

A Quality Assurance and Control Program for PM_{2.5} and PM₁₀ measurements in European Air Quality Monitoring Networks

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Summary

For the purpose of harmonizing PM measurement methods, the European Commission's Joint Research Centre and the AQUILA Network of National Air Quality Reference Laboratories have organized a PM quality assurance/quality control program in Europe. From 2006 until 2009, 18 measurement campaigns have been organized in European Member States through carrying out parallel measurements with the JRC mobile laboratory next to the Member States National Reference Laboratories and routine monitoring networks. For the campaigns purpose the JRC mobile PM laboratory was equipped with reference samplers for PM10, PM2.5, PM1, a continuous PM10 instrument and a semi-continuous elemental and organic carbon analyzer. The campaigns took place during spring and autumn in order to avoid extreme weather situations. Most of the campaigns were set up in urban background locations.

The primary objectives of the program were

- To provide information on the comparability of PM10 measurements as implemented by the NRLs with those of JRC (ERLAP)
- To investigate the comparability of routine PM10 measurements at network monitoring stations with those of JRC
- To assess, in the field, the comparability of reference and equivalent methods and the achievement of the data quality objectives (DQO)
- To assess the state of implementation and use of correction factors for automatic monitors in the monitoring networks that are used in reporting under Directive 2008/50/EC.

In addition, a considerable amount of "secondary" information was acquired throughout the implementation and evaluation of the program.

The primary conclusions of the evaluation of the results of the program were the following:

- When using all data supplied, National Reference Laboratories were found to underestimate the Reference Values for PM10 by 5.3% with a reproducibility standard deviation of 16%. Local Networks were found, on average, to almost exactly reproduce the Reference Values with a reproducibility standard deviation of 19%. For PM2.5 the underestimation of the Reference Values by National Reference Laboratories increased to about 11%, whereas the average of the Local Networks was 1.6% lower. However, the reproducibility of the Local Networks was considerably worse (50% vs. 15% for the National Reference Laboratories). On a whole, these findings indicate that – within the uncertainties associated with the measurements – the average results of National Reference Laboratories and Local Networks agree with the JRC Reference Values.
- For assessment of compliance with the uncertainty data quality objectives of Directive 2008/50/EC both uncertainties of individual results and uncertainties of grouped results have been considered. Of individual PM10 measurements, 7.1% did not comply with the Data Quality Objective at the limit value given in Directive 2008/50/EC; of individual PM2.5 measurements 23.8% did not comply with the Data Quality Objective at the target value given in EU Directive 2008/50/EC. Deviations could not be directly attributed to specific parameters like filter material, sampling temperature or instrumentation type as too many variables are influencing the measurement results. Around one third of the PM10 and half of the

PM2.5 measurements exceed the required uncertainty at the limit respectively target value, with automatic analyzers performing worse than the gravimetric methods. When considering relative uncertainties of grouped results based on reproducibility standard deviations after removal of outliers these are 28% (95% confidence) for PM10 and 33% (95% confidence) for PM2.5. For reference methodologies the uncertainties are lower than for automatic analyzers, which may partly be attributed to the use of default correction factors instead of factors derived from equivalence tests. However, the reasons for the high uncertainties require further investigation. For PM2.5 these findings will have consequences for the establishment of the reduction in the Average Exposure Indicator.

- Almost half of all users of automatic analyzers have used correction factors for the results obtained by the analyzers. The use of correction factors generally improves their results.

Furthermore, the following findings have been reported:

- When comparing low-volume sampling to high-volume sampling, results for low-volume sampling are generally found to be higher. For high-volume sampling, no difference can be found between results obtained using quartz-fibre or glass-fibre filters (the two mostly used filter types), however for low-volume sampling results obtained using quartz-fibre filters are higher.
- A considerable fraction of the field blanks examined during this study exceeds the criterion given in EN 14907, with levels of up to $6 \mu\text{g}/\text{m}^3$. The reason for this phenomenon requires further investigation.

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Nomenclature and Abbreviations

| | |
|----------|---|
| AT | Austria |
| BE | Belgium |
| CZ | Czech Republic |
| DE | Germany |
| DK | Denmark |
| EE | Estonia |
| ES | Spain |
| FI | Finland |
| FR | France |
| GB | United Kingdom |
| HU | Hungary |
| IE | Ireland |
| IT | Italy |
| NL | Netherlands |
| PT | Portugal |
| SE | Sweden |
| SI | Slovenia |
| SK | Slovak Republic |
| EU | European Union |
| AEA | AEA (Atomic Energy Authority) Technology |
| AIRPARIF | Surveillance de la Qualité de l'Air en Ile-de-France |
| ARPA | Agenzia Regionale per la Protezione dell'Ambiente |
| AdM | Ayuntamiento de Madrid |
| BV | Bureau Veritas |
| CHMI | Czech Hydrometeorological Institute |
| DCC | Dublin City Council |
| EDM | École de mines (LCSQA – Mines de Douai) |
| EERC | Estonian Environmental Research Centre |
| EIMV | Elektroinstitut Milan Vidmar |
| EHAS | Environment and Health Administration, City of Stockholm |
| EPA | Environmental Protection Agency |
| ERLAP | European Reference Laboratory of Air Pollution |
| FMI | Finnish Metrological Institute |
| GGD | Municipal Health Service Amsterdam |
| HLUG | Hessisches Landesamt fuer Umwelt und Geologie |
| HMS | Hungarian Meteorological Service |
| ISCIII | Instituto de Salud Carlos III |
| IdA | Instituto do Ambiente |
| INERIS | Institut National de l'Environnement Industriel et de Risques |
| ISPRA | Istituto Superiore per la Protezione e la Ricerca Ambientale |
| ISSeP | Institut scientifique de service public |
| ITM | University of Stockholm |
| IVL | Swedish Environmental Research Institute |
| JRC | Joint Research Centre |
| LANUV | Landesamt fuer Natur, Umwelt und Verbraucherschutz |
| LR OOe | Amt der Oberösterreichischen Landesregierung |
| LR Stmk. | Amt der Steiermärkischen Landesregierung |
| MDV | Middle Danube Valley Network Hungary |
| NERI | National Environmental Research Institute |
| NPT | Neath Port Talbot County Borough Council |
| RIVM | National Institute for Public Health and the Environment |
| SHMU | Slovak Hydrometeorological Institute |
| UBA | Umweltbundesamt Ges.m.b.H. |
| VMM | Vlaamse Milieumaatschappij |
| AQUILA | Network of Air Quality Reference Laboratories |
| NRL | National Reference Laboratories |
| DQO | Data Quality Objective (of the European Directive) |

LV
QA/QC

Limit Value
Quality Assurance / Quality Control

PM10
PM2.5
PM1
OC/EC

Particulate Matter in the size fraction $\leq 10 \mu\text{m}$
Particulate Matter in the size fraction $\leq 2.5 \mu\text{m}$
Particulate Matter in the size fraction $\leq 1 \mu\text{m}$
Organic and Elemental Carbon

1. Introduction

Legislation

Measurements of particulate matter have been carried out in Europe since many years. During the 80's total suspended particulates were measured, referring to the "Black Smoke OECD" method (Directive 80/779/EC). Studies on health impact assessment of particles have led to the revision of European air quality policy during the 90's. The PM10 and PM2.5 fraction of PM, considered as inhalable, were introduced with the publication of Directive 1999/30/EC [1]. In line with the 'Clean Air for Europe' strategy of the European Commission to minimize harmful effects of pollution on human health and the environment and to improve monitoring and assessment of air quality, the measurement of PM10 and PM2.5 has been updated by the recently adopted Air Quality Directive 2008/50/EC [2]. Member States now have to measure as well PM2.5 concentrations on the basis of "common methods and criteria". The Directive refers to the European Standards EN 12341 [3] and 14907 [4] for the measurement of fine particles in ambient air. Siting criteria are given for sampling locations. Quality objectives are set regarding the accuracy of the measured value and minimum data capture.

A need for quality control and harmonization derives from experience showing that even though common methods and criteria are applied, reported values on PM concentrations may differ considerably. To ensure compliance with the data quality objectives set in the Air Quality Directive, Member States have to establish a quality assurance and control system, as well as a traceability chain in accordance with international guidelines. In addition, institutions designated for QA/QC shall participate in the Community-wide quality assurance programs organised by the Commission.

Currently, under Directive 2008/50/EC, there are 3 different thresholds existing for fine particles:

- PM10 limit value calendar year average $40 \mu\text{g}/\text{m}^3$
- PM10 limit value daily average $50 \mu\text{g}/\text{m}^3$ not to be exceeded more than 35 times a year
- PM2.5 target value calendar year average $25 \mu\text{g}/\text{m}^3$

Since 2009 Member States are obliged to evaluate as well an Average Exposure Indicator, a three-year average based upon PM2.5 measurements in urban background locations.

CEN standards

The CEN Technical Committee 'Air Quality' - Working Group 15 (PM10 and PM2.5) has been dealing with the set up of standardized measurement methods for PM10 resulting in EN 12341 [3] and PM2.5 resulting in EN 14907 [4]. Extensive validation measurement campaigns have been carried out in order to describe the best suitable consensus method for PM measurements for the purpose of Air Quality Directives 1999/30/EC [1] and 2008/50/EC [2].

EN 12341, published in 1998, is describing three reference methods for measuring PM10 and a field test procedure to demonstrate equivalence of "candidate" methods. The three reference methods, quartz fibre filter based, are a $2.3 \text{ m}^3/\text{h}$ Low-Volume-System, a $68 \text{ m}^3/\text{h}$ High-Volume-System and a $1966 \text{ m}^3/\text{h}$ system (WRAC-Wide Range Aerosol Classifier) which has been used in the past for research purposes only.

EN 14907, published in 2005, included thus many refinements deriving from experience with the PM10 standard. The PM2.5 standard describes two sampling systems: a $2.3 \text{ m}^3/\text{h}$ Low-Volume-system and a $30 \text{ m}^3/\text{h}$ High-Volume-system. It includes more rigorous quality assurance requirements, but it allows for four different filter types namely glass fibre, quartz fibre, PTFE and PTFE coated filters.

The European PM standard methods are currently being revised by the Working Group, as the results achieved by applying the standard methods may vary considerably due to influencing factors like choice of Low-Volume or High-Volume Sampler, filter material, conditioning of filters, sampling duration, sampling time of the day, temperature, etc.

Scope and motivation of the project

The European Commission's Joint Research Centre carries out quality assurance programmes for gaseous air pollutants since many years. Gases are both generated and measured simultaneously by the participating laboratories on the spot at the ERLAP facility in Ispra (IT), or gas cylinders are sent around and measured by participants in their own laboratory.

The situation with particulate matter is slightly more complex since it is difficult to generate homogenous particle concentrations for several participants in one spot. For that reason, it was decided that ERLAP will visit Member States monitoring sites by means of a mobile laboratory equipped with reference instrumentation. This had the advantage, that both a routine monitoring network station and the National Reference Laboratory of each Member State could be involved, allowing on the one hand a comparison with the NRL, the body responsible for QA/QC in the Member State, and on the other hand to draw a statement on the quality level of routine monitoring. In particular correction factors for automated PM instrumentation could be investigated. The "Guidance on PM10 monitoring" prescribes the use of a correction factor of 1.3 in absence of self-investigated correction factors when measuring with an automated system (<http://ec.europa.eu/environment/air/quality/legislation/pdf/finalwgreporten.pdf>). The Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods (GDE - <http://ec.europa.eu/environment/air/quality/legislation/assessment.htm>) [5], first published in 2005, describes a practical approach to establish such factors. However, the level of implementation of correction factors was unclear so far.

The aims of the JRC-AQUILA QA/QC programme were

- To provide information on the comparability of PM10 measurements as implemented by the NRLs with those of JRC (ERLAP)
- To investigate the comparability of routine PM10 measurements at network monitoring stations with those of JRC
- To assess, in the field, the comparability of reference and equivalent methods and the achievement of the data quality objectives (DQO)
- To assess the state of implementation and use of correction factors for automatic monitors in the monitoring networks that are used in reporting under Directive 2008/50/EC

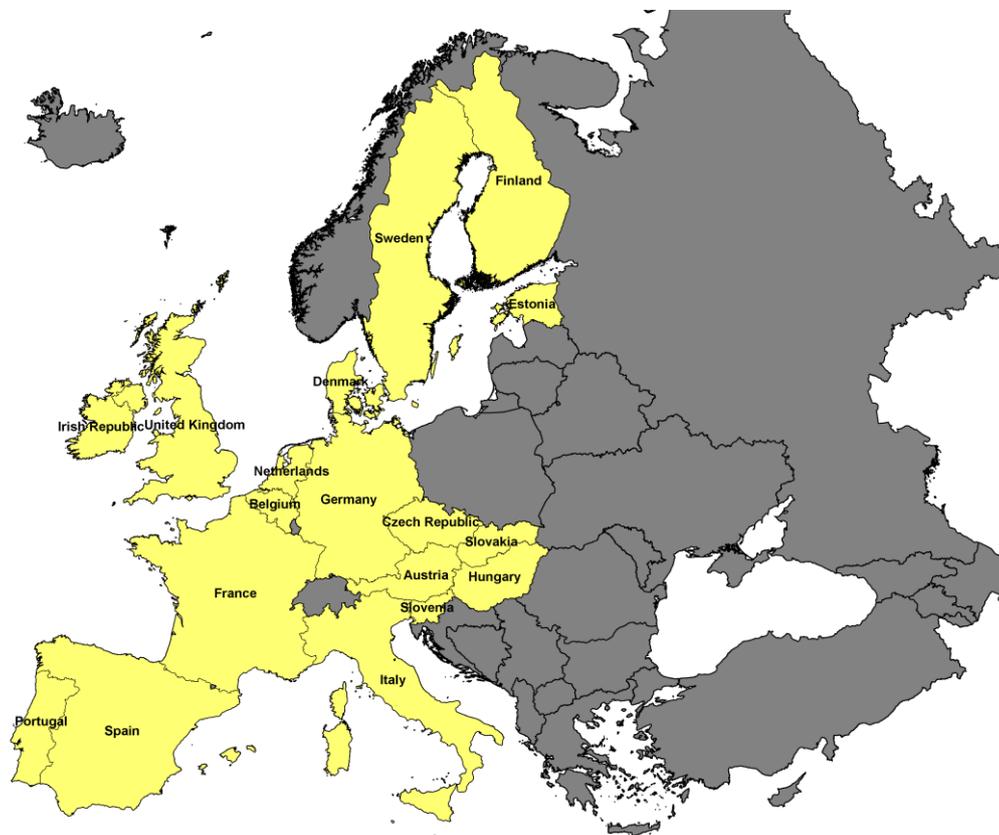
In addition to PM10 a number of participants took advantage out of the possibility to compare as well measurements of PM2.5.

