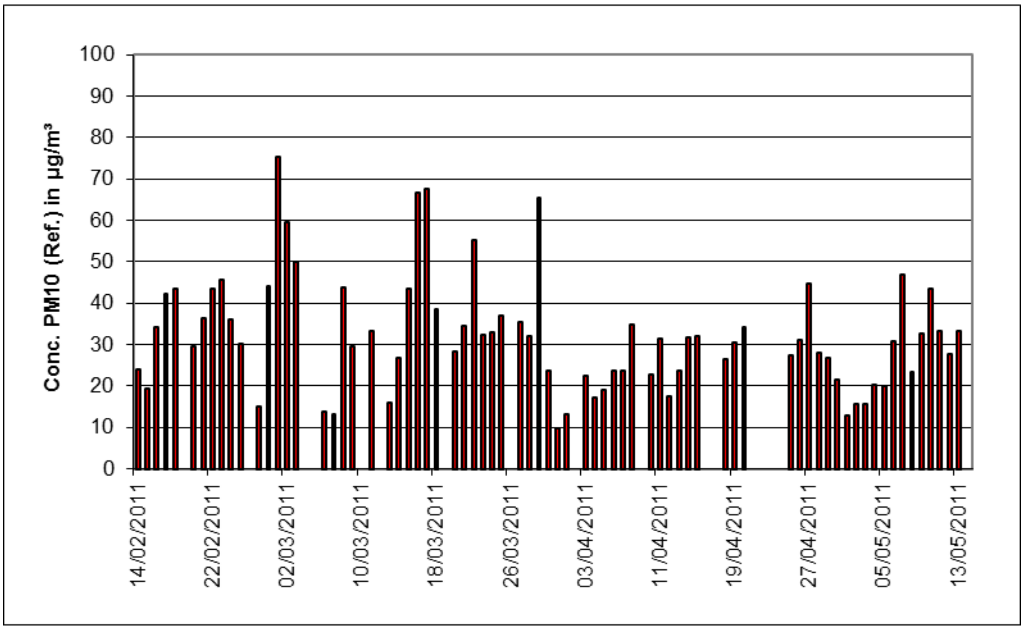


Figure 29: PM$_{10}$ (reference) levels at the site “Cologne, parking lot, 2011”

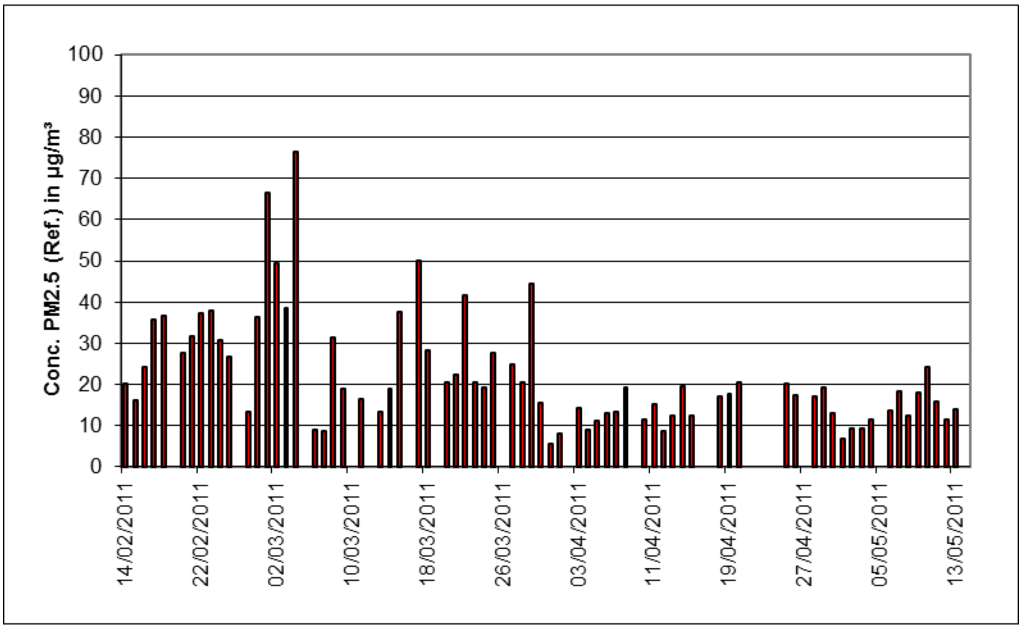


Figure 30: PM$_{2.5}$ (reference) levels at the site “Cologne, parking lot, 2011”

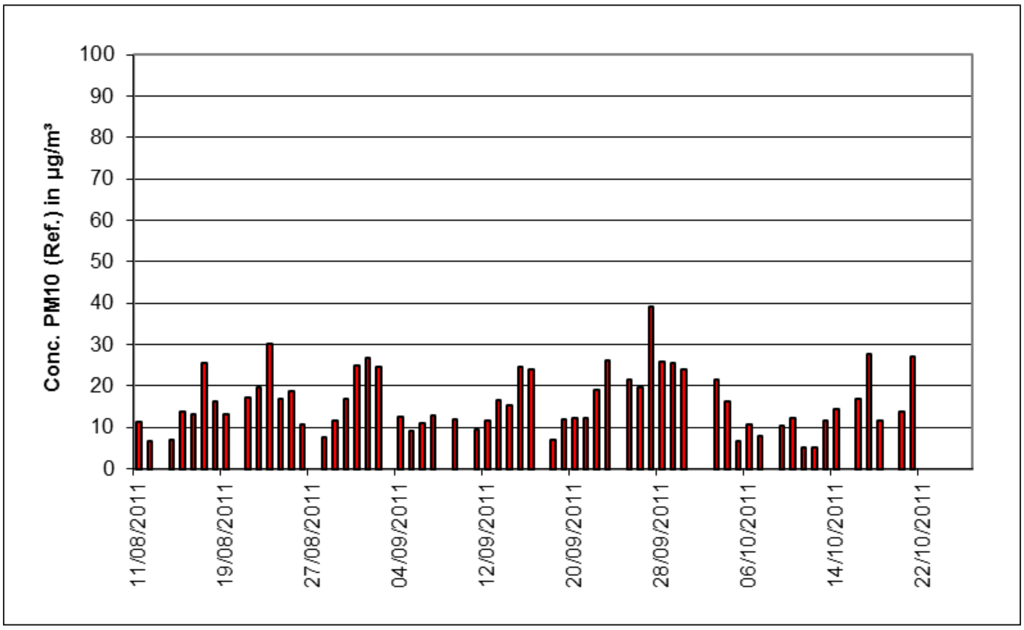


Figure 31: PM$_{10}$ (reference) levels at the site “Bornheim”

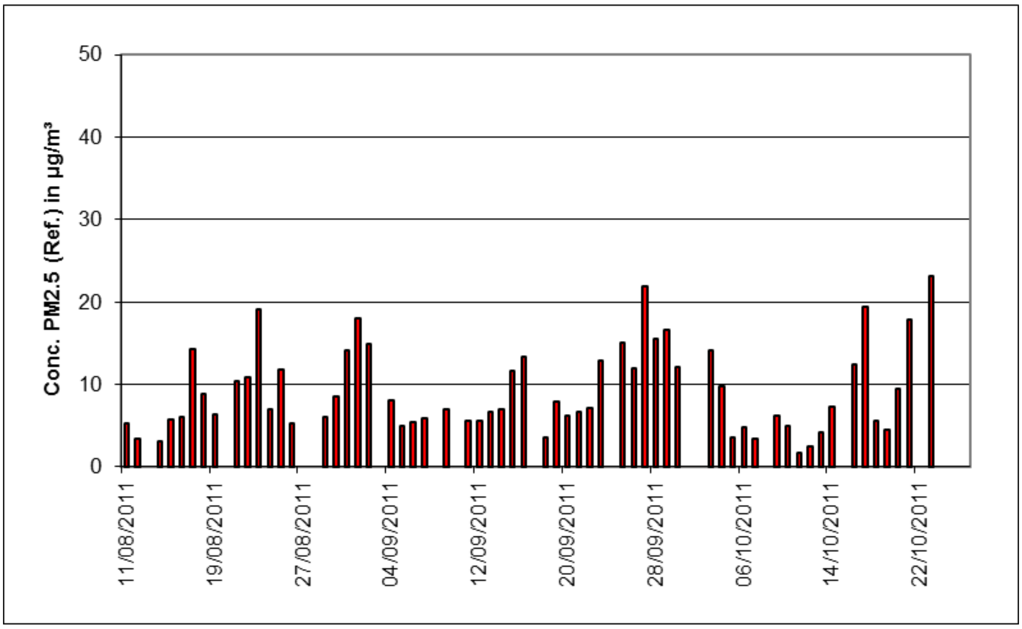


Figure 32: PM$_{2.5}$ (reference) levels at the site “Bornheim”

The following pictures show the measurement cabinet at the field test sites in cologne (parking lot) 2007 & 2011, Bonn (Belderberg), Teddington (UK), Brühl and Bornheim.

Figure 33: Field test site Cologne, parking lot, 2007

Figure 34: Field test site Bonn-Belderberg

Figure 35: Field test site Teddington

Figure 36: Field test site Brühl

Figure 37: Field test site Cologne, parking lot, 2011, reference measuring systems (LVS 3) installed in the middle trailer

Figure 38: Field test site in Bornheim, reference measuring system (LVS 3) installed in the middle trailer

In addition tothe air quality measuring systems for monitoring suspended particulate matter, a data logger for meteorological data was installed in the container. Data on air temperature, pressure, humidity, wind speed, wind direction and precipitation were continually measured. 30-minute mean values were recorded.

The following dimensions describe the design of the measurement rack and container as well as the position of the sampling probes.

- Height outdoor measurement rack: ~2.0 m above ground level
- Height sampling probe SWAM 5a DC, Line A, PM_{10}: ~3.2 m above ground level
- Height sampling probe SWAM 5a DC, Line B, $PM_{2.5}$: ~2.9 m above ground level
- Height sampling probe SWAM 5a, PM_{10} or $PM_{2.5}$: ~2.9 above ground level
- Height container roof: ~2.7 m
- Height of the sampling probe for ref: PM_{10}/ Ref. PM2,5/ TSP: ~ 1.2 / 1.2 / 1.0m above container roof i.e. ~ 3.9 / 3.9 / 3.7 m above ground level
- Height of the wind vane: ~4.5 m above ground level

In addition to an overview of the meteorological conditions determined during measurements at the 6 field test sites, the following Table 7 also provides information on the concentrations of suspended particulate matter. Given that the TÜV measurement station had to be replaced at the site in Brühl, no further meteorological data was collected after 3 November 2008. Meteorological data for the site in Teddington was only available after 17 September 2008. All individual values are presented in annexes 5 to 8.

Table 7: Ambient conditions at the field test sites indicated as daily averages

	Cologne, Parking lot, 2007	**Bonn, Belderberg**	**Teddington (UK)***	**Brühl****
Number of value pairs provided by reference PM_{10} (total)	102	65	80	51
Number of value pairs provided by reference $PM_{2.5}$ (total)	46	43	81	41
Ratio of $PM_{2.5}$ to PM_{10} [%]				
Range	54.6–91.0	53.1–90.8	22.3–83.2	41.4–90.2
Average	73.8	73.5	53.6	65.4
Air temperature [°C]				
Range	-3.4–12.4	0.6–13.6	4.2–15.4	4.4–16.2
Average	5.3	7.0	11.2	10.3
Air pressure [hPa]				
Range	982–1033	975–1034	984–1016	992–1024
Average	1012	1003	1000	1008
Rel. Humidity [%]				
Range	55.2–86.9	45.3–81.0	64–95	61.6–82
Average	72.5	64.8	81.4	74.5
Wind speed [m/s]				
Range	0.0–6.8	0.0–4.8	0.0–1.8	0–8.3
Average	2.1	1.3	0.5	2.2
Precipitation rate [mm]				
Range	0.0–31.0	0.0–20.4	Not available	0.0–16.5
Average	2.7	2.6		2.2

* Weather data only available after 17/09/2008
** Weather data not available after 03/11/2008

	Cologne, Parking lot, 2011	**Bornheim**
Number of value pairs provided by reference PM_{10} (total)	73	59
Number of value pairs provided by reference $PM_{2.5}$ (total)	71	60
Ratio of $PM_{2.5}$ to PM_{10} [%]		
Range	38.8–93.5	31.2–73.7
Average	65.7	53.7
Air temperature [°C]		
Range	-2.7–22.1	5.2–24.5
Average	10.3	15.6
Air pressure [hPa]		
Range	992–1031	997–1024
Average	1013	1008
Rel. Humidity [%]		
Range	34.2–94.2	53.8–91.1
Average	63.9	74.4
Wind speed [m/s]		
Range	0.3–5.3	0.3–3.9
Average	2.2	1.4
Precipitation rate [mm]		
Range	0.0–11.1	0.0–29.1
Average	1.0	2.3

Sampling duration

Standard EN 12341 fixes the sampling time at 24h. However, longer sampling times are permissible for low concentrations as are shorter times for higher concentrations.

Standard EN 14907 fixes the sampling time at 24h + 1h.

While the sampling time was always set to 24h in the field test, shorter times were set during some laboratory tests in order to collect a higher number of measured values.

Data handling

Prior to their assessment for each field test site, measured value pairs determined from reference values during the field test were submitted to a statistical Grubb's test for outliers (99%) in order to prevent distortions of the measured results from data, which evidently is implausible. Measured values pairs detected as significant outliers may be expunged from the pool of values as long as the test statistic remains above the the critical value. The January 2010 version of the guideline [5] requires that no more than 2.5% of the data pairs be detected and removed as outliers.

In principle, no measured value pairs are expunged for the tested AMS, unless there are justifiable technical reasons for implausible values. During the entire test, no measured values were expunged for the tested AMS.

Table 8 and Table 9 present an overview of the measured value pairs which have been detected and expunged as significant outliers (reference).

Table 8: Results of the Grubb's test for outliers – reference PM_{10}

Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
Cologne 2007	PM_{10} Reference	102	3	0	0	102
Bonn	PM_{10} Reference	65	2	0	0	65
Teddington	PM_{10} Reference	83	2	3	2	81
Bruehl	PM_{10} Reference	60	2	2	2	58
Cologne 2011	PM_{10} Reference	74	2	1	1	73
Bornheim	PM_{10} Reference	61	2	5	2	59

Table 9: Results of the Grubb's test for outliers – reference $PM_{2.5}$

Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
Cologne 2007	$PM_{2.5}$ Reference	47	1	1	1	46
Bonn	$PM_{2.5}$ Reference	43	1	0	0	43
Teddington	$PM_{2.5}$ Reference	83	2	2	2	81
Bruehl	$PM_{2.5}$ Reference	49	1	3	1	48
Cologne 2011	$PM_{2.5}$ Reference	73	2	2	2	71
Bornheim	$PM_{2.5}$ Reference	60	2	0	0	60

The following value pairs have been discarded:

Table 10: Value pairs (reference PM_{10}) discarded from the data set following Grubb's test

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Teddington	16.08.2008	13.9	21.0
Teddington	04.09.2008	10.4	5.3
Brühl	16.11.2008	19.7	16.3
Brühl	19.11.2008	32.1	27.3
Cologne, parking lot 2011	04.03.2011	83.3	87.6
Bornheim	19.10.2011	19.8	9.1
Bornheim	23.10.2011	32.6	27.6

Table 11: Value pairs (reference $PM_{2.5}$) discarded from the data set following Grubb's test

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Cologne, parking lot 2007	20.10.2007	16.1	23.0
Teddington	24.07.2008	32.5	27.8
Teddington	26.07.2008	16.1	13.8
Brühl	11.10.2008	28.5	24.5
Cologne, parking lot 2011	16.03.2011	55	57.8
Cologne, parking lot 2011	05.05.2011	11.2	14.8

Moreover, the following reference measurement values were not taken into consideration, because in each case only one measured value was available (no paired measurement).

Table 12: Measured values not taken into consideration (no paired measurement)

Fraction	Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
PM_{10}	Bonn	14.03.2008	14.3	-
PM_{10}	Bonn	21.03.2008	21.3	-
$PM_{2,5}$	Brühl	20.11.2008	11.3	-

Filter handling – Mass measurement

The following filters were used during performance testing:

Table 13: Filter material used

Measuring device	Filter material, type	Manufacturer
Reference devices Cologne 2007, Bonn, Brühl	Quartz fibre, ∅ 50 mm	Whatman
Reference devices Teddington, Cologne 2011, Bornheim	Emfab™, ∅ 47 mm	Pall

In the context of the “Combined MCERTS and TUV PM Equivalence Testing Programme” and at the request of the British project partners Emfab™ (teflon-coated glass fibre filter) was used as a filter material for the first time, since the British project partner considered this material the best suited for the measurement task at hand [10]. This filter material was also used during the measurement campaigns in 2011.

Filter handling was performed in compliance with EN 14907.

The methods used for processing and weighing filters and for weighing are described in detail in annex 2 to this report.

5. Reference Measurement Method

The following instruments were used in compliance with EN 12341 and EN 14907 in the context of the field test.

1. as PM_{10} reference system:

Sequential sampler SEQ47/50, Indoor version, (sites in Cologne 2007, Bonn, Brühl))
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2005
PM_{10} sampling head

and

Low Volume Sampler LVS3 (sites Teddington (UK), Cologne 2011 and Bornheim)
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
PM_{10} sampling head

2. as $PM_{2.5}$ reference system:

Low Volume Sampler LVS3
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
$PM_{2.5}$ sampling head

During the tests, two reference systems were operated in parallel with the flow controlled at 2.3 m³/h. Under normal conditions the accuracy of flow control is < 1% of the nominal flow rate.

At the sites in Cologne, parking lot 2007, Bonn and Brühl, two reference systems, SEQ47/50 filter changer, were used for the measured component PM_{10}. It was installed as an indoor version, i.e. the sequential sampler itself was installed inside the measurement cabinet, an sampling line ensured the connection with the sample inlet. The entire sampling system is cooled by an air jacket – this is why the actual sampling line is installed in an aluminium cladding tube.

Technically speaking, the sequential sampler is based on the low volume sampler LVS3 and, given its design, essentially complies with the requirements for reference samplers as specified in EN 12341. The filter replacement mechanism combined with the filter cartridge and unloader system facilitates continuous 24-hour sampling for a period of up to 14 days (+ field blank).

For the LVS3 and the SEQ47/50, the rotary vane vacuum pump takes in sample air via the sampling inlet. The volumetric flow is measured between the filter and the vacuum pump with the help of a measuring orifice. The air taken in flows from the pump via a separator for the abrasion of the rotary vane to the air outlet.

After sampling has been completed, the electronics display the sample air volume in standard and operating m³.

The PM_{10} and $PM_{2.5}$ concentrations were determined by dividing the quantity of suspended particulate matter on each filter determined in the laboratory with a gravimetric method by the corresponding throughput of sample air flow as operating m³.

6. Test results

6.1 1 Measuring ranges

The measuring ranges shall meet the following requirements:
0 µg/m³ to 1000 µg/m³ as a 24-hour average value
0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

It was tested, whether the measuring system's upper limit of measurement meets the requirements .

6.4 Evaluation

In theory, the upper limit of measurement for mass measurement using beta ray absorption is 10 mg/cm² (calibration of beta measurement using reference foils up to 9.773 mg/cm² (foil F16)).

Depending on the filter material used and the expected dust concentrations, the measuring system allows the use of filter cartridges with filter spot areas of varying sizes (2.54 m², 5.20 m², 7.07 m² and 11.95 m² for SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, 2.27 m² for SWAM 5a Dual Channel Hourly Mode Monitor.

For instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor this would correspond to theoretical masses of 25.4 mg to 119.5 mg. For 24h-sampling, this would in turn correspond to dust concentrations of 460 µg/m³ to > 2000 µg/m³.

A filter spot area of 5.20 cm² was used during performance testing.

For instrument version SWAM 5a Dual Channel Hourly Mode Monitor, a theoretical mass of 22.7 mg can be determined at a filter spot area of 2.27 cm². For 1h-sampling (at a throughput flow of ~2.25 m³ per 1-hour cycle), this would in turn correspond to dust concentrations of 10,100 µg/m³.

6.5 Assessment

Instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor facilitate monitoring of measuring ranges of more than 2,000 µg/m³ in the 24-h cycle. Instrument version SWAM 5a Dual Channel Hourly Mode Monitor facilitates monitoring of a measuring range of up to 10,000 µg/m³ in the 1-h cycle.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 2 Negative signals

Negative signals shall not be suppressed.

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

The possibility of displaying negative signals was tested both in the laboratory and in the field test.

6.4 Evaluation

The measuring system displays negative values for mass and concentration via its display as well as via analogue and digital outputs.

6.5 Assessment

Negative signals are directly displayed and correctly output by the measuring system.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 3 Zero level and detection limit

Zero level: ≤ 2.0 µg/m³
Detection limit: ≤ 2.0 µg/m³

6.2 Equipment

Zero filter for zero checks.

6.3 Testing

The zero level and detection limit of the AMS shall be determined by measurement of 15 24-hour average readings obtained by sampling from zero air (no rolling or overlapped averages are permitted). The mean of these 15 24-h averages is used as the zero level. The detection limit is calculated as 3,3 times the standard deviation of the 15 24h-averages.

The zero level and the detection limit were determined with zero filters installed at the AMS inlets of instruments with SN 127 and SN 131 during normal operation. Air free of suspended particulate matter was applied over a period of 18 days for a duration of 24h each.

6.4 Evaluation

The detection limit X is calculated from the standard deviation s_{x0} of the measured values sucking air free from suspended particulate matter through both candidate system. It is equal to the standard deviation of the average x_0 of the measured values x_{0i} multiplied by 3.3 for each candidate system.

$$X = 3.3 \cdot s_{x0} \qquad \text{where} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

6.5 Assessment

On the basis of testing both instruments, the zero level was determined at a maximum of 0.39 µg/m³ and the detection limit at a maximum of 0.71 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 14: Zero level and detection limit SN 127, lines A and B

		Device SN 127, Line A	Device SN 127, Line B
Number of values n		18	18
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.28	0.39
Standard deviation of the values s_{x0}	µg/m³	0.20	0.18
Detection limit x	µg/m³	**0.65**	**0.60**

Table 15: Zero level and detection limit SN 131, lines A and B

		Device SN 131, Line A	Device SN 131, Line B
Number of values n		18	18
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.22	0.24
Standard deviation of the values s_{x0}	µg/m³	0.20	0.21
Detection limit x	µg/m³	**0.65**	**0.71**

Annex 1 in the appendix 1 contains the individual measured values for the determination of the zero level and detection limit.

6.1 4 Flow rate accuracy (7.4.4)

The relative difference between the two values determined for the flow rate shall be ≤ 2.0%. The relative difference between the two values determined for the flow rate shall fulfil the following performance requirements:
≤ 2.0%

- *at 5°C and 40°C for installations in an air-conditioned environment by default*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

Climatic chamber for the temperature range of +5°C to +40°C; a reference flow meter in accordance with item 4 was provided.

6.3 Testing

The SWAM 5a measuring systems operate at a flow rate of 38.33 l/min under ambient conditions.

Using a reference flow meter, the flow rate was determined at +5°C and +40°C for both measuring systems, instrument versions SWAM 5a Dual Channel Monitor, was determined at both sampling lines by way of 10 measurements over a period of about 2 hours using the operational flow rate defined by the manufacturer. The measurements were performed at equal intervals throughout the measurement period.

6.4 Evaluation

Averages were calculated from the 10 measured values determined at each temperature and deviations from the operating flow rate determined.

6.5 Assessment

The relative difference determined for the mean of the measuring results at +5°C and at +40°C did not exceed 1.17%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 16 and Table 17 summarise the results of the flow rate measurements.

Table 16: Flow rate accuracy at +5°C and +40°C (SN 111)

		Device SN 111, Line A	Device SN 111, Line B
Nominal value flow rate	l/min	38.33	38.33
Mean value at 5°C	l/min	38.10	38.13
Dev. from nominal value	%	-0.60	-0.52
Mean value at 40°C	l/min	38.25	38.04
Dev. from nominal value	%	-0.22	-0.75

Table 17: Flow rate accuracy at +5°C and +40°C (SN 395)

		Device SN 395, Line A	Device SN 395, Line B
Nominal value flow rate	l/min	38.33	38.33
Mean value at 5°C	l/min	38.38	38.30
Dev. from nominal value	%	0.14	-0.09
Mean value at 40°C	l/min	38.60	38.78
Dev. from nominal value	%	0.69	1.17

Annex 2 in the appendix contains the individual measured values for the determination of the flow rate accuracy.

6.1 5 Constancy of sample flow rate (7.4.5)

The instantaneous flow rate and the flow rate averaged over the sampling period shall fulfil the performance requirements below.
≤ 2.0% sample flow (instantaneous flow)
≤ 5% rated flow (instantaneous flow)

6.2 Equipment

For this test, an additional reference flow meter in accordance with item 4 was provided.

6.3 Testing

The SWAM 5a measuring systems operate at a flow rate of 38.33 l/min under ambient conditions.

To determine the constancy of the sample flow rate, the flow rate was recorded and evaluated with the help of a mass flow meter over a period of 24h.

6.4 Evaluation

The average, standard deviation as well as the maximum and minimum values were determined from the measured values for the flow rate.

6.5 Assessment

The charts illustrating the constancy of the sample flow rate demonstrate that all measured values determined during sampling deviate from their respective rated values by less than ±5%. At 38.33 l/min, the deviation of the 24h-mean for the overall flow rate also remains well below the required maximum of ±2.0% from the rated value.

The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%.

Criterion satisfied? yes

6.6 Detailed presentation of test results for the rated flow

Table 18 and Table 19 present the characteristics determined for the flow rate. Figure 39 to Figure 42 provide a chart of the flow rate measurement for both instruments - SN 127 and SN 131.

Table 18: Characteristics of the total flow rate measurement (24h-mean), SN 217

		Device SN 127, Line A	Device SN 127, Line B
Mean value	l/min	38.05	37.83
Dev. from nominal value	%	-0.75	-1.31
Standard deviation	l/min	0.17	0.15
Minimum value	l/min	36.46	37.00
Maximum value	l/min	38.24	38.30

Table 19: Characteristics of the total flow rate measurement (24h-mean), SN 217131

		Device SN 131, Line A	Device SN 131, Line B
Mean value	l/min	38.13	38.97
Dev. from nominal value	%	-0.54	1.65
Standard deviation	l/min	0.10	0.14
Minimum value	l/min	37.33	37.37
Maximum value	l/min	38.24	39.15

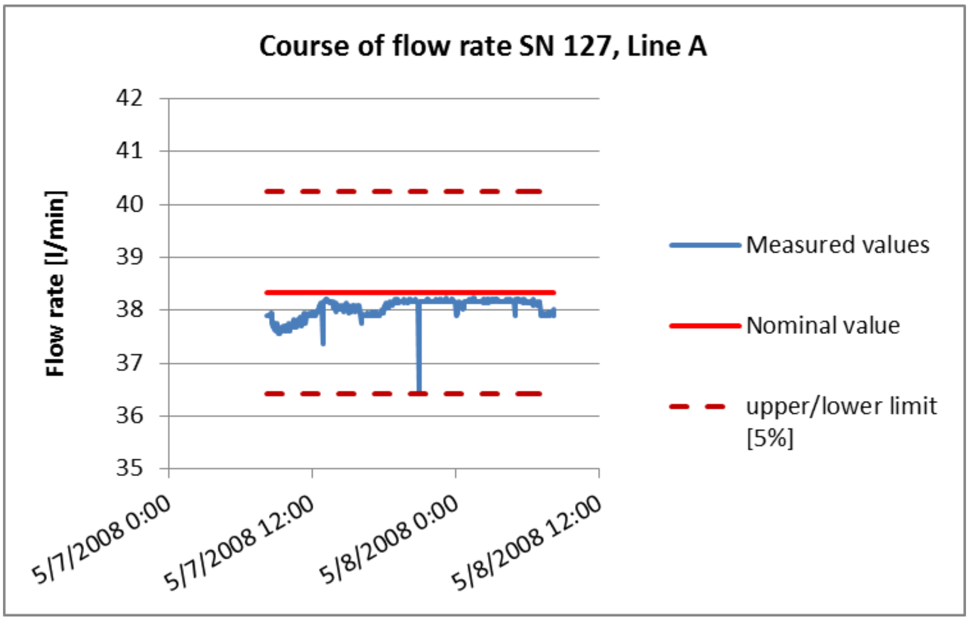


Figure 39: Flow rate for candidate system SN 127, line A

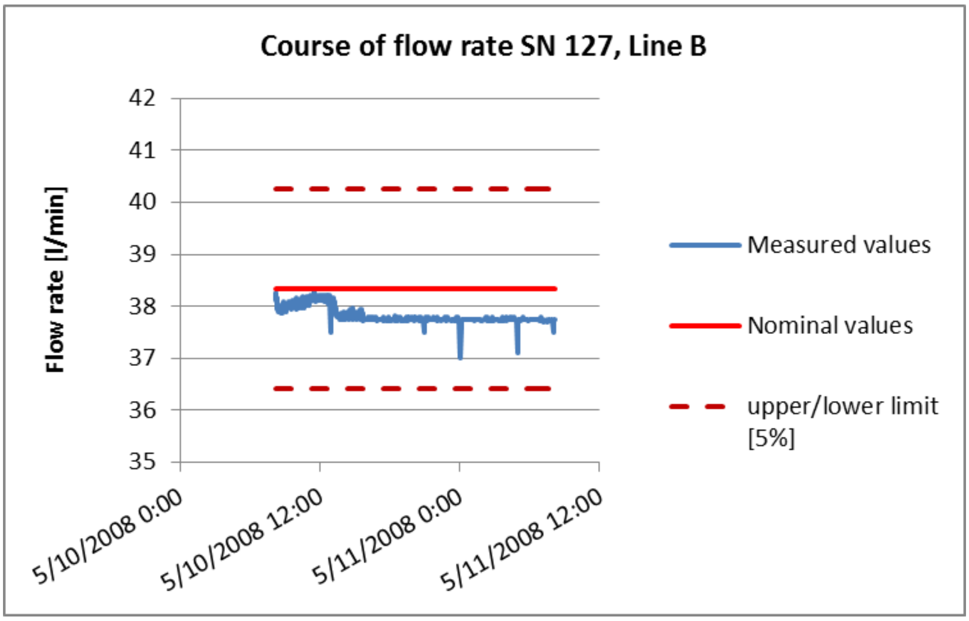


Figure 40: Flow rate for candidate system SN 127, line B

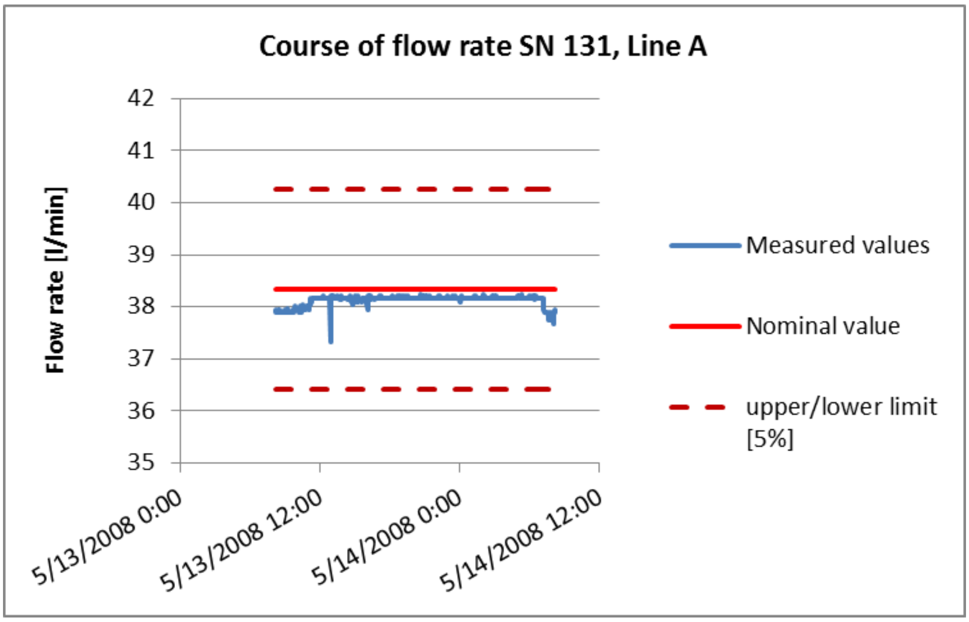


Figure 41: Flow rate for candidate system SN 131, line A

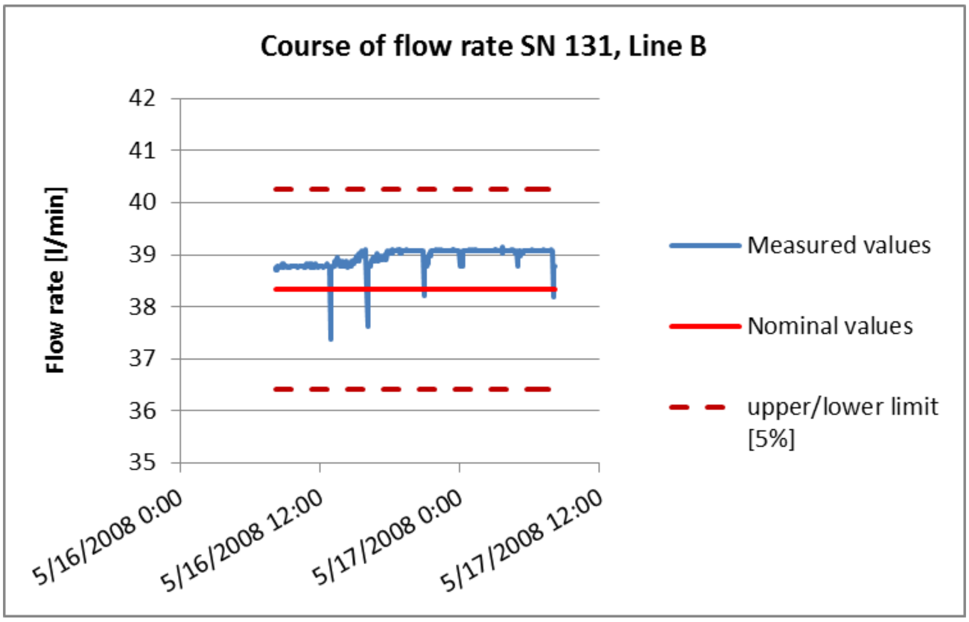


Figure 42: Flow rate for candidate system SN 131, line B

6.1 6 Leak tightness of the sampling system (7.4.6)

Leakage shall not exceed 2.0% of the sample flow rate or else meet the AMS manufacturer's specifications in complying with the required data quality objectives (DQO).

6.2 Equipment

Cover flap, clock

6.3 Testing

The test of leak tightness was performed following the instructions of the AMS manual (manual leak tightness test, case 3). During the test, a cover flap served to block the instrument inlet of the sampling line to be tested; a filter was then inserted in the sampling position. Subsequently the air was evacuated from the instrument using the pneumatic system until the minimum residual pressure was reached. After having switched of the pump, changes in the internal pressure in the system were observed. Pressure slowly increases. The speed of this increase depends on potential leaks. Taking into account the overall volume of the instrument, this procedure served to determine the leak rate.

The estimated total volume of the instrument is 1.85 l for line A and 1.75 l for line B.

6.4 Evaluation

The leak rate is $\dot{V}_L$ calculated according to the following equation:

$$\dot{V}_L = \frac{\Delta p}{p_0} \frac{V_{ges}}{\Delta t}$$

Where:

Δp is the pressure difference determined for the time interval Δt

p_0 is the pressure at t_0

V_{ges} is the estimated total volume of the system (lag volume);

Δt time interval needed for the pressure decrease by Δp

The maximum of five observed leak rates was determined.

6.5 Assessment

For instrument 1 (SN127), leakage did not exceed 0.24%. For instrument 2 (SN 131), leakage did not exceed 0.30% each at a residual pressure in the system p_0. At an air pressure of 102.8kPa, the leakage of instrument 1 (SN 127) did not exceed 0.08%, for instrument 2 (SN 131), it did not exceed 0.06%.

Thus, the values are clearly below the minimum requirement at 1%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 20 and Table 21 present the values determined for the leak tightness test.

Table 20: Determination of the leak rate, SN 127

SN 127, Line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	26.6	27.8	1.2	1	0.00185	0.083	0.218	0.056
2	12/8/2008	27.8	28.9	1.1	1	0.00185	0.073	0.191	0.052
3	12/8/2008	28.9	30	1.1	1	0.00185	0.070	0.184	0.052
4	12/8/2008	30	31	1	1	0.00185	0.062	0.161	0.047
5	12/8/2008	31	32.1	1.1	1	0.00185	0.066	0.171	0.052
1-5	12/8/2008	26.6	32.1	5.5	5	0.00185	0.077	0.200	0.052
SN 127, Line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	32.9	34.6	1.7	1	0.00175	0.090	0.236	0.076
2	12/8/2008	34.6	36.4	1.8	1	0.00175	0.091	0.238	0.080
3	12/8/2008	36.4	37.9	1.5	1	0.00175	0.072	0.188	0.067
4	12/8/2008	37.9	39.4	1.5	1	0.00175	0.069	0.181	0.067
5	12/8/2008	39.4	41	1.6	1	0.00175	0.071	0.185	0.071
1-5	12/8/2008	32.9	41	8.1	5	0.00175	0.086	0.225	0.072

Table 21: Determination of the leak rate, SN 131

SN 131, Line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	36.7	37.6	0.9	1	0.00185	0.045	0.118	0.042
2	12/8/2008	37.6	38.4	0.8	1	0.00185	0.039	0.103	0.038
3	12/8/2008	38.4	39.2	0.8	1	0.00185	0.039	0.101	0.038
4	12/8/2008	39.2	40.1	0.9	1	0.00185	0.042	0.111	0.042
5	12/8/2008	40.1	40.8	0.7	1	0.00185	0.032	0.084	0.033
1-5	12/8/2008	36.7	40.8	4.1	5	0.00185	0.041	0.108	0.039
SN 131, Line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	19.9	21.2	1.3	1	0.00175	0.114	0.298	0.058
2	12/8/2008	21.2	22.4	1.2	1	0.00175	0.099	0.258	0.053
3	12/8/2008	22.4	23.7	1.3	1	0.00175	0.102	0.265	0.058
4	12/8/2008	23.7	25	1.3	1	0.00175	0.096	0.250	0.058
5	12/8/2008	25	26.3	1.3	1	0.00175	0.091	0.237	0.058
1-5	12/8/2008	19.9	26.3	6.4	5	0.00175	0.113	0.294	0.057

6.1 7 Dependence of measured value on surrounding temperature (7.4.7)

The differences found shall comply with the performance criteria given below.
Zero point
≤ 2.0 µg/m3

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

Climatic chamber for the temperature range between +5 and +40 °C; zero filter for the zero point check

6.3 Testing

The dependence of the zero reading on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;

b) at a minimum temperature $T_{S,1}$ = +5 °C;

c) at a maximum temperature $T_{S,2}$ = +40 °C.

For the purpose of determining the dependence of the zero reading on the surrounding temperature, the measuring systems were operated in the climatic chamber without the outdoor measurement rack.

Sample air, free of suspended particles, was supplied to the two candidate systems after fitting two zero filters at the AMS inlet in order to perform zero point checks.

The tests were performed in the temperature sequence $T_{S,n}$ — $T_{S,1}$ — $T_{S,n}$ — $T_{S,2}$ — $T_{S,n}$.

Readings were recorded at zero point after an equilibration period of 24h for every temperature step (3 readings each).

6.4 Evaluation

Readings for mass values were obtained from 8-hour individual measurements and the related to the rated flow for 24h sampling for the purpose of conversion.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

6.5 Assessment

The tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of 0.64 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 22: Dependence of measured value on surrounding temperature, deviations in µg/m³, average from three readings, SN 127, lines A&B

Temperature	SN 127, Line A		SN 127, Line B	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	µg/m³	µg/m³	µg/m³	µg/m³
20	0.03	-0.12	0.23	-0.02
5	0.47	0.31	0.27	0.01
20	0.13	-0.02	0.27	0.01
40	0.60	0.44	0.63	0.38
20	0.30	0.14	0.27	0.01
Mean value at 20°C	0.16	-	0.26	-

Table 23: Dependence of measured value on surrounding temperature, deviations in µg/m³, average from three readings, SN 131, lines A&B

Temperature	SN 131, Line A		SN 131, Line B	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	µg/m³	µg/m³	µg/m³	µg/m³
20	0.17	-0.06	0.17	-0.02
5	0.23	0.01	0.13	-0.06
20	0.10	-0.12	0.13	-0.06
40	0.70	0.48	0.83	0.64
20	0.40	0.18	0.27	0.08
Mean value at 20°C	0.22	-	0.19	-

Annex 3 in the appendix contains the individual measuring results.

6.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7)

The differences found shall comply with the performance criteria given below.
Sensitivity of the measuring system (span):
≤ 5% from the value at the nominal test temperature

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

Climatic chamber for the temperature range between +5 and +40 °C; reference foils R1 & R2 for span checks

6.3 Testing

The dependence of AMS sensitivity (span) on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;

b) at a minimum temperature $T_{S,1}$ = +5 °C;

c) at a maximum temperature $T_{S,2}$ = +40 °C.

For the purpose of testing the dependence of the AMS sensitivity on the surrounding temperature, the complete measuring system without the outdoor rack was operated in the climatic chamber.

In order to allow for testing this sensitivity, the internal procedure for stability testing provided by the radiometric measuring system by means of the two reference aluminium foils implemented in the system with a known mass density was used (BETA SPAN TEST).

The tests were performed in the temperature sequence $T_{S,n}$ — $T_{S,1}$ — $T_{S,n}$ — $T_{S,2}$ — $T_{S,n}$.

Readings were recorded at zero point after an equilibration period of 24h for every temperature step (3 readings each).

6.4 Evaluation

Values for the mass density were determined from individual readings with reference aluminium foils and then evaluated.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

6.5 Assessment

The tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed 0.1%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 24: Dependence of the sensitivity (reference foil) on the surrounding temperature; deviation in %, average from three measurements, SN 127

Temperature	SN 127 R1		SN 127 R2	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[mg/cm²]	%	[mg/cm²]	%
20	3.454	0.1	6.833	0.1
5	3.451	0.0	6.831	0.0
20	3.452	0.0	6.830	0.0
40	3.448	-0.1	6.826	0.0
20	3.448	-0.1	6.825	-0.1
Mean value at 20°C	3.451	-	6.829	-

Table 25: Dependence of the sensitivity (reference foil) on the surrounding temperature; deviation in %, average from three measurements, SN 131

Temperature	SN 131 R1		SN 131 R2	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[mg/cm²]	%	[mg/cm²]	%
20	3.399	-0.1	6.869	0.0
5	3.402	0.0	6.873	0.0
20	3.402	0.0	6.874	0.0
40	3.403	0.1	6.874	0.0
20	3.402	0.0	6.869	0.0
Mean value at 20°C	3.401	-	6.871	-

Annex 3 in the appendix contains the results from 3 individual measurements.

6.1 9 Dependence of span on supply voltage (7.4.8)

The differences found shall comply with the performance criteria given below.
Sensitivity of the measuring system (span):
≤ 5% from the value at the nominal test voltage

6.2 Equipment

Isolating transformer, reference foils R1 & R2 for span point checks

6.3 Testing

In order to test the dependence of span on supply voltage, supply voltage was reduced to 195 V starting from 230 V, it was then increased to 253 V via an intermediary step of 230 V.

In order to allow for testing this sensitivity, the internal procedure for stability testing provided by the radiometric measuring system by means of the two reference aluminium foils implemented in the system with a known mass density was used (BETA SPAN TEST).

6.4 Evaluation

At span point, the percentage change of the measured value determined for every step related to the starting point at 230 V was considered.

6.5 Assessment

Voltage variations did not result in deviations > -0.4% compared to the initial value of 230 V.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 27 and Table 26 summarise the test results.

Table 26: Dependence of the measured value on supply voltage, deviation in %, SN 111

Supply voltage	SN 111, R1		SN 111, R2	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[mg/cm²]	%	[mg/cm²]	%
230	3.456	-	6.801	-
195	3.444	-0.4	6.789	-0.2
230	3.442	-0.4	6.786	-0.2
253	3.445	-0.3	6.788	-0.2
230	3.445	-0.3	6.787	-0.2

Table 27: Dependence of the measured value on supply voltage, deviation in %, SN 395

Supply voltage	SN 395, R1		SN 395, R2	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[mg/cm²]	%	[mg/cm²]	%
230	3.294	-	6.606	-
195	3.304	0.3	6.602	-0.1
230	3.293	0.0	6.601	-0.1
253	3.294	0.0	6.601	-0.1
230	3.292	-0.1	6.601	-0.1

Annex 4 in the appendix contains the individual results.

6.1 10 Effect of failure of mains voltage

Instrument parameters shall be secured against loss.
On return of main voltage the instrument shall automatically resume functioning.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

A simulated failure in the mains voltage served to test whether the instrument remained fully functional and reached operation mode on return of the mains voltage.

6.4 Evaluation

Buffering protects all instrument parameters against loss.

In the event of a failure in mains voltage, the measuring system is equipped with two rechargeable backup batteries. This enables the measuring system to continue any ongoing beta measurements and consequently allows seamless resuming of measurement operation under the previously programmed cycle conditions on return of the mains voltage.

In the event of a failure in mains voltage:

- ongoing sampling will stop (pump switches off),
- the battery status is checked (charge status, remaining operation time),
- the instrument will end any on-going beta measurements (battery capacity permitting),
- the ideal mechanical configuration of the AMS will be set in order to correctly return to the next sampling cycle on return of the mains voltage,
- the instrument will perform an automatic switch-off procedure after having set the ideal mechanical configuration until the return of the mains voltage.

Outage times due to failure in mains voltage are documented for the measurements in question.

6.5 Assessment

Buffering protects all instrument parameters against loss.
On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 11 Dependence of reading on water vapour concentration (7.4.9)

The largest difference in readings between 40% and 90% relative humidity shall fulfil the performance criterion stated below: ≤ 2.0 µg/m³ in zero air when cycling relative humidity from 40% to 90% and back.

6.2 Equipment

Climatic chamber c/w humidity control for the range between 40% and 90% relative humidity, zero filter for zero checks

6.3 Testing

The dependence of reading on water vapour concentration in the sample air was determined by feeding humidified zero air in the range between 40% and 90% relative humidity. To this effect, the measuring system, instrument version SWAM 5a Dual Channel Monitor, c/w measurement rack was operated in the climatic chamber and the relative humidity of the entire surrounding atmosphere was controlled. Sample air, free of suspended particles was supplied to the instruments SN 111 and SN 395 after fitting two zero filters at either AMS inlet in order to perform zero point checks.

The measuring systems were operated with a cycle time of 8 hours and readings for mass values were obtained from 8-hour individual measurements and the related to the rated flow for 24h sampling for the purpose of conversion. Once the humidity level had stabilised, the concentration mass values of the AMS averaged over 24h were determined at 40% relative humidity and recorded accordingly. In order to correctly synchronise the cycle time of the measuring system with the adjustment of the relative humidity, the latter was increased to 90% over a period of 24h. The time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 24h at 90% relative humidity was recorded. Subsequently, relative humidity was decreased to 40% over another 24h period. Again, the time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 24h at 40% relative humidity was recorded.

6.4 Evaluation

The measured value for the zero zero level of 8-hour individual measurements at stable humidity levels were obtained, averaged over 24 hours and then assessed. The characteristic concerned is the largest difference in µg/m³ between values in the range of 40% to 90% relative humidity.

6.5 Assessment

The maximum difference between measured values determined at 40% and at 90% humidity did not exceed 1.9 µg/m³.

Criterion satisfied? yes

Table 28: Dependence of reading on water vapour concentration, difference in µg/m³, SN 111

rel. Humidity	SN 111, Line A		SN 111, Line B	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.0	-	0.1	-
90	1.9	1.9	1.7	1.6
40	0.7	-1.2	0.6	-1.1
Maximum deviation	1.9		1.6	

Table 29: Dependence of reading on water vapour concentration, difference in µg/m³, SN 395

rel. Humidity	SN 395, Line A		SN 395, Line B	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.4	-	0.5	-
90	2.0	1.5	1.7	1.2
40	1.3	-0.6	1.1	-0.6
Maximum deviation	1.5		1.2	

6.6 Detailed presentation of test results

Table 30: Dependence of reading on water vapour concentration, difference in µg/m³, SN 111, individual readings

rel. Luftfeuchte	SN 395, Line A				SN 395, Line B			
	Messwert 1	Messwert 2	Messwert 3	Mittelwert	Messwert 1	Messwert 2	Messwert 3	Mittelwert
%	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
40	1.3	0.3	-0.4	0.4	1.3	0.1	0.0	0.5
40 → 90*	0.8	1.1	2.4	1.4	0.5	0.7	1.2	0.8
90	2.4	1.9	1.6	2.0	1.9	1.8	1.5	1.7
90 → 40*	2.3	1.8	0.7	1.6	1.4	1.2	0.6	1.1
40	0.5	1.3	2.2	1.3	0.4	1.2	1.7	1.1

* nur informativ

Table 31: Dependence of reading on water vapour concentration, difference in µg/m³, SN 395, individual readings

rel. Humidity	SN 395, Line A				SN 395, Line B			
	Measured value 1	Measured value 2	Measured value 3	Mean value	Measured value 1	Measured value 2	Measured value 3	Mean value
%	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
40	1.3	0.3	-0.4	0.4	1.3	0.1	0.0	0.5
40 → 90*	0.8	1.1	2.4	1.4	0.5	0.7	1.2	0.8
90	2.4	1.9	1.6	2.0	1.9	1.8	1.5	1.7
90 → 40*	2.3	1.8	0.7	1.6	1.4	1.2	0.6	1.1
40	0.5	1.3	2.2	1.3	0.4	1.2	1.7	1.1

* only informative

6.1 12 Zero checks (7.5.3)

During the tests, the absolute measured value of the AMS shall not exceed the following criterion:
Absolute value ≤ 3.0 µg/m³

6.2 Equipment

Zero filter for zero checks.