Further, it was expected that – as a spin-off of the programme – a considerable amount of "secondary" information would become available, e.g. comparability of different techniques and instruments and the effects of parameters such as filter types for gravimetric methods and heating of sampling lines for automatic monitors.

2. Measurement campaigns

During the period March 2006 to March 2009 a total of 18 measurement campaigns were conducted in 18 Member States of the European Union. Figure 1 shows the visited countries.

Figure 1: Visited countries



Each campaign had a duration of 14 measurement days resulting in 14 daily averages per instrument for PM10 and PM2.5 (where available) to be compared. Due to instrument malfunctions in some occasions less than 14 values were obtained. Wherever it was possible, the duration of a measurement campaign was extended to avoid scanty daily averages. In some occasions even more than 14 values were measured. To allow a better comparability of data it was foreseen to measure only in urban background sites and to avoid very cold and hot weather periods. In some countries suitable urban background sites could not be found and therefore a limited number of campaigns had to be performed in different locations. Three campaigns (ES, DK and SE) were carried out in sites with emissions dominated by traffic (see Annex 7) resulting partly in higher between sampler uncertainties. In Annex 1 a description of all measurement sites with photos and drawings showing the distance between the used measurement equipment can be found. Table 1 gives an overview of the visited sites.

Table 1: Visited measurement sites

| Country | Measurement site | Address | Type | Period |
|---------|--|---|-----------------------------|------------------------------|
| ES | Escuelas Aguirre | Crossing of Alcalá and O'Donnell Street, Madrid | traffic | March 2nd - 16th, 2006 |
| PT | Instituto do Ambiente | Rua da Murgueira, 9/9A, Amadora | urban background | March 23rd - April 6th, 2006 |
| SI | Environmental Agency | Vojkova 1b, 1000 Ljubljana | urban background | Sept. 20th - Oct. 4th, 2006 |
| AT | Graz Süd | Tiergartenweg, 8020 Graz | urban background | Oct. 9th - 22nd, 2006 |
| CZ | Czech Hydrometeorological Institute | Na Šabatce 17, 143 06 Praha 4, Komofany | urban background | Oct. 29th - Nov. 12th, 2006 |
| DE | Hessisches Landesamt für Umwelt und Geologie | Rheingaustrasse 186, 65203 Wiesbaden | urban background | Nov. 25th - Dec. 8th, 2006 |
| DK | H.C. Andersen Boulevard | H.C. Andersen Boulevard 23, Copenhagen | traffic | Feb. 19th - March 4th, 2007 |
| SE | Hornsgatan | Hornsgatan 110, 117 26 Stockholm | traffic | March 9th - 22th, 2007 |
| FI | Finnish Metrological Institute | Erik Palménin aukio 1, 00560 Helsinki | urban background | April 2nd - 16th, 2007 |
| EE | Õismäe | Õismäe tee 28 a, Tallinn | urban background | April 19th - May 2nd, 2007 |
| NL | Biest - Houtakker | Biestsestraat (next to channel), Biest-Houtakker | rural | Feb. 6th - 19th, 2008 |
| BE | Borgerhout | Plantin en Moretuslei 165 | urban background | Feb. 22nd - March 6th, 2008 |
| FR | Bobigny | Chemin lateral, Parc de la Bergère, 93008 Bobigny | urban background | March 13th - 27th, 2008 |
| IE | Phoenix Park | Ordonance survey, Ordonance Road, Dublin | urban background | April 4th - 20th, 2008 |
| GB | Port Talbot | Central Road, Margam, Port Talbot | urban background/industrial | April 24th - May 23rd, 2008 |
| IT | Parco Giuriati | Via Ponzio, Milan | urban background | Sept. 10th - 28th, 2008 |
| HU | Meteorological Observatory | Gillice ter 39, Budapest 18 | urban background | Feb. 19th - March 4th, 2009 |
| SK | Salesiane Centre | Mamatyova road, Bratislava | urban background | March 12th - 25th, 2009 |

2.1 Participating laboratories

35 laboratories from the AQUILA Network, local and private air quality monitoring networks participated in the measurement campaigns. Members of the AQUILA Network are called “National Reference Laboratories”, both local and private air quality monitoring networks are summarized as “local networks” in this report. Details of each participant can be found in Table 2.

Table 2: Participating laboratories

| Country | Institution | Type of network |
|---------|--|-----------------|
| ES | Instituto de Salud Carlos III | NRL |
| ES | Ayuntamiento de Madrid | Local network |
| PT | Instituto do Ambiente | NRL |
| SI | Environmental Agency of the Republic of Slovenia | NRL |
| SI | Elektroinstitut Milan Vidmar EIMV - department ENV | Local network |
| SI | ANHOVO | Local network |
| AT | Umweltbundesamt Ges.m.b.H | NRL |
| AT | Amt der Oberösterreichischen Landesregierung | NRL |
| AT | Amt der Steiermärkischen Landesregierung | Local network |
| CZ | Czech Hydrometeorological Institute | NRL |
| DE | Landesamt für Natur, Umwelt und Verbraucherschutz | NRL |
| DE | Hessisches Landesamt für Umwelt und Geologie | Local network |
| DK | National Environmental Research Institute | NRL |
| SE | University of Stockholm ITM, Department of Applied Environmental Science | NRL |
| SE | City of Stockholm, Environment and Health Administration | Local network |
| SE | IVL Swedish Environmental Research Institute | Local network |
| FI | Finnish Metrological Institute | NRL |
| EE | Estonian Environmental Research Centre | NRL |
| NL | RIVM - National Institute for Public Health and the Environment Laboratory for Environmental Monitoring | NRL |
| NL | GGD - Municipal Health Service Amsterdam Department of Air Research, Environmental medicine | Local network |
| BE | VMM - Vlaamse Milieumaatschappij Afdeling Lucht, Milieu en Communicatie, cdvp Immissiemeetnetten Lucht | NRL |
| BE | ISSeP, Veille Technologique, Cellule qualité de l'Air | NRL |
| FR | Ineris | NRL |
| FR | LCSQA - Mines de Douai, Département Chimie & Environnement | NRL |
| FR | AIRPARIF | Local network |
| IE | Environmental Protection Agency | NRL |
| IE | Dublin City Council | Local network |
| GB | AEA Technology | NRL |
| GB | Bureau Veritas | Local network |
| GB | Neath Port Talbot Borough Council and Air Monitors | Local network |
| IT | Istituto Superiore per la Protezione e Ricerca Ambientale | NRL |
| IT | Agenzia Regionale per la Protezione dell'Ambiente della Lombardia | Local network |
| HU | Hungarian Meteorological Service | NRL |
| HU | Middle Danube Valley Inspectorate of Environmental Protection, Nature Conservation and Water management | Local network |
| SK | Slovak Hydrometeorological Institute | NRL |

2.2 Used equipment

Each participant was asked to provide information about the equipment used in the field and in the laboratory, maintenance procedures and details how data are expressed. Detailed information regarding the used equipment is given in this report, especially with respect to sampling (e.g. inlet, flow rate, sampling temperature).

PM10 and PM2.5 measurements were made using both manual samplers and automatic instruments. In this report, manual samplers are split into “Low Volume Samplers (LVS)” and “High Volume Samplers (HVS)”.

Manual samplers are based on the gravimetric measurement of the particulate mass sampled on a filter. Samplers could either be a single filter device or equipped with an automatic filter changer. The used filter material and its manufacturer differ between the participants. The same is valid for the inlets and the flow rates of the samplers. Pictures and more details on the different types of sampling inlets can be found in Annex 2. A total of 29 LVS and 13 HVS were used by the participants during the measurement campaigns for PM10. Table 3 provides detailed information.

Table 3: PM10 manual samplers

| Country | Institution | Sampler | Flow rate | Inlet | Filter manufacturer and material |
|---------|-------------|------------------------|-----------------------|---------|--|
| EU | JRC | SEQ Leckel 47/50 A | 2.3 m ³ /h | Type 3 | Whatman QMA |
| | | SEQ Leckel 47/50 B | 2.3 m ³ /h | Type 3 | Whatman QMA |
| ES | ISCIII | Derenda MVS 6.1 A | 2.3 m ³ /h | Type 1 | Whatman QMA |
| | | Derenda MVS 6.1 B | 2.3 m ³ /h | Type 1 | Whatman QMA |
| PT | IdA | Andersen | 68 m ³ /h | Type 6 | Whatman Glass fibre |
| | | Tecora | 1 m ³ /h | Type 4 | Schleicher & Schuell Quartz |
| SI | EPA SI | Derenda Seq PNS3.1-15 | 2.3 m ³ /h | Type 1 | Whatman QMA |
| SI | EIMV | Tecora | 2.3 m ³ /h | Type 5 | Schleicher & Schuell Quartz |
| | | Andersen | 68 m ³ /h | Type 6 | Peckman environment Glass fibre |
| SI | ANHOVO | Tecora | 2.3 m ³ /h | Type 5 | unknown |
| AT | UBA | Digitel | 30 m ³ /h | Type 8 | Ederol Glass fibre |
| AT | LR OOe. | Digitel | 30 m ³ /h | Type 8 | Whatman QMA |
| AT | LR Stmk. | Digitel | 30 m ³ /h | Type 8 | Pall Quartz |
| CZ | CHMI | Thermo FH 95 KF | 2.3 m ³ /h | Type 14 | Millipore RAWP Cellulose nitrate |
| | | Thermo FH 95 KF | 2.3 m ³ /h | Type 14 | Schleicher & Schuell Glass fibre |
| | | MCZ / Andersen | 68 m ³ /h | Type 6 | Whatman QMA |
| | | Derenda SEQ High Vol A | 30 m ³ /h | Type 13 | Whatman/Schleicher & Schuell Glass fibre |

| | | | | | |
|----|--------|---------------------------|--------------------------|------------|---|
| | | Derenda SEQ High Vol B | 30 m ³ /h | Type 13 | Whatman/Schleicher & Schuell Glass fibre |
| | | Derenda SEQ Low Vol | 2.3 m ³ /h | Type 1 | Schleicher & Schuell Glass fibre |
| DE | LANUV | Digitel A | 30 m ³ /h | Type 8 | Whatman QMA |
| | | Digitel B | 30 m ³ /h | Type 8 | Whatman QMA |
| DE | HLUG | Leckel SEQ 47/50 | 2.3 m ³ /h | Type 3 | Schleicher und Schuell Glass fibre GF10 |
| SE | ITM | Leckel SEQ 47/50 | 2.3 m ³ /h | Type 3 | Pall fibre film T60A20 / heat resistant borosilicate glass fibre coated with fluorocarbon (TFE) |
| SE | IVL | IVL homemade A | 18 l/min | Type 16 | unknown |
| | | IVL homemade B | 18 l/min | Type 16 | unknown |
| EE | EERC | Digitel (container) | 30 m ³ /h | Type 8 | Ederol Glass fibre |
| | | Digitel (mob.lab) | 30 m ³ /h | Type 8 | Ederol Glass fibre |
| NL | RIVM | Leckel SEQ 47/50 | 2.3 m ³ /h | Type 11 | Whatman QMA Quartz fibre |
| NL | GGD | Derenda SEQ Low Vol | 2.3 m ³ /h | Type 1 | Whatman QMA (pre-conditioned at high humidity) |
| BE | VMM | Leckel SEQ 47/50 | 2.3 m ³ /h | Type 3 | Whatman QMA (pre - fired) |
| BE | ISSeP | FAI SW sn.126 | 2.3 m ³ /h | Type 12 | Whatman QMA |
| | | FAI SW sn.129 | 2.3 m ³ /h | Type 12 | Whatman QMA |
| FR | INERIS | Partisol + | 1 m ³ /h | Type 9 | Pallflex PTFE membrane 2 µm |
| IE | DCC | Partisol 2025 | 1 m ³ /h | Type 9 | Whatman Glass fibre |
| GB | AEA | Partisol 2025 | 1 m ³ /h | Type 9 | Emfab |
| GB | BV | Partisol 2025 | 1 m ³ /h | Type 9 | Emfab |
| | | Partisol 2025 | 1 m ³ /h | Type 9 | Quartz |
| IT | ISPRA | Tecora | 2.3 m ³ /h | Type 20 | Millipore AQFA quartz |
| IT | ARPA | Zambelli explorer plus | 1 m ³ /h | Type 22 | Pall, PTFE with support ring |
| | | Tecora | 1 m ³ /h | Type 9 | Pall, T6020 fibre film, teflonated borosilicate glass |
| HU | HMS | Digitel | 30 m ³ /h | Type 8 | Schleicher & Schuell Quartz |

A total of 17 LVS and 3 HVS were used by the participants during the measurement campaigns for PM2.5. Table 4 provides detailed information.

Table 4: PM2.5 manual samplers

| Country | Institution | Sampler | Flow rate | Inlet | Filter manufacturer and material |
|---------|-------------|------------------|-----------------------|--------|----------------------------------|
| EU | JRC | SEQ Leckel 47/50 | 2.3 m ³ /h | Type 3 | Whatman QMA |
| ES | ISCI | Derenda MVS 6.1 | 2.3 m ³ /h | Type 1 | Whatman QMA |
| PT | IdA | Tecora | 1 m ³ /h | Type 4 | Schleicher & Schuell Quartz |

| | | | | | |
|----|---------|--------------------------------------|--|------------------|--|
| SI | EPA SI | SEQ Leckel 47/50 | 2.3 m ³ /h | Type 3 | Whatman QMA |
| AT | UBA | Digitel DAH 80 | 30 m ³ /h | Type 8 | Ederol Glass fibre |
| AT | LR OOe. | Digitel DAH 80 | 30 m ³ /h | Type 8 | Whatman QMA |
| CZ | CHMI | SEQ Leckel 47/50 Derenda SEQ LVS | 2.3 m ³ /h 2.3 m ³ /h | Type 3 Type 1 | Millipore RAWP Cellulose nitrate Schleicher & Schuell Glass Fibre |
| SE | IVL | IVL homemade A | 18 l/min | Type 16 | unknown |
| | | IVL homemade B | 18 l/min | Type 16 | unknown |
| NL | GGD | Derenda SEQ LVS | 2.3 m ³ /h | Type 1 | Whatman QMA (pre-conditioned at high humidity) |
| BE | VMM | SEQ Leckel 47/50 SEQ Leckel 47/50 | 2.3 m ³ /h 2.3 m ³ /h | Type 3 Type 3 | Whatman QMA (pre-fired) Pall, Emfab (PTFE coated glass fibre) |
| BE | ISSeP | FAI SW sn. 126 | 2.3 m ³ /h | Type 12 | Whatman QMA |
| | | FAI SW sn. 129 | 2.3 m ³ /h | Type 12 | Whatman QMA |
| GB | BV | Partisol 2025 | 1 m ³ /h | Type 9 | Emfab |
| GB | NPT | Partisol 2025 | 1 m ³ /h | Type 9 | Quartz |
| IT | ARPA | Zambelli explorer plus | 1 m ³ /h | Type 21 | Pall, PTFE with support ring |
| HU | MDV | Digitel DAH 80 | 30 m ³ /h | Type 8 | Munktell, glass fibre |

Automatic samplers used during the campaigns are based on the following principles:

- Tapered Element Oscillating Microbalance (TEOM)
- Filter Dynamics Measurement System (FDMS) combined with TEOM
- β – radiation attenuation
- Light scattering

The used flow rates, sampling line temperatures and inlets differ between the participants. Pictures of the inlets can be found in Annex 2. A total of 5 TEOM, 12 FDMS, 19 β – radiation and 1 light scattering instrument were used for PM₁₀; 1 instrument used a combination of both the last techniques. Table 5 provides detailed information on the automatic PM₁₀ instruments.

Table 5: PM₁₀ automatic samplers

| Country | Institution | Instrument | Flow rate | Sampling line / heating | Inlet |
|---------|-------------|----------------------|---------------------|-------------------------|---------|
| EU | JRC | Teom FDMS Vers. B | 1 m ³ /h | straight / 30° C | Type 9 |
| ES | AdM | Teom 1400 AB | 1 m ³ /h | straight / 50° C | Type 9 |
| PT | IdA | Environnement MP 101 | 1 m ³ /h | straight / 50° C | Type 9 |
| SI | EPA SI | Teom 1400 | 1 m ³ /h | straight / 30° C | Type 9 |
| AT | UBA | Teom FDMS | 1 m ³ /h | straight / 30° C | Type 7 |
| AT | LR OOe. | Teom FDMS | 1 m ³ /h | straight / 40° C | Type 9 |
| AT | LR Stmk. | Eberline FH 62 IR | 1 m ³ /h | curved / 40° C | Type 7 |
| CZ | CHMI | FH 62 IR | 1 m ³ /h | curved / 30° C | Type 7 |
| DE | HLUG | FH 62 IR | 1 m ³ /h | curved / amb.T + 8° C | Type 7 |
| | | FH 62 IR Sharp | 1 m ³ /h | curved / amb.T + 8° C | Type 7 |
| DK | NERI | Opsis SM 200 | 1 m ³ /h | straight / no heating | Type 10 |
| | | Teom 1400 | 1 m ³ /h | straight / 50° C | Type 10 |
| SE | EHAS | Teom 1400 | 1 m ³ /h | straight / 50° C | Type 10 |
| | | Teom FDMS | 1 m ³ /h | straight / unknown | Type 9 |

| | | | | | |
|----|----------|--|--|---|--|
| FI | FMI | Thermo FH 62 IR_632 Thermo FH 62 IR_280 | 1 m ³ /h 1 m ³ /h | curved / 35° C curved / 35° C | Type 9 Type 9 |
| EE | EERC | Thermo FH 62 IR (container) Thermo FH 62 IR (mob.lab) | 1 m ³ /h 1 m ³ /h | curved / sheath air curved, no heating | Type 9 Type 9 |
| NL | RIVM | Thermo FH 62 IR | 1 m ³ /h | curved, amb. T + 10° C | Type 7 |
| BE | VMM | ESM Andersen Teom 1400 Teom FDMS | 1 m ³ /h 1 m ³ /h 1 m ³ /h | curved, dynamic heating straight / 50° C straight / 30° C | Type 9 Type 9 Type 9 |
| BE | ISSeP | FAI SW sn. 126 FAI SW sn. 129 Environnement MP 101 sn. 33 Environnement MP 101 sn 78 Grimm 180 | 2.3 m ³ /h 2.3 m ³ /h 1 m ³ /h 1 m ³ /h 72 l/h | straight / no heating straight / no heating straight / heating depending on r.h. straight / heating depending on r.h. straight / no heating | Type 12 Type 12 Type 7 Type 7 Type 15 |
| FR | INERIS | Teom FDMS Vers. C, sn. 9032 Teom FDMS Vers. C, sn. 15702 | 1 m ³ /h 1 m ³ /h | straight / 30° C straight / 30° C | Type 9 Type 9 |
| FR | EDM | Environnement MP 101M-RST | 1 m ³ /h | straight / dynamic heating (depends on amb. T & r.h.) | Type 9 |
| FR | AIRPARIF | Teom FDMS 1400 AB | 1 m ³ /h | straight / 30° C | Type 9 |
| IE | EPA IE | Teom FDMS | 1 m ³ /h | straight / 30° C | Type 10 |
| GB | NPT | Teom FDMS Vers. C | 1 m ³ /h | straight / unknown | Type 9 |
| IT | ARPA | Opsis SM 200 Teom FDMS Vers. C | 1 m ³ /h 1 m ³ /h | straight / line not heated / 40° C only at input zone straight / 40° C | Type 18 Type 9 |
| HU | HMS | FH 62 IR | 1 m ³ /h | curved / 40° C | Type 23 |
| HU | MDV | FH 62 IR | 1 m ³ /h | curved / no heating | Type 9 |
| SK | SHMU | Teom FDMS Vers. AB | 1 m ³ /h | straight / 30° C | Type 9 |

A total of 2 TEOM, 2 FDMS, 7 β – radiation and 1 light scattering instrument were used for PM_{2.5}. Table 6 provides detailed information.

Table 6: PM_{2.5} automatic samplers

| Country | Institution | Instrument | Flow rate | Sampling line | Inlet |
|---------|-------------|---|--|---|-------------------------------|
| CZ | CHMI | FH 62 IR | 1 m ³ /h | curved / 30° C | Type 7 |
| DK | NERI | Teom 1400 | 1 m ³ /h | straight / 50° C | Type 10, cyclone |
| SE | EHAS | Teom 1400 | 1 m ³ /h | straight / 50° C | Type 10, cyclone |
| EE | EERC | Thermo FH 62 IR | 1 m ³ /h | curved / 40° C | Type 7 |
| BE | VMM | ESM Andersen | 1 m ³ /h | curved / dynamic heating | Type 9, cyclone |
| BE | ISSeP | FAI SW sn. 126 FAI SW sn. 129 Grimm 180 | 2.3 m ³ /h 2.3 m ³ /h 72 l/h | straight / no heating straight / no heating straight / no heating | Type 12 Type 12 Type 15 |
| FR | AIRPARIF | Teom FDMS 1400 AB | 1 m ³ /h | straight / 30° C | Type 9, cyclone |
| GB | BV | Teom FDMS Vers. C | 1 m ³ /h | straight / 30° C | Type 9, cyclone |
| IT | ARPA | Opsis SM 200 | 1 m ³ /h | straight / line not heated / 40° only at input zone | Type 17 |
| HU | MDV | FH 62 IR | 1 m ³ /h | curved / 40° C | Type 23 |

2.3 The European Reference Laboratory of Air Pollution (ERLAP) and its equipment

Upon decision by the AQUILA Network and JRC, the ERLAP of the JRC in Ispra, Italy, took the responsibility to provide the Reference Values for the whole project. To perform the measurement campaigns, ERLAP prepared an air conditioned mobile laboratory with the following equipment on board:

- 2 Sequential Samplers SEQ 47/50 for PM10 gravimetric measurements
- 1 Sequential Sampler SEQ 47/50 for PM2.5 gravimetric measurements
- 1 Sequential Sampler SEQ 47/50 for PM1 gravimetric measurements
- 1 TEOM FDMS for online PM10 measurements
- 1 Sunset semi – continuous OC/EC analyzer
- Meteorological parameters (ambient temperature, ambient relative humidity, ambient pressure, 10m mast for wind speed and wind direction)

In addition to the equipment of the mobile laboratory, the following stationary equipment at the ERLAP laboratory in Ispra was used:

- 1 Balance room in conformity with EN standards [4] for weighing and conditioning of filters
- 1 Balance Mettler Toledo AX26, resolution 1 µg
- Reference mass pieces of 100 and 50 mg

Quality control of used equipment and material

The balance and the reference mass pieces are certified on a periodic time schedule by accredited companies, the climate conditions of the balance room are registered online and checked with certified thermo- and hygrometer.

The used filter material for the sequential samplers was 47 mm QMA (quartz with 5% borosilicate glass as a binder) filters from Whatman. Filters have been conditioned and weighed as described in EN 14907. Laboratory and travelling blanks have been used to evaluate possible changes in filter mass during the campaigns. To avoid contamination and loss of volatile material during transport, filters were always stored in petri dishes (Millipore, material of construction: molded polystyrene) inside a cool box or refrigerator. To minimize “dead time” between weighing and sampling, filters were transported in the hand luggage of airplanes to/from measurement sites, apart from a few occasions where transport was done with the mobile laboratory.

Twice a year all Sequential Samplers and the TEOM FDMS have been maintained at the Ispra site and their flow rate was recalibrated using a certified gas counter. At each measurement site, before the start of a measurement campaign, a verification of the flow rate took place. The same was done for the incorporated pressure and temperature sensors to verify if they were within their required limits (± 1 K, ± 10 hPa). Sequential Sampler inlets have been cleaned and greased before each campaign, regarding the campaign at the kerbside in Stockholm (SE) even once more during the campaign.

The OC/EC analyzer was maintained on an annual basis at the Ispra site. Its flow rate was as well verified before each campaign.

3. The Reference Value

The Reference Values for PM10 were calculated as the average of both PM10 Sequential Samplers, exceptionally on three days one sampler was taken only. These samplers were placed inside the Mobile Laboratory keeping, by means of the air conditioning system of the measurement cabin, the filter temperature $\leq 20^{\circ}\text{C}$ limiting in such a way losses of volatile material. Special care was taken in placing the outlet of the air conditioning system far away from the PM sampling points. The sampling height was ca. 3.5 m above ground.

The Reference Values for PM2.5 were taken from the PM2.5 Sequential Sampler. This sampler was placed outside next to the Mobile Laboratory. Exact distances and positions between samplers during each measurement campaign can be derived from the drawings in Annex 1. The sampling height was ca. 1.6 m above ground. The same applies to the PM1 Sequential Sampler.

Only values where the sampling took place for entire 24 hours were taken into account. In total 249 (PM10), 238 (PM2.5) and 242 (PM1) Reference Values were generated.

3.1 Equivalence test

Before the Sequential Samplers could be implemented in the measurement campaigns, they had to be compared in an Equivalence test to the Reference Method as described in EN 12341 and EN 14907, according to the "Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods" [5]. Three campaigns in three different measurement sites over the run of 41 days were conducted. The first campaign took place in Ispra (IT) during October and November 2005 for 22 days, the second in Marseille (FR) during November and December 2005 for 8 days, the third on a different site in Ispra in January 2006 for 11 days. Regarding PM10, two LVS Derenda 3.1 (Reference Method) were compared to two Leckel SEQ 47/50 (Candidate Method). The measured 24h average PM10 concentrations ranged from 17 to 131 $\mu\text{g}/\text{m}^3$.

For PM2.5 the measurement sites were the same, however only one LVS Derenda 3.1 was compared to one Leckel SEQ 47/50 over the run of 34 days. The measured 24h average PM2.5 concentrations ranged from 11 to 124 $\mu\text{g}/\text{m}^3$.

The equivalence test for PM10 was passed successfully; results and their acceptance criteria are presented in table 7.

Table 7: Results of the PM10 equivalence test for Leckel SEQ 47/50 samplers

| | Orthogonal regression | | expanded uncertainty at limit value | between sampler uncertainty | |
|---------------------|-----------------------|-------------|-------------------------------------|-----------------------------------|---------------------------------|
| | slope | intercept | | Candidate Method | Reference Method |
| Acceptance criteria | | | $\leq 25\%$ | $\leq 2.5 \mu\text{g}/\text{m}^3$ | $\leq 2 \mu\text{g}/\text{m}^3$ |
| Site | | | | | |
| Ispra 1 | 1.02 | -0.65 | 2.2 | 0.7 | 1.0 |
| Marseille | 0.98 | 0.91 | 5 | 0.6 | 0.4 |
| Ispra 2 | 0.99 | -0.08 | 9.9 | 1.0 | 1.7 |
| All sites | 0.99 | 0.53 | 5.5 | 0.8 | 1.2 |

The results of the PM2.5 comparison of one Leckel SEQ 47/50 to one Derenda LVS 3.1 (Reference Method) are given in Table 8.