6.3 Testing

This test was performed as part of the field test in the context of initial testing over a total period of about a year at the German sites.

As part of regular checks, the measuring systems were operated with zero filters fitted to the AMS inlets over a period of at least 24h about once a month (Cologne and Bonn) as well as twice near the end of the field test (Brühl) and zero readings were evaluated. The same test were performed at the site in Teddington (UK) using instruments SN 145 and SN 149.

6.4 Evaluation

During the tests, the absolute measured value of the AMS at zero point defined at 3.0 µg/m³ was not exceeded.

6.5 Assessment

The maximum measured value determined at zero point was 2.4 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 32 to Table 35 list the measured value obtained for the zero point in µg/m³.

Figure 43 to Figure 50 illustrate the zero drift observed during the test period.

Table 32: Zero checks using zero filters for SN 127, Cologne 2007, Bonn and Brühl

Date	SN 127, Line A		Date	SN 127, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
10/30/2007	0.1	ok	10/30/2007	0.3	ok
12/6/2007	0.7	ok	12/6/2007	0.6	ok
1/8/2008	1.1	ok	1/8/2008	0.0	ok
2/13/2008	0.4	ok	2/13/2008	0.6	ok
3/12/2008	0.3	ok	3/12/2008	0.5	ok
4/10/2008	1.2	ok	4/10/2008	0.7	ok
11/11/2008	1.2	ok	11/11/2008	1.2	ok
12/9/2008	1.1	ok	12/9/2008	0.8	ok

Table 33: Zero checks using zero filters for SN 131, Cologne 2007, Bonn and Brühl

Date	SN 131, Line A		Date	SN 131, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
10/30/2007	0.5	ok	10/30/2007	0.6	ok
12/6/2007	0.4	ok	12/6/2007	0.7	ok
1/8/2008	0.0	ok	1/8/2008	0.4	ok
2/13/2008	0.0	ok	2/13/2008	0.4	ok
3/12/2008	0.0	ok	3/12/2008	0.0	ok
4/10/2008	0.7	ok	4/10/2008	0.5	ok
11/11/2008	1.3	ok	11/11/2008	2.4	ok
12/9/2008	0.3	ok	12/9/2008	0.4	ok

Table 34: Zero checks using zero filters for SN 145, Teddington

Date	SN 145, Line A		Date	SN 145, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
7/24/2008	0.5	ok	7/24/2008	0.7	ok
8/18/2008	0.4	ok	8/18/2008	0.3	ok
9/23/2008	0.0	ok	9/23/2008	0.1	ok

Table 35: Zero checks using zero filters for SN 149, Teddington

Date	SN 149, Line A		Date	SN 149, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
7/24/2008	0.8	ok	7/24/2008	0.6	ok
8/18/2008	0.7	ok	8/18/2008	0.5	ok
9/23/2008	0.5	ok	9/23/2008	0.1	ok

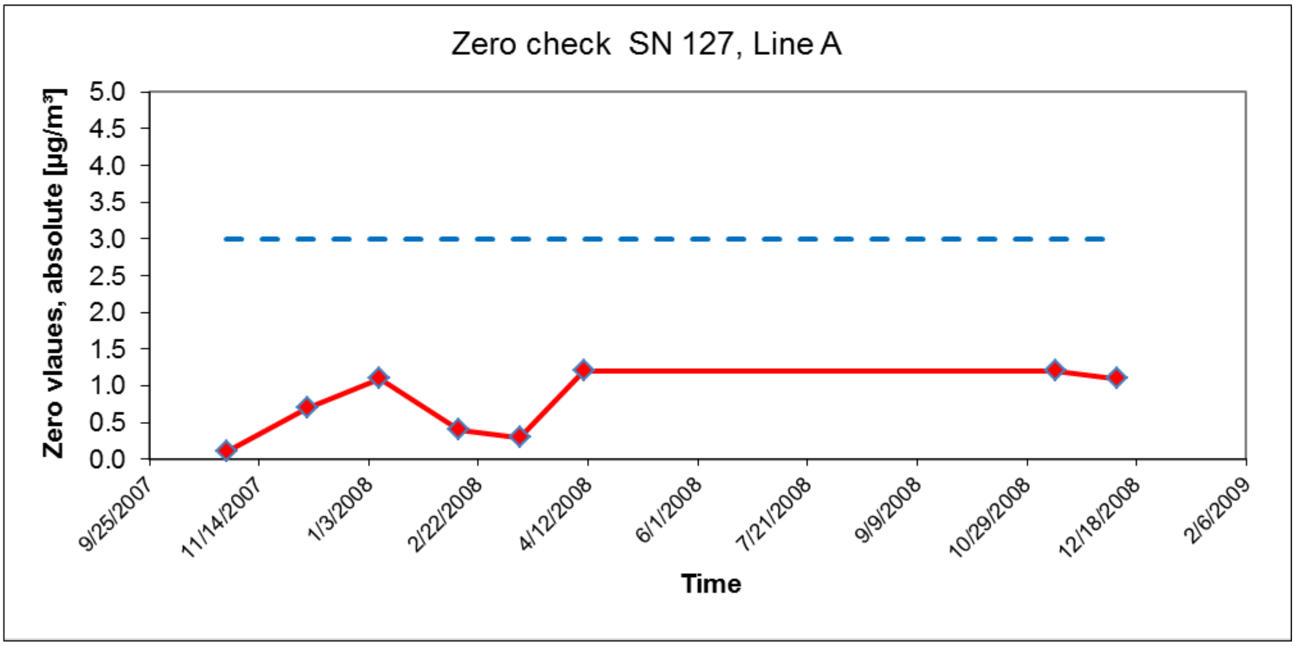


Figure 43: Zero drift SN 127, line A

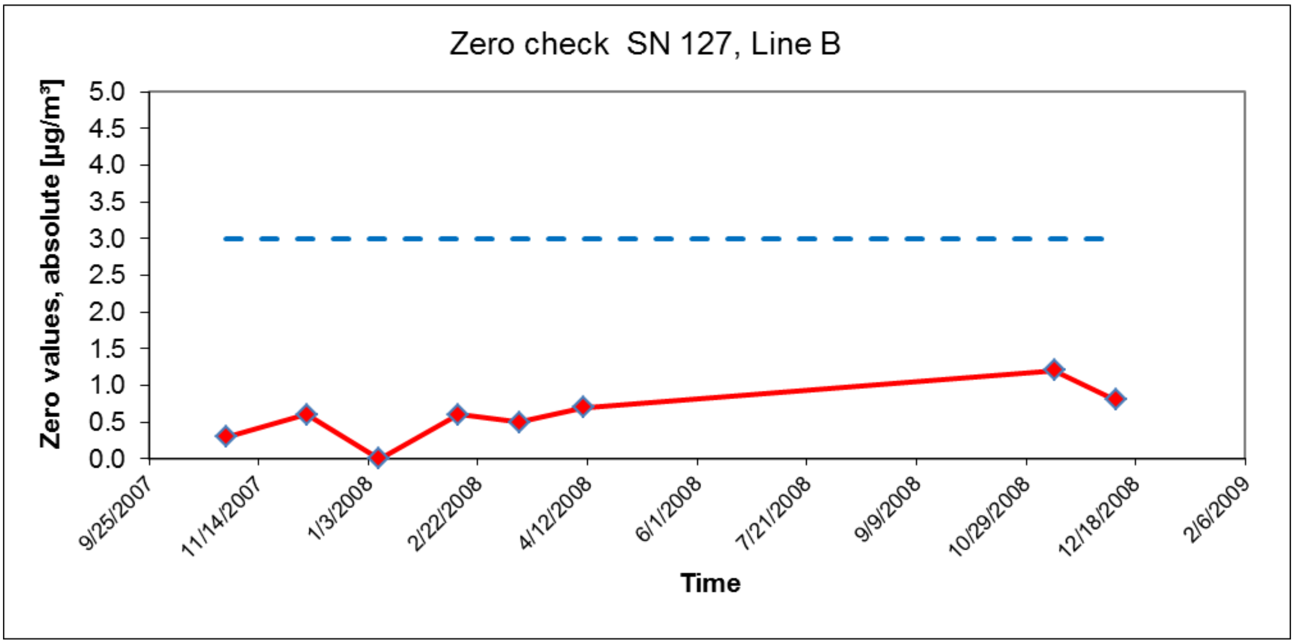


Figure 44: Zero drift SN 127, line B

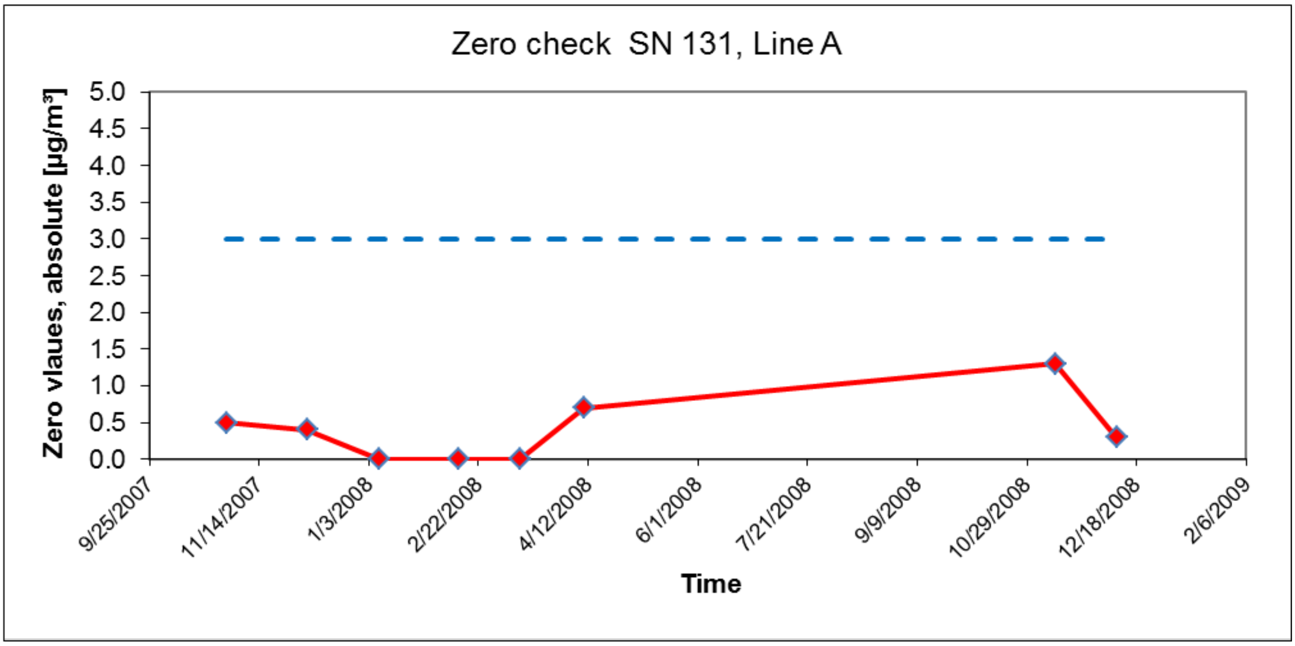


Figure 45: Zero drift SN 131, line A

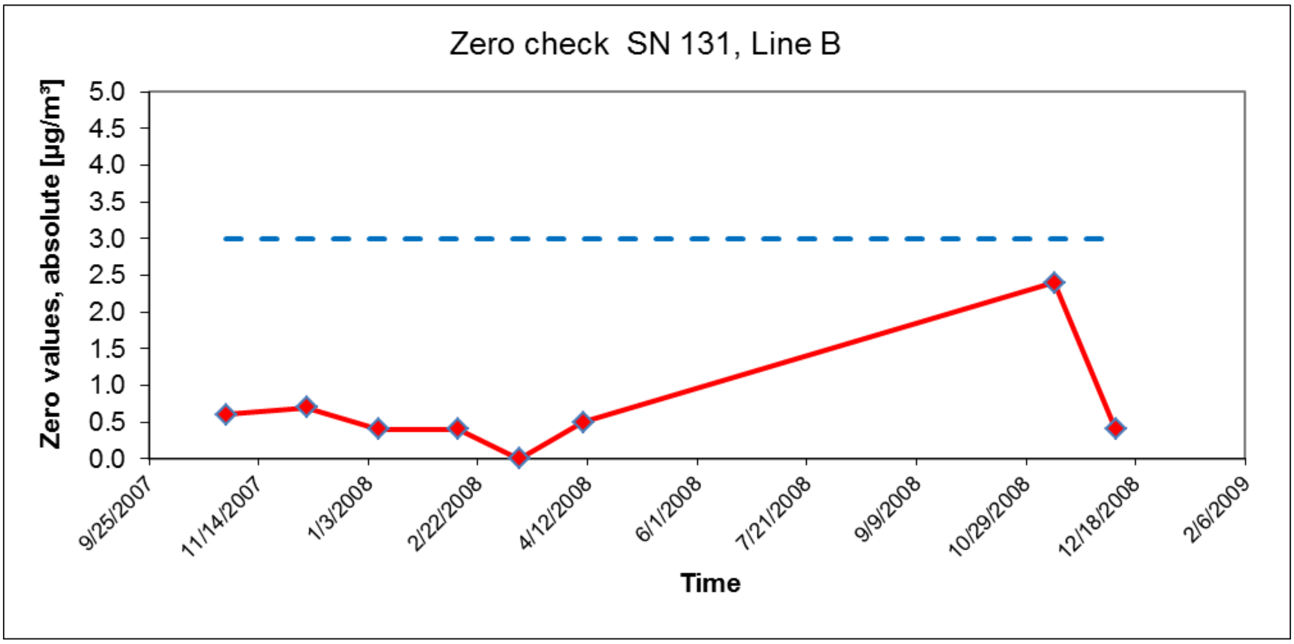


Figure 46: Zero drift SN 131, line B

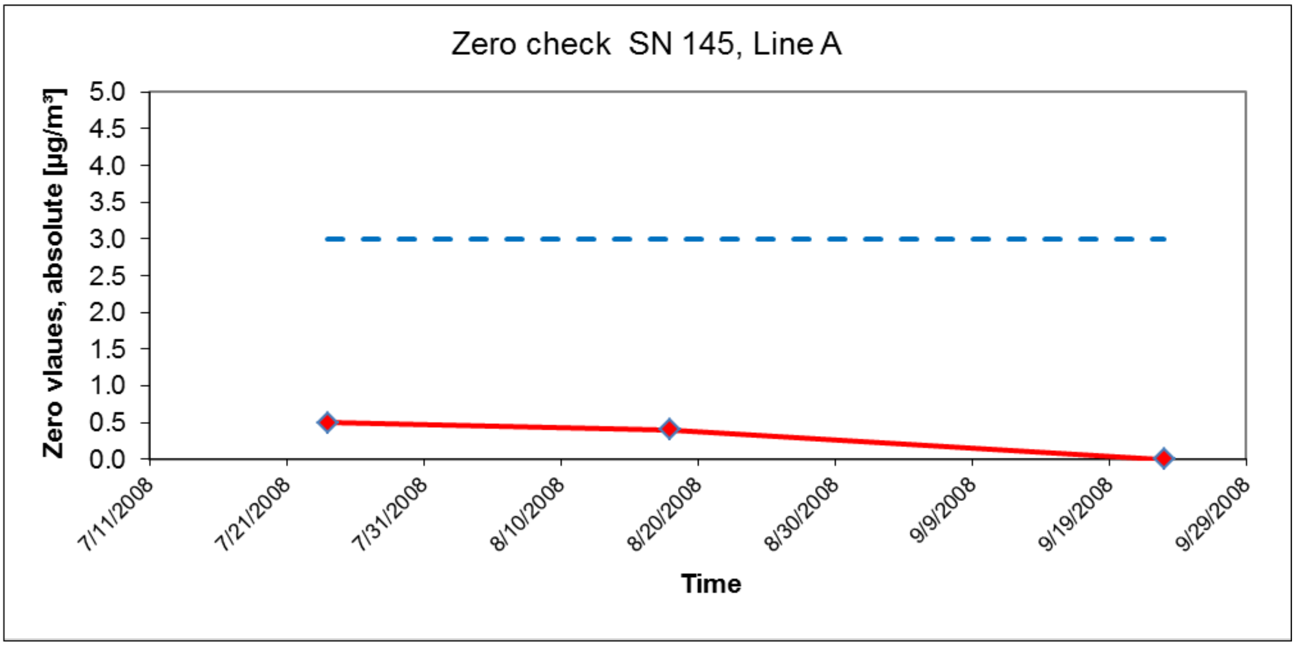


Figure 47: Zero drift SN 145, line A

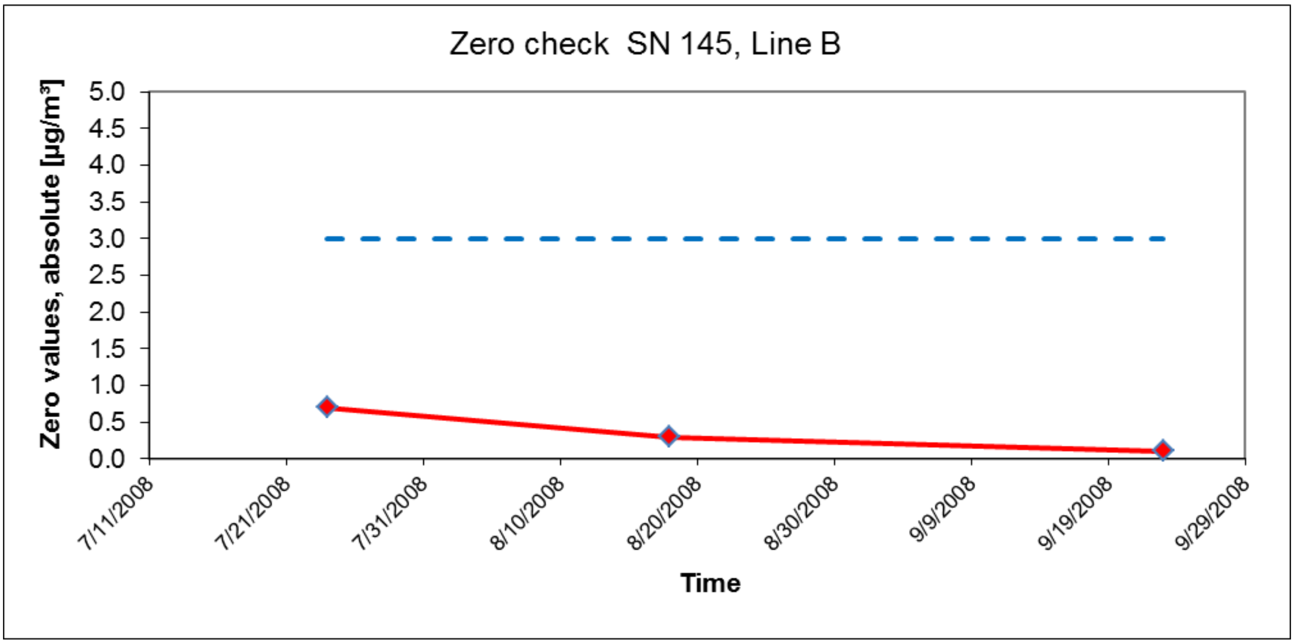


Figure 48: Zero drift SN 145, line B

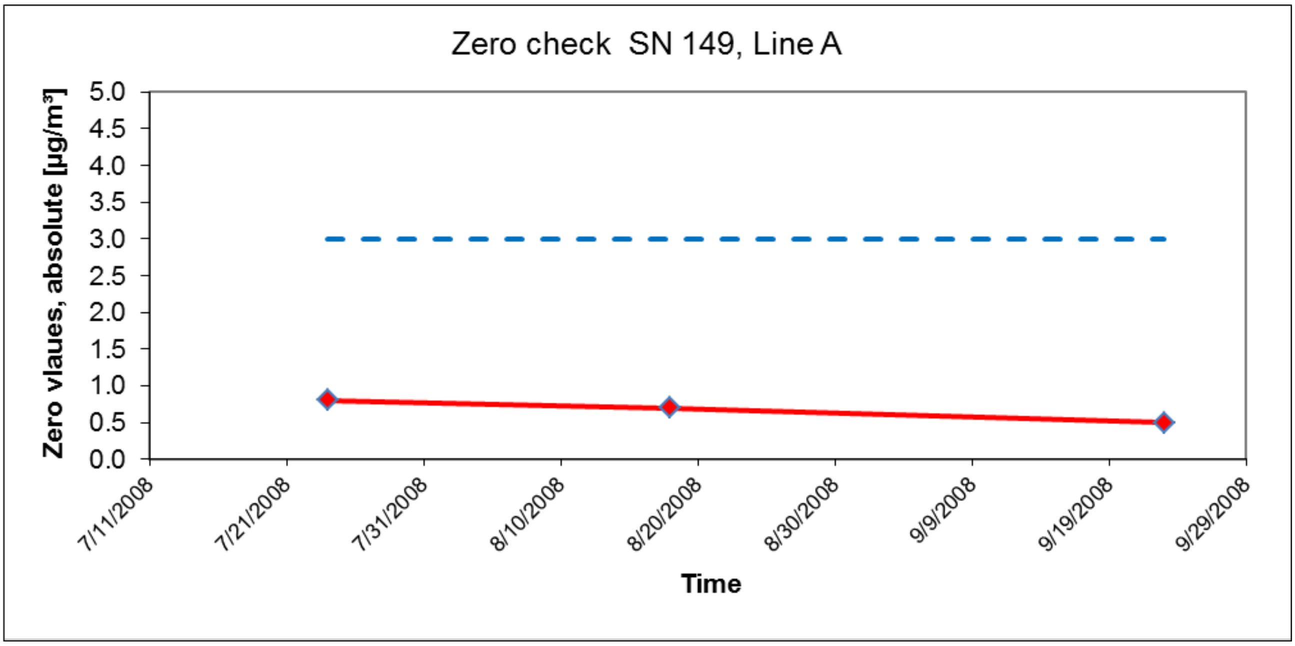


Figure 49: Zero drift SN 149, line A

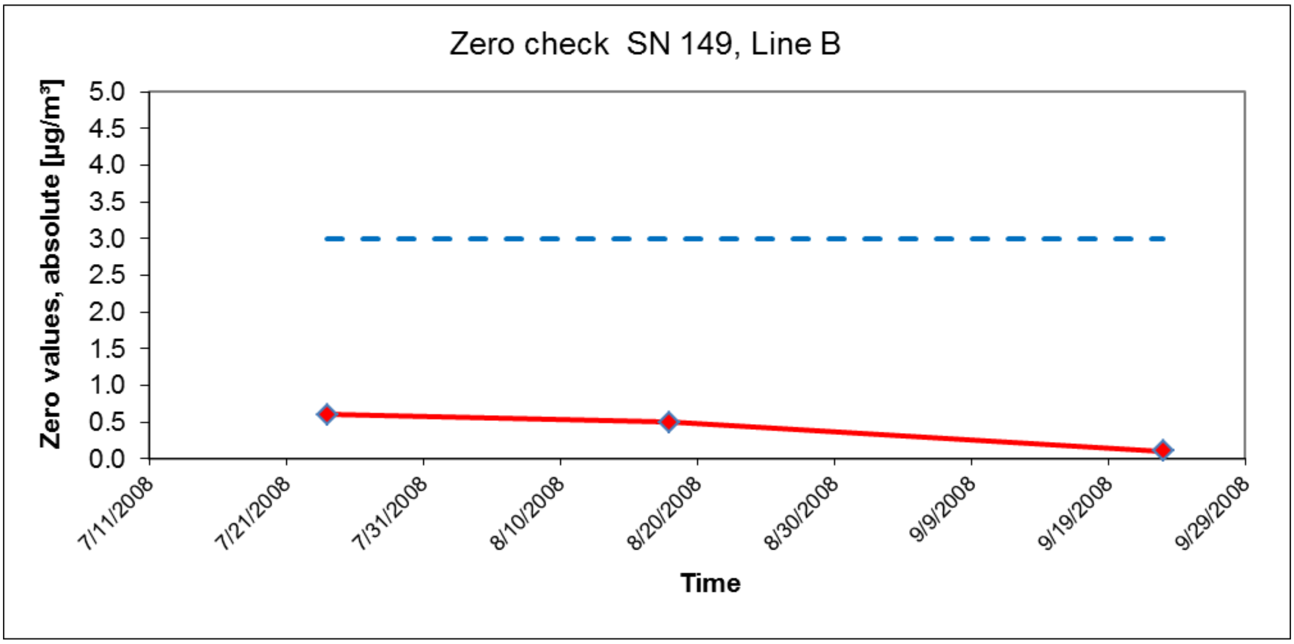


Figure 50: Zero drift SN 149, line B

6.1 13 Recording of operational parameters (7.5.4)

Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters:

- *Flow rate;*
- *Pressure drop over sample filter (if relevant);*
- *Sampling time;*
- *Sampling volume (if relevant);*
- *Mass concentration of relevant PM fraction(s);*
- *Ambient temperature,*
- *Ambient pressure,*
- *Air temperature in measuring section,*
- *Temperature of the sampling inlet if a heated inlet is used;*

Results of automated/functional checks, where available, shall be recorded.

6.2 Equipment

Modem, PC c/w software “DR FAI Manager” or Hyperterminal

6.3 Testing

A modem was connected to the measuring system. Among other, status signals provided by the AMS were recorded relying on remote data transmission.

Access options provided by the DR FAI Manager operating system and the Hyperterminal were checked.

The measuring system allows for comprehensive monitoring and control functions. A number of reading, writing and control commands are available; a complete overview of which is provided in the AMS operating manual.

It is possible to communicate the operating statuses and relevant parameters including:

- Flow rate
- Pressure drop via the sampling filter
- Sampling time
- Sample flow
- Mass concentrations of the relevant PM fraction
- Ambient temperature, pressure, humidity
- Temperature at the point of sampling (filter)...

Furthermore, the system saves the results of internal checks for the purpose of quality assurance / functional checks.

The DR FAI Manager operating software conveniently provides options to monitor the operating status and provides data saved as text files (also see Figure 13 to Figure 19 in section 3.3 AMS scope and set-up).

Remote monitoring and control is easily possible via routers or modems.

As part of the performance test, a PC was connected directly connected to the AMS via RS232 to test the transfer of data and the instrument status.

6.4 Evaluation

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.

6.5 Assessment

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 14 Daily averages (7.5.5)

The AMS shall allow for the formation of daily averages or values.

6.2 Equipment

For this test, a clock was additionally provided.

6.3 Testing

We verified whether the measuring system allows for the formation of daily averages.

6.4 Evaluation

For SWAM 5a Dual Channel Monitor / SWAM 5a Monitor

The measuring system allows for the formation of averages for sampling periods between 8h and 168h. A total of 11–12 min are required for tasks such as filter replacement/filter movements in the instrument and QA measures performed for every cycle (internal leak tests, and internal flow rate checks. This corresponds to about 0.8% of the averaging time (24h).

For SWAM 5a Dual Channel Hourly Monitor

This measuring system operates at a cycle time of 1h. About 1–2 min are required for filter replacement/filter movements in the instrument (for every cycle). Moreover, two of the 24 daily cycles include further QA measures (sensor tests) – this requires apx. 3 min per cycle; this corresponds to about 5% of the averaging time. For this instrument version, the internal leak test and the internal flow rate check are performed at each programme start and can be initiated by sending a command to this effect e.g. via RS232. The time needed for such measures amounts to about 10 minutes. Thus, in this case the real sampling time in a given cycle also adds up to more than 75% of the cycle time.

Thus, the formation of daily averages is ensured.

For every measurement, the measuring system saves the ratio of actual sampling time and cycle time as a percentage.

6.5 Assessment

It is possible to form valid daily averages.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 15 Availability (7.5.6)

The availability of the measuring system shall be at least 90%.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

The start and end times at each of the four field test sites from the initial test [11] marked the start and end time for the availability test. Proper operation of the measuring system was verified during every on-site visit (usually every working day). This daily check consisted of plausibility checks on the measured values, status signals and other relevant parameters (see 7.5.4). Time, duration and nature of any error in functioning are recorded.

The total time during the field test in which valid measurement data of ambient air concentrations were obtained was used for calculating availability. Time needed for scheduled calibrations and maintenance (cleaning; change of consumables) shall not be included.

Availability is calculated as

$$A = \frac{t_{valid} + t_{cal,maint}}{t_{field}}$$

Where:

t_{valid} is the time during which valid data have been collected;

$t_{cal,maint}$ dis the time spent for scheduled calibrations and maintenance;

t_{field} is the total duration of the field test.

As part of the initial test, a total of two identical systems were operated as follows:

- SN 127 & SN 131 at the field test sits in Cologne, Bonn and Brühl
- SN 145 & SN 145 at the field test site in Teddington

The overall availability was determined separately for the various sets of tested instruments.

6.4 Evaluation

a) SN 127 & SN 131 at the field test sits in Cologne, Bonn and Brühl

Table 36 lists all operating, maintenance and down times at the field test sites in Cologne (2007), Bonn and Brühl. During the field test, the measuring systems were operated for a total of 245 measuring days. Outages caused by external events not attributable to the measuring system were recorded on 28/10/2007 and 29/10/2007 (changing from daylight saving to regular time), on 06/01/2008 and 07/01/2008 (filter stocks exhausted), on 26/03/2008 and 27/03/2008 (change to daylight saving time), on 03/11/2008 and 04/11/2008 (filter stocks exhausted) and from 06/11/2008 to 10/11/2008 (5d for replacing the TÜV measurement station). This reduces the total time of operation to 232 measuring days.

Regular checks of the zero point as part of the drift test resulted in a total of 7 days of down time.

Maintenance tasks during the tests were primarily caused by cleaning the sampling heads (13 times) and checking flow rates as well as leak tightness (16 times during testing). Daily averages did not have to be discarded as a result of such maintenance. These tasks cause down times of less than 1h per check (16 times during testing) and did not require daily averages to be discarded.

As a result of water ingress, measured values obtained by instrument SN 127 had to be discarded on 22/10/2007 and 23/10/2007.

A cable break of the swivel arm for beta measurements resulted in down times of instrument SN 131 from 19/10/2008 to 23/10/2008. In order to prevent such down times, the cable in question will be replaced by a more stable version which will be positioned and fastened at a more suitable location inside the instrument.

No further errors in functioning were observed:

b) SN 145 & SN 149 at the field test site in Teddington

Table 37 lists the operating, maintenance and down times recorded at the field test sites in Teddington. During the field test, the measuring systems were operated for a total of 91 measuring days. Outages caused by external events not attributable to the measuring system were recorded on August 6, 2008 (power failure). This reduces the total time of operation to 90 measuring days.

Regular checks of the zero point as part of the drift test resulted in a total of 3 days of down time.

Maintenance tasks during the tests were primarily caused by cleaning the sampling heads (7 times) and checking flow rates as well as leak tightness (once). These tasks cause down times of less than 1h per check (8 times during testing) and did not require daily averages to be discarded.

A defective sensor for determining the position of the beta source's cover resulted in down times of instrument SN 145 from 27/08/2008 to 29/08/2008. FAI Instruments s.r.l replaced the defective sensor.

No further errors in functioning were observed:

6.5 Assessment

The availability for instrument 1 (SN 127) was 99.1%, for instrument 2 (SN 131) it was 97.8%, for SN 145 it was 96.7% and for SN 149, it was 100%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 36: Determination of the availability (Cologne 2007, Bonn, Brühl)

		System 1 (SN 127)	System 2 (SN 131)
Operation time (t_{field})	h	5568	5568
Outage time	h	48	120
Maintenance time incl. zero filter ($t_{cal,maint}$)	h	184	184
Actual operating time (t_{valid})	h	5336	5264
Availability	%	99.1	97.8

Table 37: Determination of the availability (Teddington)

		System 1 (SN 145)	System 2 (SN 149)
Operation time (t_{field})	h	2160	2160
Outage time	h	72	-
Maintenance time incl. zero filter ($t_{cal,maint}$)	h	80	80
Actual operating time (t_{valid})	h	2008	2080
Availability	%	96.7	100

6.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

The 2010 Guide [5] requires compliance with the following five criteria in order to recognise equivalence:

1. Of the full data set, at least 20% of the concentration values (determined with the reference method)shall be greater than the upper assessment threshold specified in 2008/50/EC [8], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.
2. Between-AMS uncertainty shall remain below 2.5 µg/m³ for the overall data and for data sets with data larger than/equal to 30 µg/m³ PM_{10} and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and at 30 µg/m³ for $PM_{2.5}$ for every individual candidate system and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for PM_{10}, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from $|b-1| \leq 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept.

The following chapter address the issue of verifying compliance with the five criteria.

Chapter 6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

Chapter 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8) contains an assessment for the case that criterion 5 is not complied with without applying correction factors.

6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4)

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

For instrument version SWAM 5a Dual Channel Monitor, this test was part of the original field test as well as of the campaigns for qualifying instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor; a total of 6 comparison campaigns have been performed. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for PM_{10}: 409 valid pairs of measured values for SN 127 / SN 145 and SN 248, 419 valid pairs of measured values for SN 131, SN 149 and SN 249; for $PM_{2.5}$: 327 valid pairs of measured values for SN 127 / SN 145 and SN 248, 325 valid pairs of measured values for SN 131, SN 149 and SN 249) 35% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 25.8% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

One exemplary measurement campaign each served to demonstrate equivalence of the reference method for the SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor instrument versions.

6.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³. A between-AMS uncertainty > 2.5 µg/m^3 is an indication of unsuitable performance of one or both instruments, and equivalence shall not be stated.

Uncertainty is determined for:

- All locations or comparisons together (full data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (basis: averages reference measurement)

Furthermore, this report also covers an informative evaluation of the following data sets:

- Every location or comparison separately
- 1 data set with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values < 30 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)

The between-AMS uncertainty u_{bs} is calculated from the differences of all daily averages (24h-values) of the AMS which are operated simultaneously as:

$$u_{bs,AMS}^2 = \frac{\sum_{i=1}^{n}(y_{i,1} - y_{i,2})^2}{2n}$$

Where: $y_{i,1}$ and $y_{i,2}$ = Results of the parallel measurements of individual 24h-values i
n = Number of 24h-values

6.5 Assessment

At no more than 0.79 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Monitor remains well below the permissible maximum of 2.5 µg/m³. At no more than 0.74 µg/m³ for $PM_{2.5}$ and no more than 0.73 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Hourly Mode Monitor remains well below the permissible maximum of 2.5 µg/m³. Finally, at no more than 0.56 µg/m³ for $PM_{2.5}$ and no more than 0.63 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Monitor also remains below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

For SWAM 5a Dual Channel Monitor:

Table 38 and Table 39 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 51 to Figure 68.

For SWAM 5a Dual Channel Hourly Mode Monitor:

Table 40 and Table 41 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 69 to Figure 70.

For SWAM 5a Monitor:

Table 42 and Table 43 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 71 to Figure 72.

Table 38: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 127 / 145 / 248 and SN 131 / 149 / 249, version SWAM 5a Dual Channel Monitor, component $PM_{2.5}$

Tested instruments	Test site	Number of measurements	Uncertainty $u_{bs,AMS}$
SN			µg/m³
All	**All test sites**	**442**	**0.71**
Individual test sites			
127 / 131	Cologne, parking lot, 2007	100	0.69
127 / 131	Bonn, Belderberg	64	0.42
127 / 131	Brühl	55	0.63
145 / 149	Teddington	83	0.44
127 / 131	Cologne, parking lot, 2011	67	1.33
248 / 249	Bornheim	73	0.32
Classing over reference values			
All	**Values ≥ 18 µg/m³**	**91**	**0.79**
All	Values < 18 µg/m³	221	0.45

Table 39: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 127 / 145 / 248 and SN 131 / 149 / 249, version SWAM 5a Dual Channel Monitor, component PM_{10}

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
SN			µg/m³
All	**All test sites**	**455**	**0.66**
Individual test sites			
127 / 131	Cologne, parking lot, 2007	100	0.87
127 / 131	Bonn, Belderberg	64	0.45
127 / 131	Brühl	55	0.56
145 / 149	Teddington	83	0.53
127 / 131	Cologne, parking lot, 2011	80	0.88
248 / 249	Bornheim	73	0.35
Classing over reference values			
All	**Values ≥ 30 µg/m³**	**91**	**1.19**
All	Values < 30 µg/m³	221	0.46

Table 40: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 111 and SN 112, version SWAM 5a Dual Channel Hourly Mode Monitor, component $PM_{2.5}$

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
111 / 112	Cologne, parking lot, 2011	77	0.74

Table 41: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 111 and SN 112, version SWAM 5a Dual Channel Hourly Mode Monitor, component PM_{10}

Tested instruments	Test site	Number of measurements	Uncertainty $u_{bs,AMS}$
111 / 112	Cologne, parking lot, 2011	77	0.73

Table 42: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 331 and SN 333, version SWAM 5a Monitor, component $PM_{2.5}$

Tested instruments	Test site	Number of measurements	Uncertainty $u_{bs,AMS}$
331 / 333	Bornheim	53	0.56

Table 43: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 329 and SN 330, version SWAM 5a Monitor, component PM_{10}

Tested instruments	Test site	Number of measurements	Uncertainty $u_{bs,AMS}$
329 / 330	Bornheim	77	0.63

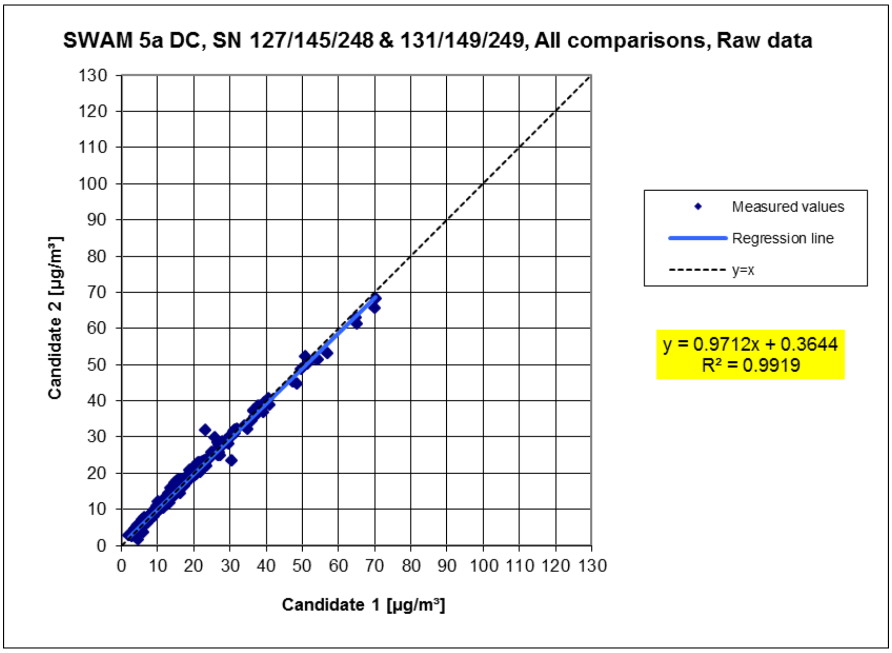


Figure 51: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites

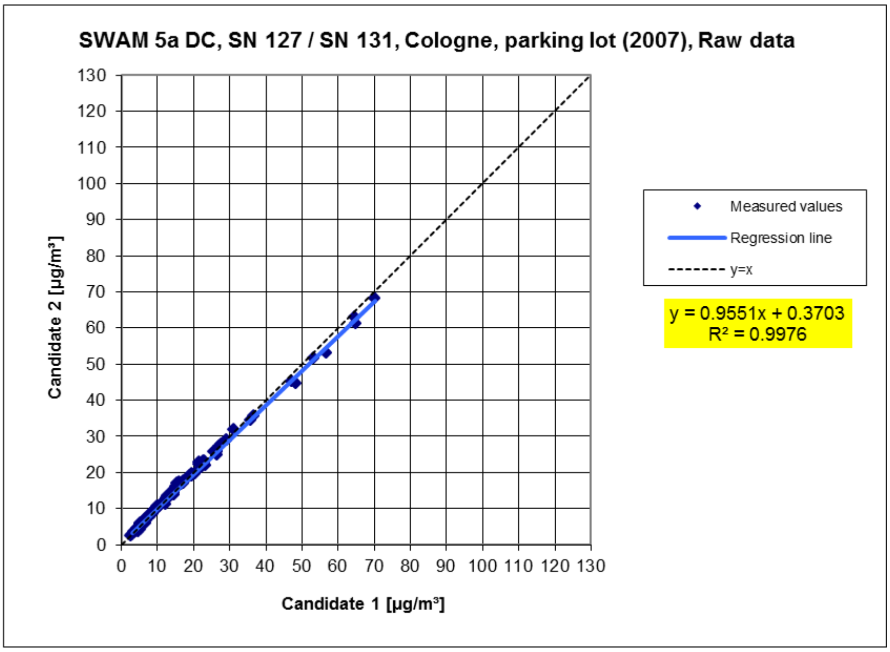


Figure 52: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Cologne, parking lot (2007)

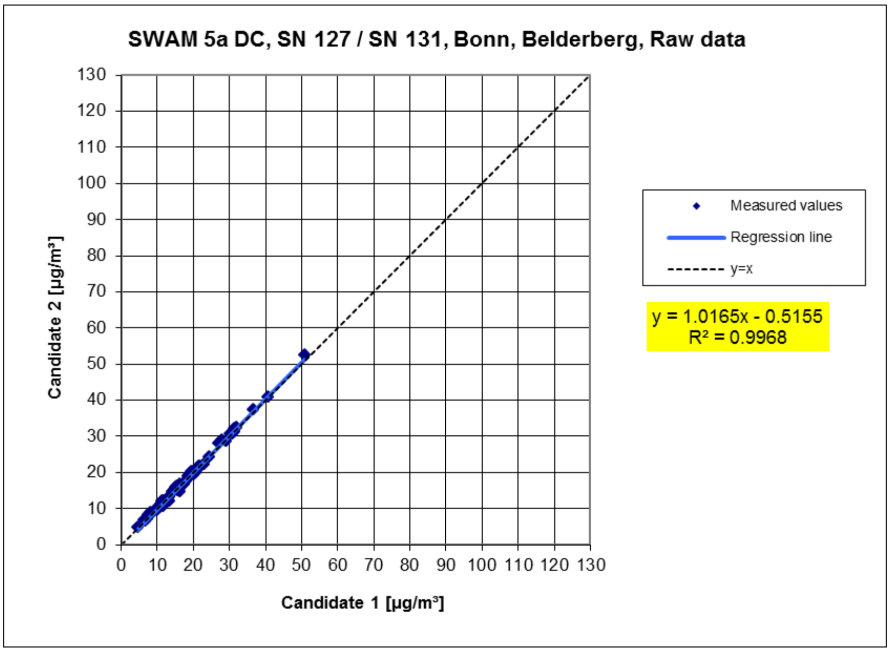


Figure 53: Results of the parallel measurement with instruments SN 127 / SN 131, Component $PM_{2,5}$, SWAM 5a DC, Bonn, Belderberg

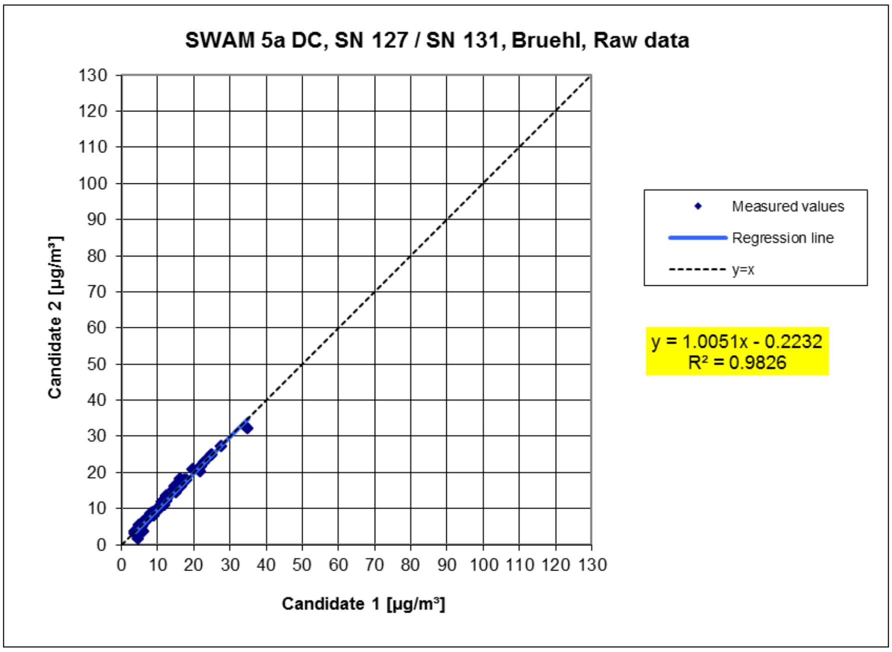


Figure 54: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Brühl

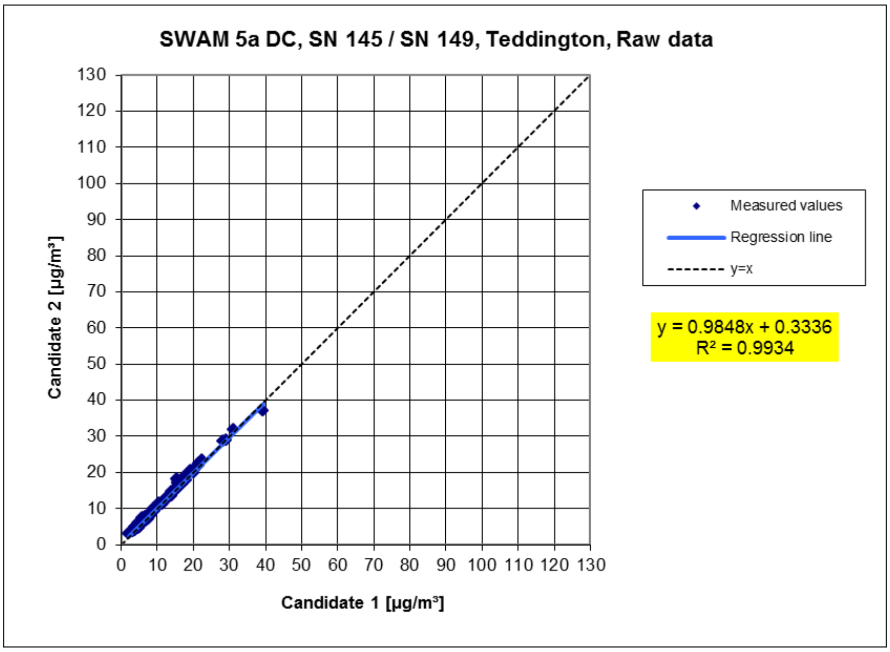


Figure 55: Results of the parallel measurement with instruments SN 145 / SN 149, component $PM_{2,5}$, SWAM 5a DC, Teddington

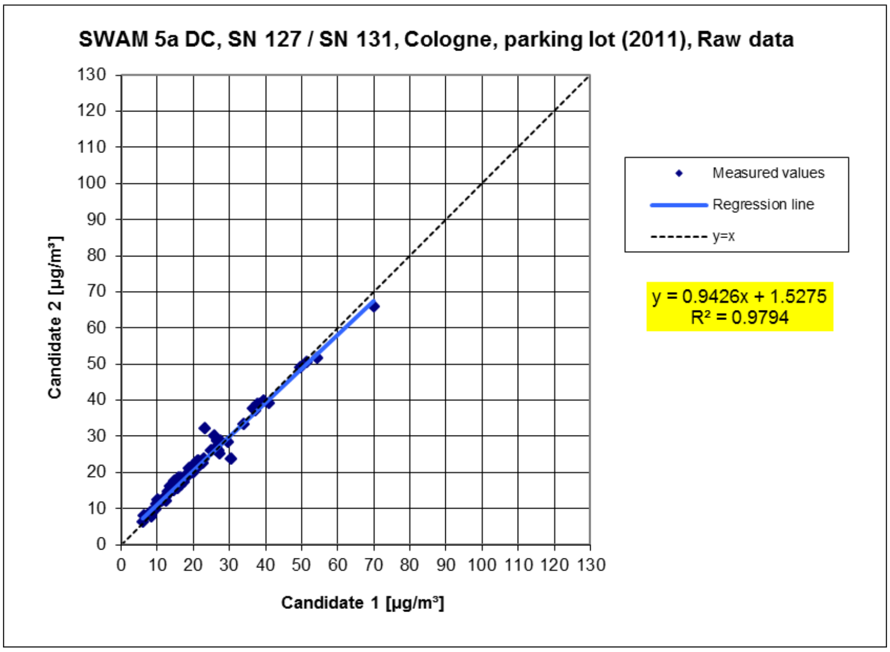


Figure 56: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Cologne, parking lot (2011)