Table 8: Results of the PM2.5 comparison of a Leckel SEQ 47/50

| | Orthogonal regression | | expanded uncertainty at target value |
|---------------------|-----------------------|-----------|--------------------------------------|
| | slope | intercept | |
| Acceptance criteria | | | ≤25% |
| Site | | | |
| All sites | 1.03 | -1.44 | 6.6 |

3.2 Uncertainty calculation

The uncertainty calculation is based on EN 14907 using the following formula to calculate the combined uncertainty:

$$u_c = \sqrt{(u_{field}^2 + u_m^2 / V^2 + C^2 * u_f^2 / 100^2)} \mu g / m^3$$

Where

V = the nominal sampled volume in cubic meters

C = the mass concentration of PM, specified as daily mean in $\mu g / m^3$

u_{field} = field uncertainty

u_m = mass uncertainty

u_f = flow uncertainty

3.2.1 Field uncertainty u_{field} :

As field uncertainty for PM10 the Between-Sampler Uncertainty of both Leckel Seq 47/50 samplers was taken. It was calculated individually for each measurement campaign according to the following formula:

$$u_{field}^2 = \frac{\sum (X_{i,1} - X_{i,2})^2}{2n}$$

Where

$X_{i,1}$ and $X_{i,2}$ are the simultaneous concentration data

n is the number of paired values

For PM2.5 and PM1 only one sampler each was operated, therefore the corresponding field uncertainty was calculated as follows:

PM10 Between-Sampler Uncertainty * ratio of PM2.5 on PM10

PM10 Between-Sampler Uncertainty * ratio of PM1 on PM10

However, due to the lack of a measured PM2.5 field uncertainty, a default value of $u_{field} = 1 \mu g / m^3$ (as proposed in [4]) was applied as uncertainty contribution of this size – fraction in the following calculations:

PM2.5 En-numbers (chapter 5.9.1, annex 5)

Calculation of uncertainty at the target value (chapter 5.4.2, annex 6)

PM2.5 uncertainties at low concentration level (chapter 5.9.3)

Table 9 shows the Between Sampler Uncertainties for PM10, the ratios of PM2.5/PM10 and PM1/PM10 are given later in figure 13 and 14.

Table 9: Number of Data pairs and Between-Sampler Uncertainties of both JRC Leckel Seq 47/50 samplers

| Measurement site | Between sampler uncertainty u_{field} in $\mu\text{g}/\text{m}^3$ | Data pairs |
|------------------|--|------------|
| Madrid | 0.8 | 14 |
| Lisbon | 0.8 | 14 |
| Ljubljana | 0.2 | 14 |
| Graz | 1.0 | 12 |
| Prague | 0.3 | 14 |
| Wiesbaden | 0.5 | 13 |
| Copenhagen | 2.0 | 12 |
| Stockholm | 1.6 | 12 |
| Helsinki | 1.3 | 14 |
| Tallin | 0.4 | 12 |
| Biest H | 0.6 | 14 |
| Borgerhout | 0.8 | 14 |
| Paris | 0.4 | 14 |
| Dublin | 0.4 | 17 |
| Port Talbot | 0.6 | 14 |
| Milan | 0.3 | 15 |
| Budapest | 1.0 | 14 |
| Bratislava | 0.3 | 13 |
| Median: | 0.6 | |
| Min: | 0.2 | |
| Max: | 2.0 | |
| Sum: | | 246 |

3.2.2 Mass uncertainty u_m :

According to EN 14907 the following contributions have been taken into account to calculate the mass uncertainty for PM10, PM2.5 and PM1:

- Uncertainty of the balance
- Repeatability weighing blank filters
- Repeatability weighing loaded filters
- Buoyancy effect

The uncertainty of the balance is derived from its certificate issued by an accredited body. It accounts for linearity, repeatability, eccentricity and thermal drifts and is evaluated once a year. The contribution of the filter-weighing repeatability is expressed as the standard deviation of the differences between the first and second weighing. It is calculated individually for each campaign, separated into blank and loaded filters. The contribution of the buoyancy effect is taken from EN 14907 as $3/\sqrt{3} \mu\text{g}/\text{m}^3$. Field blanks were collected in all campaigns with the exception of Madrid. They were generally not subtracted from the mass concentrations and not taken into account as a contribution to uncertainty.

However, the measurement campaigns in Budapest and Bratislava showed very high blank values (as described in chapter 5.10). Further investigations on the blank filters (measurements of OC/EC, etc) could not give a definitive answer on a possible source of contamination; yet one set of filter packages was identified to be associated with the mass gain. Hence, for Budapest and Bratislava the field blanks were subtracted from the measurement results. Further, for both campaigns the mass uncertainty accounts also for the repeatability of field blanks.

3.2.3 Flow uncertainty u_f :

The following contributions have been taken into account to calculate the flow uncertainty for PM10, PM2.5 and PM1:

Uncertainty of the flow calibration device (gas counter)

Calibration deviation

Flow drift over time

Temperature sensor

Pressure sensor

The uncertainty of the gas counter, given as 0.15%, was taken from its certificate issued by an accredited body. The calibration deviation taken into account was estimated to be 2% maximum with a rectangular distribution. The flow drift over the run of 6 month was estimated to be 3% maximum, as well assuming a rectangular distribution. The accuracy and drift of the temperature sensor was estimated to be 1 K resulting in an uncertainty contribution of 0.3%; the accuracy and drift of the pressure sensor was estimated to be 10 hPa resulting in an uncertainty contribution of 1%.

3.3 Robustness of the Reference Values

In order to assess the validity of the reference values taken in these 18 measurement campaigns, a number of calculations were undertaken. The following paragraphs explain in detail the performed verifications:

3.3.1 Between-Sampler Uncertainty

The Between-Sampler Uncertainty, a measure of random components, reflects the precision of the Reference Values. It is used to demonstrate the agreement of both Leckel Seq 47/50 PM10 samplers. Table 9 gives an overview of all 18 measurement sites. To evaluate the quality of the encountered Between-Sampler Uncertainties, the criteria of the "Guide for the Demonstration of equivalence of Ambient Air Monitoring Methods" [5] for the reference method, $u_{\text{field}} \leq 2 \mu\text{g}/\text{m}^3$, was taken. All values are lower than the criteria and hence demonstrating an acceptable performance. The highest values encountered were at traffic sites in Copenhagen and Stockholm (re-suspension of PM during winter period, see Annex 7). In the Stockholm dataset one daily average, identified as an outlier with the Grubbs test (ISO 5725-2 [6]), was removed to fulfil the criteria.

3.3.2 Combined uncertainties and E_n – numbers of both gravimetric PM10 samplers

Combined uncertainties, calculated separately for each Leckel Seq 47/50 as described in 3.2, are the estimated amount by which the calculated value may differ from the true one. It is expected, that ideally independent measurements of the same air mass show overlapping uncertainties. The two Leckel Seq 47/50 PM10 samplers measured 246 data-pairs of daily averages complying with the between-sampler uncertainty requirement (see table 9). Figures 2 to 5 give an overview of all data-pairs and their associated expanded uncertainties ($k=2$) which are overlapping in all cases.

Figure 2: JRC daily averages of PM10 gravimetric samplers and associated expanded uncertainties – Measurement campaigns Spain, Portugal, Slovenia, Austria and Czech Republic

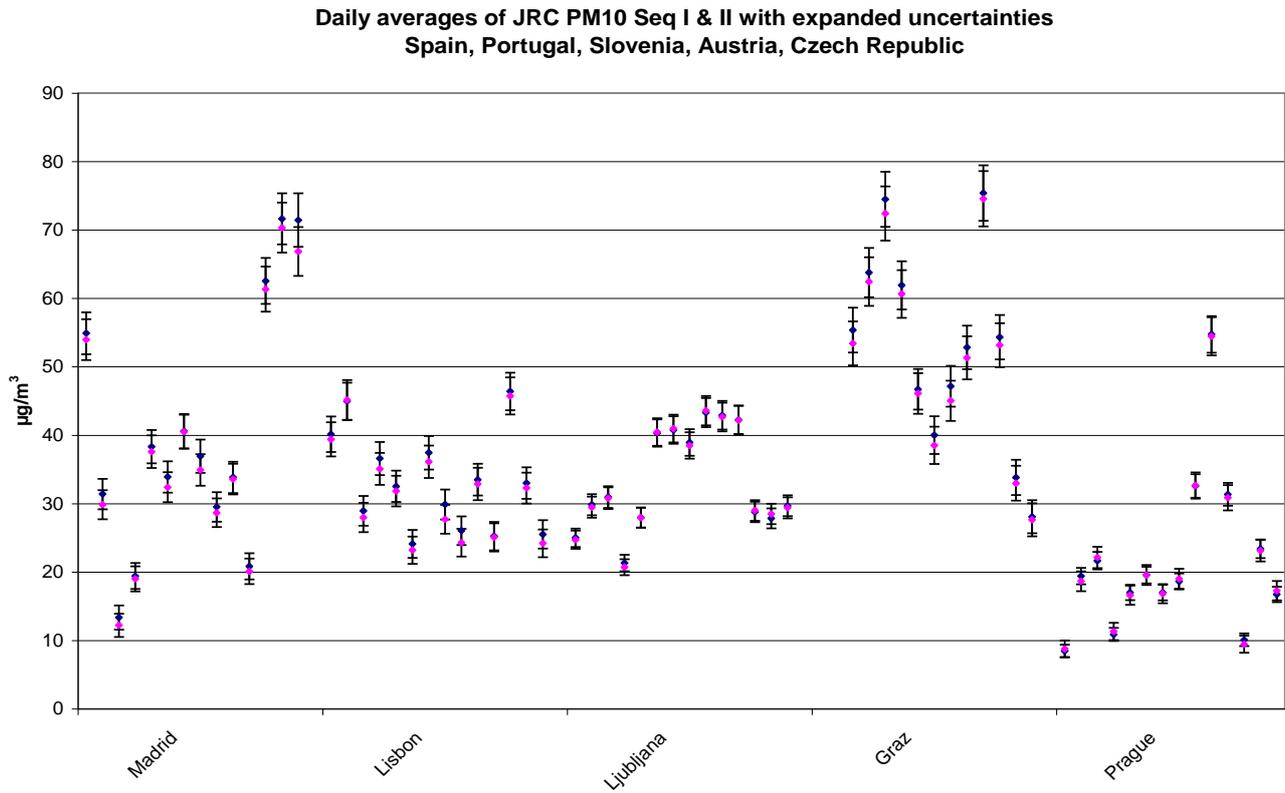


Figure 3: JRC daily averages of PM10 gravimetric samplers and associated expanded uncertainties – Measurement campaigns Germany, Denmark, Sweden, Finland and Estonia

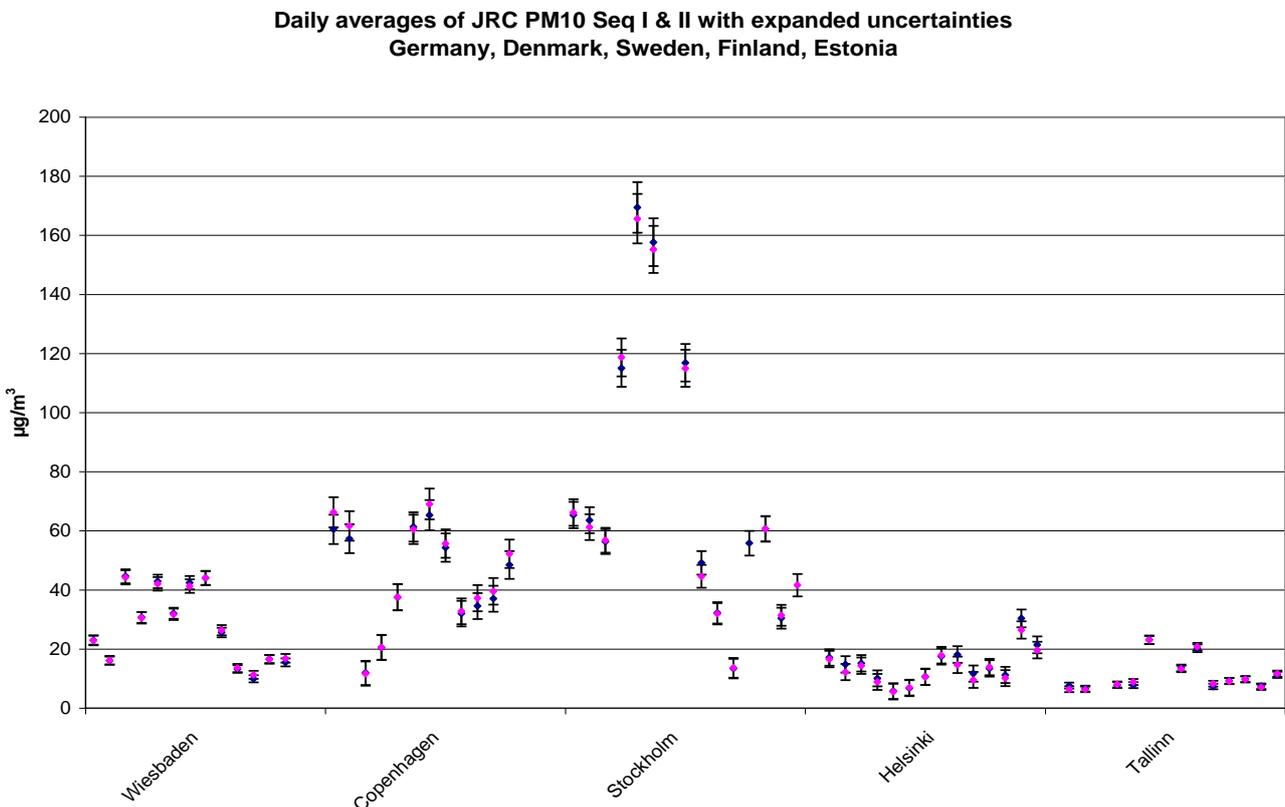


Figure 4: JRC daily averages of PM10 gravimetric samplers and associated expanded uncertainties – Measurement campaigns Netherlands, Belgium, France, Ireland and United Kingdom