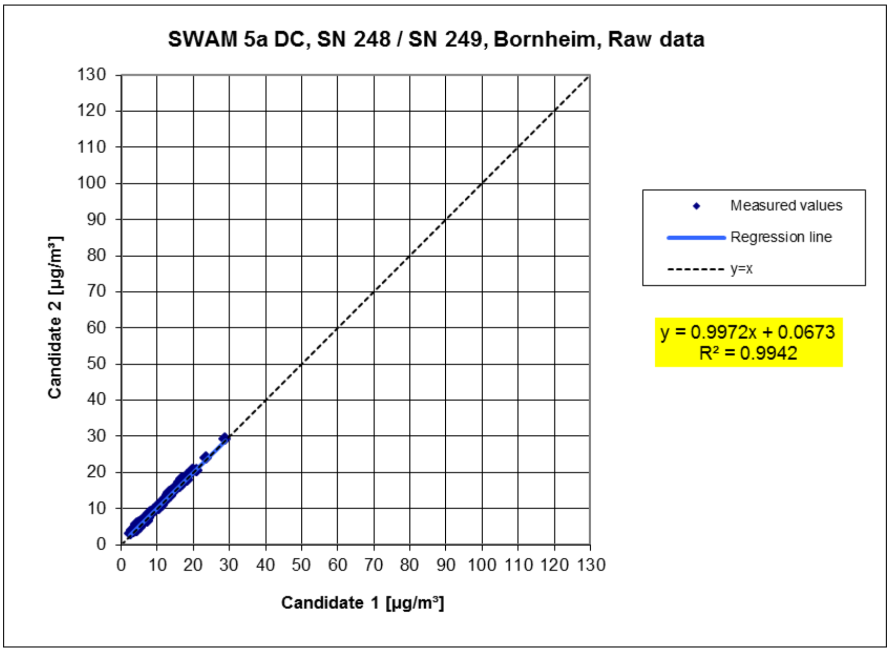


Figure 57: Results of the parallel measurement with instruments SN 248 / SN 249, component $PM_{2,5}$, SWAM 5a DC, Bornheim

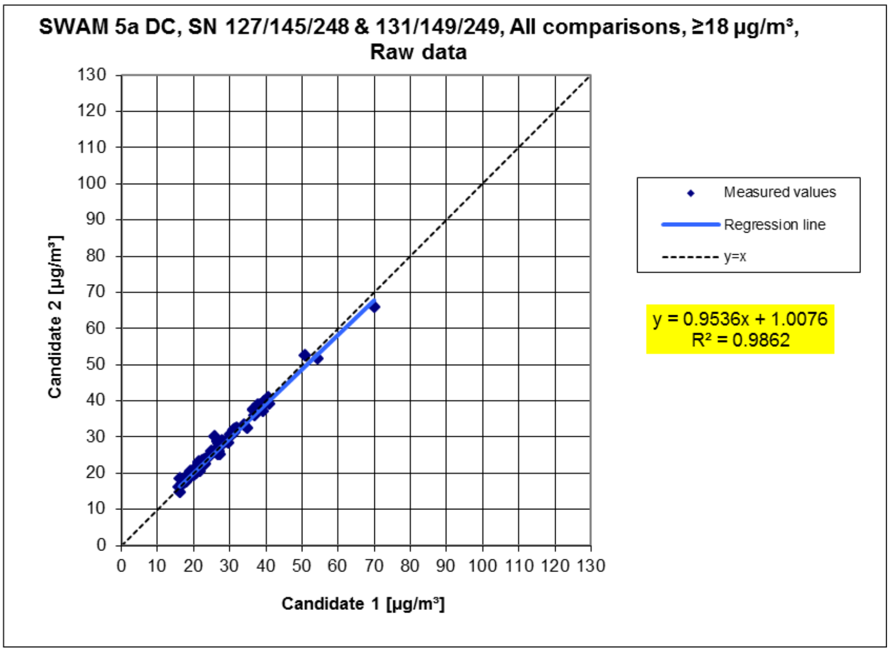


Figure 58: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites, values ≥ 18

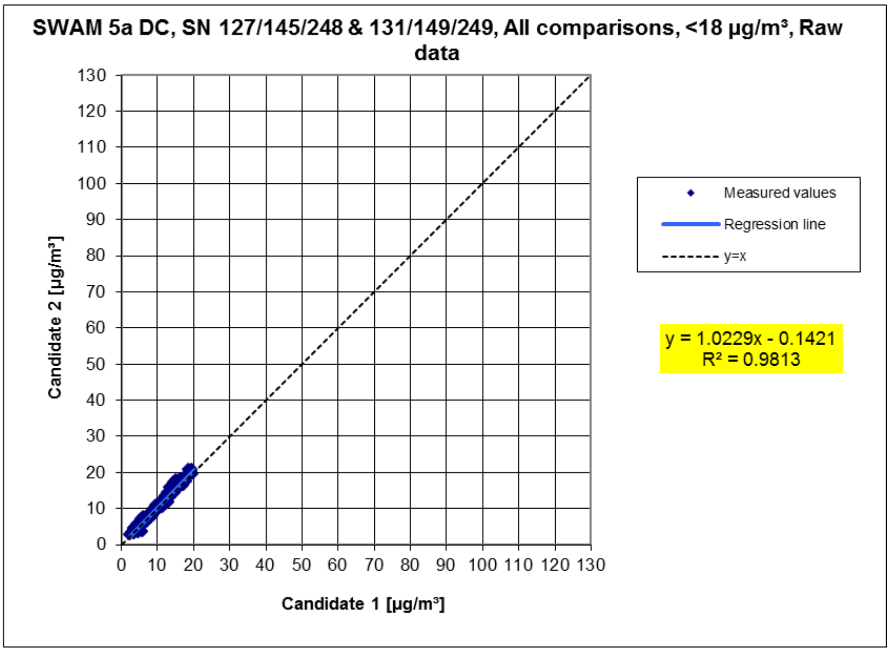


Figure 59: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites, values < 18

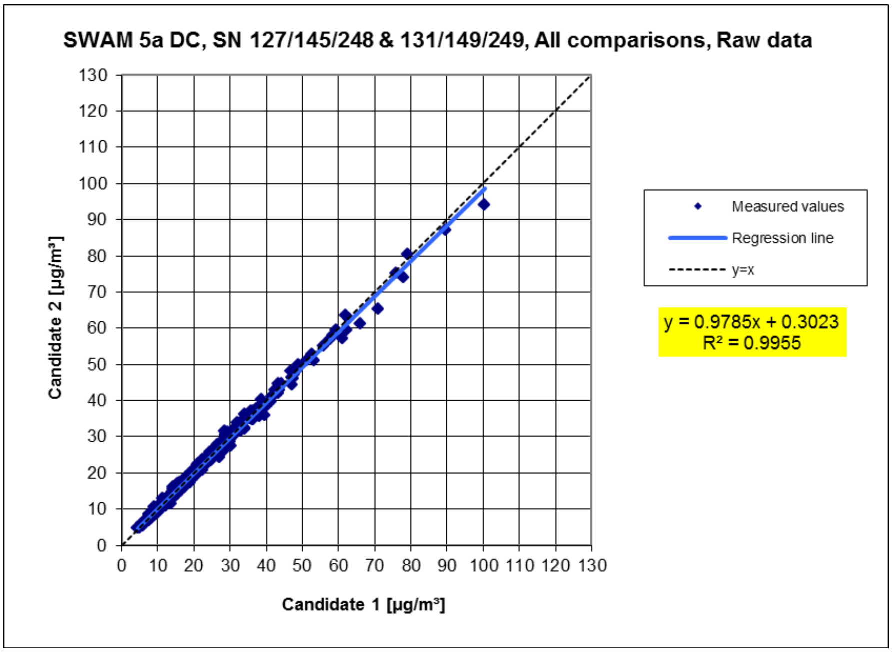


Figure 60: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites

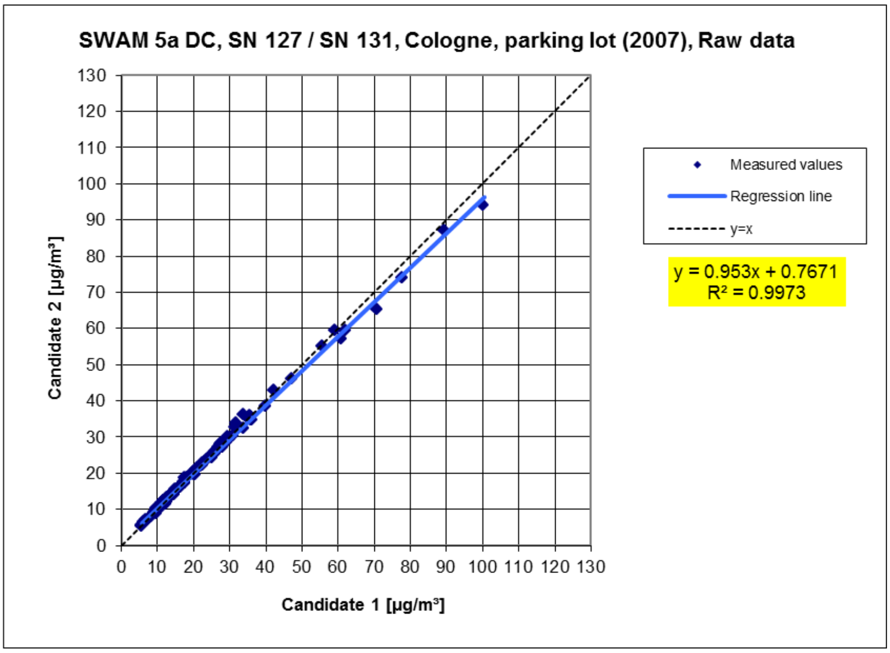


Figure 61: Results of the parallel measurement with instruments SN 127 / SN 131, Component PM_{10}, SWAM 5a DC, Cologne, parking lot (2007)

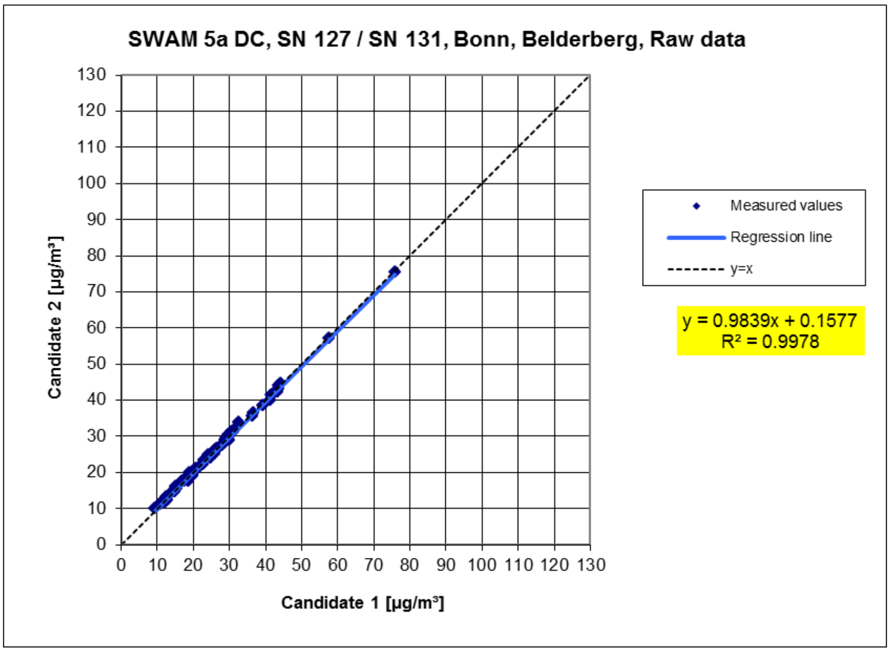


Figure 62: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Bonn, Belderberg

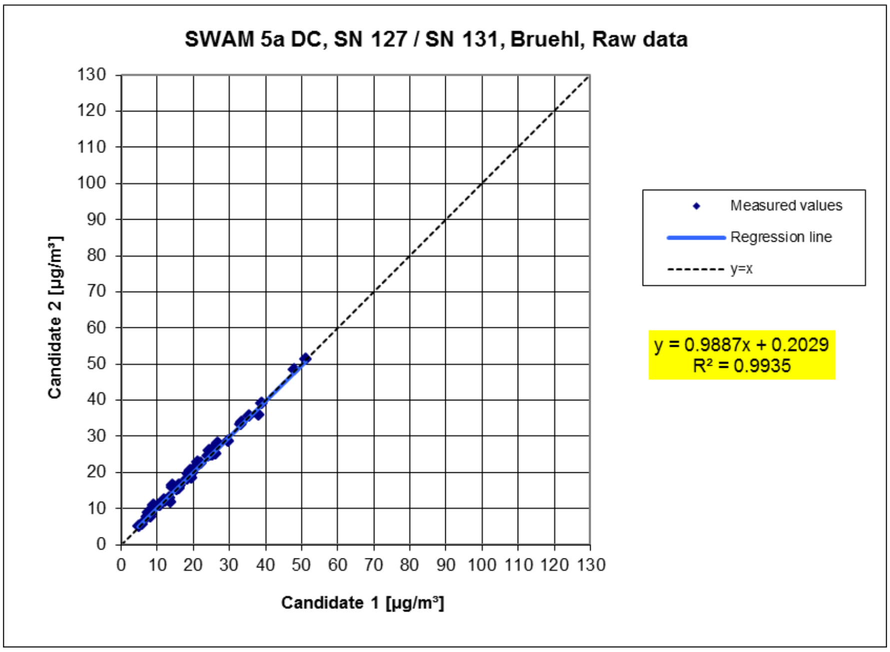


Figure 63: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Brühl

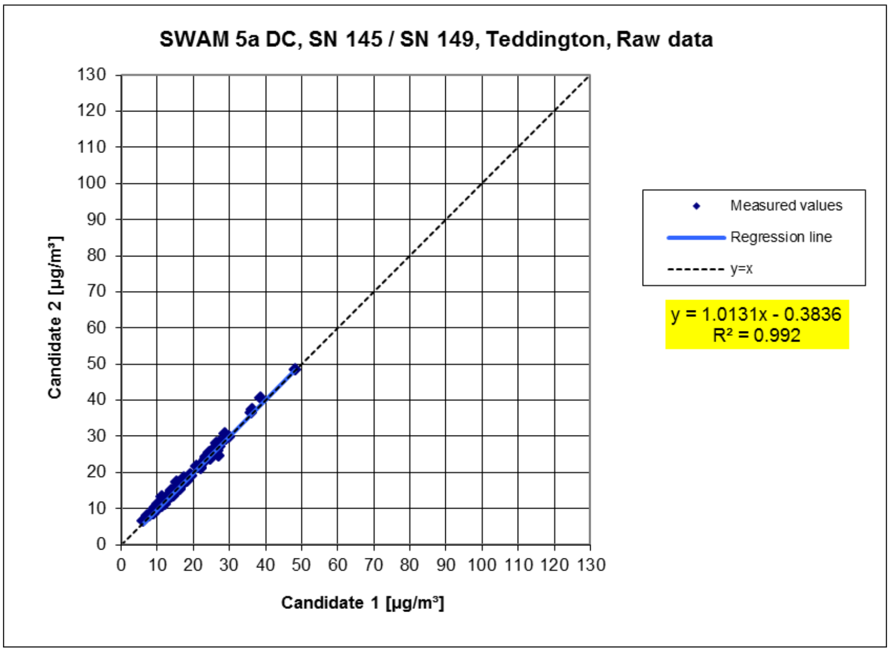


Figure 64: Results of the parallel measurement with instruments SN 145 / SN 149, Component PM_{10}, SWAM 5a DC, Teddington

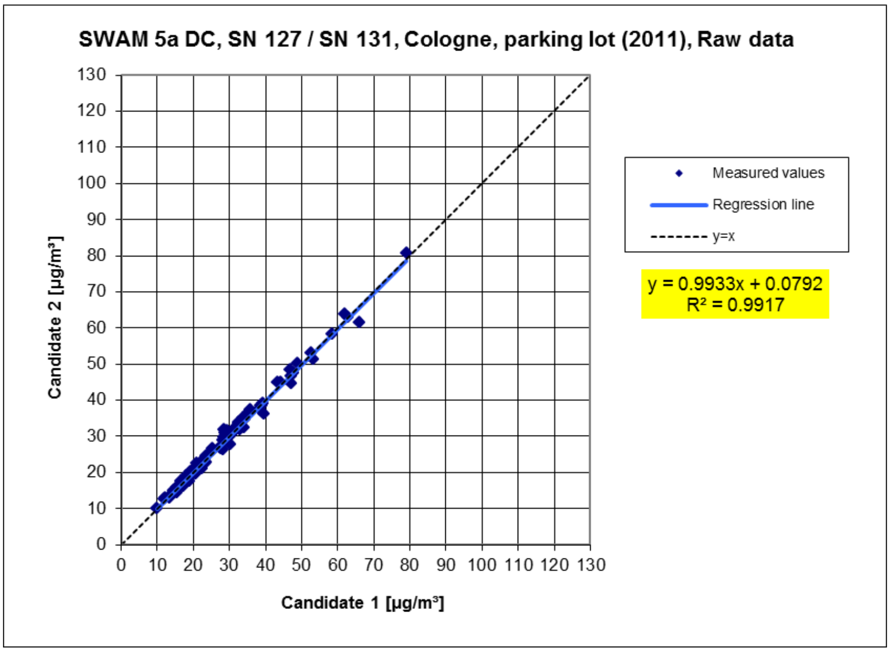


Figure 65: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Cologne, parking lot (2011)

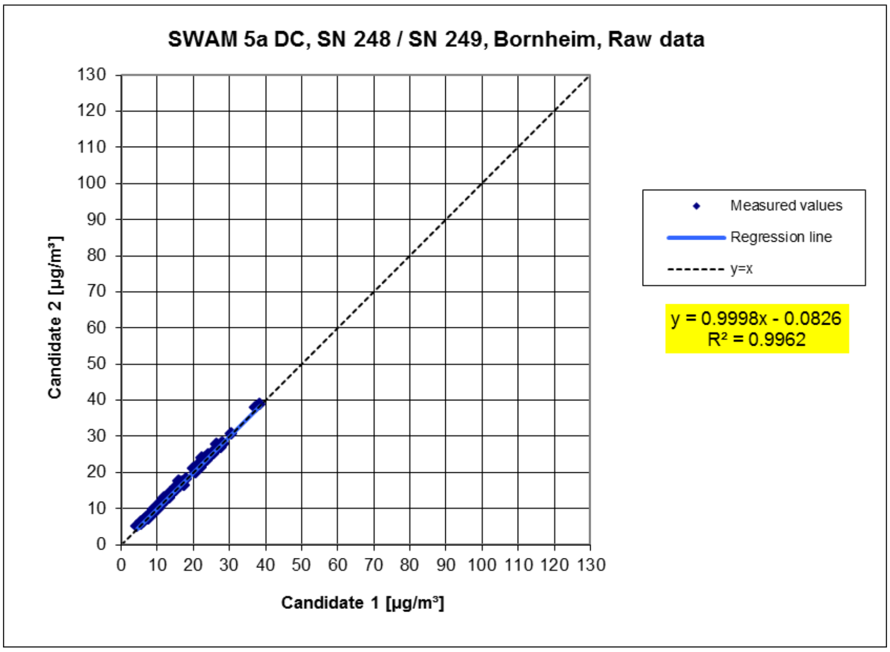


Figure 66: Results of the parallel measurement with instruments SN 248 / SN 249, Component PM_{10}, SWAM 5a DC, Bornheim

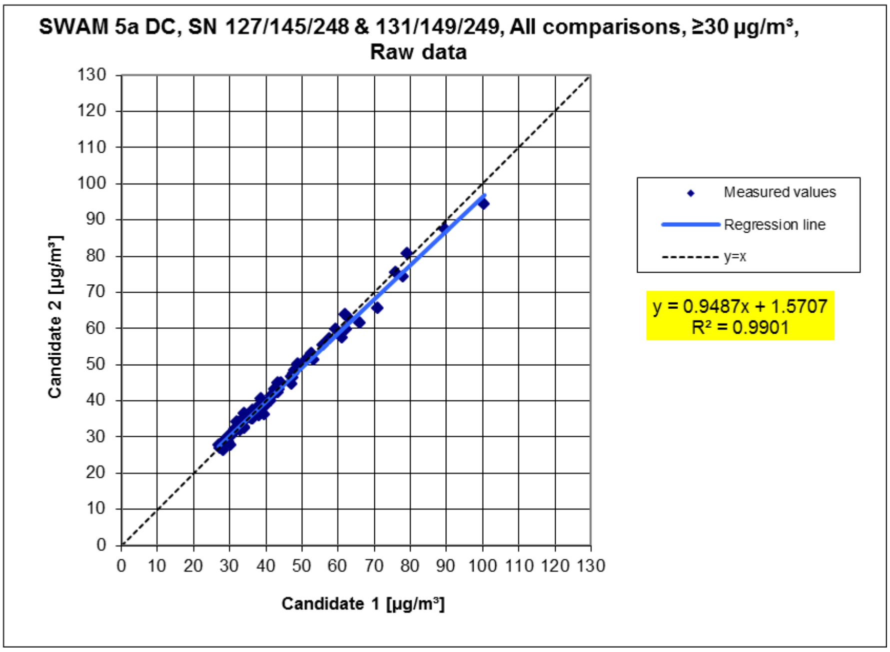


Figure 67: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites, values ≥ 30 µg/m³

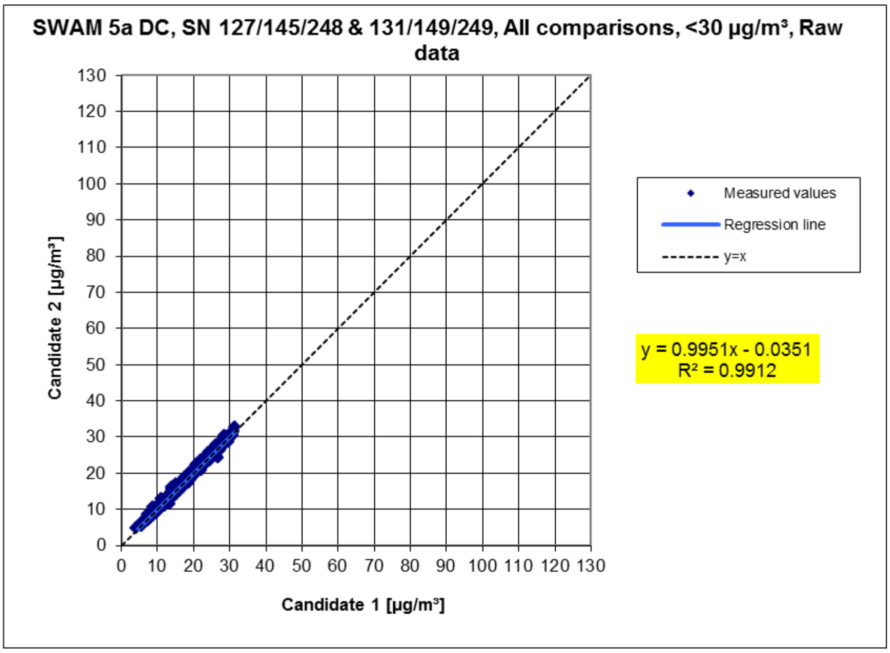


Figure 68: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites, values < 30 µg/m³

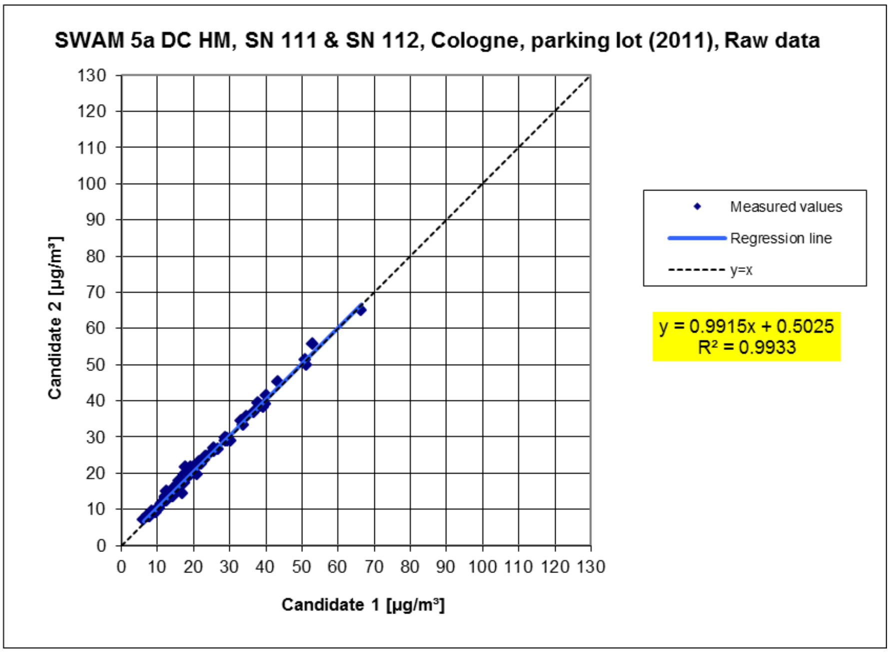


Figure 69: Results of the parallel measurement with instruments SN 111 / SN 112, component $PM_{2.5}$, SWAM 5a DC HM, Cologne, parking lot (2011)

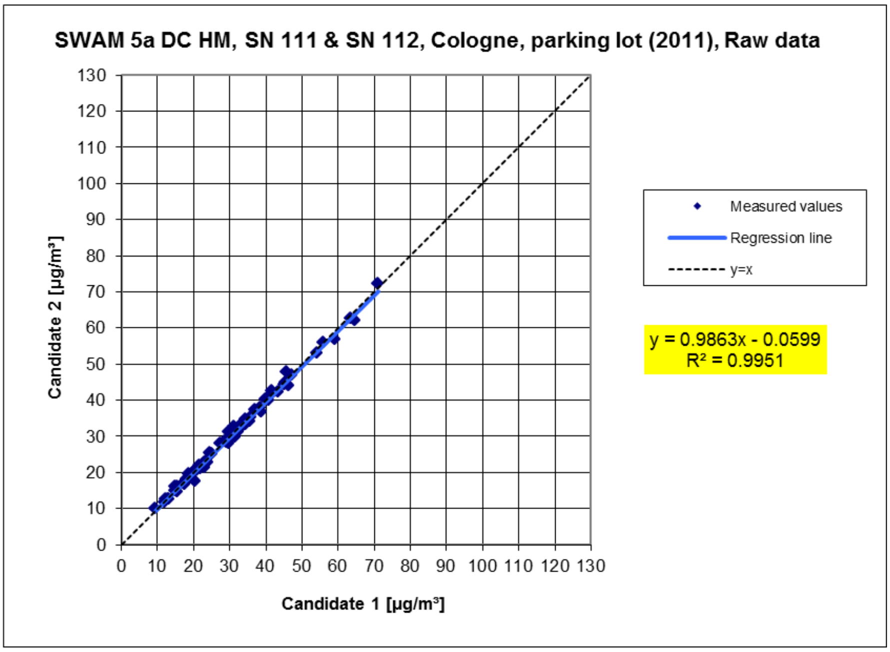


Figure 70: Results of the parallel measurement with instruments SN 111 / SN 112, Component PM_{10}, SWAM 5a DC HM, Cologne, parking lot (2011)

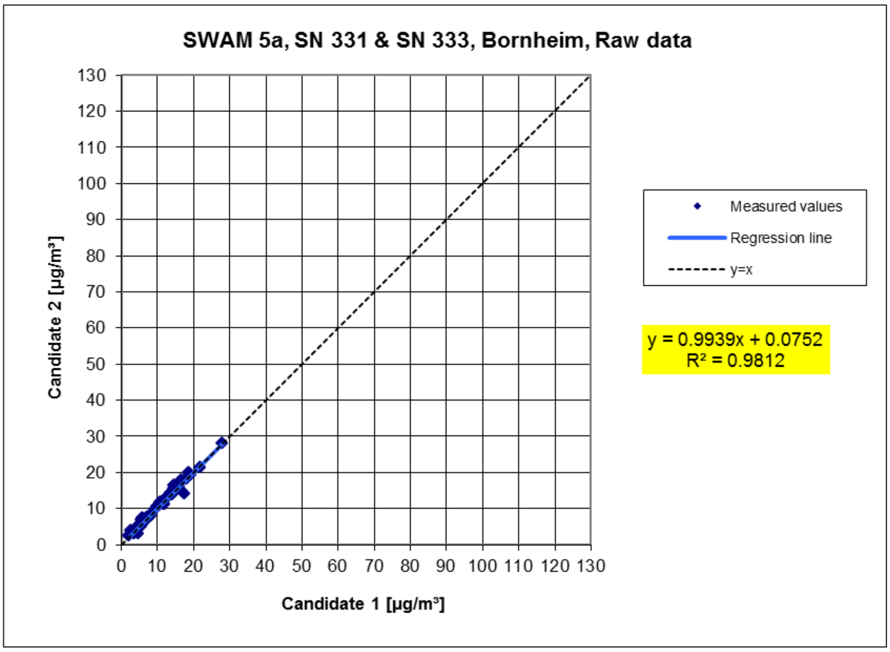


Figure 71: Results of the parallel measurement with instruments SN 331 / SN 333, component $PM_{2.5}$, SWAM 5a, Bornheim

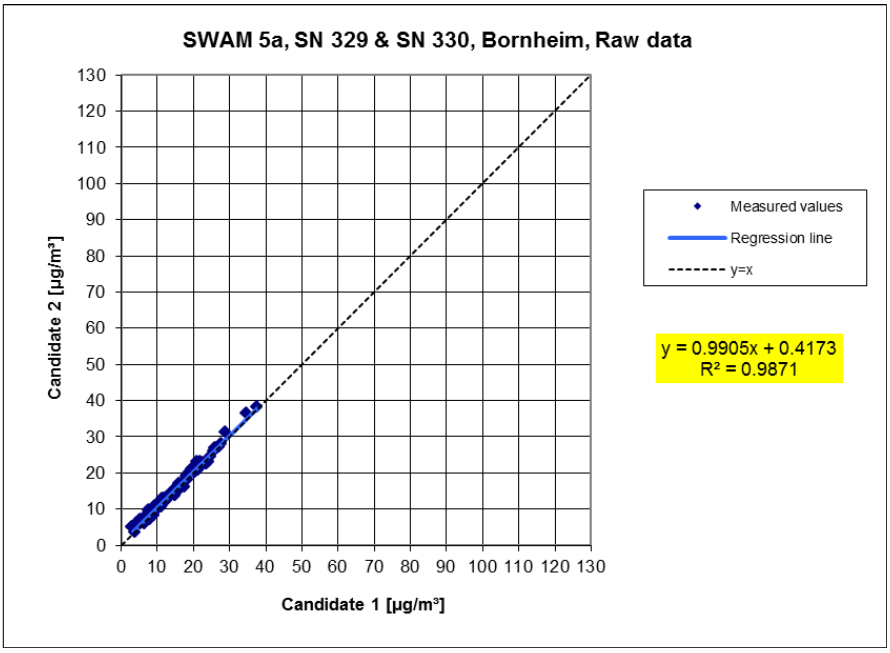


Figure 72: Results of the parallel measurement with instruments SN 329 / SN 330, Component PM_{10}, SWAM 5a DC, Bornheim

6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

The expanded uncertainty shall be ≤ 25% at the level of the relevant limit value related to the 24-hour average results – after a calibration where necessary.

6.2 Equipment

Additional equipment as described in chapter 5 of this report was used for this test.

6.3 Testing

For instrument version SWAM 5a Dual Channel Monitor, this test was part of the original field test as well as of the campaigns for qualifying instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor; a total of 6 comparison campaigns have been performed. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method shall be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for PM_{10}: 409 valid pairs of measured values for SN 127 / SN 145 and SN 248, 419 valid pairs of measured values for SN 131, SN 149 and SN 249; for $PM_{2.5}$: 327 valid pairs of measured values for SN 127 / SN 145 and SN 248, 325 valid pairs of measured values for SN 131, SN 149 and SN 249) 35% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 25.8% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

One exemplary measurement campaign each served to demonstrate equivalence of the reference method for the SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor instrument versions.

6.4 Evaluation

[EN 16450, 7.5.8.3]

Before calculating the expanded uncertainty of the candidate systems, uncertainties were established between the simultaneously operated reference measuring systems (u_{ref})

Uncertainties between the simultaneously operated reference measuring systems $u_{bs,RM}$ were established similar to the between-AMS uncertainties and shall be ≤ 2.0 µg/m³.

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

In order to assess comparability of the tested instruments y with the reference method x, a linear relationship $y_i = a + bx_i$ between the measured values of both methods is assumed. The association between the means of the reference systems and each individual candidate system to be assessed is established by means of orthogonal regression.

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately

- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (basis: averages of reference measurement)

For further assessment, the uncertainty u_{c_s} resulting from a comparison of the candidate systems with the reference method is described in the following equation which defines u_{CR} as a function of the fine dust concentration x_i.

$$u_{yi}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [a + (b-1)L]^2$$

Where RSS is the sum of the (relative) residuals from orthogonal regression

u_{RM} = is the random uncertainty of the reference method, if $u_{bs,RM}$, calculated for the use of the candidate systems can be used for this test.

The algorithms for calculating ordinate intercept a and slope b as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

The sum of (relative) residuals RSS is calculated according to the following equation:

$$RSS = \sum_{i=1}^{n} (y_i - a - bx_i)^2$$

Uncertainty u_{CR} is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (basis: averages of reference measurement)

The Guide states the following prerequisite for accepting the full data set:

- The slope be is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$

and

- The ordinate intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$, where u(a) and u(b) describe the standard uncertainty of the slope and the ordinate intercept calculated as the square root of the variance. If the prerequisites are not met, it is possible to calibrate the measuring systems in accordance with section 9.7 of the Guideline (also see 6.1 17 Use of correction factors/terms). The calibration may only be performed for the full data set.

[EN 16450, 7.5.8.7] For all datasets the combined relative uncertainty of the AMS $w_{c,CM}$ is calculated from a combination of contributions from 9.5.3.1 and 9.5.3.2 in accordance with the following equation:

$$w_{AMS}^2 = \frac{u_{yi=L}^2}{L^2}$$

For each data set the uncertainty w_{AMS} is calculated at a level of L = 30 µg/m³ for $PM_{2.5}$ as well as L = 50 µg/m³ for PM_{10}.

[EN 16450 7.5.8.8] For each data set the expanded relative uncertainty of the results measured with the candidate system is calculated by multiplying w_{AMS} by an coverage factor k according to the following equation:

$$W_{AMS} = k \cdot w_{AMS}$$

In practice, k is specified at k=2 for large n.

[Item 9.6]

The largest resulting uncertainty W_{AMS} is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

1. $W_{AMS} \leq W_{dqo}$ → The test is deemed equivalent to the reference method.
2. $W_{AMS} > W_{dqo}$ → The candidate system is not deemed equivalent to the reference method.

The expanded relative uncertainty W_{dqo} specified is 25% [8].

6.5 Assessment

Without the need for any correction factors, the expanded uncertainties WAMS for instrument version SWAM 5a Dual Channel Monitor were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. This also applies to the uncertainties W_{AMS} determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor.

Criterion satisfied? yes

Given the significance of the slope and the intercept for the full data set for $PM_{2.5}$ and the significance of the slope of the full data set for PM_{10} for instrument version SWAM 5a Dual Channel Monitor, correction factors were used in accordance with chapter 6.1 17 Use of correction factors/terms .

During the comparison campaign, no significance of the slope and intercepts were determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a. In this instance, no correction factors were used.

For SWAM 5a Dual Channel Monitor:

Table 44 and Table 45 below provide an overview of the results of all equivalence tests performed for SWAM 5a Dual Channel Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 44: Overview of equivalence testing performed for SWAM 5a Dual Channel Monitor for $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	N 127/145/248 & 131/149/249	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.71**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**312**				
Slope b	**0.973**	**significant**			
Uncertainty of b	**0.010**				
Ordinate intercept a	**0.355**	**not significant**			
Uncertainty of a	**0.184**				
Expanded meas. uncertainty W_{CM}	**11.98**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.64**	**µg/m³**			
Uncertainty between Candidates	**0.79**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**91**				
Slope b	**1.051**				
Uncertainty of b	**0.029**				
Ordinate intercept a	**-2.028**				
Uncertainty of a	**0.804**				
Expanded meas. uncertainty W_{CM}	**15.26**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**221**				
Slope b	**0.959**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.606**				
Uncertainty of a	**0.237**				
Expanded meas. uncertainty W_{CM}	**10.51**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010

Candidate	SWAM 5a DC		SN	N 127/145/248 & 131/149/249	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, parking lot (2007)					
Uncertainty between Reference	0.67	µg/m³			
Uncertainty between Candidates	0.69	µg/m³			
	SN 127			SN 131	
Number of data pairs	45			46	
Slope b	1.000			0.967	
Uncertainty of b	0.023			0.022	
Ordinate intercept a	-0.275			-0.002	
Uncertainty of a	0.382			0.380	
Expanded meas. uncertainty W_{CM}	6.63	%		9.18	%
Bonn, Belderberg					
Uncertainty between Reference	0.46	µg/m³			
Uncertainty between Candidates	0.42	µg/m³			
	SN 127			SN 131	
Number of data pairs	41			41	
Slope b	0.996			1.023	
Uncertainty of b	0.019			0.021	
Ordinate intercept a	-1.208			-2.010	
Uncertainty of a	0.443			0.490	
Expanded meas. uncertainty W_{CM}	11.52	%		12.12	%
Bruehl					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.63	µg/m³			
	SN 127			SN 131	
Number of data pairs	43			45	
Slope b	0.985			1.003	
Uncertainty of b	0.032			0.032	
Ordinate intercept a	-0.956			-1.187	
Uncertainty of a	0.495			0.519	
Expanded meas. uncertainty W_{CM}	12.41	%		11.61	%
Teddington					
Uncertainty between Reference	0.33	µg/m³			
Uncertainty between Candidates	0.44	µg/m³			
	SN 145			SN 149	
Number of data pairs	74			80	
Slope b	0.977			0.974	
Uncertainty of b	0.022			0.020	
Ordinate intercept a	1.139			1.352	
Uncertainty of a	0.282			0.245	
Expanded meas. uncertainty W_{CM}	10.00	%		9.35	%
Cologne, parking lot (2011)					
Uncertainty between Reference	0.52	µg/m³			
Uncertainty between Candidates	1.33	µg/m³			
	SN 127			SN 131	
Number of data pairs	67			53	
Slope b	1.024			0.972	
Uncertainty of b	0.026			0.031	
Ordinate intercept a	-0.511			0.642	
Uncertainty of a	0.617			0.802	
Expanded meas. uncertainty W_{CM}	15.94	%		18.43	%
Bornheim					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.32	µg/m³			
	SN 248			SN 249	
Number of data pairs	57			60	
Slope b	1.053			1.062	
Uncertainty of b	0.040			0.042	
Ordinate intercept a	0.159			0.040	
Uncertainty of a	0.429			0.443	
Expanded meas. uncertainty W_{CM}	15.19	%		16.44	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.64	µg/m³			
Uncertainty between Candidates	0.79	µg/m³			
	SN 127/145/248			SN 131/149/249	
Number of data pairs	95			95	
Slope b	1.067			1.023	
Uncertainty of b	0.029			0.029	
Ordinate intercept a	-2.358			-1.408	
Uncertainty of a	0.810			0.81	
Expanded meas. uncertainty W_{CM}	15.55	%		15.94	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.50	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 127/145/248			SN 131/149/249	
Number of data pairs	232			230	
Slope b	0.958			0.985	
Uncertainty of b	0.021			0.024	
Ordinate intercept a	0.593			0.413	
Uncertainty of a	0.226			0.252	
Expanded meas. uncertainty W_{CM}	10.20	%		10.66	%
All comparisons					
Uncertainty between Reference	0.51	µg/m³			
Uncertainty between Candidates	0.71	µg/m³			
	SN 127/145/248			SN 131/149/249	
Number of data pairs	327			325	
Slope b	0.981	not significant		0.963	significant
Uncertainty of b	0.010			0.011	
Ordinate intercept a	0.247	not significant		0.496	significant
Uncertainty of a	0.182			0.188	
Expanded meas. uncertainty W_{CM}	11.75	%		12.78	%

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing were as follows:

Criterion 1: More than 20% of the data exceed 17 µg/m³.

Criterion 2: Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.

Criterion 3: Uncertainty between reference instruments did not exceed 2.0 µg/m³.

Criterion 4: All expanded uncertainties remained below 25%.

Criterion 5: For candidate systems SN 131/149/249, the slope and the intercept for the evaluation of the full data set significantly exceeds the permissible value.

Additional: The slope determined for the full data set regarding both candidate systems combined was at 0.973, the ordinate intercept was at 0.355 at a total ex panded uncertainty of 11.98%.

Table 45: Overview of equivalence testing performed for SWAM 5a Dual Channel Monitor for PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	N 127/145/248 & 131/149/249	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.75**	**µg/m³**			
Uncertainty between Candidates	**0.66**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**404**				
Slope b	**1.051**	**significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**-0.271**	**not significant**			
Uncertainty of a	**0.240**				
Expanded meas. uncertainty W_{CM}	**12.90**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.78**	**µg/m³**			
Uncertainty between Candidates	**1.19**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**83**				
Slope b	**1.169**				
Uncertainty of b	**0.032**				
Ordinate intercept a	**-5.643**				
Uncertainty of a	**1.374**				
Expanded meas. uncertainty W_{CM}	**17.94**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.74**	**µg/m³**			
Uncertainty between Candidates	**0.46**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**321**				
Slope b	**1.013**				
Uncertainty of b	**0.016**				
Ordinate intercept a	**0.519**				
Uncertainty of a	**0.290**				
Expanded meas. uncertainty W_{CM}	**8.33**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	N 127/145/248 & 131/149/249	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, parking lot (2007)					
Uncertainty between Reference	1.12	µg/m³			
Uncertainty between Candidates	0.87	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	98			100	
Slope b	1.126			1.074	
Uncertainty of b	0.012			0.011	
Ordinate intercept a	-0.329			0.408	
Uncertainty of a	0.338			0.310	
Expanded meas. uncertainty W_{CM}	24.58	%		17.20	%
Bonn, Belderberg					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	62			62	
Slope b	1.131			1.115	
Uncertainty of b	0.022			0.020	
Ordinate intercept a	-1.185			-1.051	
Uncertainty of a	0.570			0.540	
Expanded meas. uncertainty W_{CM}	22.61	%		19.81	%
Bruehl					
Uncertainty between Reference	0.77	µg/m³			
Uncertainty between Candidates	0.56	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	51			53	
Slope b	1.048			1.037	
Uncertainty of b	0.027			0.025	
Ordinate intercept a	-1.928			-1.693	
Uncertainty of a	0.646			0.600	
Expanded meas. uncertainty W_{CM}	6.97	%		6.33	%
Teddington					
Uncertainty between Reference	0.45	µg/m³			
Uncertainty between Candidates	0.53	µg/m³			
	SN 145			**SN 149**	
Number of data pairs	73			79	
Slope b	0.949			0.970	
Uncertainty of b	0.021			0.021	
Ordinate intercept a	2.478			2.010	
Uncertainty of a	0.398			0.390	
Expanded meas. uncertainty W_{CM}	5.80	%		6.17	%
Cologne, parking lot (2011)					
Uncertainty between Reference	0.59	µg/m³			
Uncertainty between Candidates	0.88	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	69			66	
Slope b	1.034			1.034	
Uncertainty of b	0.022			0.025	
Ordinate intercept a	-1.681			-2.100	
Uncertainty of a	0.765			0.879	
Expanded meas. uncertainty W_{CM}	9.60	%		10.99	%
Bornheim					
Uncertainty between Reference	0.63	µg/m³			
Uncertainty between Candidates	0.35	µg/m³			
	SN 248			**SN 249**	
Number of data pairs	56			59	
Slope b	1.043			1.042	
Uncertainty of b	0.033			0.034	
Ordinate intercept a	-0.628			-0.786	
Uncertainty of a	0.582			0.598	
Expanded meas. uncertainty W_{CM}	9.11	%		8.85	%
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	0.78	µg/m³			
Uncertainty between Candidates	1.19	µg/m³			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	86			85	
Slope b	1.197			1.143	
Uncertainty of b	0.033			0.032	
Ordinate intercept a	-6.504			-4.923	
Uncertainty of a	1.399			1.39	
Expanded meas. uncertainty W_{CM}	19.67	%		16.62	%
All comparisons, <30 µg/m³					
Uncertainty between Reference	0.74	µg/m³			
Uncertainty between Candidates	0.46	µg/m³			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	323			334	
Slope b	1.016			1.016	
Uncertainty of b	0.016			0.015	
Ordinate intercept a	0.538			0.414	
Uncertainty of a	0.296			0.286	
Expanded meas. uncertainty W_{CM}	8.86	%		8.45	%
All comparisons					
Uncertainty between Reference	0.75	µg/m³			
Uncertainty between Candidates	0.66	µg/m³			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	409			419	
Slope b	1.062	significant		1.038	significant
Uncertainty of b	0.010			0.009	
Ordinate intercept a	-0.416	not significant		-0.091	not significant
Uncertainty of a	0.249			0.235	
Expanded meas. uncertainty W_{CM}	14.39	%		11.51	%

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing were as follows:

Criterion 1:	More than 38 valid value pairs exceed 28 µg/m³.
Criterion 2:	Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.
Criterion 3:	Uncertainty between reference instruments did not exceed 2.0 µg/m³.
Criterion 4:	All expanded uncertainties remained below 25%.
Criterion 5:	For both sets of candidate systems the slope determined when assessing the full data set exceeded permissible limits.
Additional:	The slope determined for the full data set regarding both candidate systems combined was at 1.051, the ordinate intercept was at -0.271 at a total expand ed uncertainty of 12.90%.

The January 2010 version of the Guide does not specify clearly which ordinate intercept and which slope to use for correcting candidate systems if a candidate system does not meet the requirements for equivalence testing. After double-checking with the chair of the EU working group responsible for issuing the Guide (Mr Theo Hafkenscheid), we decided to apply the requirements of the November 2005 version of the Guide and to use the slope and the intercept determined by means of orthogonal regression for the full data set. These are listed for each criterion under "Additional"

Consequently and according to Table 44, the slope and intercept of SN 131/149/249 for $PM_{2.5}$ need to be corrected. Given the significance determined for PM_{10} for both sets of candidate systems as illustrated in Table 45, the slope had to be corrected.

It should be noted here that the uncertainty W_{CM} determined without applying correction factors for all observed data sets is below the determined expanded relative uncertainty W_{dqo} of 25% for particulate matter.

For $PM_{2.5}$:

The slope for the entire data set is 0.973.

The intercept for the full data set is 0.355.

This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factors were applied to the data sets.

For PM_{10}:

The slope for the entire data set is 1.051.

This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factor was applied to the data sets.

For compliant monitoring, the revised version of the January 2010 Guide and standard EN 16450 require continuous random checks of a certain number of instruments in a measurement grid and specify the number of measurement sites to be checked as a function of the expanded uncertainty of a measuring system. The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation. However, TÜV Rheinland recommend that the expanded uncertainty of the entire data set (in the present case, the uncorrected raw data) be used for this purpose: 11.98% for $PM_{2.5}$, implying annual checks at three measurement locations and 12.90% for PM_{10} also implying checks a year at three measurement locations (Guide [5], Chapter 9.9.2, Table 6 or EN 16450 [9], Chapter 8.6.2, Table 5).

As a result of the necessary use of calibration factors, this assessment shall be based on on the evaluation of the corrected data sets (see chapter 6.1 17 Use of correction factors/terms).

For SWAM 5a Dual Channel Hourly Mode Monitor:

Table 46 and Table 47 below provide and overview of the results for equivalence testing obtained for instrument version SWAM 5a Dual Channel Hourly Mode Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 46: Overview of equivalence testing performed for SWAM 5a Dual Channel Hourly Mode Monitor for $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC HM		SN	SN 111 & SN 112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.74**	**µg/m³**			
	SN 111 & SN 112				
Number of data pairs	**61**				
Slope b	**0.998**	**not significant**			
Uncertainty of b	**0.016**				
Ordinate intercept a	**0.685**	**not significant**			
Uncertainty of a	**0.393**				
Expanded meas. uncertainty W_{CM}	**10.40**	**%**			
Cologne, parking lot (2011)					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.74**	**µg/m³**			
	SN 111			**SN 112**	
Number of data pairs	**68**			**61**	
Slope b	**1.005**			**0.992**	
Uncertainty of b	**0.018**			**0.018**	
Ordinate intercept a	**0.657**			**0.901**	
Uncertainty of a	**0.429**			**0.428**	
Expanded meas. uncertainty W_{CM}	**12.03**	**%**		**11.32**	**%**

Table 47: Overview of equivalence testing performed for SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC HM		SN	SN 111 & SN 112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.59**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 111 & SN 112				
Number of data pairs	**63**				
Slope b	**0.972**	**not significant**			
Uncertainty of b	**0.016**				
Ordinate intercept a	**-0.305**	**not significant**			
Uncertainty of a	**0.548**				
Expanded measured uncertainty WCM	**9.33**	**%**			
Cologne, parking lot (2011)					
Uncertainty between Reference	**0.59**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 111			**SN 112**	
Number of data pairs	**71**			**63**	
Slope b	**0.982**			**0.965**	
Uncertainty of b	**0.018**			**0.015**	
Ordinate intercept a	**-0.079**			**-0.314**	
Uncertainty of a	**0.634**			**0.535**	
Expanded measured uncertainty W_{CM}	**8.76**	**%**		**10.36**	**%**

For SWAM 5a Monitor:

Table 48 and Table 49 below provide an overview of the results of all equivalence tests performed for swam 5a Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 48: Overview of equivalence testing performed for SWAM 5a Monitor for $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a		SN	SN 331 & SN 333	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.56**	**µg/m³**			
	SN 331 & SN 333				
Number of data pairs	**40**				
Slope b	**0.971**	**not significant**			
Uncertainty of b	**0.041**				
Ordinate intercept a	**0.235**	**not significant**			
Uncertainty of a	**0.455**				
Expanded meas. uncertainty W_{CM}	**9.53**	**%**			
Bornheim					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.56**	**µg/m³**			
	SN 331			**SN 333**	
Number of data pairs	**40**			**60**	
Slope b	**0.976**			**1.031**	
Uncertainty of b	**0.038**			**0.047**	
Ordinate intercept a	**0.157**			**-0.022**	
Uncertainty of a	**0.419**			**0.491**	
Expanded meas. uncertainty W_{CM}	**8.50**	**%**		**13.26**	**%**

Table 49: Overview of equivalence testing performed for SWAM 5a Monitor for PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a		SN	SN 329 & SN 330	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 329 & SN 330				
Number of data pairs	**59**				
Slope b	**1.007**	**not significant**			
Uncertainty of b	**0.035**				
Ordinate intercept a	**-0.900**	**not significant**			
Uncertainty of a	**0.627**				
Expanded measured uncertainty WCM	**7.84**	**%**			
Bornheim					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 329			**SN 330**	
Number of data pairs	**59**			**59**	
Slope b	**1.012**			**1.006**	
Uncertainty of b	**0.037**			**0.036**	
Ordinate intercept a	**-1.111**			**-0.746**	
Uncertainty of a	**0.648**			**0.636**	
Expanded measured uncertainty W_{CM}	**8.09**	**%**		**7.86**	**%**

6.6 Detailed presentation of test results

Table 50 and Table 51 provide an overview of the between-RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 50: Between-RM uncertainty $u_{bs,RM}$ for $PM_{2.5}$

Reference instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,RM}$**
No.			µg/m³
1 / 2	Cologne, parking lot, 2007	46	0.67
1 / 2	Bonn, Belderberg	43	0.46
1 / 2	Brühl	48	0.65
1 / 2	Teddington	81	0.33
1 / 2	Cologne, parking lot, 2011	71	0.52
1 / 2	Bornheim	60	0.65
1 / 2	All test sites	332	0.71

Table 51: Between-RM uncertainty $u_{bs,RM}$ for PM_{10}

Reference instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,RM}$**
No.			µg/m³
1 / 2	Cologne, parking lot, 2007	102	1.12
1 / 2	Bonn, Belderberg	65	0.53
1 / 2	Brühl	58	0.77
1 / 2	Teddington	81	0.45
1 / 2	Cologne, parking lot, 2011	73	0.59
1 / 2	Bornheim	59	0.63
1 / 2	All test sites	423	0.75

At all sites, between-RM uncertainty $u_{bs,RM}$ was < 2.0 µg/m³.

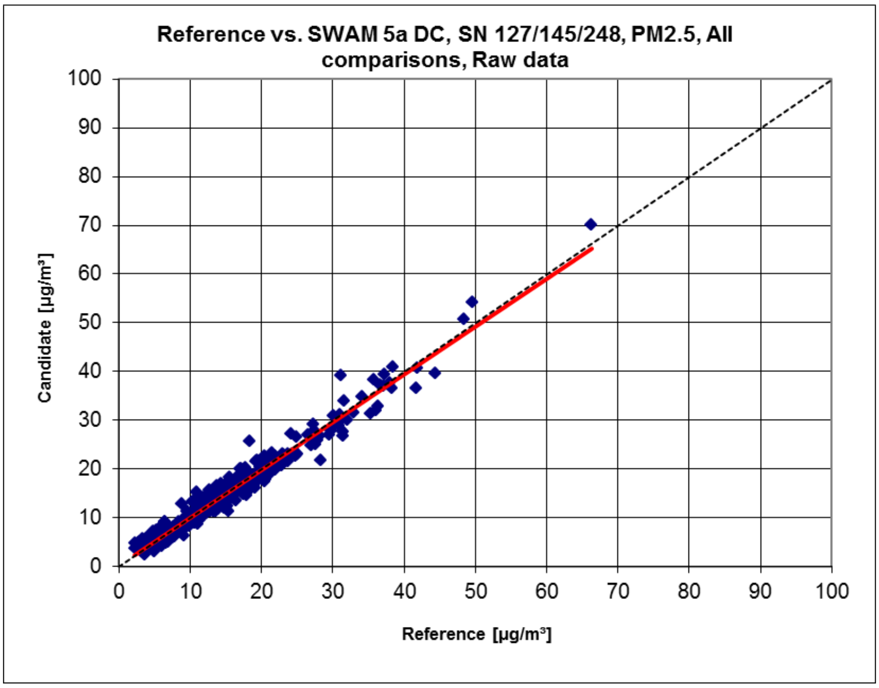


Figure 73: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component $PM_{2.5}$, all sites

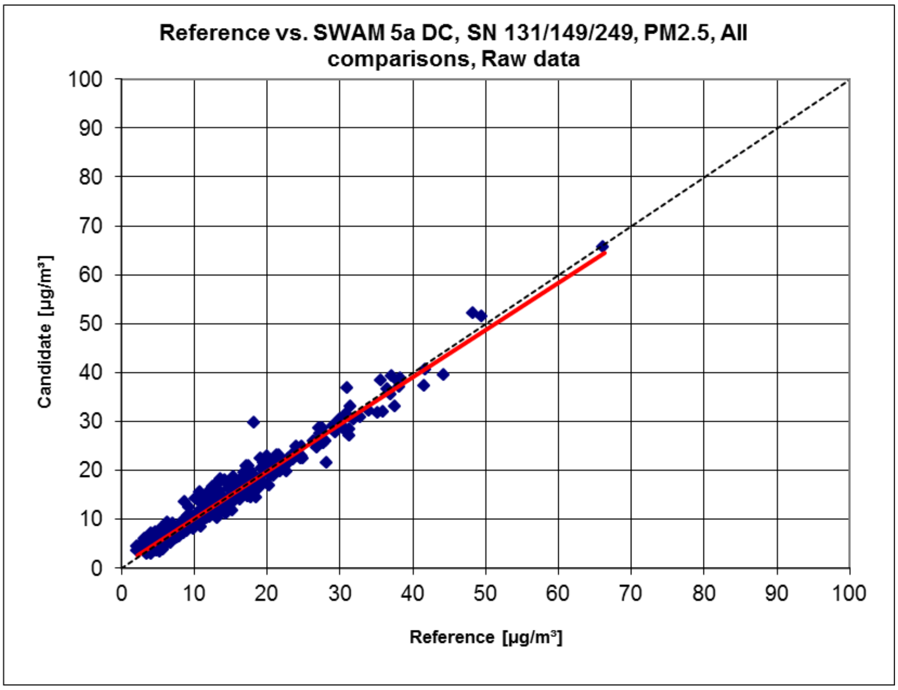


Figure 74: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component $PM_{2.5}$, all sites

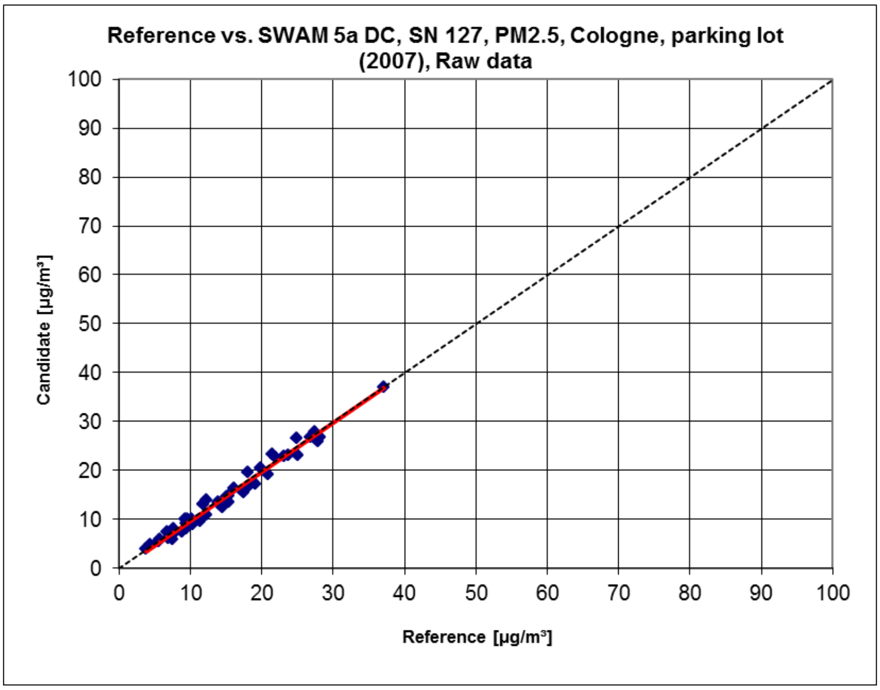


Figure 75: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Cologne, parking lot (2007)

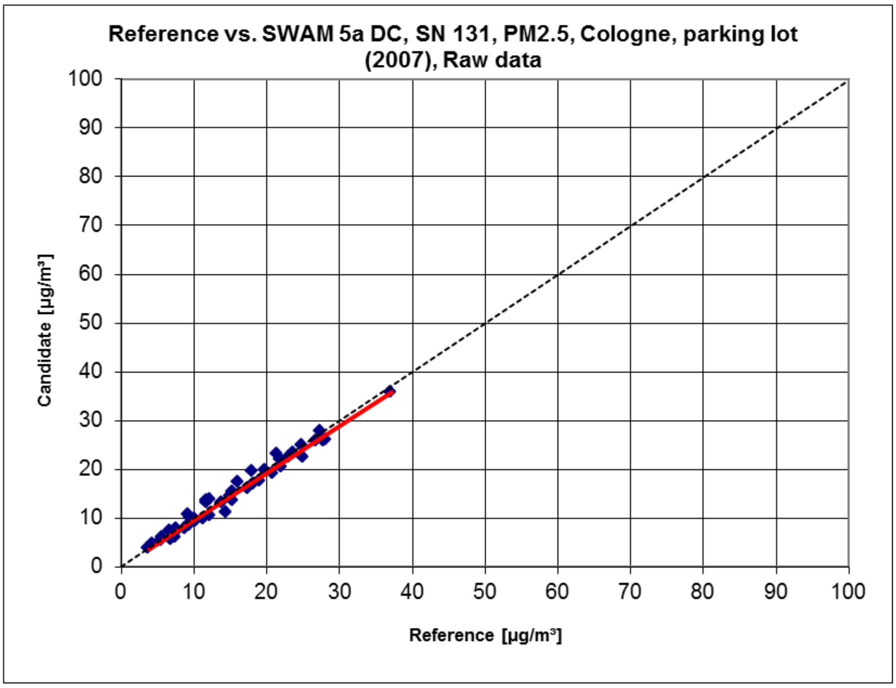


Figure 76: Reference Vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Cologne, parking lot (2007)

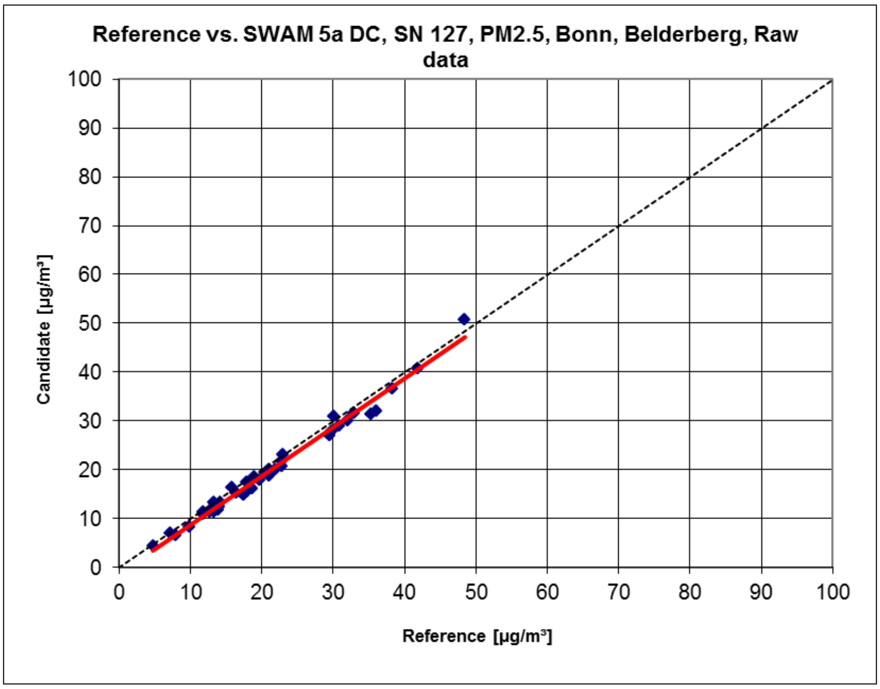


Figure 77: Reference Vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Bonn, Belderberg

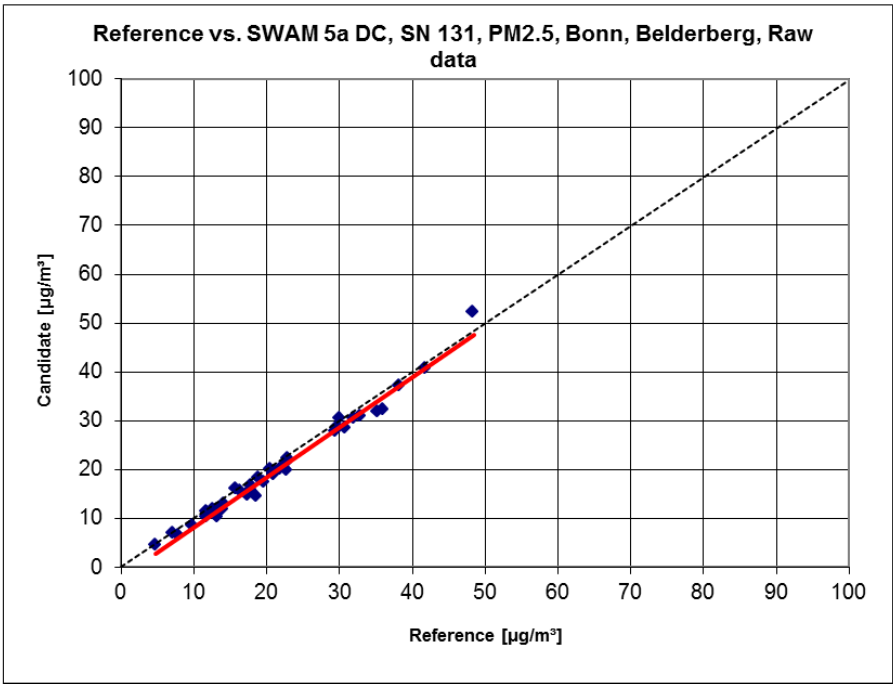


Figure 78: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Bonn, Belderberg

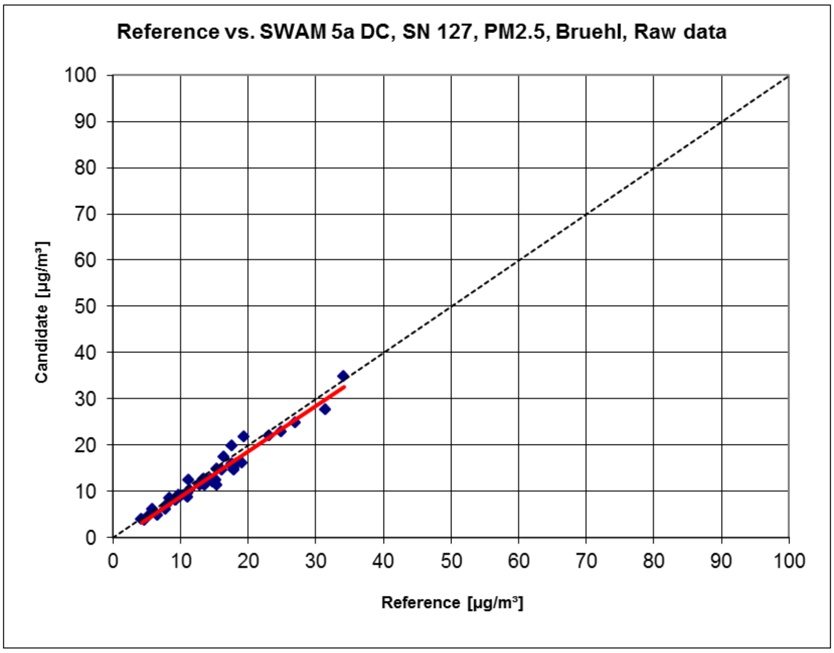


Figure 79: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Brühl

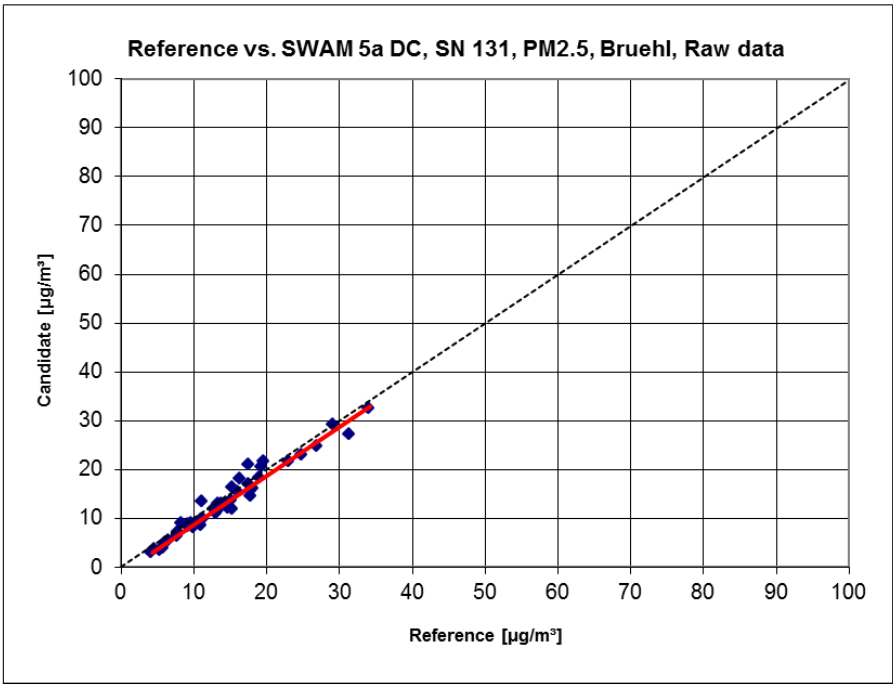


Figure 80: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Brühl

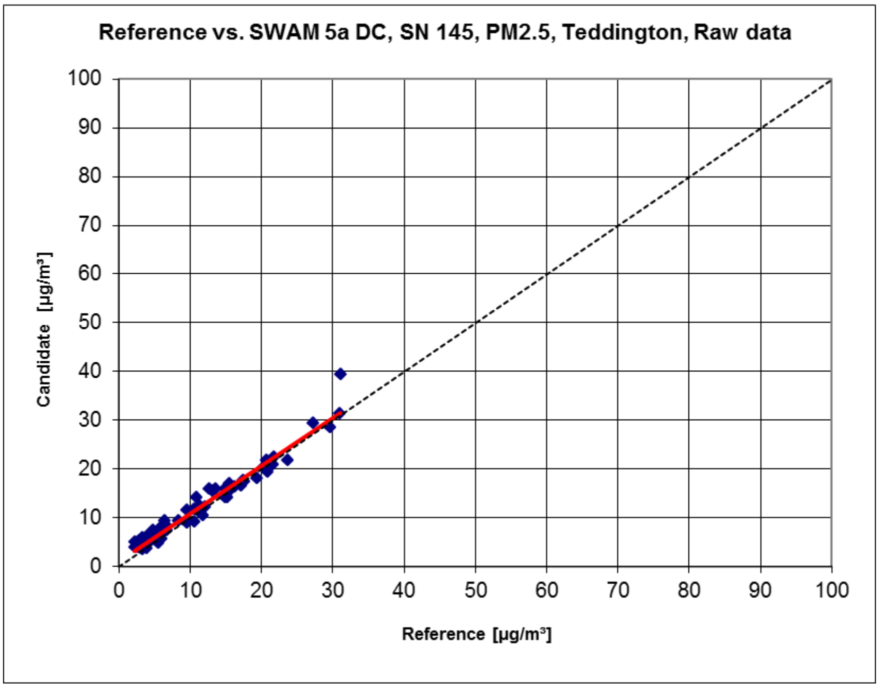


Figure 81: Reference vs. candidate system, SWAM 5a DC, SN 145, component $PM_{2.5}$, Teddington

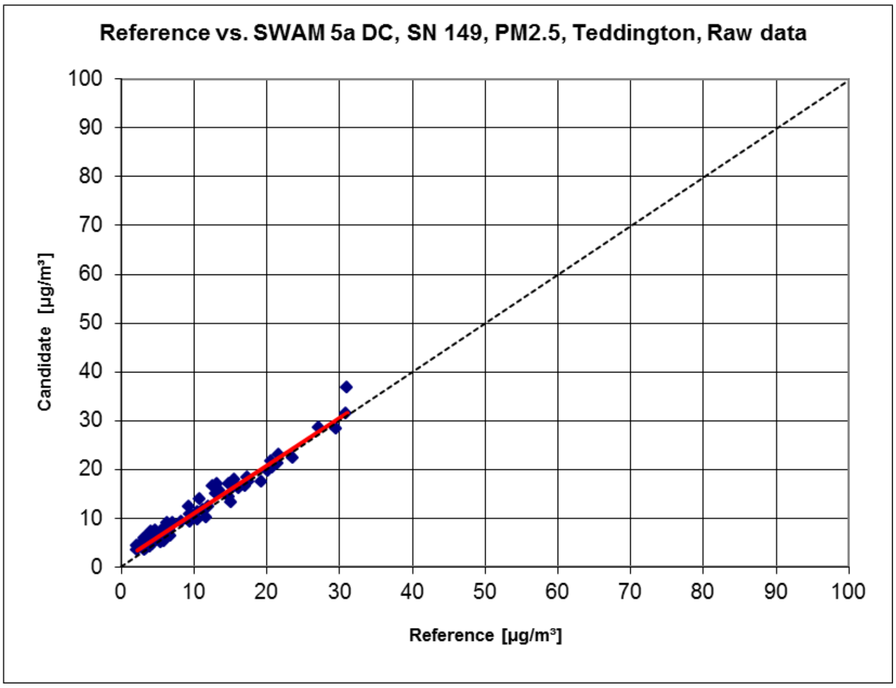


Figure 82: Reference vs. candidate system, SWAM 5a DC, SN 149, component $PM_{2.5}$, Teddington

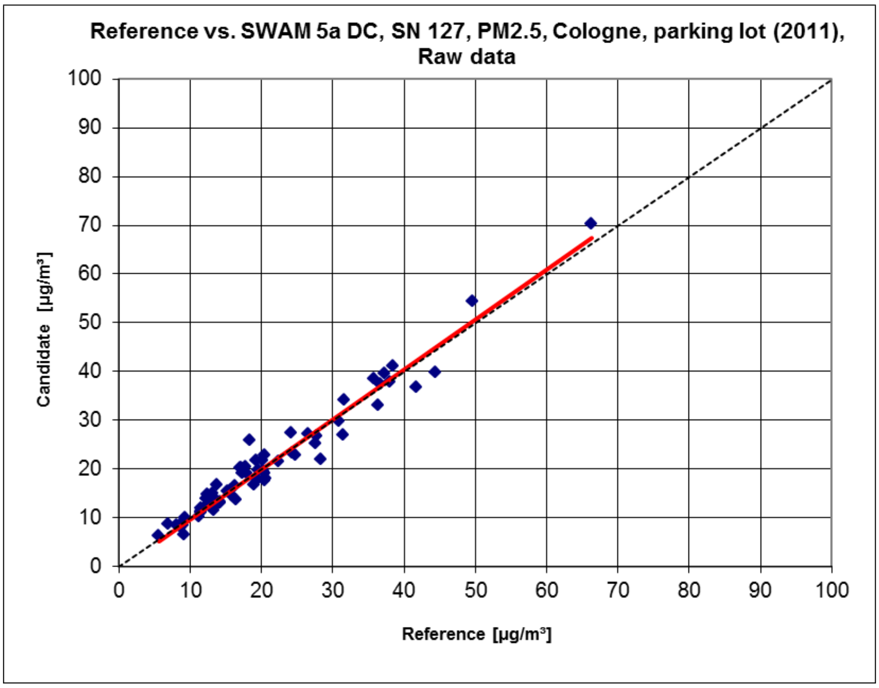


Figure 83: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Cologne, parking lot (2011)

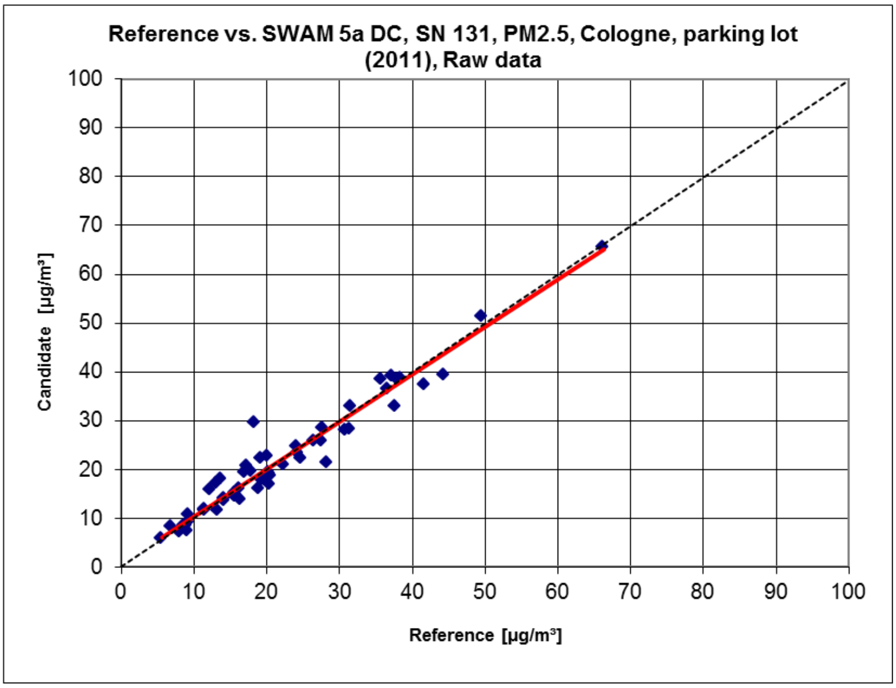


Figure 84: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Cologne, parking lot (2011)

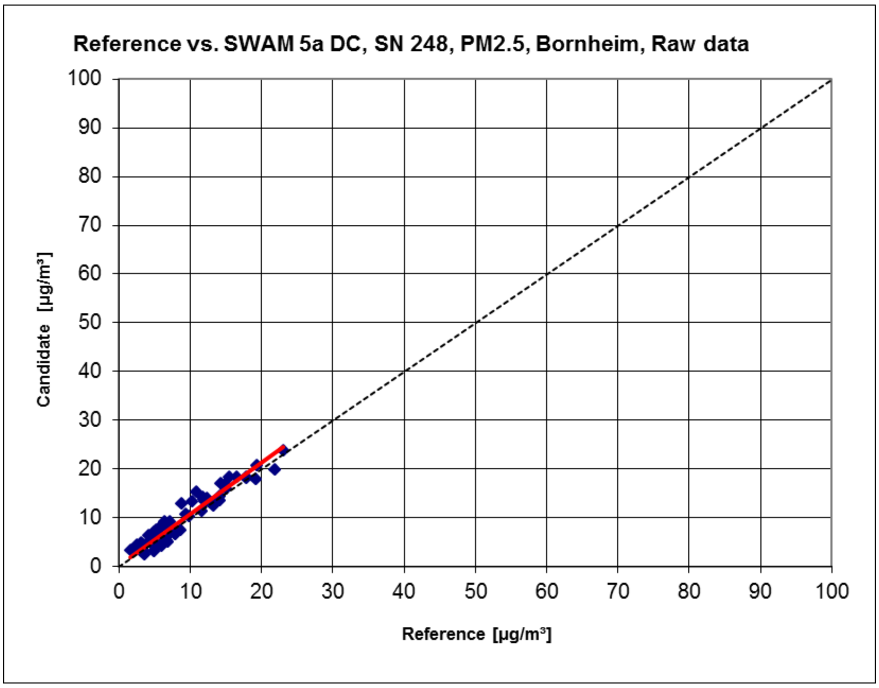


Figure 85: Reference vs. candidate system, SWAM 5a DC, SN 248, component $PM_{2.5}$, Bornheim

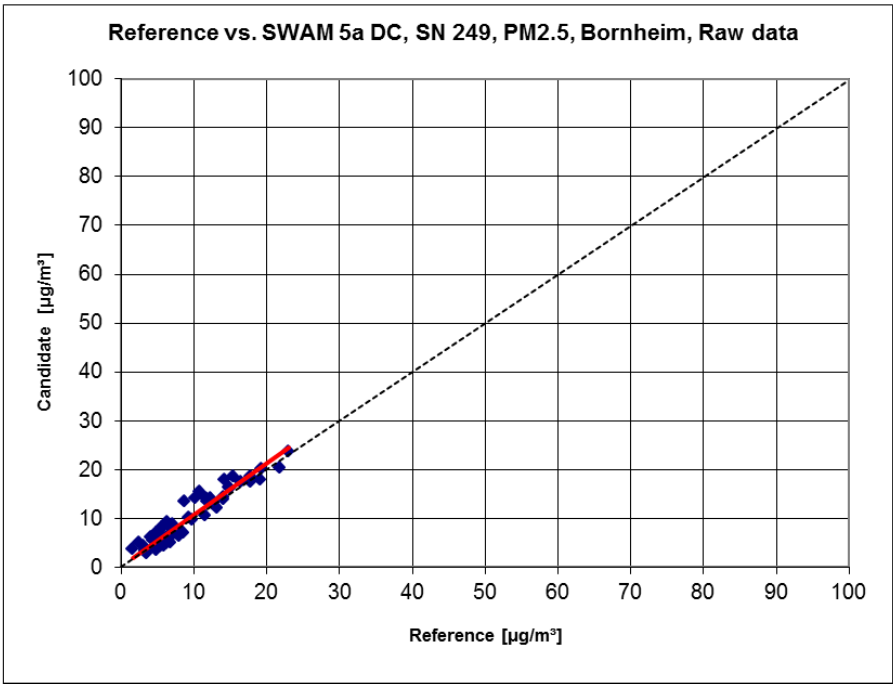


Figure 86: Reference vs. candidate system, SWAM 5a DC, SN 249, component $PM_{2.5}$, Bornheim

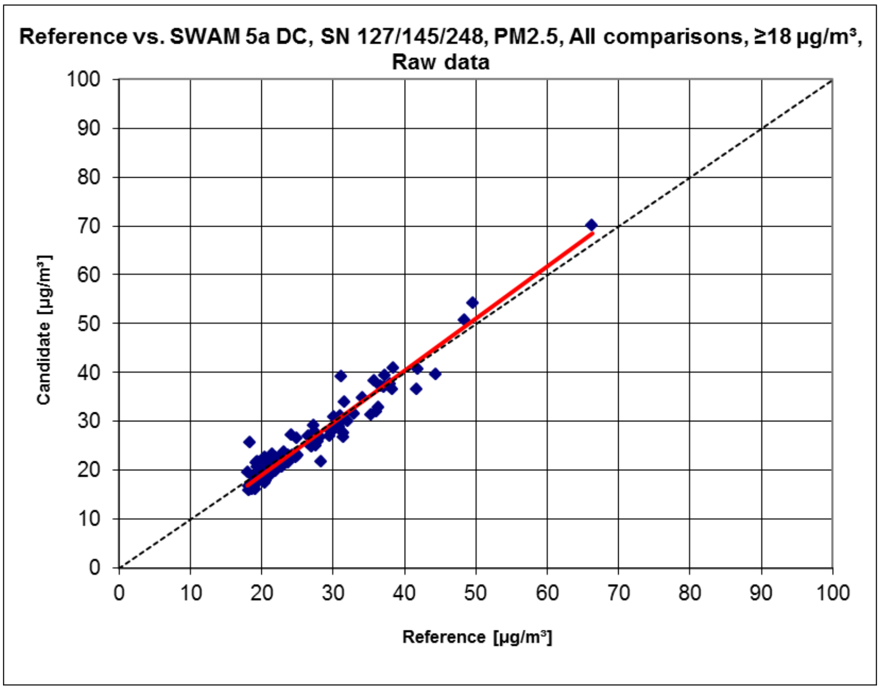


Figure 87: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component $PM_{2.5}$, values ≥ 18 µg/m³

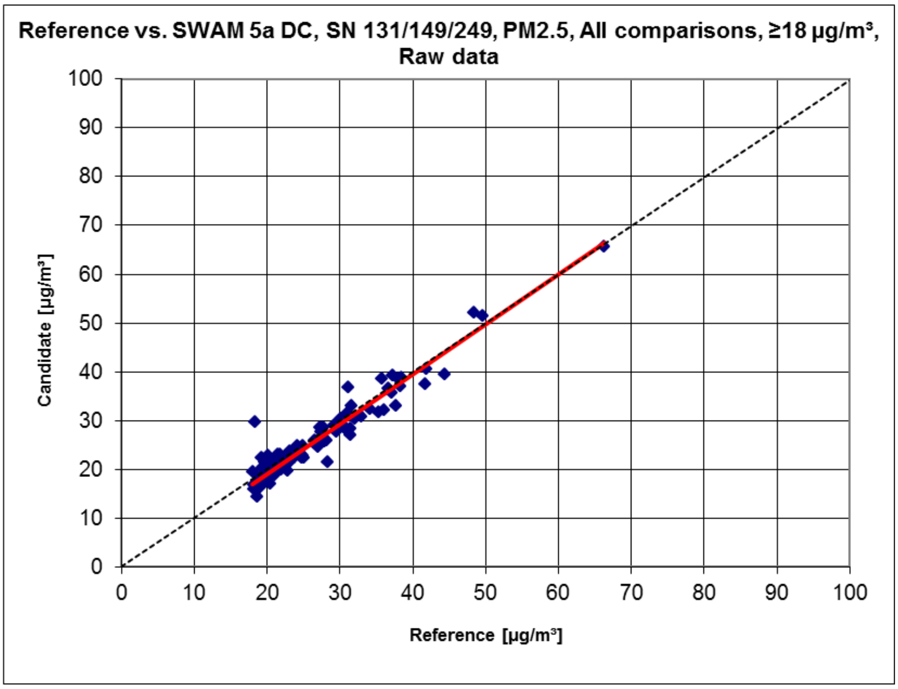


Figure 88: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component $PM_{2.5}$, values ≥ 18 µg/m³

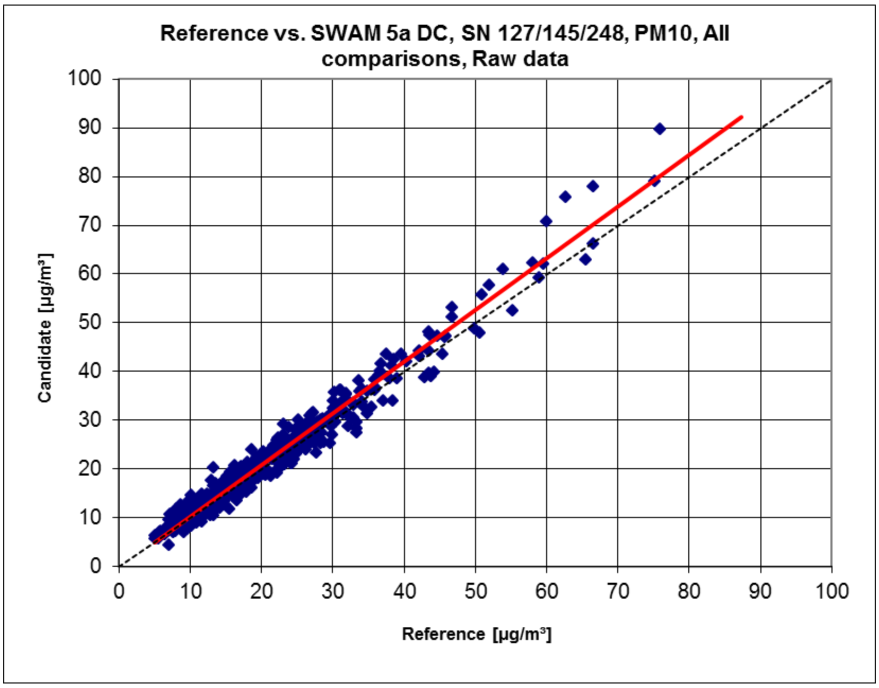


Figure 89: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component PM_{10}, all sites

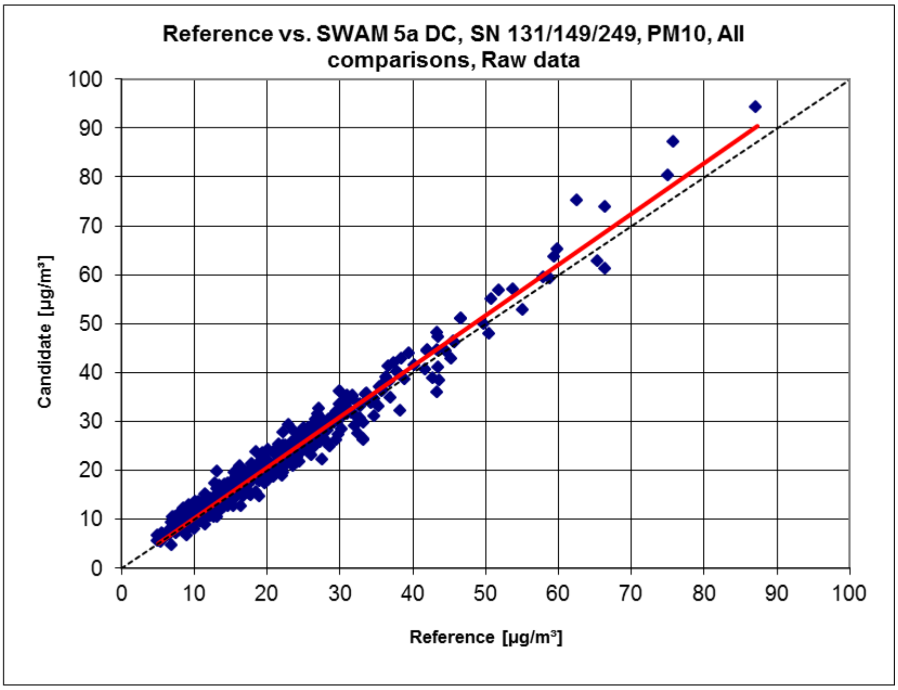


Figure 90: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component PM_{10}, all sites

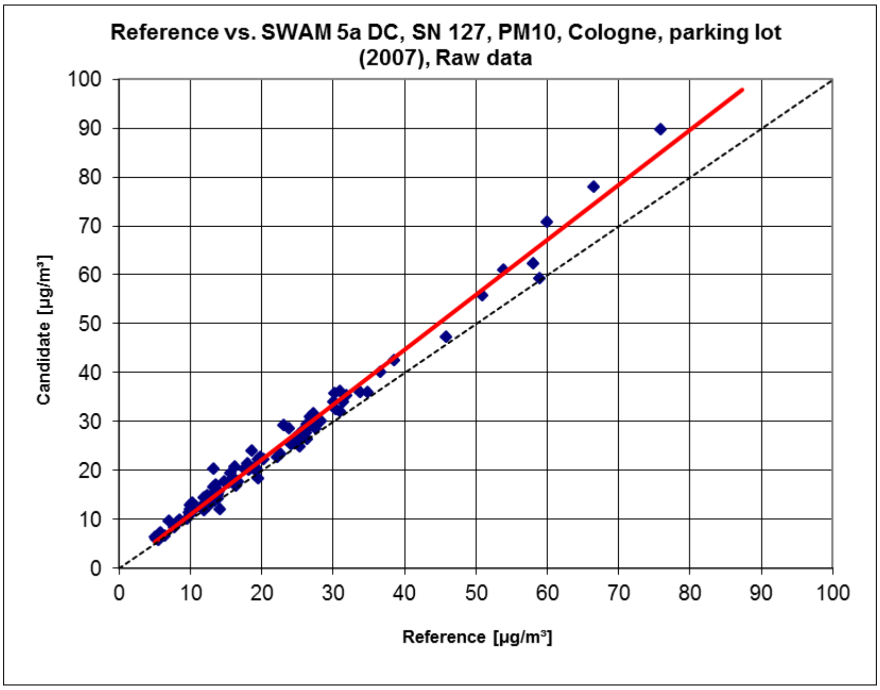


Figure 91: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Cologne, parking lot (2007)

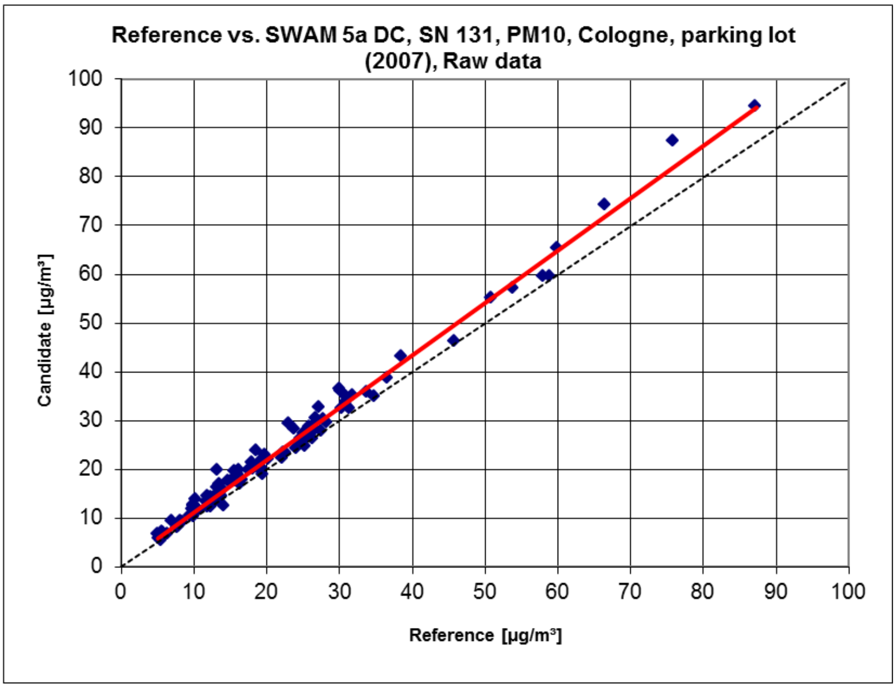


Figure 92: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Cologne, parking lot (2007)

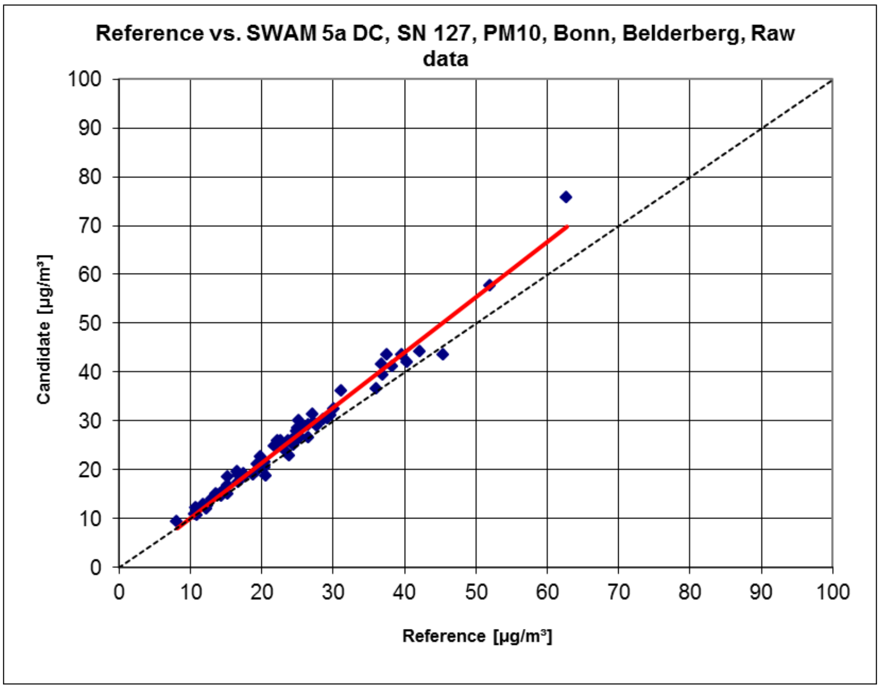


Figure 93: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Bonn, Belderberg

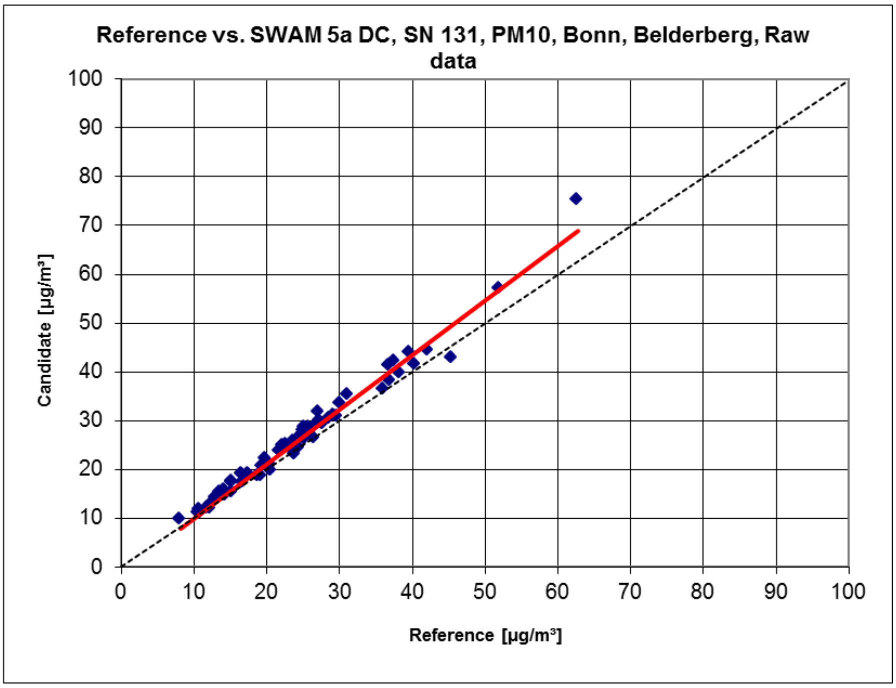


Figure 94: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Bonn, Belderberg

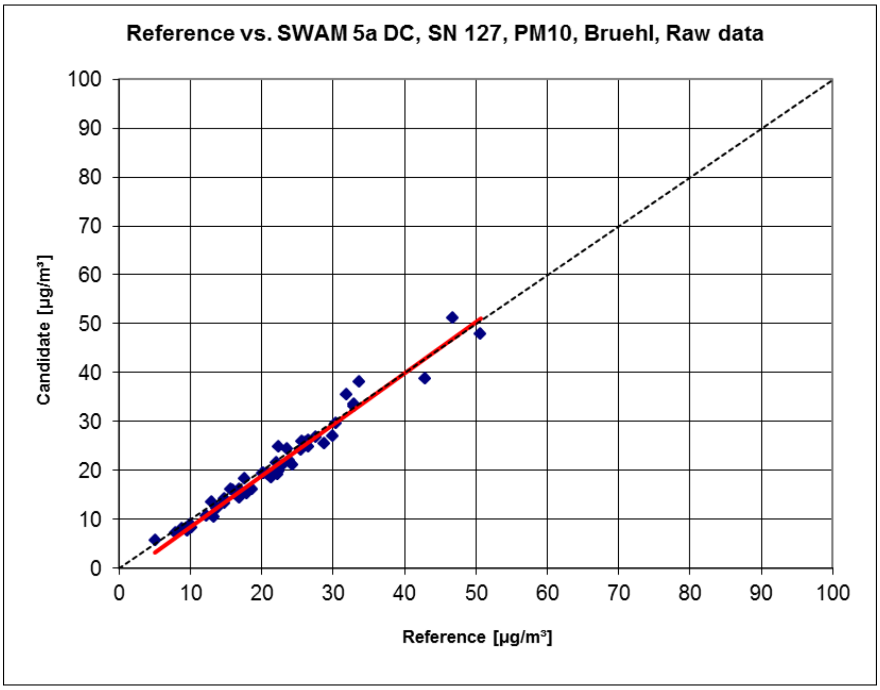


Figure 95: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Brühl

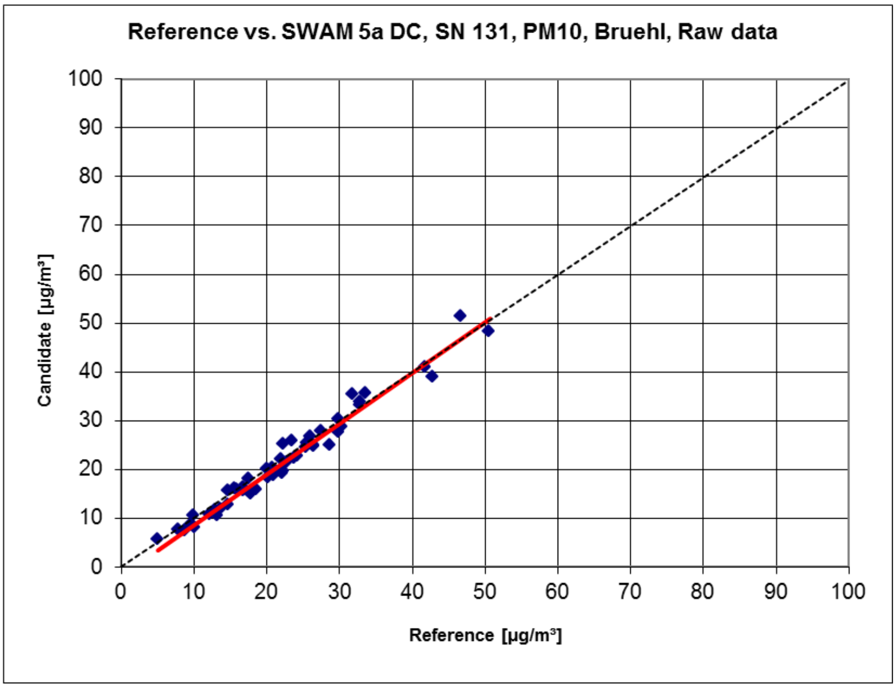


Figure 96: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Brühl

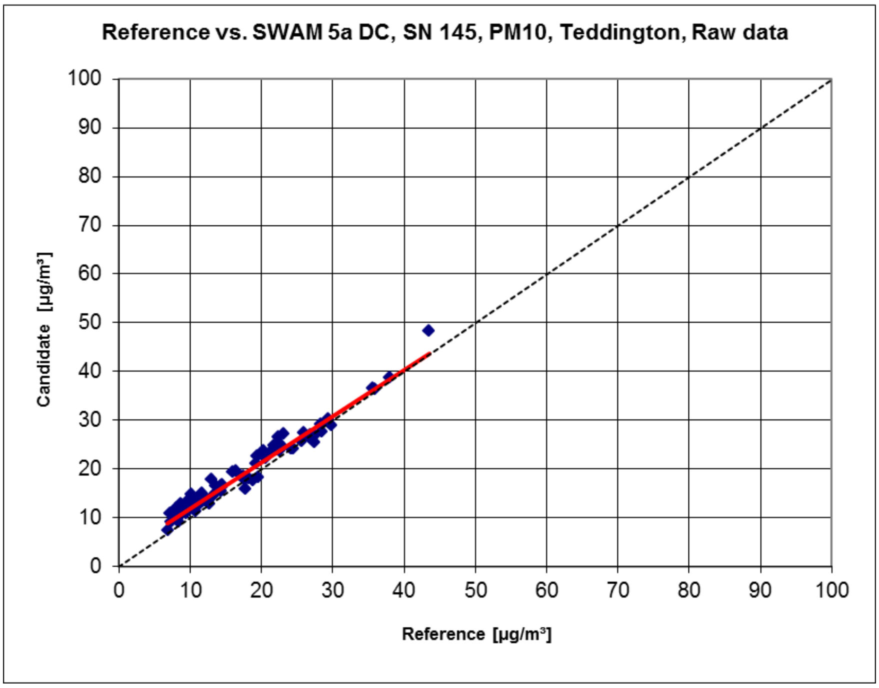


Figure 97: Reference vs. candidate system, SWAM 5a DC, SN 145, component PM_{10}, Teddington