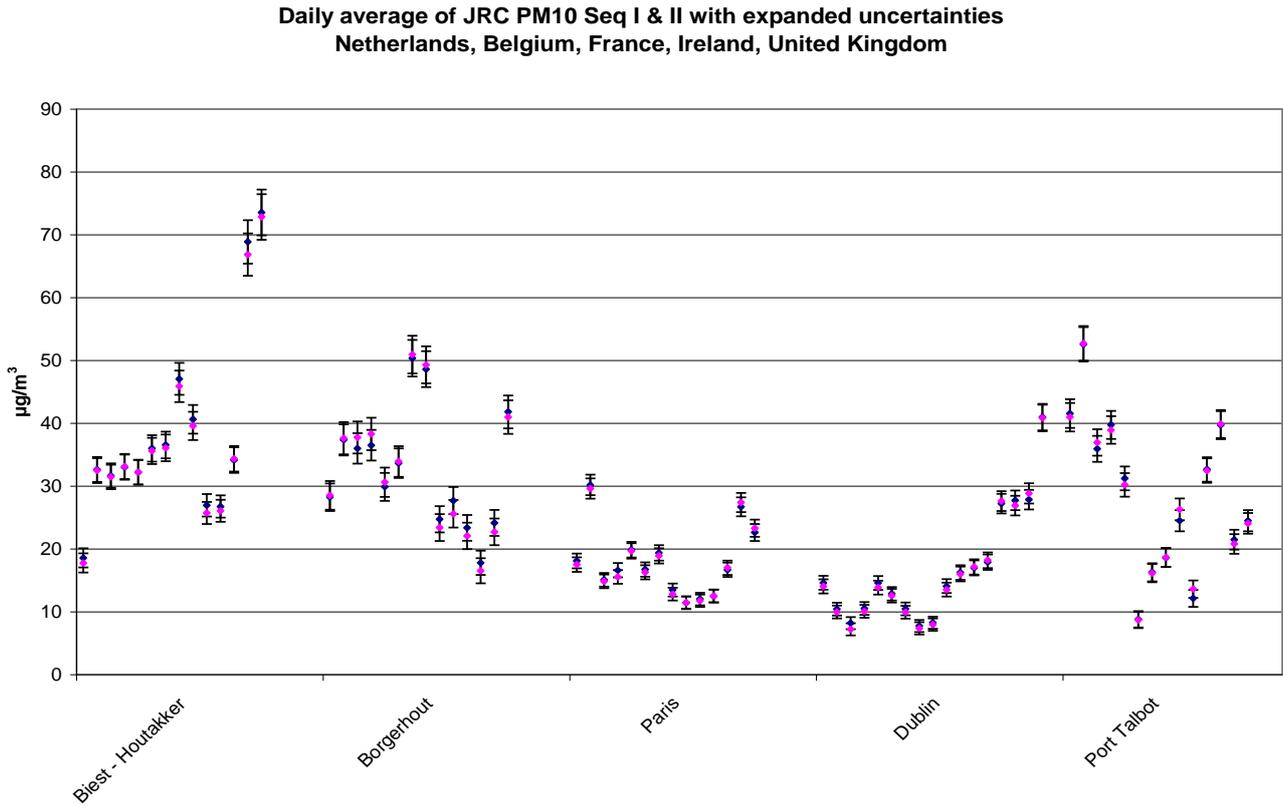
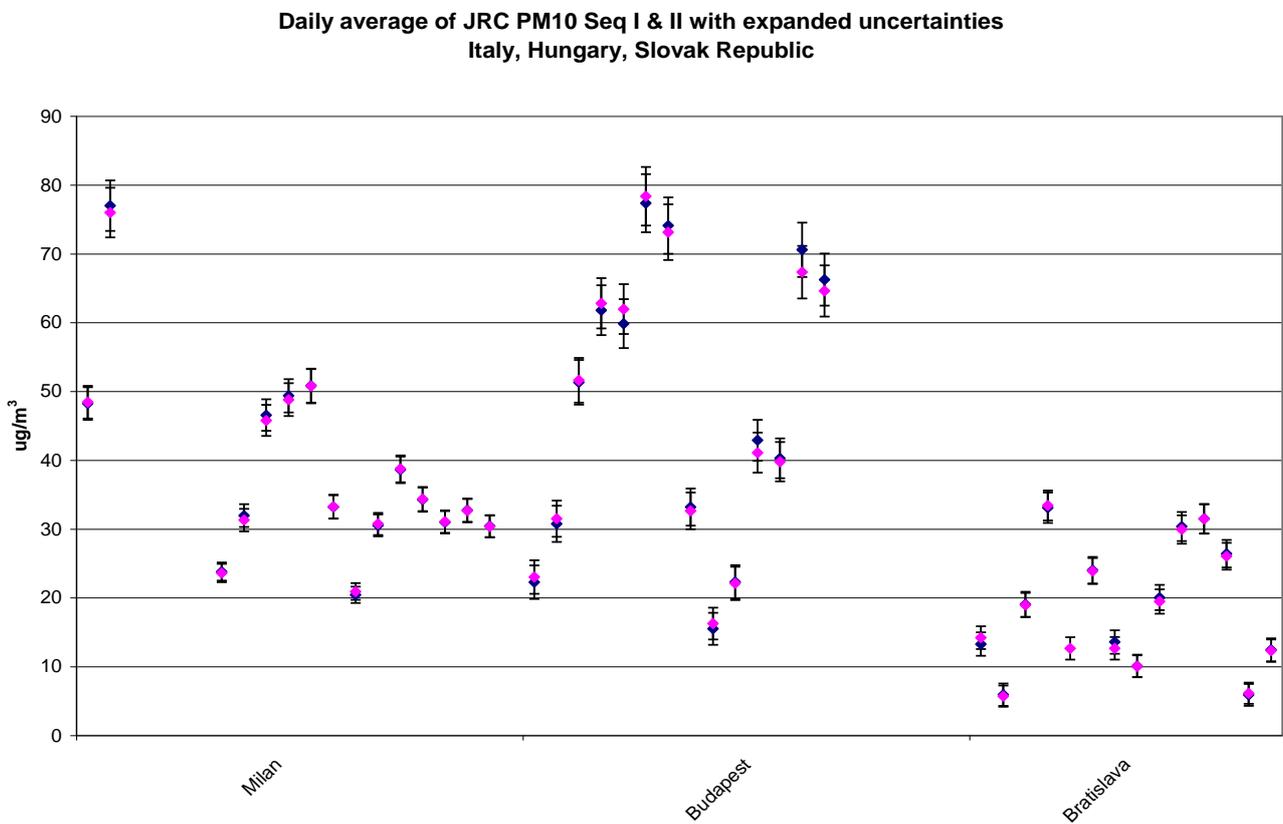


Figure 5: JRC daily averages of PM10 gravimetric samplers and associated expanded uncertainties – Measurement campaigns Italy, Hungary and Slovak Republic



The calculation of E_n – numbers is commonly used in statistics to identify if a measurement and a reference value agree within their stated uncertainties. They are calculated according to the ISO/IEC guide 43-1 [7] using the formula

$$E_n = \frac{x - X}{\sqrt{U_{lab}^2 + U_{ref}^2}}$$

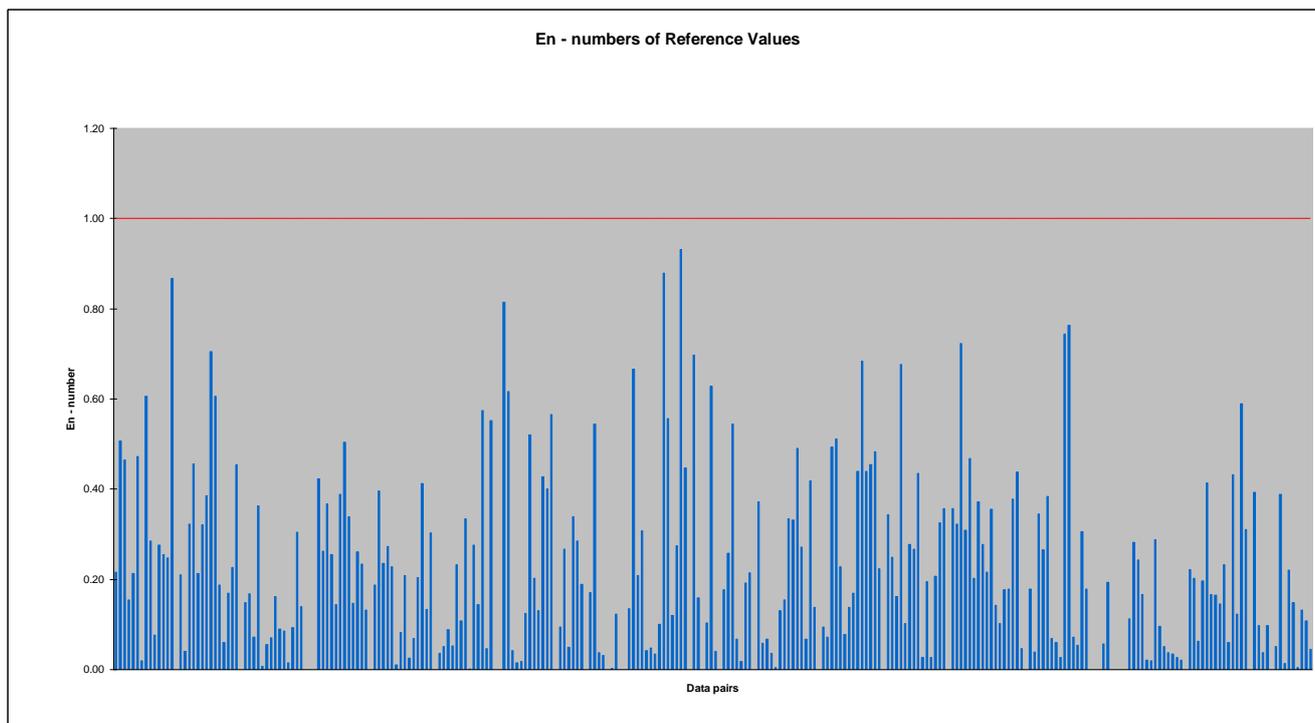
Where

x and X are the simultaneous concentration data

U_{lab} and U_{ref} are the simultaneous expanded uncertainties

One Seq 47/50 was used as “ref”, the other one as “lab” to compare both results and uncertainties. The criteria given by the guide for a satisfactory result is $|E_n| \leq 1$, $|E_n| > 1$ is considered unsatisfactory. As it can be seen in Figure 6, all 246 daily averages used for further evaluations gave a satisfactory result; two data pairs with an E_n – number slightly >1 were removed before.

Figure 6: E_n – numbers of the Reference Values



3.3.3 Bias of the Reference Values to the Grand Means – Determination of the Critical Difference

JRC values were produced in the capacity of Reference Values; this implies that biases between the grand means and the JRC values are implicit. However, to get an indication how close the Reference Values agree with the grand means of all participants, potential biases were calculated and compared to the critical differences as given in ISO 5725-6 [8]. To avoid an influence of different measurement techniques on the grand mean, these calculations were limited to LVS used during the campaigns. The bias δ of the Reference Value was calculated with the formula:

$$\delta = \mu - \bar{y}$$

Where

\bar{y} is the grand mean of all participants using LVS

μ is the average Reference Value

The critical difference CD for $|\delta = \mu - \bar{y}|$ was calculated with the formula:

$$CD = \frac{1}{\sqrt{2p}} * \sqrt{(2\sqrt{2} \cdot \sigma_R)^2 - (2\sqrt{2} \cdot \sigma_r)^2 (1 - \frac{1}{p} \sum \frac{1}{n_i})}$$

Where

p is the number of data-sets

n is the number of data pairs

σ_R is the estimate of the reproducibility standard deviation

σ_r is the estimate of the repeatability standard deviation

$2\sqrt{2}$ is a constant, see chapter 4.1.2 of the ISO standard

Note: As “data-set” is understood a series of daily averages measured by one participant with one instrument during one measurement campaign

To facilitate these calculations all data have been “normalized” dividing each daily average of a participant by the Reference Value of the same day. In an ideal case the result would be 1, in case of an underestimation of a participant the result is <1, in case of an overestimation it is >1. The bias and the CD were first calculated for all data of LVS and second for a limited number after eliminating suspect data. As suspect data was considered a data-set either identified as questionable by statistical means or with ≤ 10 daily averages. Further details about suspect data can be seen in chapter 5.1. The results for both the PM10 and PM2.5 Reference Values can be found in Table 10.

Table 10: Bias of the PM10 and PM2.5 Reference Values to the Grand Mean and Critical Difference

| PM10 (p) | Bias of the Reference Value | Critical Difference |
|--|-----------------------------|---------------------|
| all LVS (29) | 0.0142 | 0.0375 |
| LVS after elimination of suspect data (18) | 0.0336 | 0.0369 |

| PM2.5 (p) | Bias of the Reference Value | Critical Difference |
|--|-----------------------------|---------------------|
| all LVS (16) | -0.0093 | 0.1641 |
| LVS after elimination of suspect data (10) | 0.0681 | 0.0762 |

In practice this means that for PM10 the average Reference Value is 1.42 % higher than the grand mean of all LVS, this is less than the critical difference of 3.75 %. After elimination of suspect data the difference rises to 3.36 % but stays still within the critical difference of 3.69 %.

For PM2.5 the average Reference Value is 0.01 % lower than the grand mean of all LVS, this is less than the critical difference of 16.41 %. After elimination of suspect data the average Reference Value becomes 6.8 %

higher than the grand mean but stays still within the critical difference of 7.62 %.