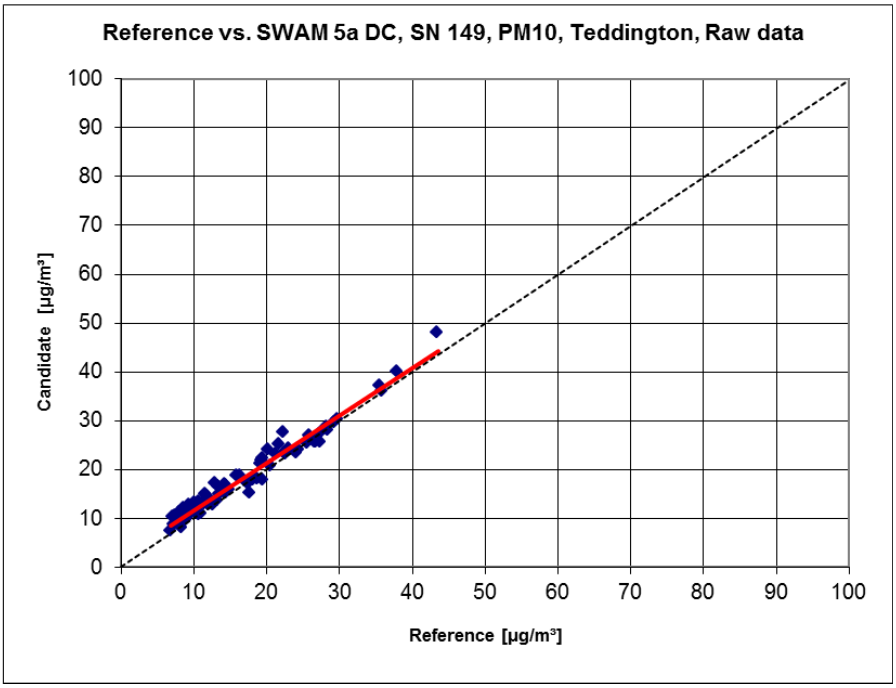


Figure 98: Reference vs. candidate system, SWAM 5a DC, SN 149, component PM_{10}, Teddington

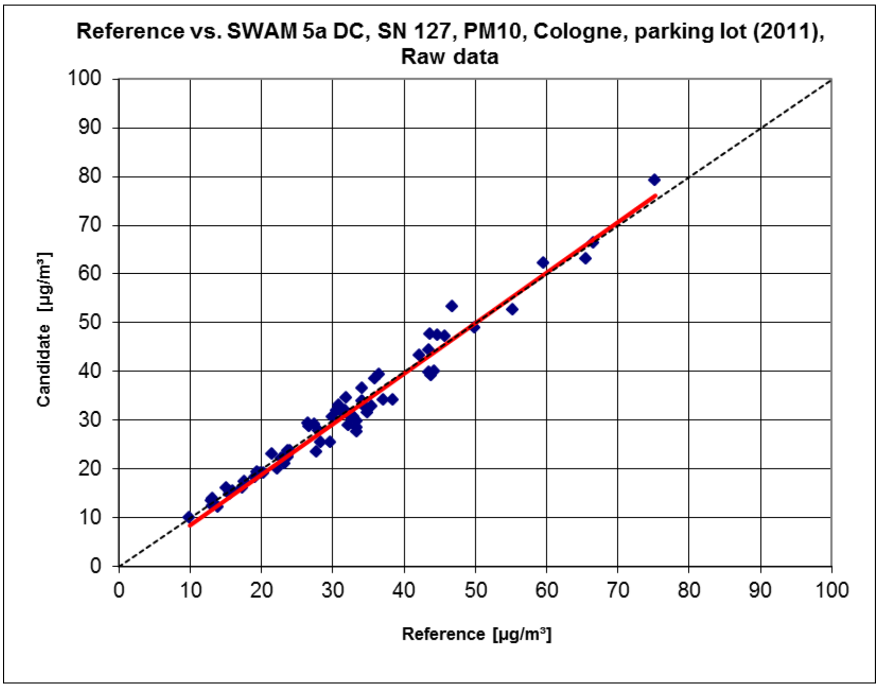


Figure 99: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Cologne, parking lot (2011)

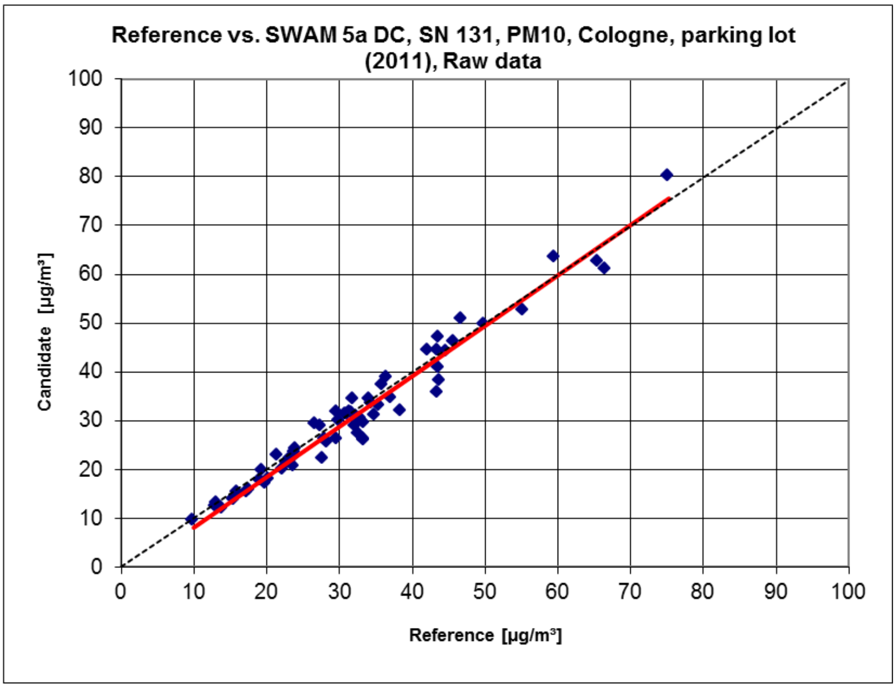


Figure 100: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Cologne, parking lot (2011)

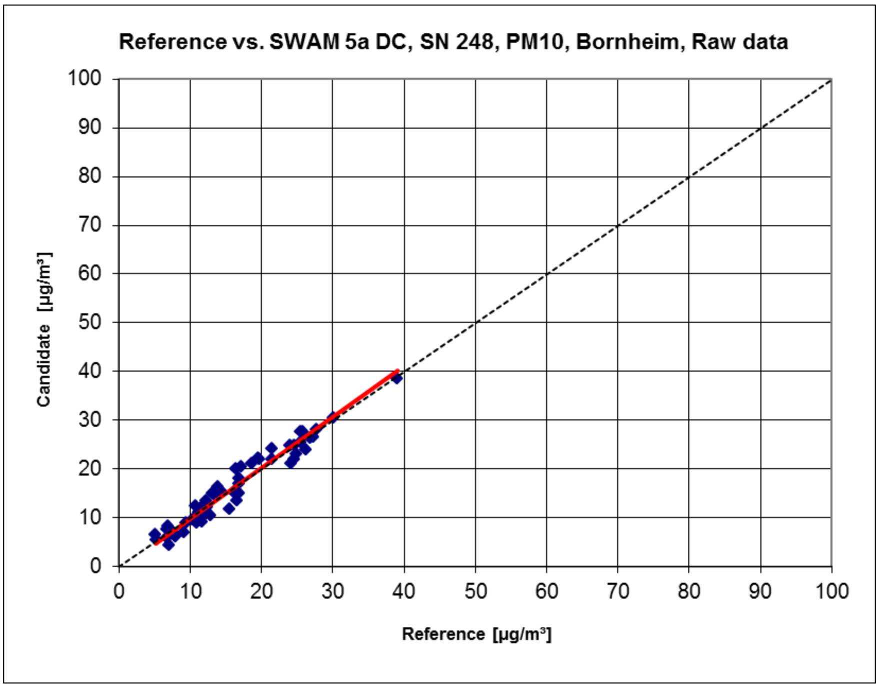


Figure 101: Reference vs. candidate system, SWAM 5a DC, SN 248, component PM_{10}, Bornheim

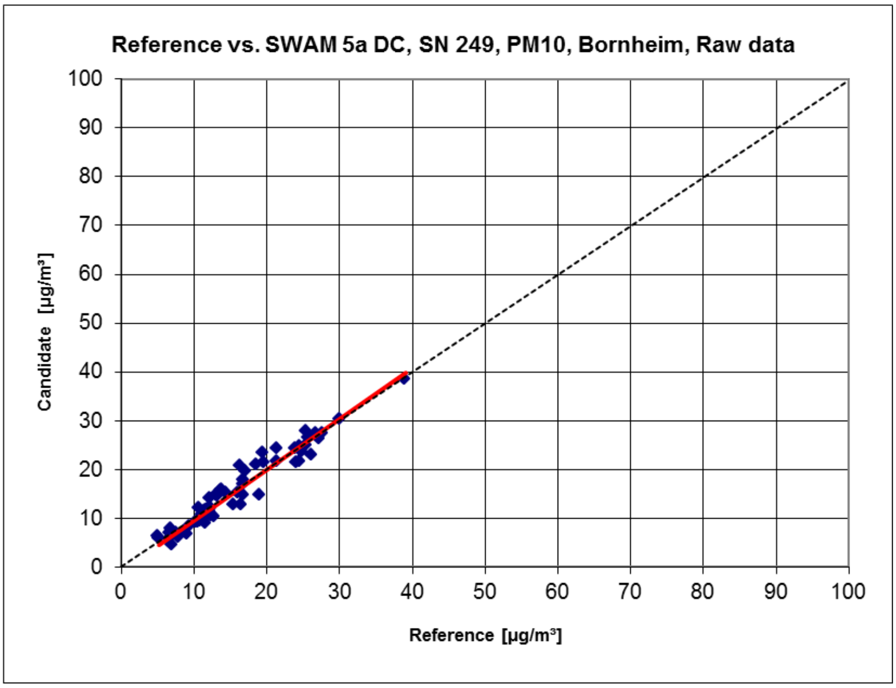


Figure 102: Reference vs. candidate system, SWAM 5a DC, SN 249, component PM_{10}, Bornheim

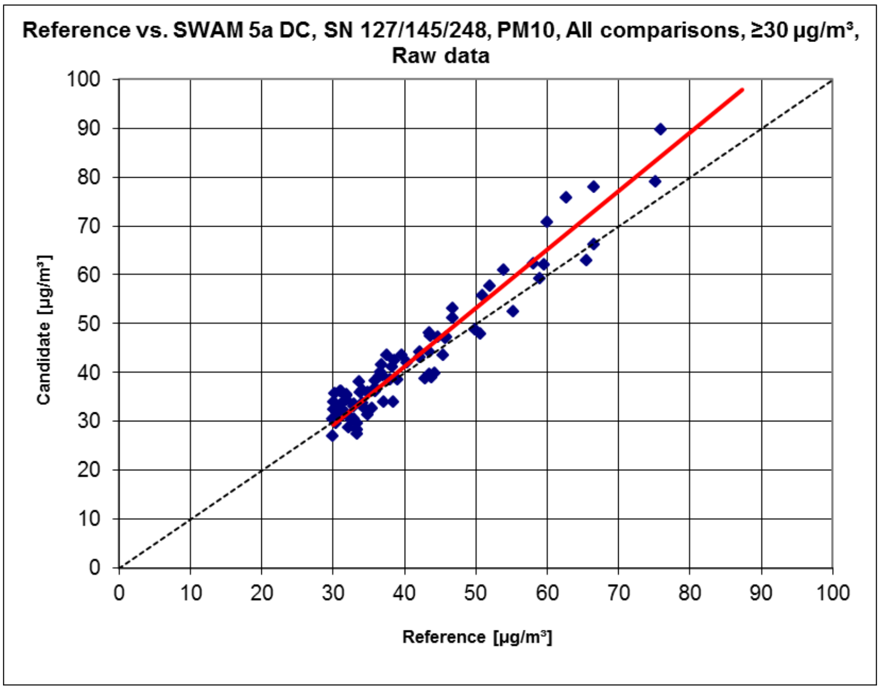


Figure 103: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component PM_{10}, values ≥ 30 µg/m³

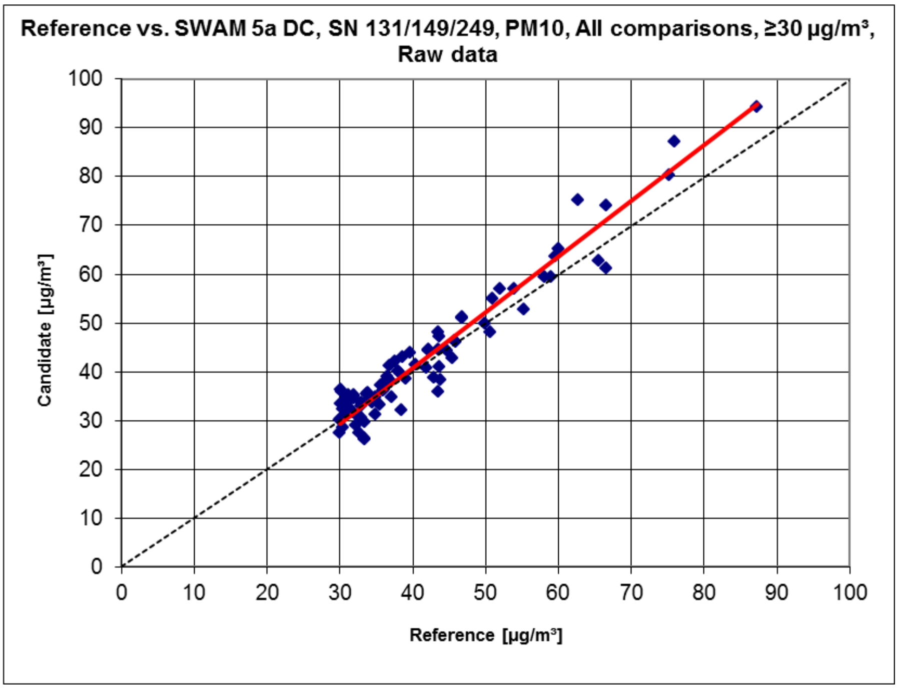


Figure 104: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component PM_{10}, values ≥ 30 µg/m³

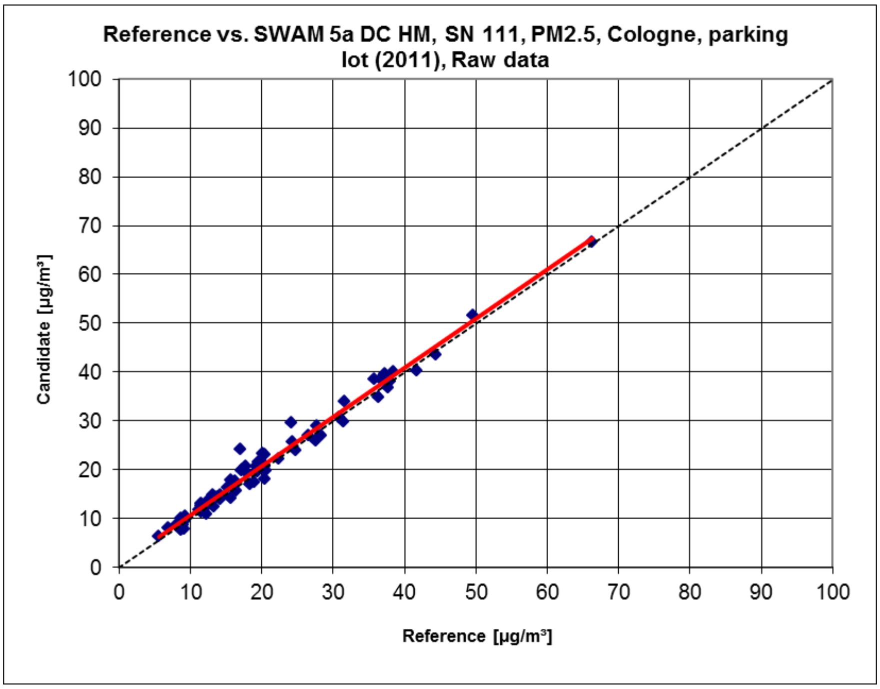


Figure 105: Reference vs. candidate system, SWAM 5a DC HM, SN 111, component $PM_{2.5}$, Cologne, parking lot (2011)

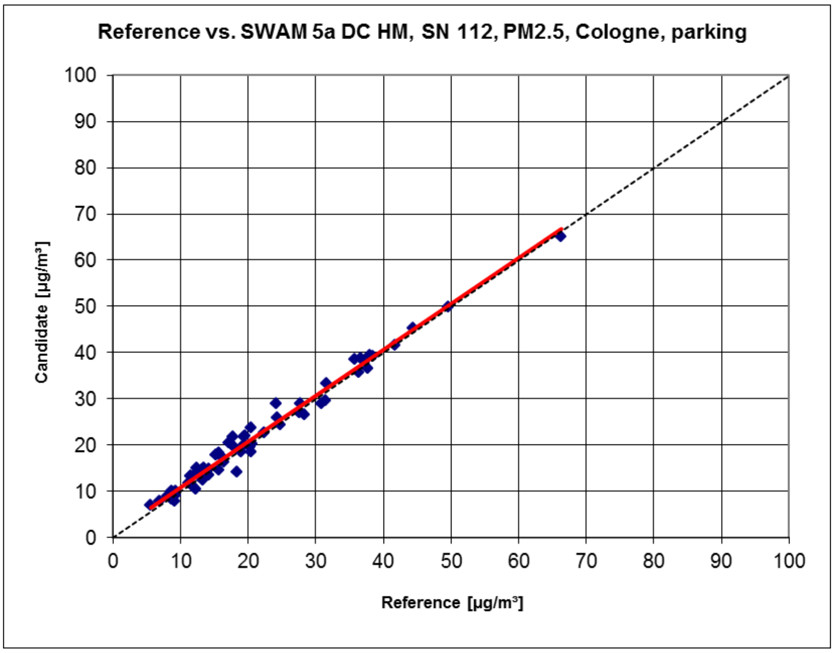


Figure 106: Reference vs. candidate system, SWAM 5a DC HM, SN 112, component $PM_{2.5}$, Cologne, parking lot (2011)

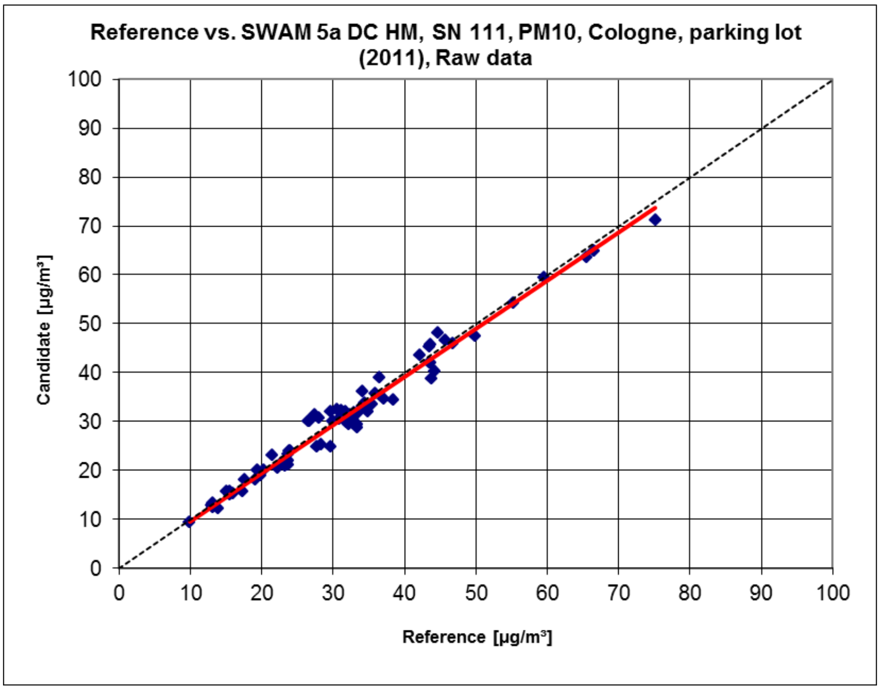


Figure 107: Reference Vs. candidate system, SWAM 5a DC HM, SN 111, component PM_{10}, Cologne, parking lot (2011)

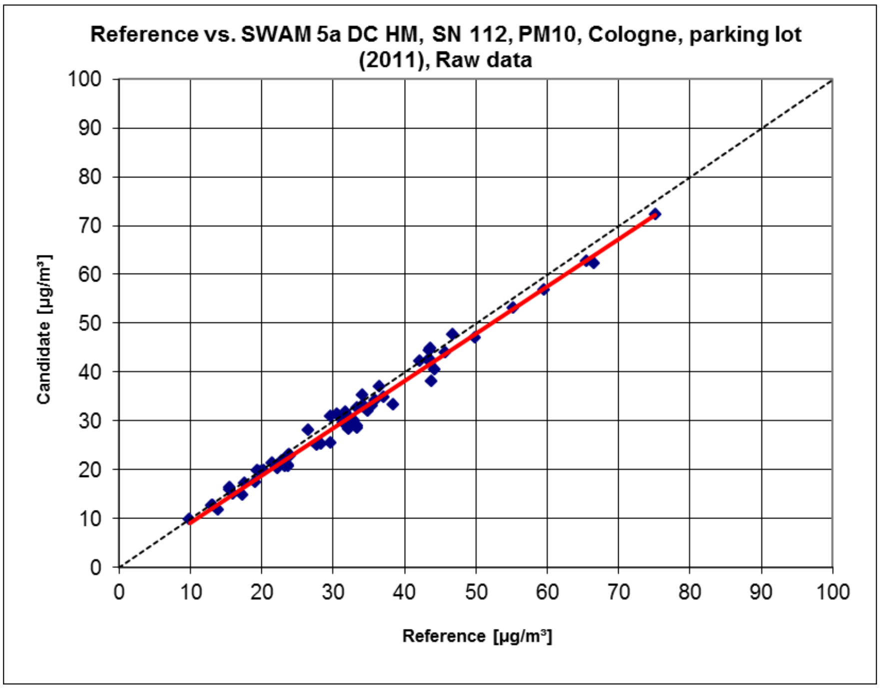


Figure 108: Reference vs. candidate system, SWAM 5a DC HM, SN 112, component PM_{10}, Cologne, parking lot (2011)

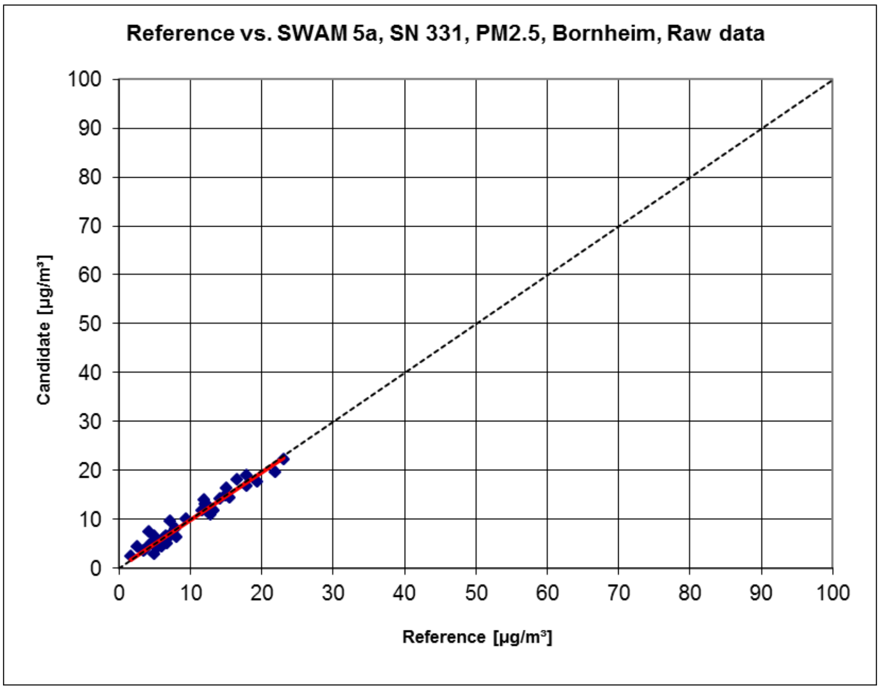


Figure 109: Reference vs. candidate system, SWAM 5a, SN 331, component $PM_{2.5}$, Bornheim

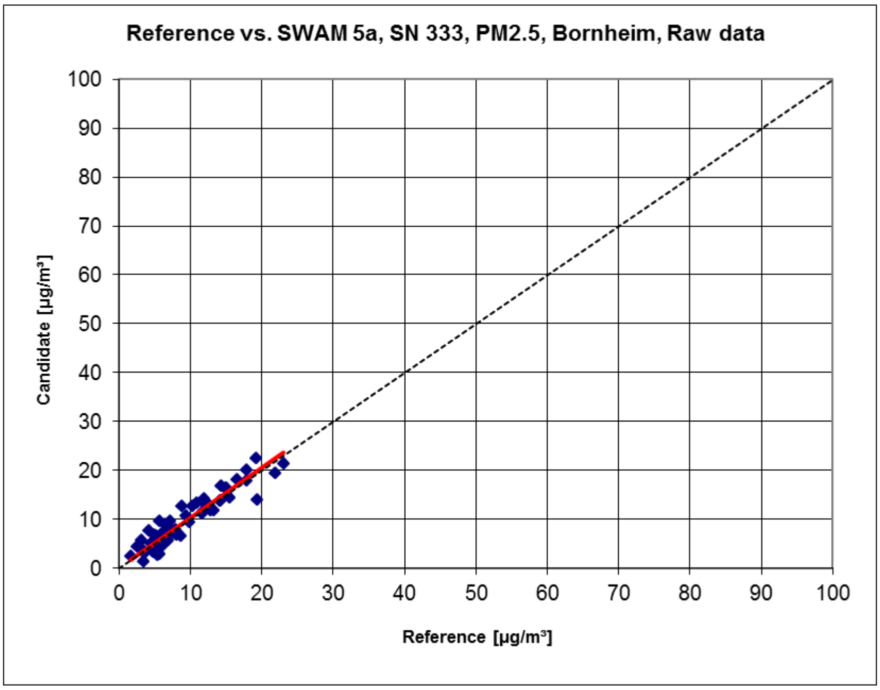


Figure 110: Reference vs. candidate system, SWAM 5a, SN 333, component $PM_{2.5}$, Bornheim

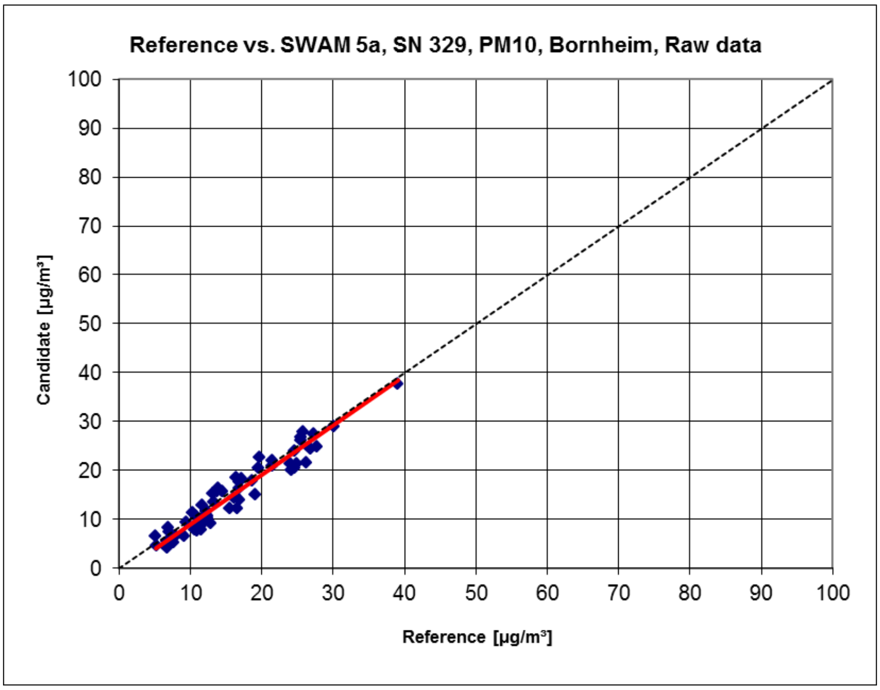


Figure 111: Reference vs. candidate system, SWAM 5a, SN 329, component PM_{10}, Bornheim

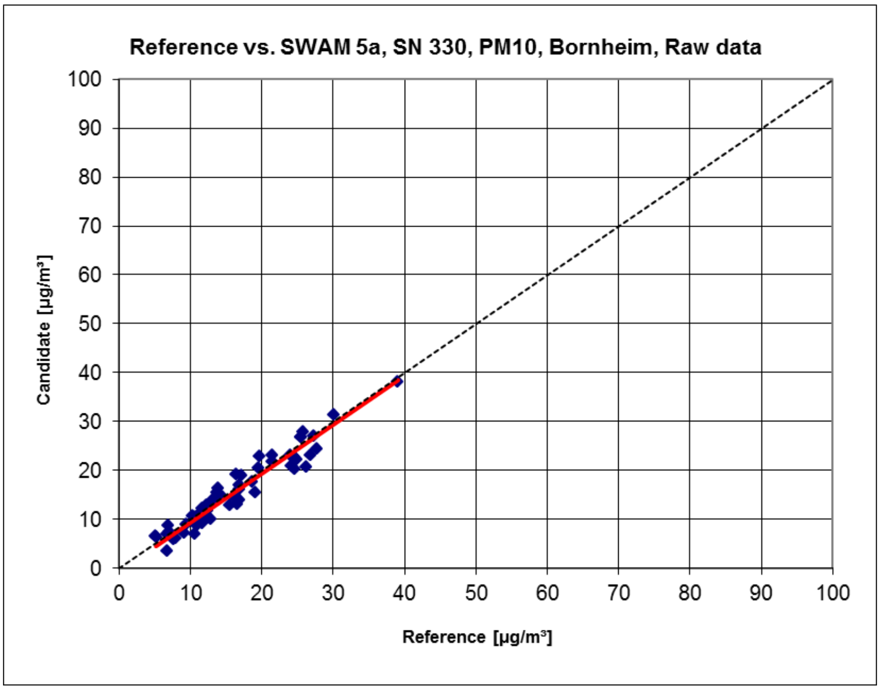


Figure 112: Reference vs. candidate system, SWAM 5a, SN 330, component PM_{10}, Bornheim

6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8)

Correction factors/terms (=calibration) shall be applied in the event the highest expanded uncertainty calculated for the tested instruments exceeds the relative expanded uncertainty specified under requirements for data quality or the test demonstrates that the slope is significantly different from 1 and/or the ordinate intercept is significantly different from 0.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

See item 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

6.4 Evaluation

If it emerges from the evaluation of raw data in accordance with 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8) that $W_{AMS} > W_{dqo}$, i.e. the tested instrument is not found to be equivalent with the reference method, then it is permissible to use a correction factor or term which results from the regression equation for <u>the full data set</u>. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

a) Slope be is not significantly different from 1: $|b-1| \leq 2u(b)$

   Ordinate intercept a is significantly different from 0: $|a| > 2u(a)$

b) Slope be is significantly different from 1: $|b-1| > 2u(b)$

   Ordinate intercept a is not significantly different from 0: $|a| \leq 2u(a)$

b) Slope be is significantly different from 1: $|b-1| > 2u(b)$

   Ordinate intercept a is significantly different from 0: $|a| > 2u(a)$

concerning a)

The value of the ordinate intercept a may be used as a correction term to correct all input values y_i according to the following equation:

$$y_{i,corr} = y_i - a$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{yi,corr} = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + u^2(a)$$

where u(a) = uncertainty of the ordinate intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating ordinate intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

concerning b)

The value of the slope b may be used as a correction term to correct all input values y_i according to the following equation:

$$y_{i,corr} = \frac{y_i}{b}$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{yi,corr} = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + L^2u^2(b)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating ordinate intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

concerning c)

The values of the slope b and the ordinate intercept a may be used as a correction terms to correct all input values y_i according to the following equation:

$$y_{i,corr} = \frac{y_i - a}{b}$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}^{\;2} + [c + (d-1)L]^2 + L^2 u^2(b) + u^2(a)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$ and u(a) = uncertainty of the original ordinate intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating ordinate intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

The values for $u_{c\_s,corr}$ are then used to calculate the combined relative uncertainty of the AMS after correction in accordance with the following equation:

$$w_{AMS,corr}^2 = \frac{u_{corr,yi=L}^2}{L^2}$$

The uncertainty $w_{AMS,corr}$ for the corrected data set is calculated at the 24h limit value using y_i as concentration at the limit value.

The relative expanded uncertainty $W_{AMS,corr}$ is calculated using the following equation:

$$W_{AMS',corr} = k \cdot w_{AMS,corr}$$

In practice, k is specified at k=2 for large n.

The largest resulting uncertainty $W_{AMS,corr}$ is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

1. $W_{AMS,corr} \leq W_{dqo}$ → The candidate system is deemed equivalent to the reference method.

2. $W_{AMS,corr} > W_{dqo}$ → The candidate system is not deemed equivalent to the reference method.

The expanded relative uncertainty W_{dqo} specified is 25% [8].

6.5 Assessment

Even without the need for any correction factors, the expanded uncertainties W_{AMS} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. After applying correction factors for instrument version SWAM 5a Dual Channel Monitor, the candidate systems continue to meet the requirements for data quality for ambient air monitoring for all data sets. A minor deterioration of the expanded uncertainty for the $PM_{2.5}$ data set was observed. However, a considerable improvement of the expanded uncertainty for the PM_{10} data set was observed at the same time.

Criterion satisfied? yes

The evaluation of the full data set resulted in a significant slope and intercept for $PM_{2.5}$ and a significant intercept for PM_{10}.

For $PM_{2.5}$:

The slope for the entire data set is 0.973. The intercept for the full data set is 0.355 (see Table 44)

For PM_{10}:

The slope for the entire data set is 1.051. The intercept for the full data set is -0.271 (see Table 45)

For the component $PM_{2.5}$, the full data set was corrected in terms of the slope and intercept. All data sets were re-evaluated using the corrected values.

For the component PM_{10}, the full data set was corrected in terms of the slope. All data sets were re-evaluated using the corrected values.

After applying the correction, all datasets comply with the requirements for data quality and measurement uncertainty improved considerably for some sites, especially for PM_{10}. As a result of the correction term applied, total uncertainty deteriorated slightly for $PM_{2.5}$.

When a measuring system is operated in the context of a measurement grid, the January 2010 version of the Guide and standard EN 16450 require that the instruments are tested annually at a number of sites which in turn depends on the highest's expanded uncertainty determined during equivalence testing. The criterion used for specifying the number of sites for annual testing is grouped into 5% steps (Guide [4], Chapter 9.9.2, Table 6 and/or EN 16450 [9], Chapter 8.6.2, Table 5). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ both before and after applying the correction was in the range between 10–15% The highest expanded uncertainty determined for PM_{10} after the correction was < 10%, before the correction it was in the range of 10–15%.

The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. TÜV Rheinland recommends the use of the expanded uncertainty of the full data set for this purpose: 11.98% ($PM_{2.5}$ uncorrected data set) and 12.16% ($PM_{2.5}$ data set after correcting slope/intercept). This would imply annual tests at 3 sites (corrected and uncorrected); 12.90% (PM_{10} uncorrected data set) and 8.85% (PM_{10} data set after correction of the slope). this would imply annual tests at 3 (uncorrected) or 2 (corrected) sites.

6.6 Detailed presentation of test results

Table 52 and Table 53 show the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 52: Summary of results for equivalence testing, SWAM 5a DC, component $PM_{2.5}$ after correction of slope/intercept

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	SN 127/145/248 & 131/149/249	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**312**				
Slope b	**1.001**	**not significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**-0.007**	**not significant**			
Uncertainty of a	**0.189**				
Expanded meas. uncertainty W_{CM}	**12.16**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.64**	**µg/m³**			
Uncertainty between Candidates	**0.79**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**91**				
Slope b	**1.051**				
Uncertainty of b	**0.029**				
Ordinate intercept a	**-2.028**				
Uncertainty of a	**0.804**				
Expanded meas. uncertainty W_{CM}	**15.45**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**221**				
Slope b	**0.959**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.606**				
Uncertainty of a	**0.237**				
Expanded meas. uncertainty W_{CM}	**10.78**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	SN 127/145/248 & 131/149/249	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
Cologne, parking lot (2007)					
Uncertainty between Reference	**0.67**	**µg/m³**			
Uncertainty between Candidates	**0.71**	**µg/m³**			
	SN 127			**SN 131**	
Number of data pairs	**45**			**46**	
Slope b	**1.029**			**0.995**	
Uncertainty of b	**0.023**			**0.023**	
Ordinate intercept a	**-0.653**			**-0.372**	
Uncertainty of a	**0.393**			**0.391**	
Expanded meas. uncertainty W_{CM}	**7.23**	**%**		**7.90**	**%**
Bonn, Belderberg					
Uncertainty between Reference	**0.46**	**µg/m³**			
Uncertainty between Candidates	**0.44**	**µg/m³**			
	SN 127			**SN 131**	
Number of data pairs	**41**			**41**	
Slope b	**1.025**			**1.052**	
Uncertainty of b	**0.020**			**0.022**	
Ordinate intercept a	**-1.611**			**-2.437**	
Uncertainty of a	**0.456**			**0.504**	
Expanded meas. uncertainty W_{CM}	**9.94**	**%**		**10.68**	**%**
Bruehl					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.65**	**µg/m³**			
	SN 127			**SN 131**	
Number of data pairs	**43**			**45**	
Slope b	**1.013**			**1.032**	
Uncertainty of b	**0.033**			**0.033**	
Ordinate intercept a	**-1.357**			**-1.595**	
Uncertainty of a	**0.509**			**0.534**	
Expanded meas. uncertainty W_{CM}	**10.83**	**%**		**10.51**	**%**
Teddington					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
	SN 145			**SN 149**	
Number of data pairs	**74**			**80**	
Slope b	**1.005**			**1.002**	
Uncertainty of b	**0.023**			**0.020**	
Ordinate intercept a	**0.801**			**1.020**	
Uncertainty of a	**0.290**			**0.252**	
Expanded meas. uncertainty W_{CM}	**11.94**	**%**		**11.62**	**%**
Cologne, parking lot (2011)					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**1.37**	**µg/m³**			
	SN 127			**SN 131**	
Number of data pairs	**67**			**53**	
Slope b	**1.053**			**1.000**	
Uncertainty of b	**0.027**			**0.032**	
Ordinate intercept a	**-0.904**			**0.277**	
Uncertainty of a	**0.634**			**0.824**	
Expanded meas. uncertainty W_{CM}	**17.18**	**%**		**19.17**	**%**
Bornheim					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.33**	**µg/m³**			
	SN 248			**SN 249**	
Number of data pairs	**57**			**60**	
Slope b	**1.084**			**1.094**	
Uncertainty of b	**0.041**			**0.043**	
Ordinate intercept a	**-0.213**			**-0.338**	
Uncertainty of a	**0.441**			**0.456**	
Expanded meas. uncertainty W_{CM}	**18.54**	**%**		**19.85**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.64**	**µg/m³**			
Uncertainty between Candidates	**0.79**	**µg/m³**			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	**95**			**95**	
Slope b	**1.067**			**1.023**	
Uncertainty of b	**0.029**			**0.029**	
Ordinate intercept a	**-2.358**			**-1.408**	
Uncertainty of a	**0.810**			**0.81**	
Expanded meas. uncertainty W_{CM}	**15.74**	**%**		**16.12**	**%**
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	**232**			**230**	
Slope b	**0.958**			**0.985**	
Uncertainty of b	**0.021**			**0.024**	
Ordinate intercept a	**0.593**			**0.413**	
Uncertainty of a	**0.226**			**0.252**	
Expanded meas. uncertainty W_{CM}	**10.49**	**%**		**10.93**	**%**
All comparisons					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 127/145/248			**SN 131/149/249**	
Number of data pairs	**327**			**325**	
Slope b	**1.009**	**not significant**		**0.991**	**not significant**
Uncertainty of b	**0.011**			**0.011**	
Ordinate intercept a	**-0.118**	**not significant**		**0.137**	**not significant**
Uncertainty of a	**0.187**			**0.193**	
Expanded meas. uncertainty W_{CM}	**12.19**	**%**		**12.77**	**%**

Table 53: Summary of results for equivalence testing, SWAM 5a DC, component PM_{10} after correction of slope

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	SWAM 5a DC		SN	SN 127/145/248 & 131/149/249	
			Limit value	50	µg/m³
Status of measured values	Slope corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.75**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**404**				
Slope b	**0.999**	**not significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**-0.240**	**not significant**			
Uncertainty of a	**0.228**				
Expanded meas. uncertainty W_{CM}	**8.85**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.78**	**µg/m³**			
Uncertainty between Candidates	**1.14**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**83**				
Slope b	**1.111**				
Uncertainty of b	**0.030**				
Ordinate intercept a	**-5.296**				
Uncertainty of a	**1.307**				
Expanded meas. uncertainty W_{CM}	**13.36**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.74**	**µg/m³**			
Uncertainty between Candidates	**0.43**	**µg/m³**			
	SN 127/145/248 & 131/149/249				
Number of data pairs	**321**				
Slope b	**0.962**				
Uncertainty of b	**0.015**				
Ordinate intercept a	**0.527**				
Uncertainty of a	**0.276**				
Expanded meas. uncertainty W_{CM}	**8.74**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010				
Candidate	SWAM 5a DC	SN	SN 127/145/248 & 131/149/249	
		Limit value	50	µg/m³
Status of measured values	Slope corrected	Allowed uncertainty	25	%
Cologne, parking lot (2007)				
Uncertainty between Reference	**1.12**	**µg/m³**		
Uncertainty between Candidates	**0.83**	**µg/m³**		
	SN 127		**SN 131**	
Number of data pairs	**98**		**100**	
Slope b	**1.070**		**1.021**	
Uncertainty of b	**0.012**		**0.011**	
Ordinate intercept a	**-0.306**		**0.394**	
Uncertainty of a	**0.321**		**0.295**	
Expanded meas. uncertainty W_{CM}	**14.16**	**%**	**7.77**	**%**
Bonn, Belderberg				
Uncertainty between Reference	**0.53**	**µg/m³**		
Uncertainty between Candidates	**0.43**	**µg/m³**		
	SN 127		**SN 131**	
Number of data pairs	**62**		**62**	
Slope b	**1.076**		**1.060**	
Uncertainty of b	**0.020**		**0.019**	
Ordinate intercept a	**-1.113**		**-0.986**	
Uncertainty of a	**0.542**		**0.513**	
Expanded meas. uncertainty W_{CM}	**12.64**	**%**	**10.25**	**%**
Bruehl				
Uncertainty between Reference	**0.77**	**µg/m³**		
Uncertainty between Candidates	**0.54**	**µg/m³**		
	SN 127		**SN 131**	
Number of data pairs	**51**		**53**	
Slope b	**0.996**		**0.985**	
Uncertainty of b	**0.026**		**0.024**	
Ordinate intercept a	**-1.815**		**-1.594**	
Uncertainty of a	**0.614**		**0.570**	
Expanded meas. uncertainty W_{CM}	**10.43**	**%**	**11.20**	**%**
Teddington				
Uncertainty between Reference	**0.45**	**µg/m³**		
Uncertainty between Candidates	**0.50**	**µg/m³**		
	SN 145		**SN 149**	
Number of data pairs	**73**		**79**	
Slope b	**0.901**		**0.921**	
Uncertainty of b	**0.020**		**0.020**	
Ordinate intercept a	**2.370**		**1.927**	
Uncertainty of a	**0.379**		**0.371**	
Expanded meas. uncertainty W_{CM}	**11.75**	**%**	**9.91**	**%**
Cologne, parking lot (2011)				
Uncertainty between Reference	**0.59**	**µg/m³**		
Uncertainty between Candidates	**0.83**	**µg/m³**		
	SN 127		**SN 131**	
Number of data pairs	**69**		**66**	
Slope b	**0.982**		**0.983**	
Uncertainty of b	**0.021**		**0.024**	
Ordinate intercept a	**-1.574**		**-1.966**	
Uncertainty of a	**0.728**		**0.836**	
Expanded meas. uncertainty W_{CM}	**13.53**	**%**	**15.44**	**%**
Bornheim				
Uncertainty between Reference	**0.63**	**µg/m³**		
Uncertainty between Candidates	**0.33**	**µg/m³**		
	SN 248		**SN 249**	
Number of data pairs	**56**		**59**	
Slope b	**0.991**		**0.990**	
Uncertainty of b	**0.031**		**0.032**	
Ordinate intercept a	**-0.575**		**-0.723**	
Uncertainty of a	**0.553**		**0.568**	
Expanded meas. uncertainty W_{CM}	**7.88**	**%**	**8.57**	**%**
All comparisons, ≥30 µg/m³				
Uncertainty between Reference	**0.78**	**µg/m³**		
Uncertainty between Candidates	**1.14**	**µg/m³**		
	SN 127/145/248		**SN 131/149/249**	
Number of data pairs	**86**		**85**	
Slope b	**1.137**		**1.085**	
Uncertainty of b	**0.031**		**0.031**	
Ordinate intercept a	**-6.111**		**-4.605**	
Uncertainty of a	**1.330**		**1.32**	
Expanded meas. uncertainty W_{CM}	**14.07**	**%**	**13.56**	**%**
All comparisons, <30 µg/m³				
Uncertainty between Reference	**0.74**	**µg/m³**		
Uncertainty between Candidates	**0.43**	**µg/m³**		
	SN 127/145/248		**SN 131/149/249**	
Number of data pairs	**323**		**334**	
Slope b	**0.964**		**0.964**	
Uncertainty of b	**0.015**		**0.015**	
Ordinate intercept a	**0.547**		**0.428**	
Uncertainty of a	**0.281**		**0.272**	
Expanded meas. uncertainty W_{CM}	**8.52**	**%**	**8.71**	**%**
All comparisons				
Uncertainty between Reference	**0.75**	**µg/m³**		
Uncertainty between Candidates	**0.63**	**µg/m³**		
	SN 127/145/248		**SN 131/149/249**	
Number of data pairs	**409**		**419**	
Slope b	**1.010**	**not significant**	**0.986**	**not significant**
Uncertainty of b	**0.009**		**0.009**	
Ordinate intercept a	**-0.376**	**not significant**	**-0.069**	**not significant**
Uncertainty of a	**0.237**		**0.223**	
Expanded meas. uncertainty W_{CM}	**9.17**	**%**	**9.23**	**%**

6.1 18 Maintenance interval (7.5.7)

The maintenance interval shall be at least 2 weeks.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Moreover, the results of the zero drift tests (see 6.1 12 Zero checks (7.5.3) were taken into account when determining the maintenance interval .

6.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed.

The maintenance interval is thus determined by the necessary maintenance works.

The measuring system comes with filter stocks of 36, 72 or 96 filters. Accordingly, the maximum period of operation is determined as follows:

SWAM 5a Dual Channel Monitor:

For 24h sampling when operating both lines, operating times of 18, 36 or 48 days can be realised.

SWAM 5a Dual Channel Hourly Mode Monitor:

At a 1h cycle time and 8-fold allocation for each filter (setting used during the test) 6 filters are used for each measurement day in operation. Consequently, maximum operating times of 6, 12 or 16 days can be realised.

SWAM 5a Monitor:

For 24h sampling, operating times of 36, 72 or 96 days can be realised.

Similar to the reference method specified in EN 12341:2014, Chapter 7.3, it is recommended to re-stock the filters when the sampling inlets are cleaned after 15 days ($PM_{2.5}$) or after 30 days (PM_{10}).

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

6.5 Assessment

The maintenance interval is determined by the necessary maintenance tasks (filter replacement/cleaning the sampling head if necessary). It is 15 days for $PM_{2.5}$ and 30 days for PM_{10}.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The necessary maintenance works are listed in chapter 8 of the operation manual.

6.1 19 Automatic diagnostic check (7.5.4)

Results of automated/functional checks, where available, shall be recorded.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

A modem was connected to the measuring system. Among other, status signals provided by the AMS were recorded relying on remote data transmission.

Access options provided by the DR FAI Manager operating system and the Hyperterminal were checked.

The measuring system allows for comprehensive monitoring and control functions. A number of reading, writing and control commands are available; a complete overview of which is provided in the AMS operating manual.

The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

The DR FAI Manager operating software conveniently provides options to monitor the operating status and provides data saved as text files (also see Figure 13 to Figure 19 in section 3.3 AMS scope and set-up).

Remote monitoring and control is easily possible via routers or modems.

As part of the performance test, a PC was connected directly connected to the AMS via RS232 to test the transfer of data and the instrument status.

6.4 Evaluation

All instrument functions described in the operation manual are available and can be activated. The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

6.5 Assessment

The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Available automatic/functional tests are listed in chapter 7 of the operation manual.

6.1 20 Checks of temperature sensors, pressure and/or humidity sensors

The verifiability of temperature sensors, pressure and/or humidity sensors shall be checked for the AMS. Deviations determined shall be within the following criteria:
T ±2 °C
p ±1 kPa
rF ± 5 %

6.2 Equipment

Not required for this performance criterion

6.3 Testing

This minimum requirement serves to verify whether AMS sensors for temperature, pressure and humidity, which are necessary for correct AMS performance, are accessible and can be checked at the field test site location. In the event, checks cannot be performed on-site, this has to be documented.

6.4 Evaluation

The SWAM 5a measuring systems use various temperature, pressure and/or humidity sensors.

All relevant sensors for temperature (ambient temperature, room temperature, temperature near the mass flow meter, temperature near the filter during sampling), pressure (air pressure, pressure drop at the filter) or relative humidity (in the area of the filter during sampling) are accessible. This allows to perform comparison measurements using transfer standards.

It is possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement), but requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,

A user can only adjust the parameters ambient air, air pressure and flow rate. In the event of excessive deviations of all other parameters, the manufacturer has to be contacted.

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6.5 Assessment

It is easy to check and adjust the relevant external sensors for determining ambient temperature and ambient pressure on-site. It is also possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement). However, this requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

7. Recommendations for use in practice

7.1 Tasks performed in the maintenance interval (15 days ($PM_{2,5}$) and 30 days (PM_{10}))

The tested measuring systems require regular performance of the following tasks:

- Verification of the instrument status incl. internal functional checks
  The instrument status can be verified by checking the AMS; alternatively it can be monitored online.
- Sampling heads have to be cleaned following the manufacturer's instruction and taking into account local concentrations of suspended particulate matter.
  These tasks should be performed when replacing the filters.

Apart from that please consider the manufacturer's instructions.

7.2 Additional maintenance tasks

In addition to the regular tasks to be performed during the maintenance interval, the following tasks need to be performed.

- Checking and cleaning of the priming rod every 3 months
  Leak tightness of the AMS needs to be checked after having perfumed maintenance tasks.
- Checking the oil level and filters of the air compressor every 6 months
- Maintenance of the pump every 12 months Air throughput needs to be checked after having performed maintenance tasks with the help of a flow transfer standard, where necessary, a re-calibration has to be performed.

Further details are provided in the operation manual.

Environmental Protection/Air Pollution Control

Guido Baum

Dipl.-Ing. Guido Baum

Dipl.-Ing. Karsten Pletscher

Cologne, 22 September 2017
936/21239762/A

8. Bibliography

[1] VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002.

[2] VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004

[3] European standard EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 1998

[4] European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005

[5] Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005 (initial testing) and of January 2010

[6] Operation manual SWAM 5a Monitor, SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor

[7] Operation manual LVS3 of 2000

[9] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

[9] European standard EN 16450 "Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2.5}$, German version dated July 2017)

[10] "UK Equivalence Programme for Monitoring of Particulate Matter" report, Report No.: BV/AQ/AD202209/DH/2396 dated 5 June 2006

[11] TÜV Rheinland report no. 936/21207522/A dated 23 March 2009, Report on the performance test of the SWAM 5a Dual Channel Monitor air quality monitor with PM_{10} and $PM_{2.5}$ pre-separator manufactured by FAI Instruments s.r.l for the components suspended particulate matter PM_{10}, $PM_{2.5}$)

[12] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 11 October 2011

[13] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 3 November 2011

2.1 SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$

Hersteller:

FAI Instruments s.r.l., Fonte Nuova (Rom), Italien

Eignung:

Zur kontinuierlichen parallelen Immissionsmessung der PM10- und der PM2,5-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche bei der Eignungsprüfung:

PM10: 0-200 µg/m3
PM2,5: 0-200 µg/m3

Softwareversion: Version

Rel 04-08.01.65-30.02.00

Hinweise:

1. Die Anforderungen gemäß des Leitfadens Demonstration of Equivalence of Ambient Air Monitoring Methods werden eingehalten.
2. Es wurden Filterhalter mit einer Beaufschlagungsfläche von 5,20 cm2 eingesetzt.
3. Die Messeinrichtung ist mit dem gravimetrischen PM10-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
4. Die Messeinrichtung ist mit dem gravimetrischen PM2,5-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.

Prüfinstitut:

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, Köln
Bericht Nr.: 936/21207522/A vom 23. März 2009

Figure 113: Original announcement in the Federal Gazette, Banz. 25 August 2009, no. 125, page 2929, chapter II no. 2.1

7. Mitteilung zur Bekanntmachung des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1)
Die Messeinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Firma FAI Instruments s.r.l. erfüllt die Anforderungen der DIN EN 12341, der DIN EN 14907 sowie des Leitfadens zum Nachweis der Gleichwertigkeit von Immissionsmesseinrichtungen in der Version vom November 2005. Darüber hinaus erfüllt die Herstellung und das Qualitätsmanagement der Messeinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 die Anforderungen der DIN EN 15267.
Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 26. März 2011

Figure 114: Notification published in the Federal Gazette, BAnz. 29 July 2011, no. 113, page 2725, chapter III 7th Notification

2 Mitteilung zu Bekanntmachungen des Umweltbundesamtes
vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und
vom 15. Juli 2011 (BAnz. S. 2725, Kapitel III 7. Mitteilung)
Die Immissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. kann auch in der Geräteversion mit 1-h-Messmodus eingesetzt werden. Die Geräteversion mit 1-h-Messmodus wird unter der Bezeichnung SWAM 5a Dual Channel Hourly Mode Monitor vertrieben.
Die Immissionsmesseinrichtung SWAM 5a Dual Channel Hourly Mode Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. wird baugleich unter der Bezeichnung Model 602 BetaPlus von der Fa. Teledyne Advanced Pollution Instrumentation, San Diego/USA vertrieben.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 11. Oktober 2011

Figure 115: Notification published in the Federal Gazette, BAnz. 2 March 2012, no. 36, page 920, chapter V, 2nd Notification

3 Mitteilung zu Bekanntmachungen des Umweltbundesamtes
vom 3.August 2009 (BAnz. S.S2929, Kapitel II Nummer 2.1) und
vom 15.Juli 2011 (BAnz. S.B2725, Kapitel III 7. Mitteilung)
Die Bekanntgabe der Immissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. umfasst auch die einkanalige Bauform der Immissionsmesseinrichtung mit der Gerätebezeichnung SWAM 5a Monitor für PM10 oder PM2,5.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 3. November 2011

Figure 116: Notification published in the Federal Gazette, BAnz. 2 March 2012, no. 36, page 920, chapter V, 3rd Notification

12 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und vom 23. Februar 2012 (BAnz. S. 920, Kapitel V, 2. und 3. Mitteilung)

Die aktuelle Softwareversion der Staubimmissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$ der Firma FAI Instruments s. r. l. lautet:

04-09.01.85-30.02.00

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 15. Oktober 2012

Figure 117: Notification published in BAnz AT 05.03.2013 B10, chapter V 12th Notification

8 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und vom 12. Februar 2013 (BAnz AT 05.03.2013 B10, Kapitel V 12. Mitteilung)

Die aktuellen Softwareversionen für die Messeinrichtung SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$ lauten:

04-09.01.85-30.02.00 (alter Mikro-Controller, bis 2008)

bzw.

04-09.01.85-30.03.00 (neuer Mikro-Controller, ab 2008)

Für die Messeinrichtung SWAM 5a Dual Channel Hourly Mode Monitor für PM_{10} und $PM_{2,5}$ ist ein optionales Ethernet Board erhältlich, welches die Kommunikation mit der Messeinrichtung via LAN-Netzwerk ermöglicht. Die aktuelle Softwareversion der Messeinrichtung lautet:

05-02.08.56-30.03.00

Die aktuelle Softwareversion für die Messeinrichtung SWAM 5a Monitor für PM_{10} oder $PM_{2,5}$ lautet:

01-05.05.13-30.03.00

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 19. September 2014

Figure 118: Notification published in BAnz AT 02.04.2015 B5, chapter IV 8th Notification

44 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2934, Kapitel II Nummer 2.1) und vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel IV 8. Mitteilung)

Für die Messeinrichtungen SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$, SWAM 5a Dual Channel Hourly Mode Monitor für PM_{10} und $PM_{2,5}$ und SWAM 5a Monitor für PM_{10} oder $PM_{2,5}$ der Firma FAI Instruments srl. sind auch Standard-Probeneinlässe gemäß Anhang A der Richtlinie DIN EN 12341 (Ausgabe: August 2014) unter den Bezeichnungen PM10-EN12341-2014 bzw. PM2.5-EN12341-2014 verfügbar.

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 17. März 2015.

Figure 119: Notification published in BAnz AT 26.08.2015 B4, chapter V 44th Notification

9. Appendixes

Appendix 1 Measured and calculated values

- Annex 1: Zero level and detection limit
- Annex 2: Flow rate accuracy
- Annex 3: Temperature dependence of the zero point and sensitivity
- Annex 4: Dependence of span on supply voltage
- Annex 5: Measured values from the field test locations (SWAM 5a DC)
- Annex 6: Measured values from the field test locations (SWAM 5a DC HM)
- Annex 7: Measured values from the field test locations (SWAM 5a)
- Annex 8: Ambient condition at the field test locations

Appendix 2: Methods used for filter weighing

Appendix 3 Operation manuals

Annex 1 **Zero level and Detection limit** **Page 1 of 2**

Manufacturer FAI Instruments s.r.l.

Type SWAM 5a DC

Standards ZP Measured values with zero filter

Serial-No. SN 127, Line A / SN 127, Line B

No.	Date	Measured values [µg/m³] SN 127, Line A	Date	Measured values [µg/m³] SN 127, Line B
1	6/29/2007	0.1	6/29/2007	0.3
2	6/30/2007	0.0	6/30/2007	0.1
3	7/1/2007	0.0	7/1/2007	0.2
4	7/2/2007	0.5	7/2/2007	0.0
5	7/3/2007	0.5	7/3/2007	0.5
6	7/4/2007	0.4	7/4/2007	0.2
7	7/5/2007	0.5	7/5/2007	0.6
8	7/6/2007	0.1	7/6/2007	0.4
9	7/7/2007	0.3	7/7/2007	0.5
10	7/8/2007	0.1	7/8/2007	0.5
11	7/9/2007	0.3	7/9/2007	0.6
12	7/10/2007	0.2	7/10/2007	0.5
13	7/11/2007	0.5	7/11/2007	0.4
14	7/12/2007	0.3	7/12/2007	0.4
15	7/13/2007	0.6	7/13/2007	0.5
16	7/14/2007	0.3	7/14/2007	0.6
17	7/15/2007	0.0	7/15/2007	0.5
18	7/16/2007	0.3	7/16/2007	0.2
	No. of values	18	No. of values	18
	Mean (Zero level)	0.28	Mean (Zero level)	0.39
	Standard deviation s_{x0}	0.20	Standard deviation s_{x0}	0.18
	Detection limit x	0.65	Detection limit x	0.60

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Annex 1 **Zero level and Detection limit** **Page 2 of 2**

Manufacturer	FAI Instruments s.r.l.			
Type	SWAM 5a DC	Standards	ZP	Measured values with zero filter
Serial-No.	SN 131, Line A / SN 131, Line B			

No.	Date	Measured values [µg/m³] SN 131, Line A	Date	Measured values [µg/m³] SN 131, Line B
1	6/29/2007	0.0	6/29/2007	0.4
2	6/30/2007	0.4	6/30/2007	0.0
3	7/1/2007	0.0	7/1/2007	0.0
4	7/2/2007	0.6	7/2/2007	0.2
5	7/3/2007	0.0	7/3/2007	0.0
6	7/4/2007	0.0	7/4/2007	0.6
7	7/5/2007	0.4	7/5/2007	0.5
8	7/6/2007	0.2	7/6/2007	0.1
9	7/7/2007	0.2	7/7/2007	0.2
10	7/8/2007	0.0	7/8/2007	0.5
11	7/9/2007	0.0	7/9/2007	0.0
12	7/10/2007	0.3	7/10/2007	0.1
13	7/11/2007	0.4	7/11/2007	0.1
14	7/12/2007	0.1	7/12/2007	0.0
15	7/13/2007	0.3	7/13/2007	0.3
16	7/14/2007	0.3	7/14/2007	0.5
17	7/15/2007	0.5	7/15/2007	0.5
18	7/16/2007	0.3	7/16/2007	0.3
	No. of values	18	No. of values	18
	Mean (Zero level)	0.22	Mean (Zero level)	0.24
	Standard deviation s_{x0}	0.20	Standard deviation s_{x0}	0.21
	Detection limit x	0.65	Detection limit x	0.71

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Annex 2 **Flow rate accuracy** **Page 1 of 2**

Manufacturer	FAI Instruments s.r.l.
Type	SWAM5a DC
Serial-No.	SN 111, Line A / SN 111, Line B
Nominal flow rate [l/min]	38.33

		SN 111, Line A			SN 111, Line B		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 10:00	38.39	1	7/26/2017 10:03	38.32
		2	7/26/2017 10:12	38.24	2	7/26/2017 10:15	38.07
		3	7/26/2017 10:24	38.10	3	7/26/2017 10:27	38.13
		4	7/26/2017 10:36	38.23	4	7/26/2017 10:39	38.04
		5	7/26/2017 10:48	37.88	5	7/26/2017 10:51	37.99
		6	7/26/2017 11:00	37.92	6	7/26/2017 11:03	38.01
		7	7/26/2017 11:12	37.94	7	7/26/2017 11:15	38.03
		8	7/26/2017 11:24	38.06	8	7/26/2017 11:27	38.05
		9	7/26/2017 11:36	38.10	9	7/26/2017 11:39	38.13
		10	7/26/2017 11:48	38.14	10	7/26/2017 11:51	38.53
			Mean	**38.10**		**Mean**	**38.13**

		SN 111, Line A			SN 111, Line B		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 16:02	38.14	1	7/26/2017 16:05	37.95
		2	7/26/2017 16:14	38.18	2	7/26/2017 16:17	37.96
		3	7/26/2017 16:26	38.60	3	7/26/2017 16:29	37.97
		4	7/26/2017 16:38	38.34	4	7/26/2017 16:41	38.00
		5	7/26/2017 16:50	38.18	5	7/26/2017 16:53	37.95
		6	7/26/2017 17:02	38.14	6	7/26/2017 17:05	38.05
		7	7/26/2017 17:14	38.17	7	7/26/2017 17:17	38.08
		8	7/26/2017 17:26	38.17	8	7/26/2017 17:29	38.09
		9	7/26/2017 17:38	38.29	9	7/26/2017 17:41	38.05
		10	7/26/2017 17:50	38.26	10	7/26/2017 17:53	38.34
			Mean	**38.25**		**Mean**	**38.04**

Annex 2 **Flow rate accuracy** **Page 2 of 2**

Manufacturer FAI Instruments s.r.l.

Type SWAM5a DC

Serial-No. SN 395, Line A / SN 395, Line B

Nominal flow rate [l/min] 38.33

		SN 395, Line A			SN 395, Line B		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 10:06	38.44	1	7/26/2017 10:09	38.02
		2	7/26/2017 10:18	38.42	2	7/26/2017 10:21	38.15
		3	7/26/2017 10:30	38.41	3	7/26/2017 10:33	38.19
		4	7/26/2017 10:42	38.42	4	7/26/2017 10:45	38.35
		5	7/26/2017 10:54	38.44	5	7/26/2017 10:57	38.32
		6	7/26/2017 11:06	38.41	6	7/26/2017 11:09	38.35
		7	7/26/2017 11:18	38.31	7	7/26/2017 11:21	38.35
		8	7/26/2017 11:30	38.36	8	7/26/2017 11:33	38.40
		9	7/26/2017 11:42	38.32	9	7/26/2017 11:45	38.42
		10	7/26/2017 11:54	38.31	10	7/26/2017 11:57	38.43
			Mean	**38.38**		**Mean**	**38.30**

		SN 395, Line A			SN 395, Line B		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 16:08	38.11	1	7/26/2017 16:11	38.48
		2	7/26/2017 16:20	38.73	2	7/26/2017 16:23	38.61
		3	7/26/2017 16:32	38.60	3	7/26/2017 16:35	38.72
		4	7/26/2017 16:44	38.60	4	7/26/2017 16:47	38.87
		5	7/26/2017 16:56	38.84	5	7/26/2017 16:59	38.87
		6	7/26/2017 17:08	38.71	6	7/26/2017 17:11	38.99
		7	7/26/2017 17:20	38.75	7	7/26/2017 17:23	39.11
		8	7/26/2017 17:32	38.40	8	7/26/2017 17:35	38.74
		9	7/26/2017 17:44	38.55	9	7/26/2017 17:47	38.71
		10	7/26/2017 17:56	38.67	10	7/26/2017 17:59	38.71
			Mean	**38.60**		**Mean**	**38.78**

Annex 3 — Dependence of zero point on surrounding temperature — Page 1 of 4

Manufacturer	FAI Instruments s.r.l.
Type	SWAM 5a DC
Serial-No.	SN 127, Line A / SN 127, Line B
Test period	06.05.2008 - 21.05.2008

SN 127, Line A	No.	Temperature [°C]	Measurement 1 Measured value [µg/m³]	Measurement 2 Measured value [µg/m³]	Measurement 3 Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.1	0.0	0.03	0.16
	2	5	0.5	0.2	0.7	0.47	
	3	20	0.2	0.2	0.0	0.13	
	4	40	0.3	0.5	1.0	0.60	
	5	20	0.2	0.7	0.0	0.30	

SN 127, Line B	No.	Temperature [°C]	Measurement 1 Measured value [µg/m³]	Measurement 2 Measured value [µg/m³]	Measurement 3 Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.1	0.0	0.6	0.23	0.26
	2	5	0.3	0.0	0.5	0.27	
	3	20	0.2	0.2	0.4	0.27	
	4	40	0.5	0.7	0.7	0.63	
	5	20	0.4	0.4	0.0	0.27	

Annex 3 Dependence of zero point on surrounding temperature Page 2 of 4

Manufacturer	FAI Instruments s.r.l.						
Type	SWAM 5a DC						
Serial-No.	SN 131, Line A / SN 131, Line B						
Test period	06.05.2008 - 21.05.2008		Measurement 1	Measurement 2	Measurement 3		
SN 131, Line A	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.1	0.4	0.17	0.22
	2	5	0.2	0.1	0.4	0.23	
	3	20	0.0	0.3	0.0	0.10	
	4	40	0.7	0.8	0.6	0.70	
	5	20	0.3	0.4	0.5	0.40	
SN 131, Line B	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.0	0.5	0.17	0.19
	2	5	0.0	0.4	0.0	0.13	
	3	20	0.0	0.4	0.0	0.13	
	4	40	1.0	0.7	0.8	0.83	
	5	20	0.0	0.6	0.2	0.27	

Annex 3 — Dependence of span on surrounding temperature — Page 3 of 4

Manufacturer: FAI Instruments s.r.l.

Used test standard: Reference foils

Type: SWAM 5a DC

Serial-No.: SN 127 R1 / SN 127 R2

Test period: 14.09.07 - 18.09.07

SN 127 R1	No.	Temperature [°C]	Measurement 1 Measured value [mg/cm²]	Measurement 2 Measured value [mg/cm²]	Meaurement 3 Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	3.457	3.455	3.451	3.454	3.451
	2	5	3.453	3.453	3.448	3.451	
	3	20	3.451	3.450	3.454	3.452	
	4	40	3.448	3.446	3.450	3.448	
	5	20	3.443	3.454	3.448	3.448	

SN 127 R2	No.	Temperature [°C]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	6.833	6.838	6.828	6.833	6.829
	2	5	6.833	6.830	6.829	6.831	
	3	20	6.833	6.829	6.828	6.830	
	4	40	6.826	6.828	6.825	6.826	
	5	20	6.821	6.829	6.826	6.825	

Annex 3 **Dependence of span on surrounding temperature** **Page 4 of 4**

Manufacturer FAI Instruments s.r.l.

Used test standard Reference foils

Type SWAM 5a DC

Serial-No. SN 131 R1 / SN 131 R2

Test period 14.09.07 - 18.09.07

			Measurement 1	Measurement 2	Meaurement 3		
SN 131 R1	No.	Temperature [°C]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	3.396	3.399	3.401	3.399	3.401
	2	5	3.399	3.404	3.403	3.402	
	3	20	3.401	3.398	3.406	3.402	
	4	40	3.406	3.402	3.401	3.403	
	5	20	3.402	3.400	3.405	3.402	
SN 131 R2	No.	Temperature [°C]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	6.863	6.873	6.871	6.869	6.871
	2	5	6.871	6.875	6.874	6.873	
	3	20	6.874	6.875	6.873	6.874	
	4	40	6.874	6.873	6.874	6.874	
	5	20	6.870	6.870	6.867	6.869	

Annex 4 **Dependence of span on supply voltage** **Page 1 of 2**

Manufacturer FAI Instruments s.r.l.

Used test standard Foils

Type SWAM 5a DC

Serial-No. SN 111, R1 / SN 111, R2

Test period 31.07.2017

			Measurement 1	Measurement 2	Measurement 3	
SN 111, R1	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	3.464	3.451	3.454	3.456
	2	195	3.445	3.442	3.444	3.444
	3	230	3.442	3.441	3.444	3.442
	4	253	3.443	3.445	3.446	3.445
	5	230	3.446	3.445	3.444	3.445
SN 111, R2	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	6.807	6.799	6.797	6.801
	2	195	6.788	6.788	6.790	6.789
	3	230	6.785	6.785	6.787	6.786
	4	253	6.785	6.791	6.788	6.788
	5	230	6.788	6.786	6.788	6.787

Annex 4 **Dependence of span on supply voltage** **Page 2 of 2**

Manufacturer	FAI Instruments s.r.l.					Used test standard Foils
Type	SWAM 5a DC					
Serial-No.	SN 395, R1 / SN 395, R2					
Test period	31.07.2017		Measurement 1	Measurement 2	Measurement 3	
SN 395, R1	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	3.294	3.294	3.293	3.294
	2	195	3.325	3.293	3.293	3.304
	3	230	3.294	3.291	3.295	3.293
	4	253	3.295	3.293	3.293	3.294
	5	230	3.290	3.293	3.293	3.292
SN 395, R2	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	6.604	6.609	6.605	6.606
	2	195	6.602	6.601	6.603	6.602
	3	230	6.599	6.602	6.601	6.601
	4	253	6.601	6.598	6.604	6.601
	5	230	6.598	6.602	6.603	6.601

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
1	10/20/2007			18.0	20.2		15.9	16.4	20.8	21.0	Outlier Ref. PM2,5	Cologne,
2	10/21/2007			18.1	19.8		15.8	17.1	20.2	20.1		parking lot
3	10/22/2007			21.6	22.9			18.8		23.4	Water inleakage SN127	
4	10/23/2007	23.1	20.9	24.4	26.6	86.2		20.4		26.5	Water inleakage SN127	
5	10/24/2007	27.1	29.2	30.7	32.0	89.7	26.8	26.1	34.0	32.4		
6	10/25/2007	24.2	25.8	26.7	28.3	91.0	23.2	22.4	28.6	27.7		
7	10/26/2007	21.8	24.5	27.7	28.9	81.6	22.8	22.4	30.2	29.5		
8	10/27/2007			33.9	35.9		29.5	28.8	36.0	34.7		
9	10/28/2007			34.4	35.7						Change to wintertime	
10	10/29/2007										Change to wintertime	
11	10/30/2007										ZP/RP-Check	
12	10/31/2007	22.8	24.6	26.4	28.2	87.1	23.1	23.3	31.7	32.7		
13	11/1/2007			29.1	31.3		27.3	27.2	35.6	36.0		
14	11/2/2007			29.1	31.0		21.9	22.8	34.0	36.3		
15	11/3/2007			23.7	23.8		17.9	18.0	28.5	28.1		
16	11/4/2007			16.9	19.1		11.8	11.8	21.4	21.3		
17	11/5/2007	14.5	16.1	18.4	18.9	82.2	13.5	13.6	24.0	23.7		
18	11/6/2007	10.8	11.9	15.8	16.8	69.4	9.6	9.8	20.7	19.7		
19	11/7/2007	15.0	15.0	23.1	23.0	65.3	14.7	14.4	29.1	29.2		
20	11/8/2007	9.5	10.6	13.5	14.7	71.6	10.0	9.8	15.8	15.7		
21	11/9/2007	7.1	7.1	10.0	10.6	68.6	7.0	6.8	13.4	13.7		
22	11/10/2007			9.8	10.3		7.5	7.5	13.0	12.7		
23	11/11/2007			6.3	7.8		5.4	5.8	9.6	9.3		
24	11/12/2007	8.8	9.6	15.1	16.2	58.7	10.2	10.6	19.5	19.5		
25	11/13/2007	11.7	11.7	15.8	15.7	74.5	13.2	13.5	17.9	17.6		
26	11/14/2007	12.2	12.2	14.7	14.9	82.3	14.0	13.7	17.8	17.5		
27	11/15/2007	17.6	18.5	22.4	25.8	74.8	19.7	19.5	25.3	24.3		
28	11/16/2007	27.5	27.2	35.0	38.3	74.6	28.0	27.7	40.1	38.6		
29	11/17/2007			55.7	60.5		47.3	45.4	62.4	59.4		
30	11/18/2007	16.0	16.3	17.4	21.5	83.0	16.3	17.3	18.3	18.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
31	11/19/2007	21.6	22.3	24.5	28.3	83.1	22.6	22.1	26.3	26.2		Cologne, parking lot
32	11/20/2007			22.5	27.5		22.3	21.4	26.2	25.5		
33	11/21/2007			24.0	28.0		21.9	22.1	28.1	27.9		
34	11/22/2007	20.8	22.2	26.2	29.5	77.2	23.4	23.1	29.6	30.2		
35	11/23/2007	17.0	17.8	24.1	28.4	66.4	15.5	16.1	27.7	28.1		
36	11/24/2007			23.8	28.2		16.0	16.3	27.9	28.2		
37	11/25/2007			13.8	14.4		5.6	6.1	12.0	12.5		
38	11/26/2007			15.3	15.4		8.3	8.1	17.5	17.7		
39	11/27/2007	18.2	18.3	26.5	27.1	68.2	16.8	16.9	31.0	30.4		
40	11/28/2007	20.1	21.6	26.4	26.2	79.3	19.3	19.1	28.3	27.3		
41	11/29/2007			19.2	19.7		14.8	13.8	22.3	22.0		
42	11/30/2007			14.0	13.8		8.4	8.2	15.1	15.5		
43	12/1/2007			10.0	9.6		4.7	4.2	11.5	11.7		
44	12/2/2007			6.0	5.7		2.9	2.5	7.3	7.0		
45	12/3/2007			10.6	10.8		5.4	5.7	12.6	11.5		
46	12/4/2007	9.4	9.4	13.2	13.9	69.6	8.1	8.4	17.0	16.9		
47	12/5/2007	6.8	7.0	11.9	12.8	56.1	6.1	5.6	14.9	14.2		
48	12/6/2007			5.8	7.6						ZP/RP-Check	
49	12/7/2007	7.4	7.8	13.3	13.4	57.2	7.0	7.2	16.5	16.2		
50	12/8/2007			8.0	8.5		4.8	3.8	9.4	9.3		
51	12/9/2007			5.6	5.9		3.9	3.8	7.1	7.1		
52	12/10/2007	11.2	12.3	17.7	17.5	66.5	13.2	13.1	20.4	19.8		
53	12/11/2007			13.2	13.3		12.1	11.5	20.4	19.8		
54	12/12/2007	26.5	27.1	32.6	31.2	84.0	26.8	25.7	35.4	35.0		
55	12/13/2007	15.2	15.6	18.9	17.8	83.9	14.9	15.2	20.3	20.3		
56	12/14/2007	13.8	14.0	17.0	15.8	84.5	13.5	13.1	17.9	17.4		
57	12/15/2007			17.2	16.2		14.9	14.5	17.7	17.7		
58	12/16/2007			25.0	24.5		23.4	22.8	26.7	26.2		
59	12/17/2007	25.0	24.6	31.1	31.0	80.0	26.7	24.9	36.2	34.8		
60	12/18/2007			66.9	66.3		57.1	53.1	77.9	74.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
61	12/19/2007			77.0	74.9		64.8	63.0	89.6	87.3		Cologne, parking lot
62	12/20/2007			88.2	86.3		70.3	68.2	100.4	94.2		
63	12/21/2007			53.5	54.2		53.5	51.6	61.0	57.1		
64	12/22/2007			59.4	60.6		65.3	61.2	70.8	65.2		
65	12/23/2007			58.6	59.2		48.6	44.6	59.3	59.4		
66	12/24/2007			25.2	25.5		23.4	21.9	24.9	24.5		
67	12/25/2007			30.3	30.6		29.3	29.1	32.6	32.4		
68	12/26/2007			33.6	34.0		31.4	31.9	36.1	35.8		
69	12/27/2007			12.3	12.7		10.9	10.7	12.7	12.5		
70	12/28/2007			12.0	12.7		11.2	11.3	12.8	12.1		
71	12/29/2007			8.9	10.0		7.2	6.7	10.0	10.4		
72	12/30/2007			16.2	16.0		9.8	9.8	17.7	18.9		
73	12/31/2007	37.2	37.2	46.0	45.6	81.1	37.0	35.6	47.3	46.1		
74	1/1/2008			22.7	22.5		19.6	19.0	23.4	23.3		
75	1/2/2008			19.4	19.3		17.3	17.0	20.2	20.1		
76	1/3/2008	19.8	19.8	21.9	22.4	89.2	20.5	19.7	22.7	22.1		
77	1/4/2008						23.1	22.7	26.5	26.4		
78	1/5/2008						7.0	6.0	11.2	11.4		
79	1/6/2008										Filter supply ran out	
80	1/7/2008										Filter supply ran out	
81	1/8/2008										ZP/RP-Check	
82	1/9/2008	8.3	9.2	12.4	13.4	68.1	7.6	7.8	14.9	14.5		
83	1/10/2008	9.4	9.6	11.3	12.1	80.6	9.1	8.7	12.8	13.3		
84	1/11/2008	6.0	5.4	7.5	8.3	71.9	6.0	6.0	8.8	8.2		
85	1/12/2008			14.1	12.7		9.1	9.0	13.8	13.8		
86	1/13/2008			16.2	16.6		12.8	13.0	16.8	16.8		
87	1/14/2008	10.3	8.8	13.2	13.6	71.6	10.1	9.9	14.3	14.0		
88	1/15/2008	4.6	4.1	7.0	5.8	67.9	4.8	4.7	6.6	6.7		
89	1/16/2008	6.8	6.6	10.0	10.1	67.3	7.4	7.4	12.1	12.3		
90	1/17/2008	7.2	7.6	12.3	11.7	61.8	5.9	6.1	12.8	13.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
91	1/18/2008			12.0	11.8		5.7	4.3	14.4	14.5		Cologne, parking lot
92	1/19/2008	3.4	4.2	5.6	4.4	75.7	4.0	3.8	6.3	6.6		
93	1/20/2008			5.7	5.3		3.7	3.4	5.7	5.4		
94	1/21/2008	5.6	5.4	8.5	8.4	65.5	5.6	5.4	9.9	9.0		
95	1/22/2008			20.3	19.4		9.4	9.6	22.7	22.8		
96	1/23/2008	12.2	12.4	20.6	20.0	60.6	10.8	10.5	22.2	21.9		
97	1/24/2008	14.1	14.7	26.7	26.0	54.6	12.5	11.1	29.5	28.7		
98	1/25/2008	10.1	10.3	18.3	18.0	56.3	9.0	9.2	20.0	20.0		
99	1/26/2008			26.3	25.5		17.1	17.0	28.4	28.6		
100	1/27/2008			31.6	30.3		17.3	17.0	32.1	33.8		
101	1/28/2008	27.5	28.3	39.2	38.1	72.2	25.9	25.6	42.5	42.9		
102	1/29/2008			51.0	50.8		36.2	34.4	55.8	55.0		
103	1/30/2008	18.8	19.4	24.7	25.7	75.9	17.4	17.5	27.2	27.3		
104	1/31/2008			7.7	7.7		5.6	5.6	8.4	8.1		
105	2/1/2008			10.8	10.2		5.4	5.0	11.9	12.1		
106	2/2/2008			13.4	14.2		7.1	6.8	14.1	14.4		
107	2/3/2008			11.5	12.2		9.1	8.9	11.9	12.3		
108	2/4/2008	7.6	7.6	9.7	10.4	75.6	8.1	7.7	10.9	10.3		
109	2/5/2008			5.2	5.3		3.3	2.8	5.8	5.7		
110	2/14/2008	32.6	33.3	38.2	38.2	86.3	31.6	30.9	41.2	39.8		Bonn
111	2/15/2008			15.0	15.5		11.6	11.9	16.7	17.5		
112	2/16/2008			18.3	19.2		15.0	14.9	19.0	18.6		
113	2/17/2008	30.3	29.9	37.7	37.4	80.2	31.0	30.4	43.5	42.0		
114	2/18/2008	48.4	48.5	63.0	62.4	77.2	50.8	52.2	75.8	75.1		
115	2/19/2008	41.7	42.1	52.0	51.9	80.5	40.7	40.6	57.7	56.9		
116	2/20/2008	38.8	37.6	41.6	42.6	90.8	36.6	37.1	44.2	44.4		
117	2/21/2008	30.7	31.0	39.9	39.5	77.7	29.0	28.5	43.5	43.9		
118	2/22/2008	17.8	17.9	24.8	25.1	71.4	15.5	15.7	27.9	27.2		
119	2/23/2008			27.4	27.2		21.4	21.5	29.6	30.1		
120	2/24/2008			30.1	29.2		24.4	24.0	31.3	30.9		

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
121	2/25/2008	19.0	18.8	24.1	24.6	77.5	18.6	18.3	26.1	26.1		Bonn
122	2/26/2008	12.5	13.0	23.9	23.4	53.8	11.6	11.4	25.9	25.7		
123	2/27/2008	18.8	18.6	27.6	27.8	67.5	16.2	14.5	29.0	29.3		
124	2/28/2008	20.8	21.5	28.4	30.0	72.5	19.1	19.4	30.5	31.0		
125	2/29/2008	9.8	9.8	14.7	14.0	68.1	8.2	8.5	14.7	14.5		
126	3/1/2008			15.6	14.8		7.2	6.9	15.1	15.4		
127	3/2/2008			23.3	23.1		11.2	10.9	24.1	24.5		
128	3/3/2008	12.9	13.5	20.1	19.6	66.4	13.3	11.7	22.8	22.1		
129	3/4/2008	13.9	14.4	22.2	22.2	63.7	13.4	13.0	25.9	24.8		
130	3/5/2008	16.2	15.2	26.1	25.4	61.2	16.4	16.0	28.7	28.6		
131	3/6/2008	20.8	21.1	30.0	30.2	69.7	18.7	18.8	32.5	33.5		
132	3/7/2008	16.9	15.9	25.5	24.5	65.5	15.2	15.6	28.6	27.9		
133	3/8/2008			20.7	20.1		14.4	14.6	20.6	20.7		
134	3/9/2008			11.5	9.9		6.8	6.1	12.2	11.6		
135	3/10/2008	4.1	5.4	8.6	7.6	58.6	4.5	4.5	9.4	9.8		
136	3/11/2008	7.1	7.3	13.6	13.4	53.1	6.9	6.8	15.2	15.2		
137	3/12/2008			19.1	19.2						ZP/RP-Check	
138	3/13/2008	12.0	11.6	16.5	16.9	70.7	10.9	10.2	19.1	18.9		
139	3/14/2008	20.8	20.3				19.5	19.9	30.1	29.9	Ref. PM10 not considered	
140	3/15/2008			10.7	11.1		8.0	7.6	10.8	11.0		
141	3/16/2008			16.9	18.4		11.9	11.3	18.7	18.8		
142	3/17/2008	13.5	12.9	22.0	23.3	58.5	11.4	11.0	26.0	25.1		
143	3/18/2008	14.8	13.1	21.6	22.0	64.0	12.5	11.7	24.8	23.6		
144	3/19/2008	12.8	13.7	18.7	20.0	68.6	11.7	10.2	21.1	20.6		
145	3/20/2008	8.0	7.8	10.3	10.8	74.8	6.7	6.5	11.0	11.1		
146	3/21/2008						7.5	7.8	10.7	10.9	Ref. PM10 not considered	
147	3/22/2008			24.7	26.0		22.0	21.1	26.7	26.3		
148	3/23/2008			19.8	21.1		15.3	14.9	21.6	21.1		
149	3/24/2008			12.0	12.5		7.7	7.9	12.0	11.9		
150	3/25/2008	13.0	12.4	16.6	16.7	76.1	11.5	11.7	17.5	17.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
151	3/26/2008	20.1	20.3	22.2	22.6	90.1					Change to summertime	Bonn
152	3/27/2008	7.6	7.6								Change to summertime	
153	3/28/2008			12.8	13.2		6.5	6.6	13.9	14.2		
154	3/29/2008			14.3	14.6		7.9	7.6	15.5	15.4		
155	3/30/2008			15.0	15.3		9.8	9.3	18.6	17.2		
156	3/31/2008	11.6	12.1	16.7	16.5	71.3	11.4	11.4	19.7	19.1		
157	4/1/2008	14.3	13.5	25.0	25.4	55.2	11.9	11.8	30.1	28.6		
158	4/2/2008	17.2	17.6	26.6	27.7	64.1	14.9	14.6	31.5	31.7		
159	4/3/2008	22.2	23.3	30.9	31.5	72.9	20.6	19.8	36.3	35.3		
160	4/4/2008	30.1	29.4	36.9	36.8	80.7	27.8	28.6	41.6	41.3		
161	4/5/2008			14.4	13.9		11.1	11.1	15.0	15.7		
162	4/6/2008			17.3	17.5		12.7	12.3	19.3	19.2		
163	4/7/2008	22.5	23.0	26.3	26.7	86.1	21.9	21.3	29.3	28.7		
164	4/8/2008	31.7	32.3	37.3	36.7	86.6	30.1	30.3	39.3	38.2		
165	4/9/2008	35.6	35.0	40.8	39.9	87.6	31.3	31.7	42.1	41.5		
166	4/10/2008			30.5	30.2						ZP/RP-Check	
167	4/11/2008	36.4	35.7	45.5	45.3	79.5	31.9	32.1	43.7	42.8		
168	4/12/2008			12.6	12.1		7.7	7.6	12.6	12.8		
169	4/13/2008			11.7	11.9		10.0	9.8	12.8	12.0		
170	4/14/2008	29.3	29.6	36.2	36.0	81.6	27.0	27.7	36.6	36.4		
171	4/15/2008	22.0	21.9	27.2	25.8	82.7	20.1	19.9	26.6	26.3		
172	4/16/2008	17.6	18.3	25.6	24.7	71.4	17.4	16.5	26.4	26.2		
173	4/17/2008	20.1	19.2	23.9	23.9	82.3	18.0	17.3	23.0	23.1		
174	4/18/2008	21.2	20.7	25.0	24.0	85.5	20.2	19.2	25.1	24.4		
175	4/19/2008			21.4	19.6		16.3	16.4	18.8	19.7		
176	4/20/2008			19.7	18.8		15.7	14.6	19.7	18.7		
177	4/21/2008	23.2	22.7	29.1	28.0	80.3	23.1	22.1	30.2	30.3		
178	9/30/2008	3.5	5.0	5.0	5.0	84.0	3.9	2.9	5.8	5.5		Brühl
179	10/1/2008	5.6	5.2	10.4	9.2	55.3	4.9	3.3	8.3	8.4		
180	10/2/2008	5.3	6.2	13.2	12.6	44.5	6.1	3.7	13.6	11.6		

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
181	10/3/2008	7.8	8.0	13.8	12.6	59.6	7.0	7.2	10.5	10.5		Brühl
182	10/4/2008			13.8	13.6		5.6	4.9	12.3	11.7		
183	10/5/2008						4.7	1.7	4.8	4.9		
184	10/6/2008						6.5	6.4	11.9	12.0		
185	10/7/2008	8.3	8.5	14.7	14.8	57.0	8.6	8.8	14.2	15.5		
186	10/8/2008	11.6	10.9	22.5	22.3	50.2	12.5	13.2	24.9	25.0		
187	10/9/2008	16.2	16.6	34.1	33.2	48.8	17.4	18.0	38.1	35.6		
188	10/10/2008	15.4	15.2	25.8	26.3	58.8	14.8	16.1	25.8	26.6		
189	10/11/2008			32.4	31.4		25.1	24.8	35.6	35.3	Outlier Ref. PM2,5	
190	10/12/2008			23.7	23.4		16.5	17.4	24.3	25.7		
191	10/13/2008	18.0	17.1	33.7	32.1	53.3	19.8	20.8	33.6	33.6		
192	10/14/2008	17.5	21.2	46.6	47.0	41.4	21.7	20.4	51.2	51.2		
193	10/15/2008	9.7	9.7	15.0	16.2	61.8	9.2	8.9	16.2	16.0		
194	10/16/2008	9.4	9.1	17.8	17.5	52.3	8.1	8.7	18.3	17.9		
195	10/17/2008	12.9	13.4	25.9	25.2	51.5	11.9	10.9	25.9	25.3		
196	10/18/2008	16.1	14.5	19.7	20.5	76.2	11.4	11.8	19.3	20.0		
197	10/19/2008			16.7	17.2						Failure SN131 - cable break	
198	10/20/2008	13.9	13.3	22.6	20.3	63.4					Failure SN131 - cable break	
199	10/21/2008	9.4	9.8	16.1	15.5	60.7					Failure SN131 - cable break	
200	10/22/2008			25.8	24.3						Failure SN131 - cable break	
201	10/23/2008										Failure SN131 - cable break	
202	10/24/2008	18.9	19.3	26.3	26.6	72.3	16.2	18.2	24.8	24.6		
203	10/25/2008	15.2	14.3	16.3	17.3	87.8	12.1	12.0	14.9	15.6		
204	10/26/2008			8.0	9.7		5.7	5.2	8.1	7.4		
205	10/27/2008	11.4	11.4	19.9	20.8	56.0	10.4	9.8	19.5	18.3		
206	10/28/2008	14.0	12.7	21.9	22.9	59.5	11.5	11.4	19.9	19.6		
207	10/29/2008	31.5	31.5	42.4	43.4	73.3	27.8	27.1	38.9	38.9		
208	10/30/2008	17.6	18.1	21.6	22.7	80.7	15.1	14.5	19.2	19.0		
209	10/31/2008	15.6	16.5	21.0	21.6	75.3	14.8	15.3	18.5	19.5		
210	11/1/2008			23.8	24.8		18.0	17.9	21.2	22.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
211	11/2/2008			22.5	23.0		16.5	16.2	21.0	21.3		Brühl
212	11/3/2008	19.9	19.4	30.3	29.7	65.6		21.5		30.2	SN127 - Filter depleted	
213	11/4/2008	29.0	29.2	41.9	41.8	69.6		29.1		40.7	SN127 - Filter depleted	
214	11/5/2008	34.5	33.8	50.1	51.3	67.4	34.9	32.3	48.0	48.1		
215	11/6/2008	22.8	23.7	36.1	36.5	64.1					Replacement TÜV-cabinet	
216	11/7/2008										Replacement TÜV-cabinet	
217	11/8/2008										Replacement TÜV-cabinet	
218	11/9/2008										Replacement TÜV-cabinet	
219	11/10/2008										Replacement TÜV-cabinet	
220	11/11/2008										ZP/RP-Check	
221	11/12/2008	10.9	11.1	20.2	22.0	52.1	8.7	8.4	19.2	18.7		
222	11/13/2008	17.9	18.5	31.2	28.8	60.7	16.0	15.9	27.0	27.4		
223	11/14/2008	14.3	14.5	20.9	21.8	67.5	12.7	13.0	19.3	19.4		
224	11/15/2008			17.4	16.4		11.1	10.8	14.3	16.0		
225	11/16/2008	8.9	9.8				8.2	8.1	16.0	15.3	Outlier Ref. PM10	
226	11/17/2008	13.8	14.0	30.8	29.9	45.7	12.5	12.8	29.6	28.5		
227	11/18/2008	12.5	13.2	25.1	22.7	53.8	11.4	11.9	22.1	22.2		
228	11/19/2008	12.8	14.1				12.7	12.8	25.3	24.6	Outlier Ref. PM10	
229	11/20/2008			19.3	17.9		8.5	8.0	16.1	15.7	Ref PM2,5 not considered	
230	11/21/2008	5.8	3.4	10.8	9.5	45.5	3.8	3.6	8.3	8.0		
231	11/22/2008			12.2	12.1		7.0	6.7	10.8	10.6		
232	11/23/2008	6.4	6.8	10.9	8.1	69.6	5.0	5.3	7.7	8.5		
233	11/24/2008	17.7	17.5	22.2	21.9	79.8	16.1	16.8	21.5	21.9		
234	11/25/2008	17.7	17.9	28.9	28.7	61.9	14.7	15.4	25.5	24.8		
235	11/26/2008	9.6	10.4	18.0	17.9	55.9	9.0	8.1	15.3	14.9		
236	11/27/2008	13.4	13.0	16.5	17.1	78.8	12.6	12.2	16.1	16.2		
237	11/28/2008	23.1	23.2	26.3	26.6	87.5	22.0	21.6	26.2	24.9		
238	11/29/2008	24.3	25.4	27.1	28.0	90.2	22.9	22.9	26.8	27.7		
239	11/30/2008			24.8	26.2		21.4	21.2	24.2	24.4		
240	12/1/2008	27.2	26.8	32.4	33.3	82.2	24.9	24.7	33.2	33.0		