Concluding these calculations it can be stated that the Reference Values for PM10 and PM2.5 have sufficient accuracy and robustness to be used as such during further evaluations of all data in this report. Nevertheless the Reference Values show a tendency to be higher than the measurement results of the participating laboratories.

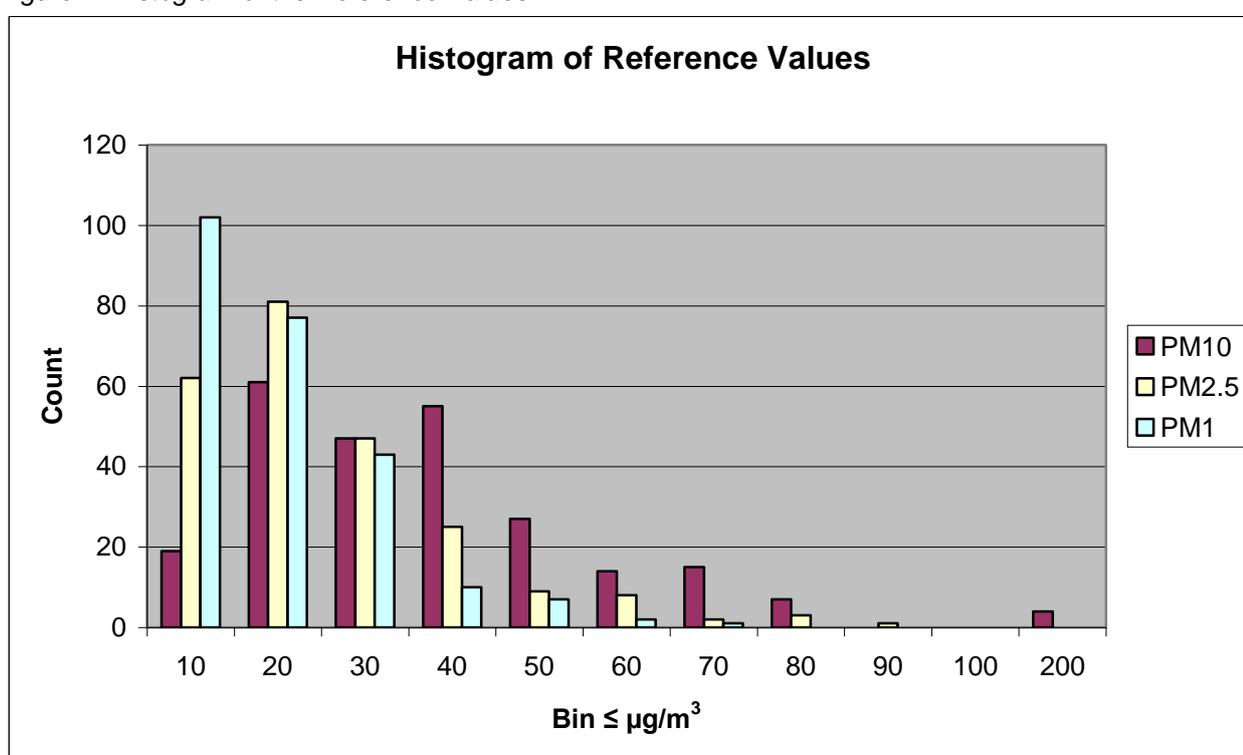
4. Overview of data measured by ERLAP during the measurement campaigns

The following chapter describes the data (Reference Values) measured by ERLAP during all measurement campaigns.

4.1 Concentration ranges

Due to different site characteristics (see Annex 7) and meteorological conditions the PM concentrations could differ significantly from one campaign to another. To see how often a certain concentration level occurred as Reference Value, a histogram of the three size fractions was drawn. PM10 presents two modes, one between 10 and 20 $\mu\text{g}/\text{m}^3$ and the other between 30 and 40 $\mu\text{g}/\text{m}^3$, while PM2.5 and PM1 present one distinct mode between 10 and 20 $\mu\text{g}/\text{m}^3$ and $<10 \mu\text{g}/\text{m}^3$ respectively. An overview is given in Figure 7.

Figure 7: Histogram of the Reference Values



To summarize and compare the measurement campaigns, for each of them the minimum, maximum, median, the 25 and 75 percentiles of the Reference Value were calculated. The overall lowest values measured were in Finland with 5.7 $\mu\text{g}/\text{m}^3$ for PM10, 2.8 $\mu\text{g}/\text{m}^3$ for PM2.5 and 1.5 $\mu\text{g}/\text{m}^3$ for PM1; the overall highest values measured were 167.5 $\mu\text{g}/\text{m}^3$ for PM10 (Sweden), 81.4 $\mu\text{g}/\text{m}^3$ for PM2.5 (Sweden) and 61.0 $\mu\text{g}/\text{m}^3$ for PM1 (Hungary). Data measured in the kerbside in Stockholm have the biggest spread. On the other hand, due to constantly low concentration levels, comparisons between reference and participants particularly in Helsinki and Tallinn might result in large relative deviations, but the absolute differences approach the between-sampler uncertainty. Descriptive statistics of each campaign are illustrated in Figure 8 (PM10), Figure 9 (PM2.5) and Figure 10 (PM1).

Figure 8: Box and whisker diagram for the PM10 Reference Values

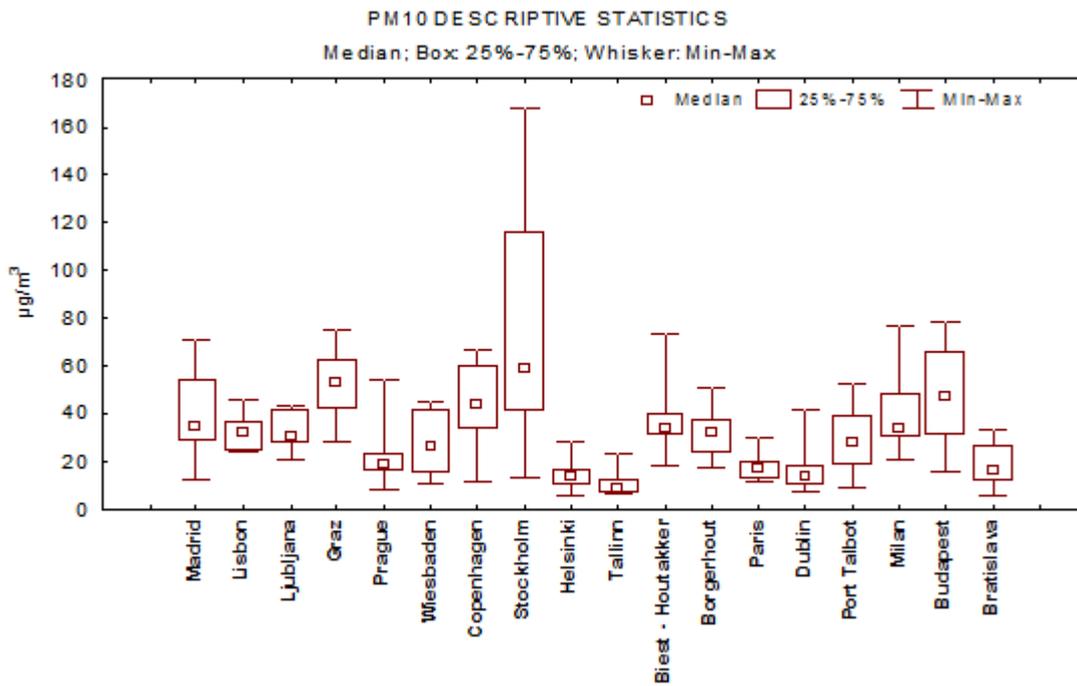


Figure 9: Box and whisker diagram for the PM2.5 Reference Values

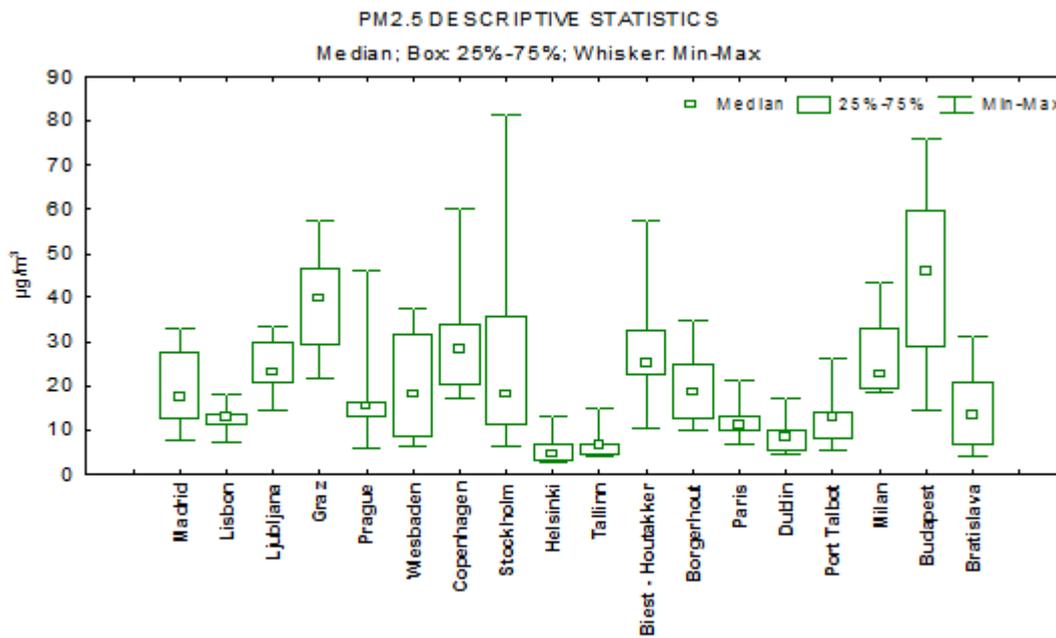
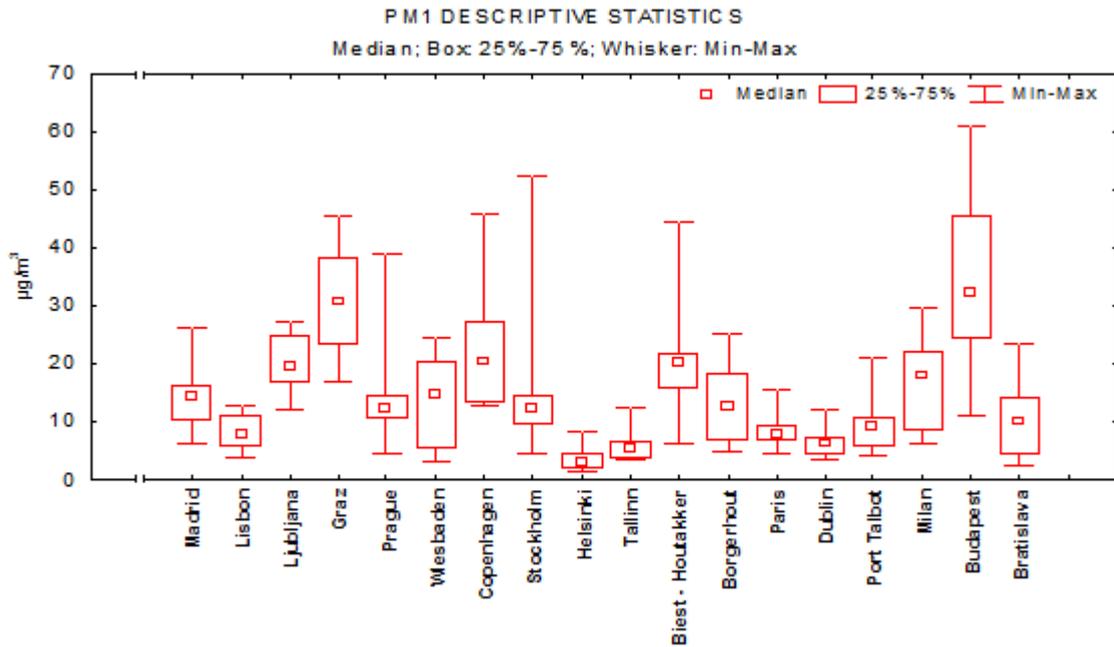


Figure 10: Box and whisker diagram for the PM1 Reference Values



The assigned uncertainties to the PM10 and PM2.5 Reference Values are summarized in Figure 11 and 12 displaying the minimum, maximum and average combined uncertainty associated with each campaign.