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC

Serial-No.: SN 127 / SN 131
SN 145 / SN 149 (Teddington)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 / SN 145 PM2,5 [µg/m³]	SN 131 / SN 149 PM2,5 [µg/m³]	SN 127 / SN 145 PM10 [µg/m³]	SN 131 / SN 149 PM10 [µg/m³]	Remark	Test site
241	12/2/2008	10.9	11.1	14.5	14.9	74.7	9.6	9.6	13.3	12.6		Brühl
242	12/3/2008	13.6	13.6	15.2	16.6	85.6	11.4	11.8	16.0	15.7		
243	12/4/2008	6.0	6.4	7.1	8.8	77.6	5.6	4.9	7.3	7.5		
244	12/5/2008	7.5	8.1	9.8	10.1	78.4	6.2	6.3	9.1	10.5		
245	12/6/2008	14.5	15.8	20.6	21.3	72.3	12.6	13.5	19.2	20.3		
246	7/24/2008			32.9	32.0						ZP/RP-Check	Teddington
247	7/25/2008	15.4	15.1	22.5	23.6	65.9	13.9	13.2	27.1	24.4		
248	7/26/2008			21.0	21.6		14.1	14.2	23.3	23.3	Outlier Ref. PM2,5	
249	7/27/2008	13.1	13.2	19.0	19.9	67.8	15.3	15.0	22.4	22.0		
250	7/28/2008	13.5	13.6	20.3	20.3	66.9	15.7	15.8	23.5	24.1		
251	7/29/2008	4.2	4.7	11.8	12.1	37.4	6.0	6.4	14.0	14.7		
252	7/30/2008	9.6	9.5	16.2	16.5	58.4	11.3	10.9	19.4	18.8		
253	7/31/2008	10.8	11.0	22.2	22.4	49.0	14.0	14.0	26.4	27.8		
254	8/1/2008	4.2	5.5	16.3	15.5	30.3	6.8	7.5	19.3	18.9		
255	8/2/2008	2.4	2.2	8.5	6.0	31.6	4.8	4.5	8.9	8.9		
256	8/3/2008	2.0	2.5	8.2	8.4	26.8	3.9	3.6	10.2	10.8		
257	8/4/2008	3.4	4.4	9.4	9.6	41.1	6.0	5.6	13.2	12.5		
258	8/5/2008	3.1	3.6	7.5	7.3	45.1	5.8	6.0	10.8	10.6		
259	8/6/2008										Power loss	
260	8/7/2008	5.4	6.2	11.9	11.4	50.2	7.7	7.5	15.0	15.0		
261	8/8/2008	5.2	6.2	9.9	9.6	58.5	7.5	6.9	12.5	11.9		
262	8/9/2008	2.3	3.3	7.1	7.3	39.3	4.9	4.5	10.7	10.4		
263	8/10/2008	3.9	4.1	11.7	11.2	34.7	4.8	5.4	13.8	13.0		
264	8/11/2008	5.6	6.0	13.7	13.5	42.7	6.5	7.1	16.3	15.0		
265	8/12/2008	3.5	3.5	10.6	10.5	33.2	4.5	4.6	12.8	12.6		
266	8/13/2008	3.5	3.8	11.8	11.4	31.7	4.7	5.0	13.1	13.4		
267	8/14/2008	6.1	6.5	11.0	11.1	56.9	7.0	6.6	12.3	11.0		
268	8/15/2008	5.6	6.3	10.0	11.6	55.4	5.5	5.3	11.2	10.9		
269	8/16/2008	5.5	5.5				4.7	5.1	9.1	9.0	Outlier Ref. PM10	
270	8/17/2008	2.7	2.7	8.7	8.5	31.2	3.9	4.5	12.7	12.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 145 / SN 149

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 145 PM2,5 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
271	8/18/2008										ZP/RP-Check	Teddington
272	8/19/2008	4.6	4.7	12.5	13.0	36.6	5.7	5.7	12.6	12.8		
273	8/20/2008	3.9	4.1	10.2	10.1	39.6	5.3	5.6	14.6	13.2		
274	8/21/2008	6.5	6.8	13.2	13.5	50.2	7.3	7.7	14.3	13.8		
275	8/22/2008	5.2	4.9	9.5	9.3	53.6	6.1	5.9	10.7	10.8		
276	8/23/2008	4.5	4.4	9.2	9.5	47.4	6.2	6.5	11.4	12.9		
277	8/24/2008	3.5	3.5	8.6	8.7	40.3	4.7	5.6	11.7	11.4		
278	8/25/2008	6.5	6.5	12.9	13.0	50.0	9.2	9.1	17.6	17.4		
279	8/26/2008	4.8	4.9	10.7	9.5	47.9	7.3	7.0	13.3	13.3		
280	8/27/2008	7.4	7.0	13.4	13.6	53.2		9.0		16.7	SN145 Sensor defective	
281	8/28/2008	9.6	9.3	14.1	14.2	66.8		12.4		16.5	SN145 Sensor defective	
282	8/29/2008	13.7	12.8	20.1	19.1	67.8		17.1		22.4	SN145 Sensor defective	
283	8/30/2008	31.6	30.5	43.8	43.2	71.4	39.3	36.8	48.2	48.2		
284	8/31/2008	13.3	12.1	22.0	21.6	58.5	15.7	16.6	24.6	25.3		
285	9/1/2008	2.9	2.6	8.1	8.1	33.9	4.3	4.5	11.7	11.2		
286	9/2/2008	3.0	2.4	11.8	12.4	22.3	3.8	4.7	13.3	12.8		
287	9/3/2008	3.6	3.3	14.2	14.3	24.2	5.0	5.1	16.4	15.4		
288	9/4/2008	4.1	3.7				5.7	5.4	12.7	12.8	Outlier Ref. PM10	
289	9/5/2008	2.6	2.7	7.5	7.6	35.0	4.8	4.5	10.4	10.0		
290	9/6/2008	3.4	3.6	8.0	7.6	44.9	4.1	4.8	9.9	9.2		
291	9/7/2008	3.1	2.7	8.4	8.2	34.8	5.0	4.6	9.7	9.8		
292	9/8/2008	6.4	6.6	14.7	14.2	45.0	8.4	8.1	16.5	16.8		
293	9/9/2008	6.0	5.2	14.4	14.2	39.1	6.8	7.4	15.3	17.2		
294	9/10/2008	4.3	4.1	11.0	10.6	38.6	5.8	7.2	13.5	13.6		
295	9/11/2008	6.5	5.4	17.2	17.5	34.2	6.6	6.3	18.4	17.4		
296	9/12/2008	5.5	5.1	9.4	9.1	57.3	6.8	6.7	11.4	10.5		
297	9/13/2008	15.5	15.4	20.4	20.7	75.5	16.8	16.5	22.0	20.9		
298	9/14/2008	10.9	10.3	18.1	17.4	60.0	11.6	11.3	18.0	17.7		
299	9/15/2008	11.8	12.3	17.5	17.5	68.6	12.1	12.5	17.7	17.2		
300	9/16/2008	17.7	17.4	24.6	24.2	72.0	17.3	17.5	23.9	24.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 145 / SN 149

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 145 PM2,5 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
301	9/17/2008	19.4	19.2	26.9	28.1	70.3	18.0	17.6	25.4	25.8		Teddington
302	9/18/2008	17.0	17.2	24.5	23.6	71.3	16.3	16.6	23.9	23.5		
303	9/19/2008	20.7	20.9	29.3	29.4	70.9	20.4	20.6	30.0	29.7		
304	9/20/2008	21.7	21.4	26.9	26.6	80.6	20.7	21.2	26.8	25.7		
305	9/21/2008	21.6	22.0	28.6	28.1	76.9	22.3	23.2	29.0	28.9		
306	9/22/2008	14.8	15.0	22.3	22.6	66.3	15.8	17.0	23.5	23.5		
307	9/23/2008	6.3	6.1	18.0	17.8	34.5					ZP/RP-Check	
308	9/24/2008	11.4	11.4	18.8	19.7	59.1	12.3	11.8	21.0	21.3		
309	9/25/2008	16.1	16.5	26.7	26.4	61.2	16.1	16.2	26.5	25.8		
310	9/26/2008	17.5	17.4	29.9	29.7	58.5	17.5	18.4	28.9	30.4		
311	9/27/2008	27.2	27.2	35.7	35.6	76.4	29.1	28.7	36.4	37.2		
312	9/28/2008						16.9	16.8	24.7	25.1		
313	9/29/2008	4.3	4.4	7.4	8.5	54.9	4.8	4.6	9.7	10.1		
314	9/30/2008	3.2	3.3	6.9	6.7	48.3	3.3	3.5	7.3	7.6		
315	10/1/2008						3.5	3.7	8.8	8.4		
316	10/2/2008						4.5	4.3	8.0	7.8		
317	10/3/2008						5.2	6.0	9.4	9.8		
318	10/4/2008						2.1	2.9	6.2	6.3		
319	10/5/2008										Not in operation	
320	10/6/2008										Not in operation	
321	10/7/2008										Not in operation	
322	10/8/2008						10.4	11.1	17.3	16.5		
323	10/9/2008	8.9	10.1	18.4	18.0	52.2	8.9	9.3	17.8	18.0		
324	10/10/2008	10.5	10.6	19.5	19.6	54.1	9.0	9.8	18.1	18.0		
325	10/11/2008	15.6	15.8	22.6	22.6	69.5	15.5	17.9	24.8	23.4		
326	10/12/2008	20.4	21.1	25.9	25.9	80.1	21.6	21.7	27.2	27.0		
327	10/13/2008	8.3	8.4	14.6	14.4	57.6	9.2	9.3	16.2	15.3		
328	10/14/2008	6.1	6.4	11.4	12.2	52.7	7.2	7.5	14.1	13.6		
329	10/15/2008	3.9	3.8	8.2	8.6	46.0	3.7	4.5	9.0	8.3		
330	10/16/2008										ZP-Check	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 12 of 18**

Manufacturer	FAI Instruments s.r.l.	PM10 & PM2.5
Type of instrument	SWAM 5a DC	Measured values in µg/m³ (ACT)
Serial-No.	SN 145 / SN 149 SN 127 / SN 131 (Cologne, parking lot)	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 145 / SN 127 PM2,5 [µg/m³]	SN 149 / SN 131 PM2,5 [µg/m³]	SN 145 / SN 127 PM10 [µg/m³]	SN 149 / SN 131 PM10 [µg/m³]	Remark	Test site
331	10/17/2008										ZP-Check	Teddington
332	10/18/2008										ZP-Check	
333	10/19/2008										Not in operation	
334	10/20/2008										Not in operation	
335	10/21/2008										Not in operation	
336	10/22/2008										Not in operation	
337	10/23/2008										Not in operation	
338	10/24/2008										Not in operation	
339	10/25/2008										Not in operation	
340	10/26/2008										Not in operation	
341	10/27/2008										Not in operation	
342	10/28/2008										Not in operation	
343	10/29/2008						16.3	16.1	22.1	21.2		
344	10/30/2008						10.2	10.5	13.9	13.8		
345	10/31/2008	11.7	12.0	16.9	18.5	66.9	10.2	10.3	15.8	15.2		
346	11/1/2008	14.8	15.1	18.3	19.2	79.9	14.1	14.3	17.6	18.2		
347	11/2/2008	20.4	20.0	25.5	25.8	78.7	20.0	19.7	25.6	25.5		
348	11/3/2008	20.7	20.9	27.0	27.8	76.0	19.2	20.4	26.7	27.4		
349	11/4/2008	31.1	30.9	37.5	38.4	81.7	31.1	31.5	38.7	40.2		
350	11/5/2008	29.7	29.6	35.5	36.2	82.8	28.3	28.4	36.2	36.2		
351	11/6/2008	23.5	23.8	28.2	28.6	83.2	21.7	22.3	27.5	28.2		
352	11/7/2008	6.8	6.7	15.2	14.7	45.4		6.5		15.9	SN 145, Filter supply ran out	
353	11/8/2008	3.5	3.5	8.6	9.4	39.1		3.7		9.8	SN 145, Filter supply ran out	
354	11/9/2008	4.1	4.0	11.5	11.9	34.8		4.3		13.7	SN 145, Filter supply ran out	
355	2/14/2011	21.1	19.5	23.8	24.2	84.5	19.4	19.6	23.6	24.4		Cologne, parking lot
356	2/15/2011	16.4	16.0	19.0	19.7	83.7	16.3	16.2	19.2	19.9		
357	2/16/2011	24.5	24.0	34.0	34.2	71.1	23.1	23.4	33.8	34.7		
358	2/17/2011	36.0	35.5	42.2	42.1	84.8	38.3	38.5	43.2	44.6		
359	2/18/2011	36.5	36.7	43.4	43.5	84.3	37.2	36.7	44.2	44.6		
360	2/19/2011						51.4	50.1	58.4	58.2		

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
361	2/20/2011	27.6	27.8	29.5	29.8	93.5	26.7	28.6	0.0	31.9		Cologne, parking lot
362	2/21/2011	31.3	31.8	36.6	36.2	86.6	33.9	33.0	39.3	39.0		
363	2/22/2011	36.5	37.9	43.3	43.8	85.4	39.5	39.3	47.6	47.3		
364	2/23/2011	38.0	37.9	45.7	45.7	83.0	37.8	38.5	47.1	46.3		
365	2/24/2011	30.3	31.4	36.0	35.8	85.9	29.7	28.2	38.4	37.4		
366	2/25/2011	26.4	26.7	30.4	29.6	88.6	27.1	25.9	30.6	30.2		
367	2/26/2011						14.4	14.7	17.6	17.9		
368	2/27/2011	13.5	13.3	15.4	14.8	88.5	13.8		15.9		SN 131 in Ending Mode, Filter supply depleted	
369	2/28/2011	36.7	36.0	44.7	43.7	82.3	33.0		39.8		SN 131 in Ending Mode, Filter supply depleted	
370	3/1/2011	66.6	66.0	75.6	74.7	88.2	70.1	65.6	79.1	80.4		
371	3/2/2011	49.4	49.7	60.6	58.5	83.1	54.3	51.5	62.0	63.6		
372	3/3/2011	39.4	37.5	50.8	48.9	77.1	41.0	38.8	48.8	49.9		
373	3/4/2011	76.3	76.5								Maintenance / Flow checks - Values discarded	
374	3/5/2011						26.4	26.6	35.9	37.2		
375	3/6/2011	8.9	9.2	13.6	14.1	65.1	6.4	7.6	12.0	12.3		
376	3/7/2011	8.3	9.0	13.8	12.4	66.2	8.0	8.6	12.2	12.6		
377	3/8/2011	31.1	31.8	43.9	43.8	71.7	26.9	28.4	38.9	38.4		
378	3/9/2011	19.1	18.8	30.5	28.7	63.9	16.6	16.3	25.3	26.3		
379	3/10/2011						8.0	7.9	14.5	14.6		
380	3/11/2011	16.7	16.1	33.5	33.1	49.2	13.5	14.0	29.6	29.8		
381	3/12/2011						16.0	18.2	28.9	30.7		
382	3/13/2011	13.3	13.1	16.2	15.6	83.1	11.4	11.7	15.4	15.5		
383	3/14/2011	18.2	20.0	27.7	25.6	71.5					Power loss due to AC SN127	
384	3/15/2011	37.4	37.9	44.1	43.1	86.3		33.0		41.0	SN127 no value after power loss	
385	3/16/2011			67.3	65.8		49.8	48.7	66.1	61.2	Outlier Ref PM2,5	
386	3/17/2011	50.7	49.6	68.0	67.1	74.1					Geiger instabilities on both systems, cause unknown	
387	3/18/2011	28.4	28.1	38.4	38.4	73.5	21.9	21.6	34.0	32.2		
388	3/19/2011						10.9	11.6	16.6	17.3		
389	3/20/2011	20.4	20.4	28.6	28.0	72.0	17.5	17.0	25.2	25.7		
390	3/21/2011	22.4	22.3	34.7	34.3	64.8	21.3	21.0	32.7	33.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 14 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
391	3/22/2011	41.7	41.6	55.7	54.8	75.4	36.6	37.4	52.6	52.8		Cologne, parking lot
392	3/23/2011	20.3	20.4	33.1	31.6	63.0	19.1	19.3	31.0	31.0		
393	3/24/2011	18.6	20.2	33.3	32.7	58.8	17.6	17.9	30.6	30.7		
394	3/25/2011	27.6	27.5	36.9	37.2	74.2	25.1	25.9	34.1	34.9		
395	3/26/2011						12.6	12.9	18.1	18.8		
396	3/27/2011	24.6	24.8	35.6	35.4	69.5	22.7	22.4	32.7	33.2		
397	3/28/2011	20.5	20.7	32.4	31.9	64.2	17.9	18.8	28.8	29.1		
398	3/29/2011	44.7	44.2	65.4	65.6	67.8	39.7	39.5	62.9	62.7		
399	3/30/2011	15.6	15.6	24.0	23.4	65.8	14.6	14.6	22.6	22.9		
400	3/31/2011	6.0	5.1	10.5	9.3	56.2	6.1	6.0	9.9	9.8		
401	4/1/2011	8.5	7.7	13.3	13.0	61.7	8.3	7.3	13.7	13.3		
402	4/2/2011						20.7	22.4	35.2	36.2		
403	4/3/2011	14.6	13.7	22.1	22.4	63.6	13.0	13.7	19.9	20.2		
404	4/4/2011	8.8	9.0	17.9	16.6	51.6	8.4	8.6	15.9	15.5		
405	4/5/2011	11.0	11.4	19.2	19.0	58.7	10.1		18.2	17.9	SN131, Pump Line A defective	
406	4/6/2011	13.0	12.9	23.6	23.8	54.6	12.8		23.5	22.7	SN131, Pump Line A defective	
407	4/7/2011	13.7	13.1	23.2	24.2	56.7	12.1		22.3	20.9	SN131, Pump Line A defective	
408	4/8/2011	19.0	19.8	34.9	34.8	55.7	17.8		31.5	31.2	SN131, Pump Line A defective	
409	4/9/2011						14.1		29.5	31.2	SN131, Pump Line A defective	
410	4/10/2011	11.1	11.8	23.4	22.3	50.1	11.2		22.0	21.6	SN131, Pump Line A defective	
411	4/11/2011	15.2	15.1	31.3	31.5	48.2	15.2		31.3	31.9	SN131, Pump Line A defective	
412	4/12/2011	9.0	8.2	18.0	17.1	49.0	8.4		17.2	15.9	SN131, Pump Line A defective	
413	4/13/2011	12.5	12.2	24.4	23.2	51.9	12.4		23.2	23.7	SN131, Pump Line A defective	
414	4/14/2011	19.6	19.5	32.0	31.5	61.5	19.7		31.9	31.8	SN131, Pump Line A defective	
415	4/15/2011	13.3	11.5	31.9	31.9	38.8	14.7		34.4	34.6	SN131, Pump Line A defective	
416	4/16/2011						23.3		46.9	48.2	SN131, Pump Line A defective	
417	4/17/2011						14.3		21.9	21.4	SN131, Pump Line A defective	
418	4/18/2011	17.0	17.3	26.4	26.6	64.6	20.1		29.3		SN131, Pump Line A defective, Line B lost due to cycle interruption	
419	4/19/2011	17.5	17.9	30.3	30.7	58.0	20.3		31.9			
420	4/20/2011	20.0	20.8	33.9	34.2	59.8	22.8		36.5			

Annex 5 **Measured values from field test sites, related to actual conditions**

Manufacturer	FAI Instruments s.r.l.
Type of instrument	SWAM 5a DC
Serial-No.	SN 127 / SN 131 SN 248 / SN 249 (Bornheim)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 / SN 248 PM2,5 [µg/m³]	SN 131 / SN 249 PM2,5 [µg/m³]	SN 127 / SN 248 PM10 [µg/m³]	SN 131 / SN 249 PM10 [µg/m³]	Remark	Test site
421	4/21/2011						21.7		33.1	33.6	SN131, Repair of pump Line A	Cologne, parking lot
422	4/22/2011						21.1	22.9	28.2	28.6		
423	4/23/2011						30.5	23.4	38.7	38.4		
424	4/24/2011						23.3	31.9	28.5	31.5		
425	4/25/2011	19.6	20.7	27.4	27.4	73.6	21.6	22.9	29.1	29.1		
426	4/26/2011	17.1	17.6	31.0	31.3	55.7	18.9	20.9	31.8	31.6		
427	4/27/2011			44.3	45.1		27.6	28.4	47.2	44.3		
428	4/28/2011	16.2	17.8	28.0	28.0	60.8	20.1	19.6	27.6	26.4		
429	4/29/2011	19.0	19.4	25.9	27.3	72.0	21.5	22.5	28.5	29.5		
430	4/30/2011	12.9	13.3	21.0	22.0	61.0	14.8	17.2	23.0	23.1		
431	5/1/2011	6.7	7.0	13.0	12.9	52.9	8.6	8.5	13.3	12.7		
432	5/2/2011	9.3	9.2	16.1	14.9	59.8	9.8	10.8	14.6	14.0		
433	5/3/2011	9.1	9.3	15.9	15.1	59.2	9.5	9.4	15.4	14.2		
434	5/4/2011	11.4	11.5	20.5	20.2	56.1	11.9	12.0	18.9	18.1		
435	5/5/2011			20.1	19.5		12.6	11.7	19.0	17.4	Outlier Ref. PM2.5	
436	5/6/2011	13.7	13.6	30.7	31.1	44.2	16.7	18.2	33.0	31.6		
437	5/7/2011	19.1	17.6	46.1	47.5	39.2	25.8	29.7	53.2	51.0		
438	5/8/2011	12.3	12.2	23.4	23.0	53.0	13.7	15.9	20.9	22.4		
439	5/9/2011	17.9	17.9	32.4	32.8	54.9	18.9	19.7	30.2	27.6		
440	5/10/2011	24.4	23.9	43.8	43.2	55.5	27.2	24.9	39.6	35.9		
441	5/11/2011	15.6	15.8	33.1	33.6	47.1	15.6	15.4	27.4	26.5		
442	5/12/2011	11.4	11.7	28.1	27.4	41.4	11.0	11.7	23.4	22.3		
443	5/13/2011	13.5	14.7	32.6	34.0	42.4	13.1	14.3	28.3	26.2		
444	5/14/2011						10.1	12.0	20.6	19.5		
445	8/11/2011	5.5	5.2	11.4	11.1	47.3	5.0	4.7	11.2	10.9		Bornheim
446	8/12/2011	3.0	3.8	6.4	7.0	50.2	4.4	3.7	7.6	7.0		
447	8/13/2011						5.4	5.4	8.6	8.2		
448	8/14/2011	2.6	3.7	7.0	6.7	45.9	4.8	4.4	8.4	8.0		
449	8/15/2011	6.0	5.4	13.5	13.9	41.6	7.9	8.3	15.2	15.7		
450	8/16/2011	6.0	6.0	13.7	12.9	45.1	8.2	8.5	14.8	14.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 16 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
451	8/17/2011	14.7	14.0	25.8	25.0	56.3	17.0	18.0	27.8	27.9		Bornheim
452	8/18/2011	9.0	8.7	16.8	15.9	54.1	13.0	13.5	20.0	20.8		
453	8/19/2011	6.6	6.2	13.3	12.8	48.8	9.1	9.3	15.0	14.9		
454	8/20/2011						10.7	10.7	17.5	16.3		
455	8/21/2011	10.4	10.3	17.1	17.2	60.4	13.3	14.2	20.6	19.7		
456	8/22/2011	10.9	10.8	19.7	19.3	55.8	15.2	15.6	22.3	23.6		
457	8/23/2011	19.2	19.1	29.9	30.1	63.7	17.9	17.9	30.5	30.4		
458	8/24/2011	6.7	7.4	16.9	16.7	41.9	7.8	7.9	17.0	17.0		
459	8/25/2011	11.5	12.1	18.8	18.6	63.4	14.2	14.3	21.2	21.0		
460	8/26/2011	4.9	5.5	10.7	10.7	48.7	7.4	6.9	12.4	12.3		
461	8/27/2011						3.1	3.7	5.4	5.5		
462	8/28/2011			7.7	7.6		3.3	3.8	7.1	7.1		
463	8/29/2011	6.0	6.2	11.4	11.5	53.0	4.9	5.6	10.0	10.2		
464	8/30/2011	9.1	8.2	17.1	16.6	51.1	7.5	7.2	15.0	14.8		
465	8/31/2011	14.5	13.9	26.0	23.6	57.2	13.6	14.0	23.2	23.8		
466	9/1/2011	17.7	18.2	27.5	26.1	66.9	18.1	17.5	26.5	27.4		
467	9/2/2011	14.9	15.0	25.1	24.1	60.6	16.8	16.5	24.9	24.8		
468	9/3/2011						16.3	17.0	26.1	25.9		
469	9/4/2011	8.2	8.0	12.7	12.1	65.3	7.3	6.4	12.2	12.2		
470	9/5/2011	4.9	5.0	9.2	9.1	53.8	3.1	3.5	7.0	6.8		
471	9/6/2011	5.2	5.6	11.1	10.6	49.8	4.1	4.2	9.0	9.5		
472	9/7/2011	6.1	5.8	12.5	13.2	46.1	4.1	4.4	10.5	10.5		
473	9/8/2011						4.2	3.8	8.8	8.2		
474	9/9/2011	6.8	7.1	12.1	11.8	58.0	6.4	6.7	12.1	12.0		
475	9/10/2011						9.2	9.3	13.3	13.1		
476	9/11/2011	5.7	5.5	9.4	9.3	59.5	5.2	4.5	8.9	8.4		
477	9/12/2011	5.2	6.1	11.6	11.6	48.6	4.7	4.8	9.3	9.0		
478	9/13/2011	6.3	7.2	16.3	16.8	40.6	5.4	6.0	13.5	12.8		
479	9/14/2011	6.7	7.2	15.3	15.6	44.9	5.1	5.1	11.9	12.8		
480	9/15/2011	11.1	12.2	24.3	24.9	47.3	11.4	10.6	22.1	21.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 17 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
481	9/16/2011	13.0	13.7	23.0	25.1	55.4	12.5	12.1	21.1	21.6		Bornheim
482	9/17/2011						6.1	5.6	9.6	9.3		
483	9/18/2011	3.2	3.9	7.0	7.1	50.4	2.5	2.9	4.5	4.7		
484	9/19/2011	7.8	8.2	12.5	11.6	66.2	6.6	6.9	10.8	11.2		
485	9/20/2011	6.2	6.2	12.3	12.3	50.6		4.9		11.6	SN 248 main board defective	
486	9/21/2011	6.6	6.6	12.4	12.3	53.6		6.4		10.7	SN 248 main board defective	
487	9/22/2011	6.4	7.8	19.2	18.9	37.3		6.9		14.8	SN 248 main board defective	
488	9/23/2011	12.2	13.4	26.1	26.2	49.1	13.1	13.4	23.9	23.1		
489	9/24/2011							14.3		20.7	SN 248 wrong sampled volume - cause unknown	
490	9/25/2011	15.7	14.5	21.3	21.7	70.0	15.9	16.1	22.0	21.8		
491	9/26/2011	12.0	12.0	18.8	20.6	60.8	13.8	13.5	22.1	21.5		
492	9/27/2011	21.9	21.9	38.3	39.8	56.0	19.9	20.3	38.5	38.6		
493	9/28/2011	15.5	15.5	25.7	25.7	60.2	18.3	18.7	27.7	26.6		
494	9/29/2011	17.1	16.0	25.4	25.4	65.1	18.3	17.5	25.6	25.0		
495	9/30/2011	12.4	11.8	23.4	24.5	50.6	13.4	13.6	24.8	24.3		
496	10/1/2011						13.7	13.2	21.2	21.4		
497	10/2/2011						28.8	28.9	37.1	37.7		
498	10/3/2011	13.5	14.8	21.4	21.4	66.2	14.5	14.4	24.2	24.5		
499	10/4/2011	9.9	9.8	15.9	16.3	60.9	10.4	9.7	15.3	15.3		
500	10/5/2011	4.5	2.5	7.0	6.5	51.7	4.1	3.6	6.0	6.0		
501	10/6/2011	5.5	4.1	10.8	10.4	45.6	4.4	4.3	9.6	9.4		
502	10/7/2011	3.6	3.1	8.1	7.6	42.9	3.4	3.3	6.2	6.3		
503	10/8/2011						4.4	5.5	7.9	8.0		
504	10/9/2011	6.0	6.4	10.1	10.4	60.7	5.5	5.7	9.7	9.4		
505	10/10/2011	4.7	5.2	11.9	12.5	40.9	7.1	7.2	13.6	14.1		
506	10/11/2011	1.3	2.0	5.5	5.0	31.2	3.4	3.7	5.5	6.0		
507	10/12/2011	1.9	3.2	5.3	5.0	49.3	4.5	5.2	6.5	6.5		
508	10/13/2011	4.2	4.2	11.5	11.7	36.3	6.3	6.2	12.3	11.8		
509	10/14/2011	5.9	8.5	14.8	14.0	50.2	9.1	8.8	15.3	15.2		
510	10/15/2011						10.6	10.5	14.3	14.4		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 18 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
511	10/16/2011	11.1	13.8	17.0	16.7	73.7	14.1	14.3	18.1	17.9		Bornheim
512	10/17/2011	18.6	20.2	28.0	27.3	70.0	20.8	20.1	28.2	27.5		
513	10/18/2011	4.3	6.7	11.6	11.5	47.7	6.4	6.8	11.8	11.5		
514	10/19/2011	3.8	5.2				5.6	5.6	10.5	9.9	Outlier Ref. PM10	
515	10/20/2011	9.3	9.5	11.9	15.8	67.9	10.7	10.3	16.4	16.0		
516	10/21/2011	17.6	18.1	28.0	26.4	65.5	18.4	18.6	26.7	26.5		
517	10/22/2011						20.0	20.3	23.6	23.7		
518	10/23/2011	23.0	23.2				23.7	23.8	28.2	27.8	Outlier Ref. PM10	
519	10/24/2011						16.2	15.9	22.1	21.2		
520	10/25/2011						12.2	12.3	16.1	17.2		
521	10/26/2011						7.2	7.1	12.5	12.3		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 1 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC HM

Serial-No. SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
1	2/14/2011	21.1	19.5	23.8	24.2	84.5	21.2	19.7	24.0	22.9		Cologne, parking lot
2	2/15/2011	16.4	16.0	19.0	19.7	83.7	17.6	17.3	20.0	19.9		
3	2/16/2011	24.5	24.0	34.0	34.2	71.1	25.8	26.0	33.2	33.0		
4	2/17/2011	36.0	35.5	42.2	42.1	84.8	38.7	38.6	43.5	42.3		
5	2/18/2011	36.5	36.7	43.4	43.5	84.3	38.6	38.9	45.4	44.4		
6	2/19/2011						51.2	51.3	56.2	56.0		
7	2/20/2011	27.6	27.8	29.5	29.8	93.5	29.1	29.1	32.1	31.0		
8	2/21/2011	31.3	31.8	36.6	36.2	86.6	34.0	33.3	39.0	37.0		
9	2/22/2011	36.5	37.9	43.3	43.8	85.4	39.6	38.2	45.7	44.9		
10	2/23/2011	38.0	37.9	45.7	45.7	83.0	38.2	39.5	46.6	44.0		
11	2/24/2011	30.3	31.4	36.0	35.8	85.9	30.7	29.1	35.7	34.3		
12	2/25/2011	26.4	26.7	30.4	29.6	88.6	27.0		30.0		SN 112 error 26 (Filter-loader not properly inserted)	
13	2/26/2011						14.8	15.2	17.9	17.5		
14	2/27/2011	13.5	13.3	15.4	14.8	88.5	14.2		15.7		SN 112 no data available	
15	2/28/2011	36.7	36.0	44.7	43.7	82.3	34.8	35.8	40.2	40.5		
16	3/1/2011	66.6	66.0	75.6	74.7	88.2	66.6	65.1	71.2	72.4		
17	3/2/2011	49.4	49.7	60.6	58.5	83.1	51.6	49.8	59.4	56.9		
18	3/3/2011	39.4	37.5	50.8	48.9	77.1	40.1	39.2	47.4	47.0		
19	3/4/2011	76.3	76.5								Maintenance / Flow checks - Values discarded	
20	3/5/2011						29.1	29.8	37.1	37.3		
21	3/6/2011	8.9	9.2	13.6	14.1	65.1	7.8	7.9	12.2	11.8		
22	3/7/2011	8.3	9.0	13.8	12.4	66.2	7.6	8.4	12.5	12.6		
23	3/8/2011	31.1	31.8	43.9	43.8	71.7	29.8	29.6	38.8	38.1		
24	3/9/2011	19.1	18.8	30.5	28.7	63.9	17.5	18.6	24.9	25.6		
25	3/10/2011										Power loss	
26	3/11/2011	16.7	16.1	33.5	33.1	49.2	15.8	16.5	29.4	28.9		
27	3/12/2011						16.0	17.0	27.8	28.1		
28	3/13/2011	13.3	13.1	16.2	15.6	83.0	12.4	12.5	15.2	15.1		
29	3/14/2011	18.2	20.0	27.8	25.6	71.5					Power loss	
30	3/15/2011	37.4	37.9	44.1	43.1	86.3	36.9	36.7	42.0	42.0		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 2 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC HM

Serial-No. SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
31	3/16/2011			67.3	65.8		53.3	55.7	64.9	62.2		Cologne,
32	3/17/2011	50.7	49.6	68.0	67.1	74.1					Geiger instabilities on all systems, cause unknown	parking lot
33	3/18/2011	28.4	28.1	38.4	38.4	73.5	27.0	26.6	34.5	33.4		
34	3/19/2011						12.7	12.3	17.7	16.9		
35	3/20/2011	20.4	20.4	28.6	28.0	72.0	18.2	18.6	25.4	25.3		
36	3/21/2011	22.4	22.3	34.7	34.3	64.8	22.4	22.7	33.8	32.8		
37	3/22/2011	41.7	41.6	55.7	54.8	75.4	40.4	41.6	54.3	53.2		
38	3/23/2011	20.3	20.4	33.1	31.6	63.0	20.7		31.3		SN112 filter blocked	
39	3/24/2011	18.6	20.2	33.3	32.7	58.8	19.8	20.1	31.7	30.2		
40	3/25/2011	27.6	27.5	36.9	37.2	74.2	25.9	27.0	34.7	34.8		
41	3/26/2011						12.6	13.5	18.3	18.2		
42	3/27/2011	24.6	24.8	35.6	35.4	69.5	24.0	24.5	33.6	33.1		
43	3/28/2011	20.5	20.7	32.4	31.9	64.2	19.9	20.3	29.4	28.3		
44	3/29/2011	44.7	44.2	65.5	65.6	67.8	43.6	45.4	63.6	62.6		
45	3/30/2011	15.6	15.6	24.0	23.4	65.8	14.2	14.7	21.2	20.7		
46	3/31/2011	6.0	5.1	10.5	9.3	56.2	6.4	7.0	9.5	10.0		
47	4/1/2011	8.5	7.7	13.3	13.1	61.7	8.8	9.0	13.2	12.7		
48	4/2/2011						17.6	19.8	31.4	31.9		
49	4/3/2011	14.6	13.7	22.1	22.4	63.6	15.0	14.9	20.5	20.2		
50	4/4/2011	8.8	9.0	17.9	16.6	51.6	8.9	9.4	15.7	14.8		
51	4/5/2011	11.0	11.4	19.2	19.0	58.7	11.7	11.8	18.2	17.6		
52	4/6/2011	13.0	12.9	23.6	23.8	54.6	13.5	13.9	23.3	23.0		
53	4/7/2011	13.7	13.1	23.2	24.2	56.7	14.4	15.1	22.1	21.0		
54	4/8/2011	19.0	19.8	34.9	34.8	55.7	19.6	21.8	32.1	32.0		
55	4/9/2011						15.9	16.5	30.1	29.6		
56	4/10/2011	11.1	11.8	23.4	22.3	50.1	12.6	13.3	21.7	21.9		
57	4/11/2011	15.2	15.1	31.3	31.5	48.2	16.4	18.0	31.8	29.7		
58	4/12/2011	9.0	8.2	18.0	17.1	49.0	10.1	10.2	18.0	17.3		
59	4/13/2011	12.5	12.2	24.4	23.2	51.9	13.6	14.1	23.9	23.1		
60	4/14/2011	19.6	19.5	32.0	31.5	61.5	21.5	22.1	32.1	31.8		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 3 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC HM

Serial-No. SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
61	4/15/2011	13.3	11.5	31.9	31.9	38.8	12.8	15.0	29.8	31.3		Cologne,
62	4/16/2011						18.0	21.6	41.0	40.1		parking lot
63	4/17/2011						14.6	15.6	21.8	21.5		
64	4/18/2011	17.0	17.3	26.4	26.6	64.6	19.9	20.6	30.0	28.1		
65	4/19/2011	17.5	17.9	30.3	30.7	58.0	20.7	21.9	32.4	31.4		
66	4/20/2011	20.0	20.8	33.9	34.2	59.8	23.2	23.7	36.1	35.4		
67	4/21/2011						23.6	24.6	34.5	34.0		
68	4/22/2011						21.8	23.2	30.2	29.6		
69	4/23/2011						33.5	34.6	40.7	40.7		
70	4/24/2011						25.6		32.6		SN 112 filter blocked	
71	4/25/2011	19.6	20.7	27.4	27.4	73.6	23.4		31.3		SN 112 filter blocked	
72	4/26/2011	17.1	17.6	31.0	31.3	55.7	20.0		32.2		No measurement SN112 due to wrong set-up	
73	4/27/2011			44.4	45.1		33.4		48.2		No measurement SN112 due to wrong set-up	
74	4/28/2011	16.2	17.8	28.0	28.0	60.8	24.2		30.8		No measurement SN112 due to wrong set-up	
75	4/29/2011	19.0	19.4	25.9	27.3	72.0	20.8		30.1		No measurement SN112 due to wrong set-up	
76	4/30/2011	12.9	13.3	21.0	22.0	61.0	14.8	14.7	23.2	21.4		
77	5/1/2011	6.7	7.0	13.0	12.9	52.9	8.2	7.9	13.0	12.6		
78	5/2/2011	9.3	9.2	16.1	14.9	59.8	10.5	10.1	15.6	16.3		
79	5/3/2011	9.1	9.3	15.9	15.1	59.2	9.7	9.3	15.2	16.1		
80	5/4/2011	11.4	11.5	20.5	20.2	56.1	13.0	13.3	20.0	19.9		
81	5/5/2011			20.1	19.5		12.2	12.2	19.0	19.6	Outlier Ref. PM2.5	
82	5/6/2011	13.7	13.6	30.7	31.1	44.2	14.4	13.5	30.5	30.9		
83	5/7/2011	19.1	17.6	46.1	47.5	39.2	17.0	14.3	46.1	47.8		
84	5/8/2011	12.3	12.2	23.4	23.0	53.0	10.8	10.5	21.0	20.7		
85	5/9/2011	17.9	17.9	32.4	32.8	54.9	19.4	19.6	30.4	29.7		
86	5/10/2011	24.4	23.9	43.8	43.2	55.5	29.6	29.1	42.0	42.7		
87	5/11/2011	15.6	15.8	33.1	33.6	47.1	17.8	18.4	31.6	32.8		
88	5/12/2011	11.4	11.7	28.1	27.4	41.4	11.5	11.5	24.9	25.1		
89	5/13/2011	13.5	14.7	32.6	34.0	42.4	14.0	13.6	28.8	28.6		
90	5/14/2011						9.9	9.2	20.6	17.7		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 1 of 3**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a

Serial-No.: SN 331 & SN 333 (PM2.5)
SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
1	8/11/2011	5.5	5.2	11.4	11.1	47.3		2.6	9.7	10.9	SN 331 Instability power supply of Geiger counter	Bornheim
2	8/12/2011	3.0	3.8	6.4	7.0	50.2		3.4	5.6	7.1	SN 331 Instability power supply of Geiger counter	
3	8/13/2011							3.1	5.8	6.5	SN 331 Instability power supply of Geiger counter	
4	8/14/2011	2.6	3.6	7.0	6.7	45.9		5.7	8.4	8.8	SN 331 Instability power supply of Geiger counter	
5	8/15/2011	6.0	5.4	13.5	13.9	41.7		9.7	15.8	15.5	SN 331 Instability power supply of Geiger counter	
6	8/16/2011	6.0	6.0	13.7	12.9	45.1		7.0	13.5	13.8	SN 331 Instability power supply of Geiger counter	
7	8/17/2011	14.7	14.0	25.8	25.0	56.3		16.8	26.2	26.8	SN 331 Instability power supply of Geiger counter	
8	8/18/2011	9.0	8.7	16.8	15.9	54.1		12.6	18.5	19.2	SN 331 Instability power supply of Geiger counter	
9	8/19/2011	6.6	6.2	13.3	12.8	48.8		8.9	15.2	13.9	SN 331 Instability power supply of Geiger counter	
10	8/20/2011							10.2	16.2	16.9	SN 331 Instability power supply of Geiger counter	
11	8/21/2011	10.4	10.3	17.1	17.2	60.4		12.7	18.3	19.0	SN 331 Instability power supply of Geiger counter	
12	8/22/2011	10.9	10.8	19.7	19.3	55.8		13.3	20.5	20.5	SN 331 Instability power supply of Geiger counter	
13	8/23/2011	19.2	19.1	29.9	30.1	63.7		22.5	29.0	31.4	SN 331 Instability power supply of Geiger counter	
14	8/24/2011	6.7	7.4	16.9	16.7	41.9		8.3	16.4	17.0	SN 331 Instability power supply of Geiger counter	
15	8/25/2011	11.5	12.1	18.8	18.6	63.4		11.6	17.9	17.8	SN 331 Instability power supply of Geiger counter	
16	8/26/2011	4.9	5.5	10.7	10.7	48.8		6.5	10.8	10.6	SN 331 Instability power supply of Geiger counter	
17	8/27/2011							2.9	3.3	5.2	SN 331 Instability power supply of Geiger counter	
18	8/28/2011	1.8		7.7	7.6			2.4	5.4	6.0	SN 331 Instability power supply of Geiger counter	
19	8/29/2011	5.9	6.2	11.4	11.5	53.0		5.1	7.8	9.9	SN 331 Instability power supply of Geiger counter	
20	8/30/2011	9.1	8.1	17.1	16.6	51.1		6.5	13.9	13.9	SN 331 Instability power supply of Geiger counter	
21	8/31/2011	14.5	13.9	26.0	23.6	57.2		13.8	21.3	22.2	SN 331 problem solved (cable break)	
22	9/1/2011	17.7	18.2	27.5	26.1	66.9	16.9	17.9	24.5	23.1		
23	9/2/2011	14.9	15.0	25.1	24.1	60.6	14.8	16.4	23.9	22.6		
24	9/3/2011						14.8	15.5	23.3	22.6		
25	9/4/2011	8.2	8.0	12.7	12.1	65.3	6.4	6.8	10.3	10.4		
26	9/5/2011	4.8	5.0	9.2	9.1	53.8	2.9	4.0	6.7	7.2		
27	9/6/2011	5.2	5.6	11.1	10.6	49.8	4.1	3.7	7.7	8.7		
28	9/7/2011	6.1	5.8	12.5	13.2	46.1	4.5	4.4	9.1	10.0		
29	9/8/2011						3.6	3.7	8.1	8.2		
30	9/9/2011	6.8	7.1	12.1	11.8	57.9	6.4	6.7	10.6	11.0		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 2 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a

Serial-No. SN 331 & SN 333 (PM2.5)
SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
31	9/10/2011						8.5	7.9	11.5	11.2		Bornheim
32	9/11/2011	5.7	5.5	9.4	9.3	59.5	4.8	4.6	9.4	9.0		
33	9/12/2011	5.2	6.1	11.6	11.6	48.5	4.8	3.0	8.9	9.3		
34	9/13/2011	6.3	7.2	16.3	16.8	40.6	5.1	5.5	12.2	13.1		
35	9/14/2011	6.7	7.2	15.3	15.6	44.9	6.2	5.7	12.2	12.9		
36	9/15/2011	11.1	12.2	24.3	24.9	47.4	11.9	11.2	20.6	20.2		
37	9/16/2011	13.0	13.7	23.0	25.1	55.4	11.8	11.9	20.0	21.0		
38	9/17/2011						4.2	4.3	6.9	7.5		
39	9/18/2011	3.2	3.9	7.0	7.1	50.4	3.7	3.2	7.5	7.5		
40	9/19/2011	7.8	8.2	12.5	11.6	66.2	8.2	7.8	10.8	10.8		
41	9/20/2011	6.2	6.2	12.3	12.3	50.6	5.7	7.0	11.8	12.3		
42	9/21/2011	6.6	6.6	12.4	12.3	53.6	6.6	6.9	10.8	11.8		
43	9/22/2011	6.4	7.8	19.2	18.9	37.3	6.9	7.2	15.0	15.6		
44	9/23/2011	12.2	13.4	26.1	26.2	49.1	11.0	11.9	21.5	20.7		
45	9/24/2011						14.5	14.1	19.9	21.1		
46	9/25/2011	15.7	14.5	21.3	21.7	70.0	16.3	16.3	20.9	21.9		
47	9/26/2011	12.0	12.0	18.8	20.6	60.8	13.9	14.3	22.6	23.0		
48	9/27/2011	21.9	21.9	38.3	39.8	56.0	19.6	19.4	37.8	38.2		
49	9/28/2011	15.5	15.5	25.7	25.7	60.2	14.5	14.5	28.0	28.0		
50	9/29/2011	17.1	16.0	25.4	25.4	65.1	18.2	18.2	26.9	26.8		
51	9/30/2011	12.4	11.8	23.4	24.5	50.6	13.1	13.2	21.3	23.2		
52	10/1/2011						12.3	12.5	18.7	19.7		
53	10/2/2011						28.1	28.2	34.9	36.5		
54	10/3/2011	13.5	14.8	21.4	21.4	66.2	14.2	13.8	22.1	23.2		
55	10/4/2011	9.8	9.8	15.9	16.3	60.9		9.4	14.4	14.7	SN 331 carousel blocked by filter	
56	10/5/2011	4.5	2.5	7.0	6.5	51.8		1.4	4.1	3.6	SN 331 carousel blocked by filter	
57	10/6/2011	5.5	4.1	10.8	10.4	45.6		3.4	8.0	7.1	SN 331 carousel blocked by filter	
58	10/7/2011	3.6	3.1	8.1	7.6	42.9	3.5	3.6	6.6	6.1		
59	10/8/2011						5.8	5.1	9.2	8.3		
60	10/9/2011	6.0	6.4	10.1	10.4	60.7	6.1	7.3	11.3	10.7		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 3 of 3**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a

Serial-No.: SN 331 & SN 333 (PM2.5)
SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
61	10/10/2011	4.7	5.2	11.9	12.5	40.9	6.7	6.9	11.7	12.9		Bornheim
62	10/11/2011	1.3	2.0	5.5	5.0	31.2	2.4	2.4	4.7	6.4		
63	10/12/2011	1.9	3.2	5.3	5.0	49.3	4.5	4.4	6.5	6.6		
64	10/13/2011	4.2	4.2	11.5	11.7	36.3	7.5	7.6	12.9	12.3		
65	10/14/2011	5.9	8.5	14.8	14.0	50.2	9.7	9.7	15.7	14.7		
66	10/15/2011						10.7	10.9	15.1	13.9		
67	10/16/2011	11.1	13.7	17.0	16.7	73.7	13.0	13.3	17.7	16.1		
68	10/17/2011	18.6	20.1	28.0	27.3	70.0	17.6	14.0	24.9	24.5		
69	10/18/2011	4.3	6.7	11.6	11.5	47.7	5.1	5.0	9.4	10.3		
70	10/19/2011	3.8	5.2				5.0	5.1	9.4	10.0	Outlier Ref. PM10	
71	10/20/2011	9.3	9.5	11.9	15.8	67.9	10.1	10.7	16.3	16.3		
72	10/21/2011	17.6	18.1	28.0	26.4	65.5	18.9	20.0	27.4	27.1		
73	10/22/2011						19.2	19.7	23.4	22.8		
74	10/23/2011	23.0	23.2				22.2	21.4	25.9	26.0	Outlier Ref. PM10	
75	10/24/2011						13.2	13.2	18.7	18.2		
76	10/25/2011						12.3	11.1	15.4	15.7		
77	10/26/2011						6.8	6.4	11.6	11.7		