Figure 11: Minimum, maximum and average combined uncertainty of the PM10 Reference Value for each measurement campaign

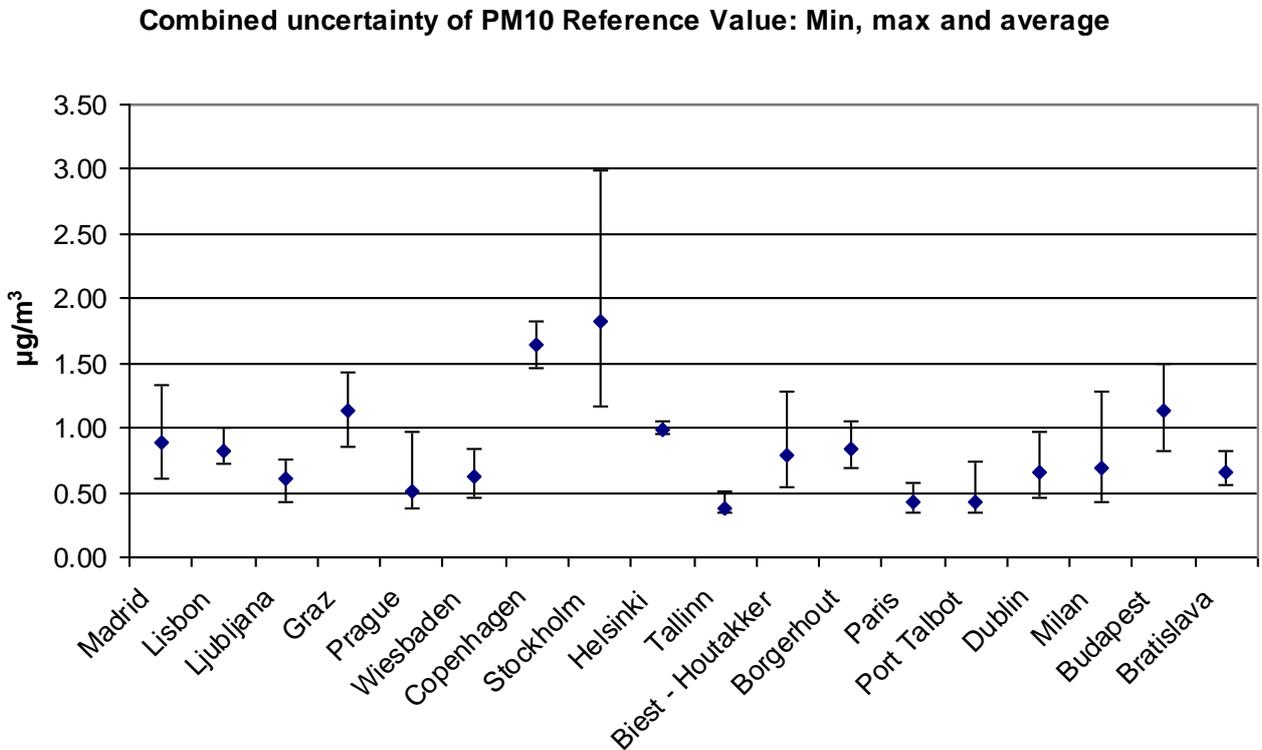
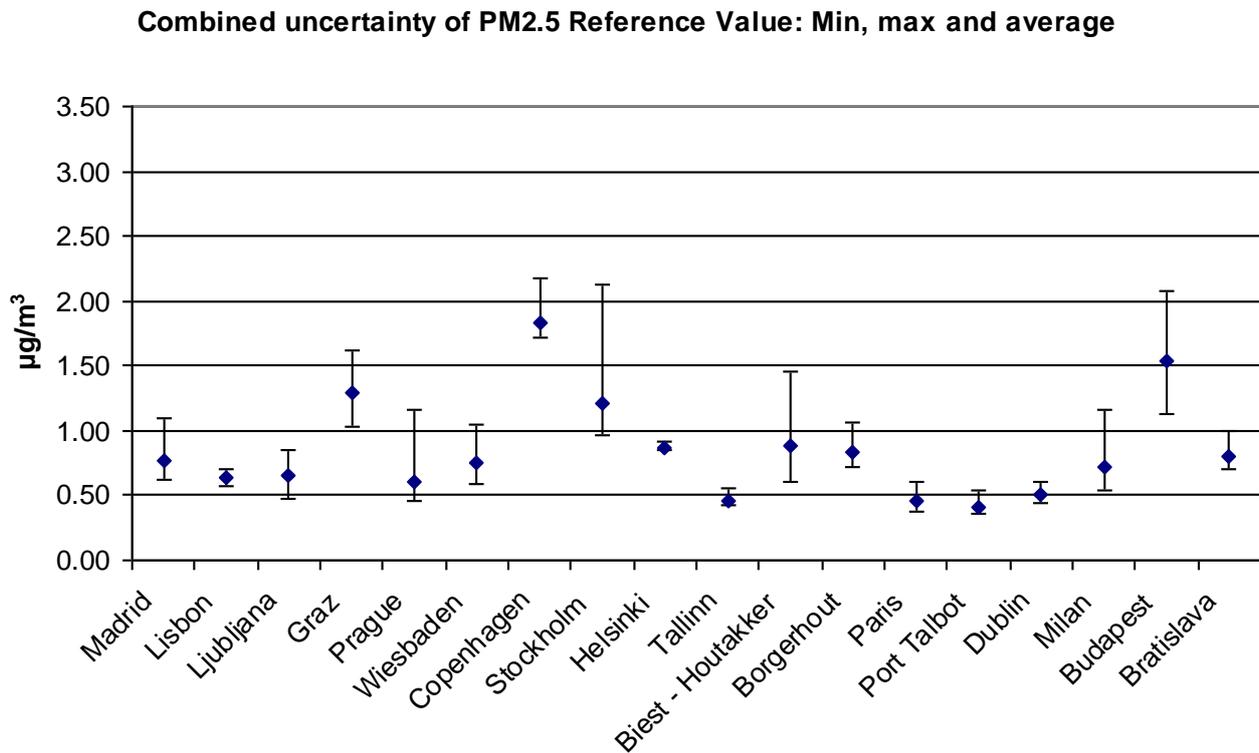


Figure 12: Minimum, maximum and average combined uncertainty of the PM2.5 Reference Value for each measurement campaign



4.2 Ratios of PM2.5 and PM1 on PM10

The percentage of PM2.5 on PM10 was generally in line with other European results, as reported in the 2nd position paper on particulate matter [9] or recent results reported by Putaud et al [10]. In some situations close to traffic, the contribution of re-suspension was dominating the importance of the coarse fraction. In other cases natural contributions like sea salt decreased the ratio fine/coarse fraction (see Annex 7).

The minimum, maximum and average ratios for all campaigns can be found in Figure 13 (PM2.5 on PM10) and Figure 14 (PM1 on PM10).

Figure 13: Minimum, maximum and average ratios of PM2.5 on PM10

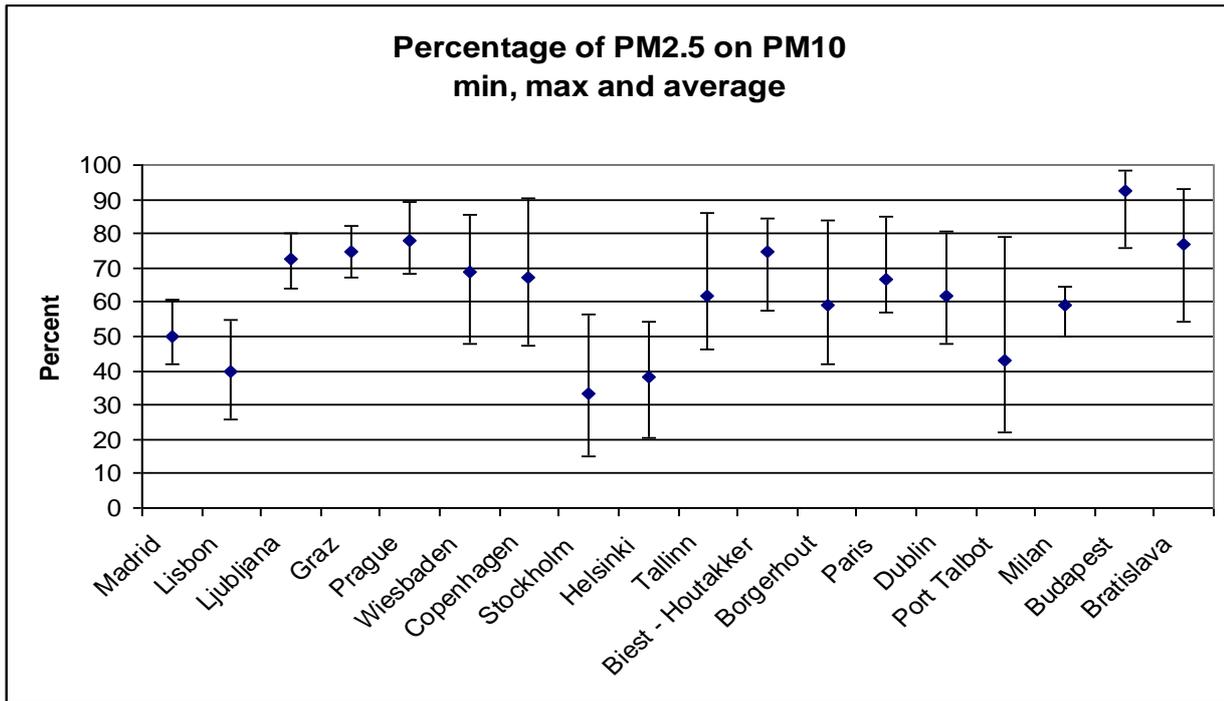
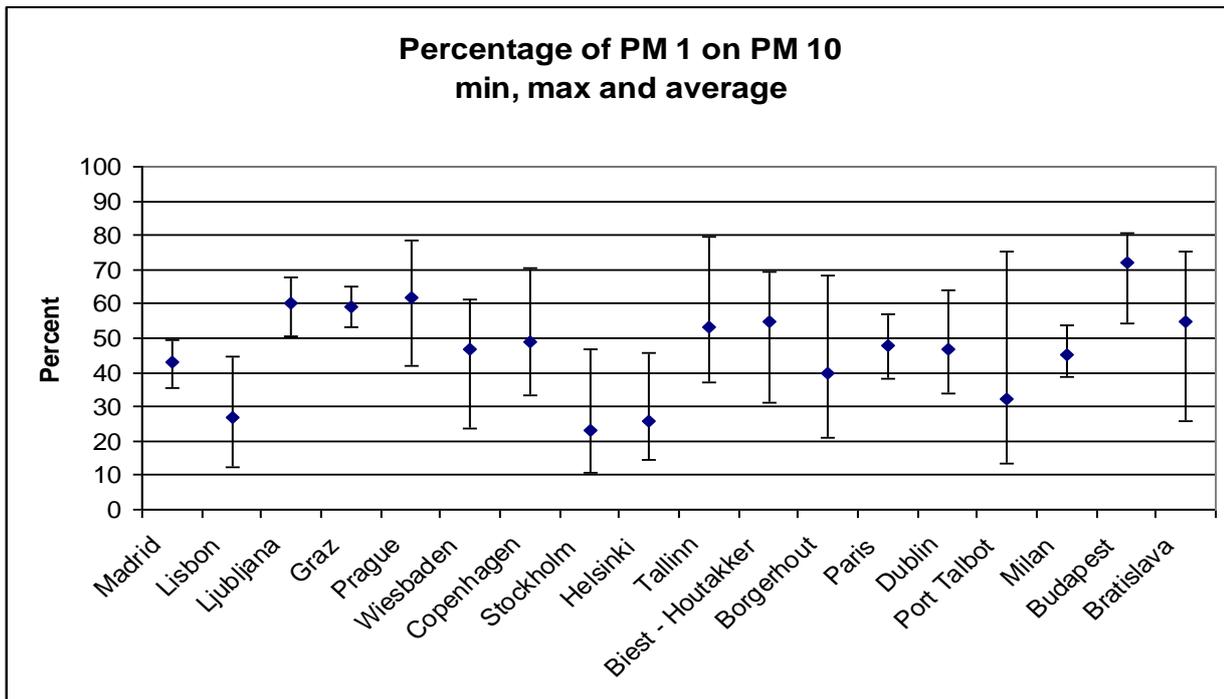
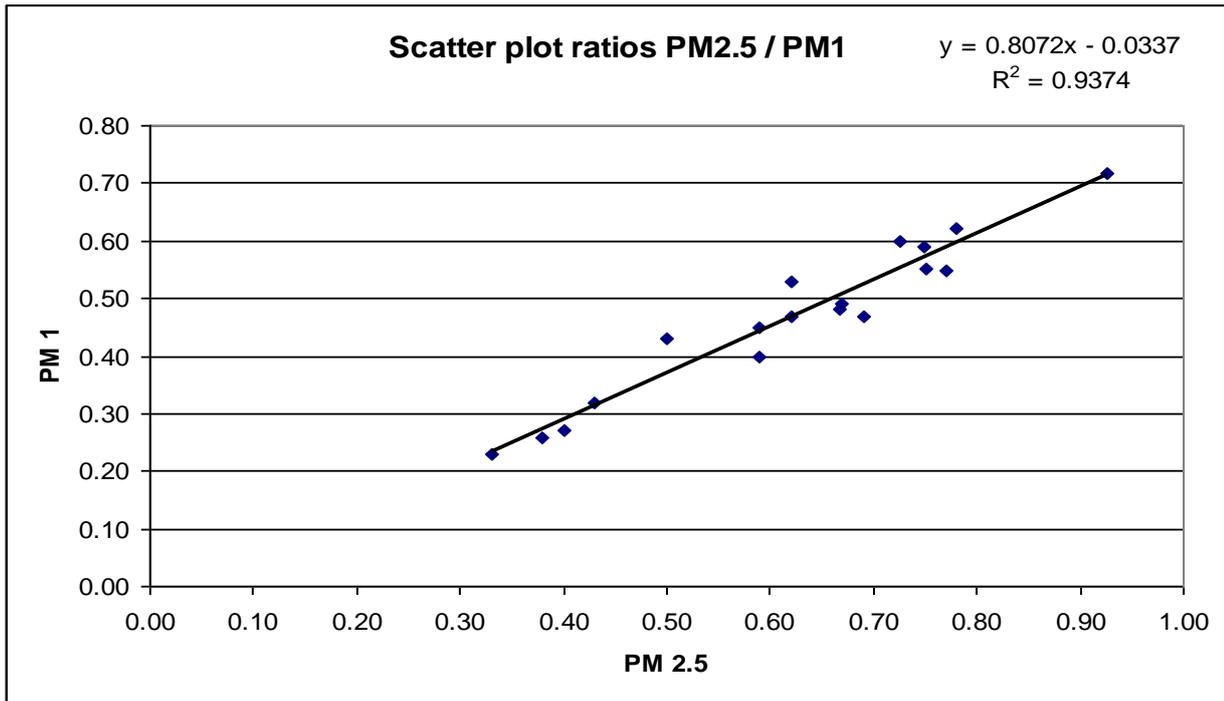


Figure 14: Minimum, maximum and average ratios of PM1 on PM10



To investigate if the PM2.5 Reference Values are influenced by the coarse fraction, a scatter plot of the ratios PM2.5/PM10 and PM1/PM10 was drawn (Figure 15). The regression of this plot is showing ratios arranged along a straight line indicating that the contribution of PM2.5 to PM10 is proportional to the contribution of the sub-micrometric fraction to PM10. Considering that contribution from road dust re-suspension to PM1 is negligible (~3%, Amato et al., 2009) these findings underpin the assumption that the PM2.5 Reference Values are not influenced by local re-suspension.