Annex 8 **Ambient conditions at the field test sites** **Page 1 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	10/20/2007	Cologne,	6.6	1027	65.3	0.0	153	0.3
2	10/21/2007	parking lot	5.4	1020	81.5	0.0	197	3.0
3	10/22/2007		3.1	1020	71.8	0.5	155	0.0
4	10/23/2007		4.5	1018	68.1	0.0	99	0.0
5	10/24/2007		7.6	1017	70.7	0.0	66	0.3
6	10/25/2007		9.2	1015	68.3	0.3	110	0.0
7	10/26/2007		8.7	1016	69.3	0.0	201	0.0
8	10/27/2007		8.7	1020	69.9	0.2	182	0.0
9	10/28/2007		8.7	1012	68.4	2.3	154	0.0
10	10/29/2007		8.9	1005	82.0	0.9	208	31.0
11	10/30/2007		7.1	1015	76.7	0.3	235	0.3
12	10/31/2007		5.8	1023	80.8	0.1	136	0.0
13	11/1/2007		9.0	1024	79.5	0.0	168	0.0
14	11/2/2007		12.0	1023	86.9	0.0	262	5.7
15	11/3/2007		11.5	1019	80.2	0.0	291	0.9
16	11/4/2007		9.3	1021	70.6	0.0	153	0.0
17	11/5/2007		9.3	1016	70.1	1.0	228	3.0
18	11/6/2007		7.7	1019	71.7	1.9	261	2.7
19	11/7/2007		9.2	1012	78.2	2.6	254	5.9
20	11/8/2007		8.7	1003	73.8	2.4	260	9.8
21	11/9/2007		5.5	1009	73.7	5.4	266	5.0
22	11/10/2007		8.6	1003	76.6	3.8	254	17.4
23	11/11/2007		6.2	1005	73.7	4.0	289	3.6
24	11/12/2007		5.7	1011	71.4	3.0	272	1.5
25	11/13/2007		3.6	999	79.0	1.1	184	10.9
26	11/14/2007		2.0	1010	69.8	1.5	173	0.0
27	11/15/2007		1.7	1019	69.5	0.6	101	0.0
28	11/16/2007		3.6	1021	67.4	0.0	217	0.0
29	11/17/2007		2.5	1016	78.6	0.0	175	0.0
30	11/18/2007		4.0	1002	70.1	5.2	133	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 2 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	11/19/2007	Cologne, parking lot	3.8	1004	74.7	4.1	136	6.2
32	11/20/2007		6.9	1002	62.0	4.9	128	0.3
34	11/21/2007		7.9	1001	76.6	1.4	133	0.9
34	11/22/2007		8.5	1000	79.4	1.2	155	0.0
35	11/23/2007		4.8	1013	78.4	0.6	209	1.2
36	11/24/2007		4.4	1014	75.1	0.5	216	2.1
37	11/25/2007		5.4	1013	74.9	4.3	284	6.2
38	11/26/2007		4.4	1019	73.2	2.6	273	2.4
39	11/27/2007		3.6	1020	76.2	0.4	196	0.0
40	11/28/2007		2.2	1010	73.9	2.7	143	0.0
41	11/29/2007		4.8	1002	79.5	1.3	203	4.7
42	11/30/2007		7.7	1000	76.4	1.6	188	5.1
43	12/1/2007		8.1	999	69.4	1.9	217	3.2
44	12/2/2007		9.2	984	70.4	3.8	226	7.1
45	12/3/2007		6.2	996	71.4	3.6	271	11.8
46	12/4/2007		7.8	1010	75.8	1.3	202	0.6
47	12/5/2007		10.9	1007	70.3	3.1	191	0.9
48	12/6/2007		11.1	997	76.7	2.4	209	21.0
49	12/7/2007		7.9	995	67.5	3.4	251	1.8
50	12/8/2007		6.7	991	69.5	4.0	192	6.5
51	12/9/2007		7.2	982	71.3	2.9	187	6.5
52	12/10/2007		6.1	1001	81.4	2.0	271	5.4
53	12/11/2007		4.6	1021	76.7	1.9	292	0.6
54	12/12/2007		4.8	1031	72.7	0.4	126	0.0
55	12/13/2007		3.8	1033	68.6	0.0	83	0.0
56	12/14/2007		1.1	1030	63.2	0.9	56	0.0
57	12/15/2007		-0.5	1029	64.1	1.2	59	0.0
58	12/16/2007		-0.8	1030	68.3	0.2	69	0.0
59	12/17/2007		-1.7	1028	68.8	0.8	81	0.0
60	12/18/2007		-2.4	1030	74.3	0.0	118	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 3 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	12/19/2007	Cologne, parking lot	-1.9	1031	74.8	0.0	104	0.0
62	12/20/2007		-3.4	1026	81.5	0.0	121	0.0
63	12/21/2007		-0.9	1020	71.0	0.7	133	0.0
64	12/22/2007		-2.2	1020	70.5	1.5	151	0.0
65	12/23/2007		-0.4	1022	76.7	0.6	142	0.0
66	12/24/2007		-0.5	1020	78.2	2.5	124	0.0
67	12/25/2007		-0.9	1014	71.0	3.6	133	0.3
68	12/26/2007		1.2	1023	80.3	1.2	143	0.6
69	12/27/2007		3.9	1024	76.0	3.8	150	0.3
70	12/28/2007		4.1	1016	75.0	4.8	154	0.6
71	12/29/2007		4.9	1009	76.1	1.7	198	5.0
72	12/30/2007		5.1	1018	75.3	1.9	248	1.5
73	12/31/2007		3.3	1021	81.8	0.0	150	0.6
74	1/1/2008		-1.5	1017	79.6	0.5	115	0.0
75	1/2/2008		-0.7	1008	65.4	3.5	106	0.0
76	1/3/2008		1.2	1001	59.9	4.9	142	0.0
77	1/4/2008		3.3	1001	62.8	5.9	139	0.9
78	1/5/2008		6.3	997	75.6	1.3	183	4.8
79	1/6/2008		4.4	1005	74.0	1.5	192	4.1
80	1/7/2008		6.8	1008	67.5	3.0	243	1.8
81	1/8/2008		5.4	1010	72.8	3.6	155	0.0
82	1/9/2008		4.8	1008	76.2	0.6	186	3.8
83	1/10/2008		8.7	1003	68.5	4.5	173	0.0
84	1/11/2008		10.4	993	64.5	5.5	164	2.4
85	1/12/2008		4.0	1006	72.1	1.8	190	0.3
86	1/13/2008		3.6	1005	69.1	4.7	138	0.0
87	1/14/2008		7.4	1000	68.7	4.7	162	0.9
88	1/15/2008		9.2	988	63.6	6.8	173	0.0
89	1/16/2008		6.8	995	76.5	0.6	188	7.4
90	1/17/2008		8.3	1000	70.6	3.9	199	5.6

Annex 8 **Ambient conditions at the field test sites** **Page 4 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	1/18/2008	Cologne, parking lot	11.1	1008	72.2	2.7	217	3.6
92	1/19/2008		12.4	1014	75.8	2.9	235	4.5
93	1/20/2008		11.7	1013	72.3	4.5	239	0.0
94	1/21/2008		9.0	1003	70.6	4.3	233	6.5
95	1/22/2008		3.3	1020	71.0	1.6	220	0.0
96	1/23/2008		6.0	1021	68.9	2.7	153	0.0
97	1/24/2008		5.9	1024	74.4	1.0	225	2.7
98	1/25/2008		7.1	1029	62.7	1.7	233	0.0
99	1/26/2008		7.5	1024	64.8	3.5	244	0.0
100	1/27/2008		7.5	1025	73.7	2.0	246	0.0
101	1/28/2008		7.4	1025	65.8	0.0	230	0.0
102	1/29/2008		3.4	1018	71.6	0.1	220	0.0
103	1/30/2008		2.2	1017	80.7	0.6	224	3.9
104	1/31/2008		4.7	999	67.7	5.6	190	2.4
105	2/1/2008		4.1	994	70.1	3.0	227	6.5
106	2/2/2008		1.3	1011	69.1	1.9	195	1.2
107	2/3/2008		3.8	1001	55.2	5.9	131	0.0
108	2/4/2008		4.0	1002	77.0	2.1	171	5.6
109	2/5/2008		8.2	1003	73.8	4.0	175	19.2
110	2/14/2008	Bonn	2.5	1028	70.7	1.0	187	0.0
111	2/15/2008		0.6	1033	54.3	1.9	188	0.0
112	2/16/2008		0.8	1034	46.4	0.7	187	0.0
113	2/17/2008		1.7	1028	54.8	0.2	197	0.0
114	2/18/2008		2.0	1021	53.1	0.2	161	0.0
115	2/19/2008		4.6	1013	63.9	0.6	157	0.9
116	2/20/2008		4.9	1013	77.5	0.2	160	0.9
117	2/21/2008		10.1	1015	66.3	0.4	179	0.6
118	2/22/2008		11.1	1017	65.5	1.7	127	0.0
119	2/23/2008		8.6	1015	69.4	0.3	134	0.0
120	2/24/2008		9.7	1011	70.3	0.4	188	0.3

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	2/25/2008	Bonn	11.3	1006	65.2	0.8	153	0.0
122	2/26/2008		9.3	1004	65.5	2.2	72	2.4
123	2/27/2008		7.9	1012	60.6	0.7	150	0.0
124	2/28/2008		8.9	1009	72.4	0.5	117	7.7
125	2/29/2008		9.7	994	66.8	4.7	132	9.2
126	3/1/2008		10.5	999	63.7	4.8	121	0.6
127	3/2/2008		9.6	1001	66.1	1.8	124	2.1
128	3/3/2008		4.4	1004	64.3	1.0	150	9.1
129	3/4/2008		2.9	1017	65.8	2.2	147	0.9
130	3/5/2008		2.8	1019	59.1	0.3	131	0.0
131	3/6/2008		7.1	1010	66.9	0.3	131	0.0
132	3/7/2008		7.7	1004	63.4	0.3	139	0.0
134	3/8/2008		8.1	998	59.4	0.4	153	0.0
134	3/9/2008		8.6	989	58.8	0.8	120	0.0
135	3/10/2008		8.2	979	63.2	2.8	159	2.1
136	3/11/2008		9.7	984	63.5	4.0	122	4.8
137	3/12/2008		7.7	1001	59.9	4.3	122	0.0
138	3/13/2008		9.0	1002	69.2	1.7	134	10.3
139	3/14/2008		8.1	1005	67.8	1.0	173	0.0
140	3/15/2008		11.6	993	66.7	0.4	148	7.7
141	3/16/2008		7.3	998	72.8	2.1	183	16.5
142	3/17/2008		4.3	1005	62.6	2.0	123	0.0
143	3/18/2008		4.7	1005	65.6	2.3	164	0.9
144	3/19/2008		3.6	1007	72.5	1.7	105	5.1
145	3/20/2008		5.5	983	69.0	3.4	133	5.6
146	3/21/2008		2.5	975	75.2	1.2	123	6.8
147	3/22/2008		1.7	989	63.9	3.1	233	1.8
148	3/23/2008		0.7	988	60.3	0.4	171	2.1
149	3/24/2008		1.2	990	74.2	2.5	126	2.7
150	3/25/2008		1.1	995	74.4	0.7	141	7.7

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	3/26/2008	Bonn	3.8	991	81.0	0.3	178	4.2
152	3/27/2008		6.8	997	69.5	0.5	131	0.0
153	3/28/2008		9.5	1002	55.4	2.7	124	0.3
154	3/29/2008		11.4	1003	45.3	1.4	107	0.0
155	3/30/2008		12.3	1002	56.5	0.6	181	0.0
156	3/31/2008		10.8	1012	58.3	0.6	171	0.0
157	4/1/2008		10.6	1011	62.8	2.2	184	2.7
158	4/2/2008		8.0	1014	70.2	2.6	194	1.5
159	4/3/2008		7.7	1019	70.3	0.7	160	2.1
160	4/4/2008		9.4	1009	70.8	0.0	125	3.9
161	4/5/2008		4.9	996	76.8	0.6	136	13.6
162	4/6/2008		4.3	991	67.7	0.9	241	2.1
163	4/7/2008		4.1	997	65.3	1.0	150	0.3
164	4/8/2008		6.5	993	61.7	0.6	220	0.0
165	4/9/2008		7.1	990	68.4	0.3	219	2.4
166	4/10/2008		8.8	990	58.1	0.7	224	0.0
167	4/11/2008		9.8	996	52.9	0.7	129	0.0
168	4/12/2008		10.3	1002	61.9	1.0	110	1.5
169	4/13/2008		8.6	1002	77.7	0.5	163	20.4
170	4/14/2008		7.0	1009	75.7	0.5	112	8.6
171	4/15/2008		4.7	1013	75.0	0.3	188	5.9
172	4/16/2008		5.6	1006	57.7	0.8	214	0.0
173	4/17/2008		8.5	995	51.2	2.2	171	0.0
174	4/18/2008		10.2	989	55.6	1.5	190	0.0
175	4/19/2008		9.0	996	73.0	1.7	175	0.0
176	4/20/2008		12.1	995	60.9	2.0	211	0.0
177	4/21/2008		13.6	995	56.0	1.5	259	0.0
178	9/30/2008	Brühl	11.4	996	74.2	2.0	214	16.5
179	10/1/2008		12.4	992	68.9	6.6	241	5.0
180	10/2/2008		9.4	996	67.4	4.6	217	0.6

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	10/3/2008	Brühl	8.7	1001	72.6	3.4	216	2.1
182	10/4/2008		9.6	1006	61.6	6.1	225	0.0
183	10/5/2008		12.6	997	71.2	8.3	213	9.8
184	10/6/2008		13.4	1007	79.7	0.8	200	2.7
185	10/7/2008		15.4	1005	75.3	2.3	144	0.3
186	10/8/2008		12.5	1012	82.0	1.2	254	5.3
187	10/9/2008		10.1	1024	78.8	0.5	246	0.0
188	10/10/2008		11.6	1024	77.6	0.2	185	0.3
189	10/11/2008		13.0	1020	78.0	0.8	145	0.0
190	10/12/2008		12.9	1017	79.4	1.0	163	0.3
191	10/13/2008		16.2	1011	74.4	1.5	174	0.3
192	10/14/2008		14.1	1012	72.5	1.9	206	0.0
193	10/15/2008		14.3	1006	72.8	4.4	203	4.1
194	10/16/2008		9.3	1005	75.9	3.2	246	6.2
195	10/17/2008		8.3	1012	71.4	2.3	228	0.0
196	10/18/2008		8.7	1012	71.0	0.2	199	0.0
197	10/19/2008		9.5	1013	70.0	1.8	196	0.0
198	10/20/2008		14.2	1004	68.9	3.6	171	0.0
199	10/21/2008		10.3	1006	76.2	1.7	228	2.1
200	10/22/2008		7.8	1017	72.7	1.3	208	0.0
201	10/23/2008		7.5	1019	73.0	2.6	151	0.0
202	10/24/2008		9.7	1018	73.3	1.3	158	0.3
203	10/25/2008		9.9	1021	78.6	1.2	161	0.3
204	10/26/2008		12.6	1007	70.2	3.5	191	7.4
205	10/27/2008		8.0	1000	76.8	1.4	249	3.9
206	10/28/2008		4.5	1002	74.9	0.9	209	0.0
207	10/29/2008		4.7	996	76.8	0.0	212	0.0
208	10/30/2008		4.4	992	77.9	1.5	109	1.8
209	10/31/2008		6.5	998	78.3	1.6	122	4.2
210	11/1/2008		8.4	1001	80.1	0.7	139	1.8

Annex 8 **Ambient conditions at the field test sites** **Page 8 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	11/2/2008	Brühl	8.9	1006	79.3	0.2	194	0.0
212	11/3/2008							
213	11/4/2008							
214	11/5/2008							
215	11/6/2008							
216	11/7/2008							
217	11/8/2008							
218	11/9/2008							
219	11/20/2008							
220	11/21/2008							
221	11/22/2008							
222	11/23/2008							
223	11/24/2008							
224	11/25/2008							
225	11/26/2008							
226	11/27/2008				No weather data available			
227	11/28/2008							
228	11/29/2008							
229	11/20/2008							
230	11/21/2008							
231	11/22/2008							
232	11/23/2008							
234	11/24/2008							
234	11/25/2008							
235	11/26/2008							
236	11/27/2008							
237	11/28/2008							
238	11/29/2008							
239	11/30/2008							
240	12/1/2008							

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	12/2/2008	Brühl	No weather data available					
242	12/3/2008							
243	12/4/2008							
244	12/5/2008							
245	12/6/2008							
246	7/24/2008	Teddington	No weather data available					
247	7/25/2008							
248	7/26/2008							
249	7/27/2008							
250	7/28/2008							
251	7/29/2008							
252	7/30/2008							
253	7/31/2008							
254	8/1/2008							
255	8/2/2008							
256	8/3/2008							
257	8/4/2008							
258	8/5/2008							
259	8/6/2008							
260	8/7/2008							
261	8/8/2008							
262	8/9/2008							
263	8/10/2008							
264	8/11/2008							
265	8/12/2008							
266	8/13/2008							
267	8/14/2008							
268	8/15/2008							
269	8/16/2008							
270	8/17/2008							

Annex 8 **Ambient conditions at the field test sites** **Page 10 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	8/18/2008	Teddington	No weather data available					
272	8/19/2008							
273	8/20/2008							
274	8/21/2008							
275	8/22/2008							
276	8/23/2008							
277	8/24/2008							
278	8/25/2008							
279	8/26/2008							
280	8/27/2008							
281	8/28/2008							
282	8/29/2008							
283	8/30/2008							
284	8/31/2008							
285	9/1/2008							
286	9/2/2008							
287	9/3/2008							
288	9/4/2008							
289	9/5/2008							
290	9/6/2008							
291	9/7/2008							
292	9/8/2008							
293	9/9/2008							
294	9/10/2008							
295	9/11/2008							
296	9/12/2008							
297	9/13/2008							
298	9/14/2008							
299	9/15/2008							
300	9/16/2008							

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
301	9/17/2008	Teddington	14.5	1005	68.1	0.6	153	
302	9/18/2008		11.6	1007	72.0	0.5	195	
303	9/19/2008		12.8	1012	70.1	0.3	170	
304	9/20/2008		13.1	1011	70.5	0.5	116	
305	9/21/2008		13.2	1008	70.0	0.6	168	
306	9/22/2008		14.8	1006	76.5	1.1	211	
307	9/23/2008		14.4	1006	76.0	1.8	228	
308	9/24/2008		14.8	1010	81.9	0.8	168	
309	9/25/2008		13.3	1016	74.7	0.7	89	
310	9/26/2008		13.4	1016	75.6	0.7	146	
311	9/27/2008		12.0	1011	80.6	0.1	206	
312	9/28/2008		13.9	1005	70.7	0.2	300	
313	9/29/2008		14.0	997	71.7	0.3	235	
314	9/30/2008		13.7	984	83.8	0.4	210	
315	10/1/2008		10.4	985	71.9	0.4	232	
316	10/2/2008		9.5	988	69.7	0.7	272	
317	10/3/2008		9.3	999	64.0	0.6	279	
318	10/4/2008		14.1	985	87.0	1.1	179	
319	10/5/2008		10.1	987	88.7	0.6	259	
320	10/6/2008		14.8	991	87.0	0.9	161	
321	10/7/2008		12.7	991	89.6	0.6	219	
322	10/8/2008		9.6	1008	80.6	0.2	276	
323	10/9/2008		13.3	1013	80.2	0.3	184	
324	10/10/2008		12.0	1009	84.4	0.4	210	
325	10/11/2008		12.8	1007	85.9	0.2	198	
326	10/12/2008		15.4	1001	86.5	0.3	206	
327	10/13/2008		12.5	1001	90.9	0.1	209	
328	10/14/2008		14.4	998	90.5	0.3	192	
329	10/15/2008		12.1	994	86.8	0.3	255	
330	10/16/2008		8.2	1001	78.7	0.4	241	

Annex 8 **Ambient conditions at the field test sites** **Page 12 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
331	10/17/2008	Teddington	9.0	1002.0	83.8	0.0	228.9	
332	10/18/2008		10.6	1001	83.3	0.1	213	
333	10/19/2008		14.0	995	76.3	0.8	192	
334	10/20/2008		11.2	989	90.2	0.4	203	
335	10/21/2008		6.7	999	80.5	0.2	214	
336	10/22/2008		9.4	1006	80.9	0.2	226	
337	10/23/2008		13.6	1000	79.8	1.0	195	
338	10/24/2008		6.5	1011	85.1	0.2	250	
339	10/25/2008		14.1	1002	81.8	0.9	194	
340	10/26/2008		9.2	995	95.0	0.0	227	
341	10/27/2008		4.2	994	85.6	0.1	285	
342	10/28/2008		4.3	994	81.7	0.5	253	
343	10/29/2008		4.3	984	77.8	0.4	153	
344	10/30/2008		5.3	985	79.6	1.1	161	
345	10/31/2008		5.7	992	80.1	0.9	245	
346	11/1/2008		8.8	989	91.5	1.2	233	
347	11/2/2008		10.1	997	88.9	0.8	224	
348	11/3/2008		10.6	998	93.6	0.9	151	
349	11/4/2008		11.4	1001	86.2	0.8	179	
350	11/5/2008		10.5	998	92.6	0.5	284	
351	11/6/2008		10.5	992	90.7	0.4	161	
352	11/7/2008							
353	11/8/2008		No weather data available					
354	11/9/2008							
355	2/14/2011	Cologne, parking lot	6.0	998	87.5	2.5	143	5.1
356	2/15/2011		5.4	992	86.9	3.5	110	1.8
357	2/16/2011		4.0	994	86.7	1.4	125	0.0
358	2/17/2011		4.1	1002	76.8	1.7	124	0.0
359	2/18/2011		2.7	1009	78.4	1.5	104	0.0
360	2/19/2011		2.7	1010	73.6	4.5	95	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 13 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
361	2/20/2011	Cologne,	-0.5	1011	67.1	4.1	77	0.0
362	2/21/2011	parking lot	-2.7	1011	65.5	3.1	94	0.0
363	2/22/2011		-1.6	1015	56.2	3.0	124	0.0
364	2/23/2011		1.2	1016	59.6	5.0	132	0.0
365	2/24/2011		2.2	1019	94.2	2.6	102	5.7
366	2/25/2011		5.3	1018	87.1	3.4	111	0.0
367	2/26/2011		6.3	1005	86.0	4.3	196	10.5
368	2/27/2011		4.2	1010	86.0	3.9	251	1.5
369	2/28/2011		3.8	1022	83.3	0.9	202	0.0
370	3/1/2011		5.2	1026	69.9	2.1	139	0.3
371	3/2/2011		4.8	1024	54.7	2.2	137	0.0
372	3/3/2011		3.7	1024	50.4	1.4	90	0.0
373	3/4/2011		3.4	1021	67.8	1.2	222	0.0
374	3/5/2011		2.7	1021	73.4	2.2	206	0.0
375	3/6/2011		3.0	1024	52.4	1.9	84	0.0
376	3/7/2011		4.0	1023	34.2	5.1	101	0.0
377	3/8/2011		7.9	1013	54.0	2.3	147	0.0
378	3/9/2011		7.1	1010	75.8	3.5	232	0.9
379	3/10/2011		9.2	1008	68.9	5.3	231	0.0
380	3/11/2011		8.1	1008	69.5	3.8	197	0.3
381	3/12/2011		12.1	998	61.6	3.3	147	0.3
382	3/13/2011		11.2	1001	77.3	2.0	156	1.5
383	3/14/2011		9.8	1010	81.2	0.3	114	0.0
384	3/15/2011		12.3	1006	66.2	2.2	96	0.0
385	3/16/2011		9.5	1000	71.9	2.5	126	0.0
386	3/17/2011		5.7	1009	86.9	4.7	267	0.0
387	3/18/2011		6.0	1018	89.1	1.1	135	11.1
388	3/19/2011		5.0	1027	59.5	1.2	123	0.0
389	3/20/2011		5.3	1027	57.7	0.9	150	0.0
390	3/21/2011		6.9	1029	56.5	1.0	166	0.0

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
391	3/22/2011	Cologne,	9.4	1031	62.7	1.1	184	0.0
392	3/23/2011	parking lot	10.7	1030	66.8	1.2	161	0.0
393	3/24/2011		10.9	1021	67.2	1.0	174	0.0
394	3/25/2011		11.8	1010	59.4	1.6	183	0.0
395	3/26/2011		7.7	1010	64.8	1.5	105	0.0
396	3/27/2011		9.3	1006	60.9	1.1	196	0.0
397	3/28/2011		7.2	1009	60.2	1.9	172	0.0
398	3/29/2011		9.6	1007	62.1	1.1	168	0.0
399	3/30/2011		12.6	1008	66.7	2.4	170	0.0
400	3/31/2011		13.8	1011	78.2	3.7	230	6.5
401	4/1/2011		13.9	1014	78.1	2.3	175	0.0
402	4/2/2011		17.6	1006	62.2	2.6	159	0.0
403	4/3/2011		10.9	1009	85.3	2.0	251	8.7
404	4/4/2011		10.0	1017	65.3	2.7	214	0.0
405	4/5/2011		11.8	1020	71.9	2.1	173	0.9
406	4/6/2011		16.2	1019	73.9	1.8	196	0.0
407	4/7/2011		13.8	1019	67.2	3.0	245	0.0
408	4/8/2011		12.9	1018	64.7	2.9	255	0.0
409	4/9/2011		11.3	1018	59.8	1.3	183	0.0
410	4/10/2011		14.0	1016	60.2	1.1	191	0.0
411	4/11/2011		16.0	1012	58.8	3.9	244	2.7
412	4/12/2011		7.7	1018	66.7	4.1	257	0.9
413	4/13/2011		10.1	1013	57.1	2.0	203	0.0
414	4/14/2011		8.0	1013	65.4	0.6	159	0.0
415	4/15/2011		10.4	1014	53.6	1.2	169	0.0
416	4/16/2011		11.9	1017	51.7	0.9	166	0.0
417	4/17/2011		11.4	1017	53.7	1.2	139	0.0
418	4/18/2011		14.3	1011	48.6	1.9	149	0.0
419	4/19/2011		15.5	1009	52.4	1.2	146	0.0
420	4/20/2011		16.6	1008	51.3	1.1	154	0.0

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
421	4/21/2011	Cologne, parking lot	17.8	1006	54.1	0.7	180	0.0
422	4/22/2011		20.0	1003	51.8	1.3	146	8.3
423	4/23/2011		18.0	1005	58.0	0.7	152	0.0
424	4/24/2011		18.1	1011	51.7	1.0	172	0.0
425	4/25/2011		16.8	1013	50.3	1.2	153	0.0
426	4/26/2011		16.7	1011	51.5	1.8	166	2.1
427	4/27/2011		10.8	1010	90.4	0.7	213	8.9
428	4/28/2011		14.2	1005	77.6	0.7	176	0.3
429	4/29/2011		17.2	1002	56.8	1.7	112	3.0
430	4/30/2011		16.9	1002	47.4	1.7	141	0.0
431	5/1/2011		14.8	1002	44.5	1.6	111	0.0
432	5/2/2011		11.0	1004	53.3	2.0	116	0.0
433	5/3/2011		10.0	1011	49.4	1.0	164	0.0
434	5/4/2011		9.7	1016	61.5	1.3	168	0.0
435	5/5/2011		14.1	1015	46.9	2.2	119	0.0
436	5/6/2011		18.6	1012	41.1	2.5	110	0.0
437	5/7/2011		21.9	1011	37.0	3.4	109	0.0
438	5/8/2011		22.1	1013	34.7	4.1	97	0.0
439	5/9/2011		19.5	1016	48.6	2.1	131	0.0
440	5/10/2011		19.2	1017	66.8	1.6	221	2.1
441	5/11/2011		18.1	1013	55.0	1.6	247	0.0
442	5/12/2011		14.0	1013	58.9	2.6	206	0.0
443	5/13/2011		15.0	1011	56.4	1.2	199	0.0
444	5/14/2011		12.6	1011	60.6	3.1	240	9.8
445	8/11/2011	Bornheim	20.9	1004	53.8	1.2	220	0.3
446	8/12/2011		18.5	1003	78.9	1.1	228	2.1
447	8/13/2011		20.1	1001	77.0	0.7	185	0.0
448	8/14/2011		17.4	1000	86.2	1.1	219	17.4
449	8/15/2011		17.9	1009	71.8	1.2	230	0.0
450	8/16/2011		19.1	1010	69.0	0.7	190	0.6

Annex 8 **Ambient conditions at the field test sites** **Page 16 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
451	8/17/2011	Bornheim	21.1	1007	73.8	0.7	206	4.7
452	8/18/2011		22.5	1004	76.6	1.2	174	20.9
453	8/19/2011		16.8	1011	80.0	1.5	235	3.3
454	8/20/2011		20.7	1011	66.6	0.8	157	0.0
455	8/21/2011		23.2	1007	74.8	1.0	184	0.3
456	8/22/2011		20.4	1009	76.5	1.2	253	0.0
457	8/23/2011		22.6	1005	78.4	0.9	206	0.0
458	8/24/2011		20.1	1007	76.6	0.7	192	0.6
459	8/25/2011		20.8	1003	83.4	1.0	176	2.1
460	8/26/2011		19.4	999	83.7	1.5	195	29.1
461	8/27/2011		15.3	1007	77.0	1.1	207	0.3
462	8/28/2011		15.6	1009	69.2	1.3	212	0.0
463	8/29/2011		14.5	1008	66.7	2.0	243	0.0
464	8/30/2011		13.6	1008	73.6	0.8	236	0.0
465	8/31/2011		14.8	1007	72.0	0.7	225	0.0
466	9/1/2011		16.4	1006	71.6	0.6	182	0.0
467	9/2/2011		21.2	1004	72.2	0.8	160	0.0
468	9/3/2011		24.5	1002	67.0	1.3	132	3.6
469	9/4/2011		20.2	1002	79.5	1.1	223	0.6
470	9/5/2011		16.6	1009	62.9	1.9	217	0.0
471	9/6/2011		17.4	1005	66.8	2.6	219	4.8
472	9/7/2011		14.9	1004	73.1	2.2	246	5.7
473	9/8/2011		14.7	1003	84.7	1.1	209	3.3
474	9/9/2011		19.0	1004	86.9	0.4	167	0.0
475	9/10/2011		23.8	1001	73.0	1.5	155	0.0
476	9/11/2011		16.2	1003	86.0	0.7	165	16.2
477	9/12/2011		19.4	1004	71.1	1.7	204	0.0
478	9/13/2011		16.7	1006	67.3	1.6	219	0.0
479	9/14/2011		15.2	1011	65.1	1.5	224	0.0
480	9/15/2011		14.1	1013	75.3	0.6	207	0.0

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
481	9/16/2011	Bornheim	17.1	1006	72.6	1.4	145	0.0
482	9/17/2011		16.8	1001	70.6	1.0	207	3.6
483	9/18/2011		13.3	998	76.4	1.0	200	4.5
484	9/19/2011		13.6	1008	75.8	1.4	231	0.9
485	9/20/2011		15.6	1014	78.0	0.5	196	0.0
486	9/21/2011		16.9	1011	69.5	0.8	204	0.0
487	9/22/2011		15.2	1011	72.2	1.2	231	0.0
488	9/23/2011		Outage of weather station					
489	9/24/2011							
490	9/25/2011							
491	9/26/2011							
492	9/27/2011							
493	9/28/2011							
494	9/29/2011							
495	9/30/2011		18.4	1017	68.3	1.2	155	0.0
496	10/1/2011		18.1	1018	70.6	0.5	176	0.0
497	10/2/2011		17.8	1016	75.4	0.3	213	0.0
498	10/3/2011		18.8	1013	65.9	0.8	168	0.0
499	10/4/2011		17.8	1013	72.4	1.6	214	0.0
500	10/5/2011		17.5	1011	70.8	1.2	199	0.0
501	10/6/2011		13.2	1001	71.2	2.3	213	0.3
502	10/7/2011		9.9	1005	81.6	3.6	272	5.7
503	10/8/2011		8.7	1009	85.5	2.1	258	6.0
504	10/9/2011		12.2	1011	84.5	1.4	190	5.4
505	10/10/2011		17.7	1009	74.4	3.2	261	0.3
506	10/11/2011		16.3	1010	77.4	3.6	251	0.0
507	10/12/2011		12.5	1012	91.1	0.9	226	17.9
508	10/13/2011		9.9	1022	76.3	0.6	209	0.0
509	10/14/2011		8.7	1024	69.6	1.0	151	0.0
510	10/15/2011		7.8	1020	68.8	1.2	162	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 18 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
511	10/16/2011	Bornheim	8.5	1016	73.8	1.5	157	0.0
512	10/17/2011		10.5	1011	78.5	0.8	163	0.0
513	10/18/2011		9.2	1003	82.0	1.2	197	3.0
514	10/19/2011		8.1	1010	74.4	1.5	225	0.0
515	10/20/2011		5.6	1018	79.8	1.0	223	0.0
516	10/21/2011		5.2	1019	79.3	1.1	154	0.0
517	10/22/2011		6.8	1013	69.3	3.9	128	0.0
518	10/23/2011		7.4	1007	71.6	2.3	138	0.0
519	10/24/2011		9.8	999	67.2	3.8	132	0.0
520	10/25/2011		10.9	997	68.8	1.9	132	0.0
521	10/26/2011		9.4	1006	74.9	0.9	171	0.0

Appendix 2:

Methods used for filter weighing

A) Locations in Germany (Cologne, Bonn, Brühl, Bornheim)

A.1 Performance of weighing

Weighing takes place in an air-conditioned weighing chamber. Conditions are as follows: 20 °C ±1 °C and 50% ±5% rel. humidity and thus meet the requirements of EN 14907.

Filters for the field test are weighed manually. For further processing, filters incl. the control filters are placed sieves to avoid cross-loading.
Conditions for initial and back weighing had previously been defined and are in line with the standard.

Before sampling = initial weighing	After sampling = back weighing
Processing 48 hours + 2 hours	Processing 48 hours + 2 hours
Filter weighing	Filter weighing
additional processing 24 hours + 2 hours	additional processing 24 hours + 2 hours
Filter weighing and immediate packaging	Filter weighing

The balance is available ready for operation at all times. The balance is calibrated before every weighing series. If everything turns out to be okay, the reference with is weighed against the calibration weight of 200 mg and peripheral parameters are recorded. Deviations from the previous weighing meet the standard’s requirements and do not exceed 20 µg (see Figure 120). The six control filters are weighed this way. For control filters deviating by more than 40 µg a warning is displayed on the evaluation page. This filters are not used for back weighing. The first three flawless control filters are used for back weighing, remaining filters remain safely stored in their can to be used in the event the first three filters are damaged or experience excessive deviations. Figure 121 presents the exemplary trend over a period of four weeks.

Filters, for which there is a difference or more than 40 µg between the first and the second weighing, are not used for initial weighing. For back weighing, filters with differences exceed-ing 60 µg are removed from the evaluation as required by the standard.

Weighed filters are separately kept in polystyrene boxes for transports to and from the measurement site and for storage. The box is not opened until the filter is inserted in the filter cartridge. Virgin filters can be stored in the weighing chamber up to 28 days until sampling. Should this period be exceeded, initial weighing will be repeated.

Deposited filters can be stored for a maximum of 15 days at temperatures up to 23°C. Filters are stored in a fridge at 7°C.

A2 Evaluation of the filters

Filters are evaluated using a correction term. The purpose of this corrective calculation is to minimise changes in the mass as a result of conditions in the weighing chamber.

Equation:

$$Dust = MF_{rück} - (M_{Tara} \times (MKon_{rück} / MKon_{hin})) \qquad (F1)$$

$MKon_{hin}$ = mean mass of the 3 control filters determined on 48 h and 72h initial weighing

$MKon_{rück}$ = mean mass of the 3 control filters determined on 48 h and 72 h back weighing

M_{Tara} = mean mass of the filter determined on 48 h and 72 h initial weighing

$MF_{rück}$ =mean mass of the filter determined on 48 h and 72 h back weighing

Dust = corrected dust load on the filter

The corrective calculation proved to render the method independent of the conditions in the weighing chamber. This way, the influence of water contents on the filter mass comparing virgin and deposited filters can be controlled and do not influence the dust concentrations deposited on the used filters. This is sufficient to meet the requirements of EN 14907, chapter 9.3.2.5.

The exemplary trend for the calibration weight for Nov 2008 to Feb 2009 shows that the permissible difference of 20 µg compared to the previous measurement is not exceeded.

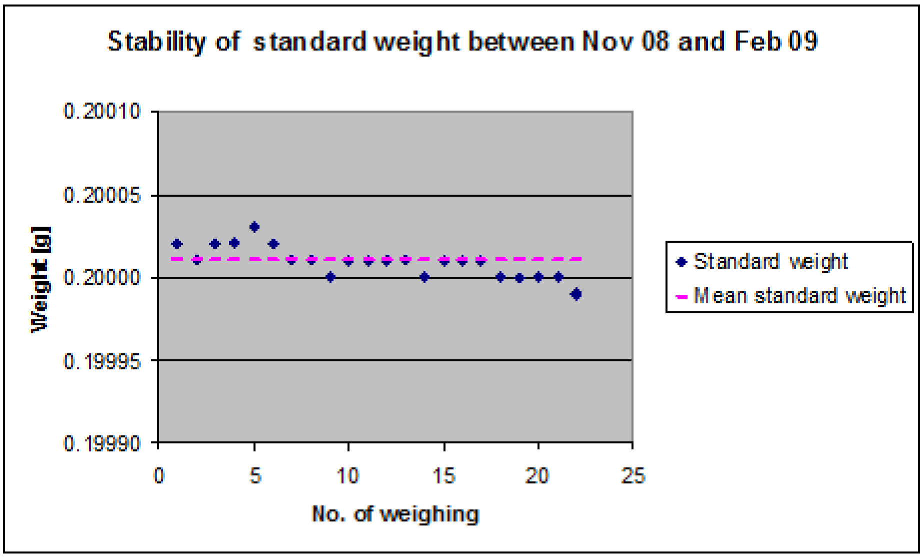


Figure 120: Stability of the calibration weight

Table 54: Stability of the calibration weight

Date	Weighing no.	Standard weight	Difference compared to previous weighing
		g	µg
12.11.2008	1	0.20002	
13.11.2008	2	0.20001	-10
10.12.2008	3	0.20002	10
11.12.2008	4	0.20002	0
17.12.2008	5	0.20003	10
18.12.2008	6	0.20002	-10
07.01.2009	7	0.20001	-10
08.01.2009	8	0.20001	0
14.01.2009	9	0.20000	-10
15.01.2009	10	0.20001	10
21.01.2009	11	0.20001	0
22.01.2009	12	0.20001	0
29.01.2009	13	0.20001	0
30.01.2009	14	0.20000	-10
04.02.2008	15	0.20001	10
05.02.2009	16	0.20001	0
11.02.2009	17	0.20001	0
12.02.2009	18	0.20000	-10
18.02.2009	19	0.20000	0
19.02.2009	20	0.20000	0
26.02.2009	21	0.20000	0
27.02.2009	22	0.19999	-10

Marked yellow = mean
Marked green = lowest value
Marked blue = highest value

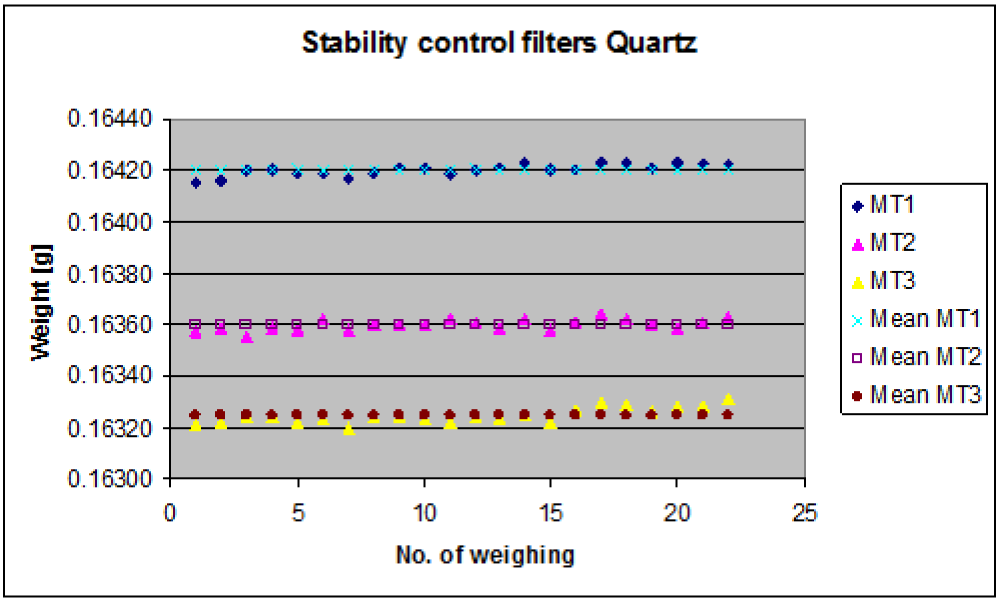


Figure 121: Stability of the control filter

Table 55: Stability of the control filter

Weighing no.	MT1 [g]	MT2 [g]	MT3 [g]
1	0.16415	0.16357	0.16321
2	0.16416	0.16359	0.16322
3	0.16420	0.16355	0.16324
4	0.16420	0.16359	0.16324
5	0.16419	0.16358	0.16322
6	0.16419	0.16362	0.16323
7	0.16417	0.16358	0.16320
8	0.16419	0.16360	0.16324
9	0.16421	0.16360	0.16324
10	0.16421	0.16360	0.16323
11	0.16419	0.16362	0.16322
12	0.16420	0.16361	0.16324
13	0.16421	0.16359	0.16323
14	0.16423	0.16362	0.16325
15	0.16420	0.16358	0.16322
16	0.16420	0.16361	0.16327
17	0.16423	0.16364	0.16330
18	0.16423	0.16362	0.16329
19	0.16421	0.16360	0.16326
20	0.16423	0.16359	0.16328
21	0.16422	0.16361	0.16328
22	0.16422	0.16363	0.16331
Average	0.16420	0.16360	0.16325
Standard dev.	2,19602E-05	2,1157E-05	3,0165E-05
rel. std. dev.	0.013	0.013	0.018
Median	0.16420	0.16360	0.16324
lowest value	0.16415	0.16355	0.16320
highest value	0.16423	0.16364	0.16331

Marked yellow = mean
Marked green = lowest value
Marked blue = highest value

B) Site in the United Kingdom (Teddington)

B.1 Implementation of weighing protocols

NPL (National Physical Laboratory) was commissioned to weigh filters for the field test manually. In compliance with EN EN14907, the filter was stored in the weighing chamber for less than 28 days. The plexiglas chamber used for weighing was kept at 20 ± 1°C and 50 ± 5 %. Filters were weighed twice each before and after sampling. Table 56 summarises weighing conditions and weighing times.

Table 56: Weighing conditions and weighing times

Pre Sampling	Post Sampling
Condition minimum of 48 hours Weigh Filters Condition 24 hours Weigh Filters	Condition 48 hours Weigh Filters Condition 24 hours Weigh Filters

The beam balance was checked before every weighing series in order to remove mechanical rigidity. Calibration took place after that. At the beginning and the end of every filter lot, a 50 mg and a 200 mg reference weight were weighed. In accordance with the UK PM Equivalence Report [11], the filter was weighed against a 100 mg reference weight rather than against a zero filter since the latter experiences weight loss over time. Four filters each were weighed between the reference weights, since the weighing drift over this period is small.

The **mass of the reference weight (CM)** for the filters was calculated for each weighing series according to equation **E A.1**.

$$CM = \frac{(m_{check,Beg} + m_{check,End})}{2}$$ **E A.1**

Where:

$M_{check,Beg}$ = mass of the reference weight, weighed just upstream of of the sampling filter.

$M_{check,End}$ = mass of the reference filter, weighed just downstream of the sampling filter.

The **relative mass (RM)** of the filters was determined for every weighing series in accordance with equation **E A.2**.

$$RM = m_{filter} - CM$$ **E A.2**

Where:

m_{filter} = mass of the sampling filter

EN 14907 defines the **particle mass (PM)** as calculated in accordance with the following equation:

$$PM = \left(\frac{RM_{End1} + RM_{End2}}{2}\right) - \left(\frac{RM_{Beg1} + RM_{Beg2}}{2}\right)$$ **E A.3**

Where:

Beg1 marks weighing series 1 before sampling

Beg2 marks weighing series 2 before sampling

End1 marks weighing series 2 after sampling

End2 marks weighing series 2 after sampling

End scattering range (S_{Pre}), Beg scattering range (S_{Post}) and reference weight scattering range (S_{Blank}) were calculated according to the following equation:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2} \qquad \textbf{E A.4}$$

$$S_{Post} = RM_{End1} - RM_{End2} \qquad \textbf{E A.5}$$

$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2} \right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2} \right) \qquad \textbf{E A.6}$$

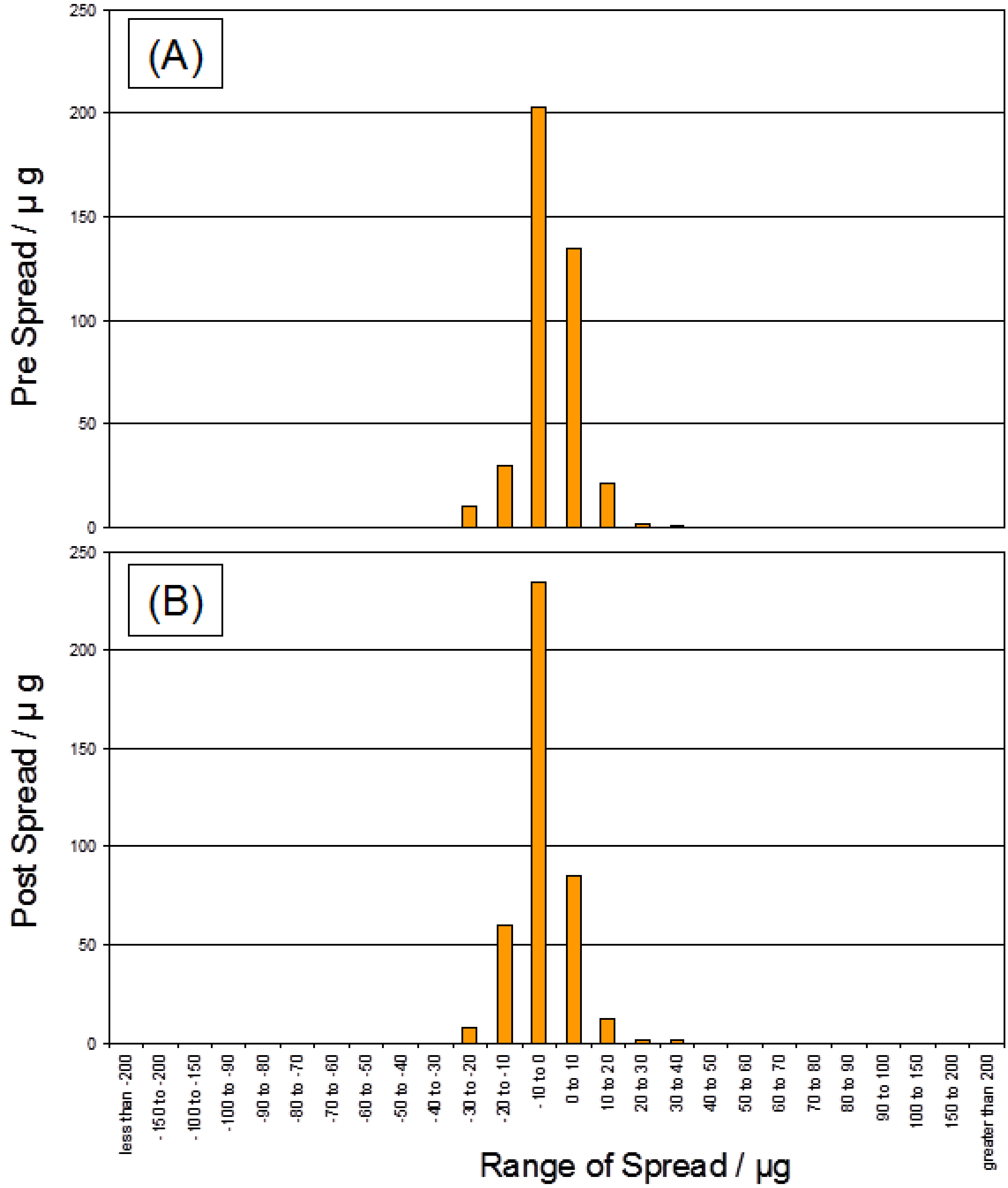
As described in the UK PM Equivalence Report [11], it was not possible to weigh all filters within the 15-day period as required by EN 14907.

However, the filters were immediately taken from the reference sampler to be put in the fridge which is why it was unnecessary to establish whether $T_{Umgebung}$ exceeded 23°C. 15 days appear unfeasible for a relatively small field test scope. The method is unlikely to be copied in national or regional grids. The method used here is representative for the operation of the reference sampler in practice

A.2 Analysis of the weighing protocol used

Figure 122 presents the scattering behaviour of the initial and back weighing for all EMFAB filters collected referred to the carrying weight and the reference weight. If all filters lose relative weight , scattering shifts to the right. Conversely, scattering will shift left if the filters increase in mass. Standard EN EN14907 requires undeposited filters to be discarded if the mass difference between the two initial weighings exceeds 40 µg. By the same token, EN 14907 requires filters to be discarded if the difference between the two back weighings exceeds 60 µg. This criterion did not result in any filters being discarded. It is considered unlikely that the defined scattering of repeated mass determinations significantly affect the results.

Figure 122: Scattering of the EMFAB filter for (**A**) initial weighing compared to the reference weight and (**B**) back weighing compared to the reference weight.



Appendix 3:

Manual