Figure 15: Scatter plot of the ratios PM2.5 on PM10 and PM1 on PM10



5. Evaluation of all data sets

5.1 Calculation of the “Grand mean” and identification of suspect data using “normalized” data-sets

This chapter presents the comparability of all measured data using ISO 5725-2 [6] to perform the necessary calculations. In a first step all data were “normalized” dividing each daily average of a participant by the Reference Value of the same day. In an ideal case the result would be 1, in case of an underestimation of a participant the result is <1 , in case of an overestimation it is >1 . Such a relative approach allows on the one hand calculation of statistical parameters like average, standard deviation and Mandel’s h and k statistics for each participant, on the other hand identification of outliers and calculation of statistical parameters for the entire lot of data.

To verify the graphical consistency of data-sets, Mandel’s h and k statistics were used. Mandel’s h statistic describes the between-laboratory and Mandel’s k statistic the within-laboratory consistency. Both statistics were plotted together with indicator lines serving to identify suspect data-sets. Cochran’s and Grubb’s test were applied on the entire lot of data to identify outliers with a numerical technique, their results were compared to their corresponding critical values.

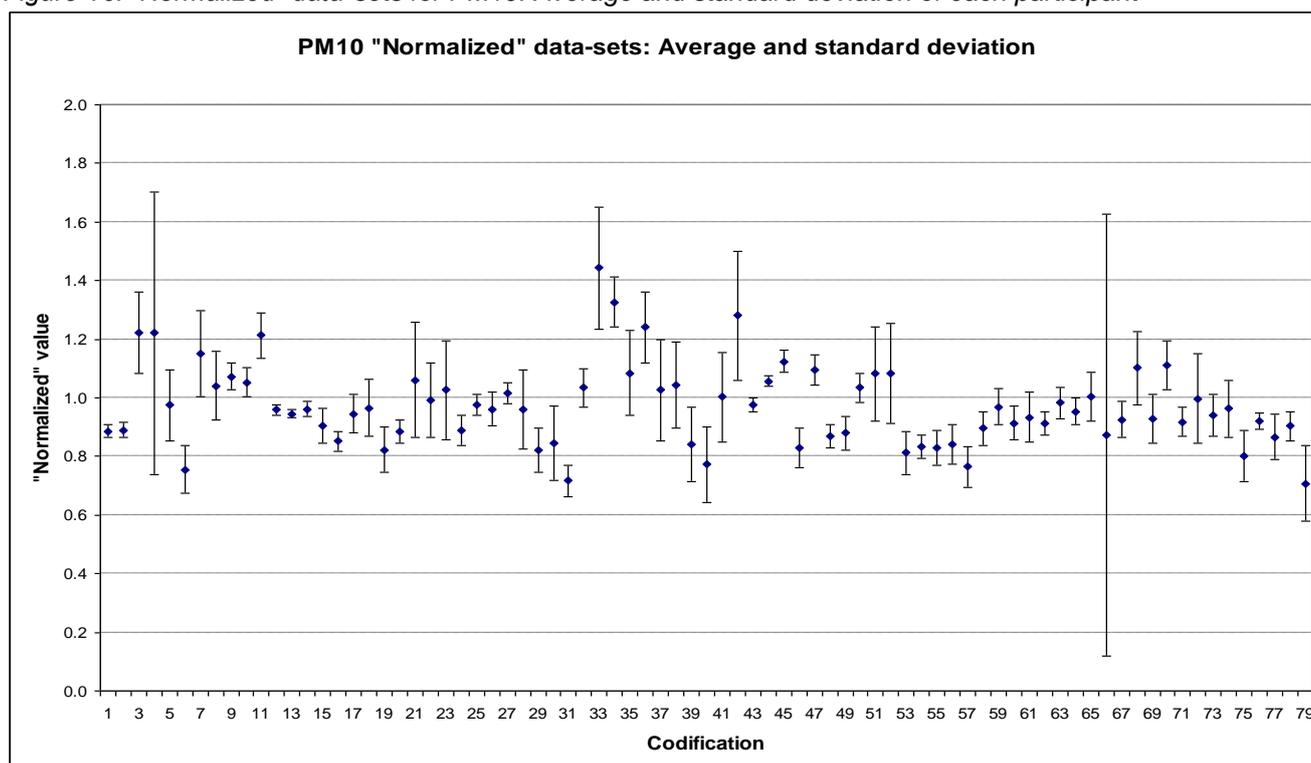
A detailed numeric overview of all “normalized” data-sets and their corresponding codification (used in the following graphs) is given in Annex 4.

5.1.1 Calculations for PM10

5.1.1.1 Averages and standard deviation

For PM10, 79 data-sets were evaluated. The averages of the “normalized” data-sets range from 0.71 to 1.44, their standard deviations from 0.01 to 0.75; an overview is given in figure 16.

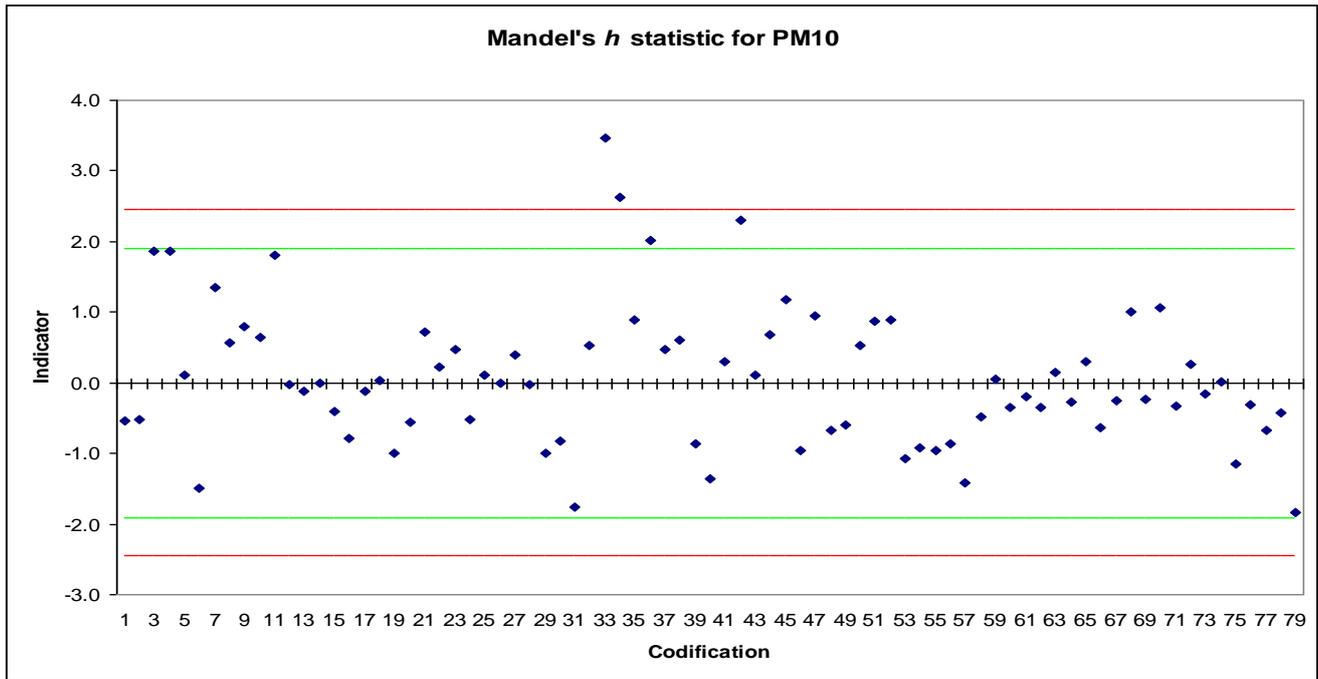
Figure 16: “Normalized” data-sets for PM10: Average and standard deviation of each participant



5.1.1.2 Mandel's *h* and *k* statistics

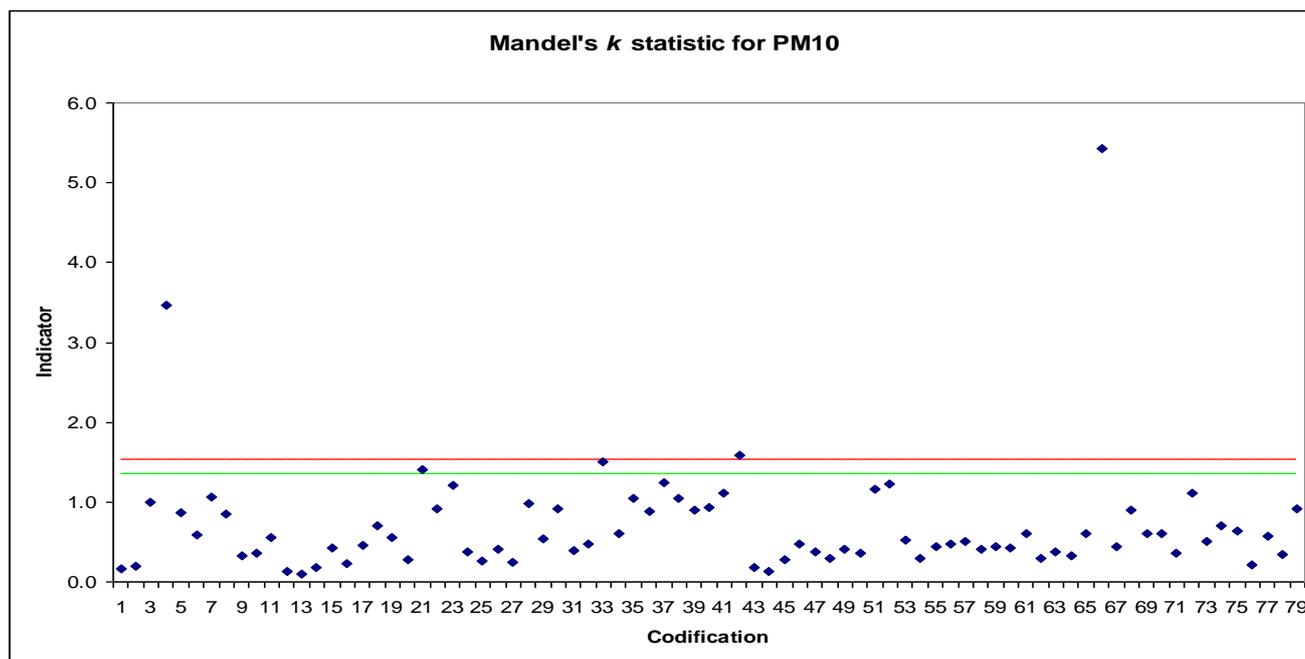
Mandel's *h* values can either be positive or negative, in an ideal case they should be evenly distributed around zero. The Critical Value at the 5% significance level is represented by a green line, at the 1% significance level by a red line. Critical Values taken are based on $p = 30$ (maximum number of reporting labs given in ISO 5725-2) assuming that they remain constant for a higher number of laboratories ($p = 79$). Two data-sets, code 33 and 34, exceed even the 1% significance level. A summary of *h* statistics is given in figure 17.

Figure 17: Mandel's *h* statistic for PM10 with Critical Values for the 5% (green) and 1% (red) significance level



Mandel's *k* values are always positive, high values indicate a poor repeatability. The Critical Value at the 5% significance level is represented by a green line, at the 1% significance level by a red one. Critical Values taken are based on $p = 30$ and 10 replicates (maximum value given in ISO 5725-2) assuming that they remain constant for a higher number of laboratories and replicates ($p = 79$, 14 replicates usually). Three data-sets, code 4, 42 and 66, exceed even the 1% level while code 33 is exactly on the red line. A summary of *k* values is given in Figure 18.

Figure 18: Mandel's k statistic for PM10 with Critical Values for the 5% (green) and 1% (red) significance level



5.1.1.3 Grubbs outlier test

A Grubbs outlier test for one maximum or minimum observation was performed with all 79 data-sets. Starting G_{\max} (3.4680) was between the 5% (3.3061) and 1% (3.6729) critical values [11] for Grubbs' test ($p = 80$), identifying data set 33 as a straggler.

5.1.1.4 Cochran test

In order to test the within laboratory variances, Cochran test was performed with all 79 data-sets (consisting of 12 data each on average). Eliminating five doubtful data-sets improved the result from an original value of 0.3718 to a lower value of 0.0501, but still higher than the critical value for the Cochran test interpolated from tables: 0.0475 at the 1% and 0.0415 at the 5% level of significance ($p = 74$ and $n = 12$) [12].

5.1.1.5 Summary of consistency and outlier tests

Mandel's h statistic identifies data-sets 33 and 34 as suspect. The examination of figure 16 confirms the lack of consistency of the two data-sets presenting the highest deviations from the reference value. On the other hand, Mandel's k statistic identifies data-sets 4, 42 and 66 as suspect which in figure 16 are those with the highest standard deviation. The Grubbs test identifies data-set 33 as a straggler as well.

In the Cochran test, critical value was exceeded even after the exclusion of suspect data-sets (4, 21, 33, 42 and 66). This demonstrates that differences in the within-laboratory variance are not negligible.

To summarize all PM10 measurements, the grand mean, median, repeatability and reproducibility (both expressed as standard deviation) were calculated for all data-sets (uncensored) and a reduced amount of data-sets (censored) with suspect data-sets 4, 21, 33, 34, 42 and 66 excluded. Table 11 presents the consensus values in detail.

Table 11: PM10 consensus values for uncensored and censored data-sets

| | uncensored | censored |
|---------------------|------------|----------|
| number of data-sets | 79 | 73 |
| grand mean | 0.962 | 0.950 |
| median | 0.94 | 0.94 |
| repeatability | 0.124 | 0.090 |
| reproducibility | 0.171 | 0.141 |

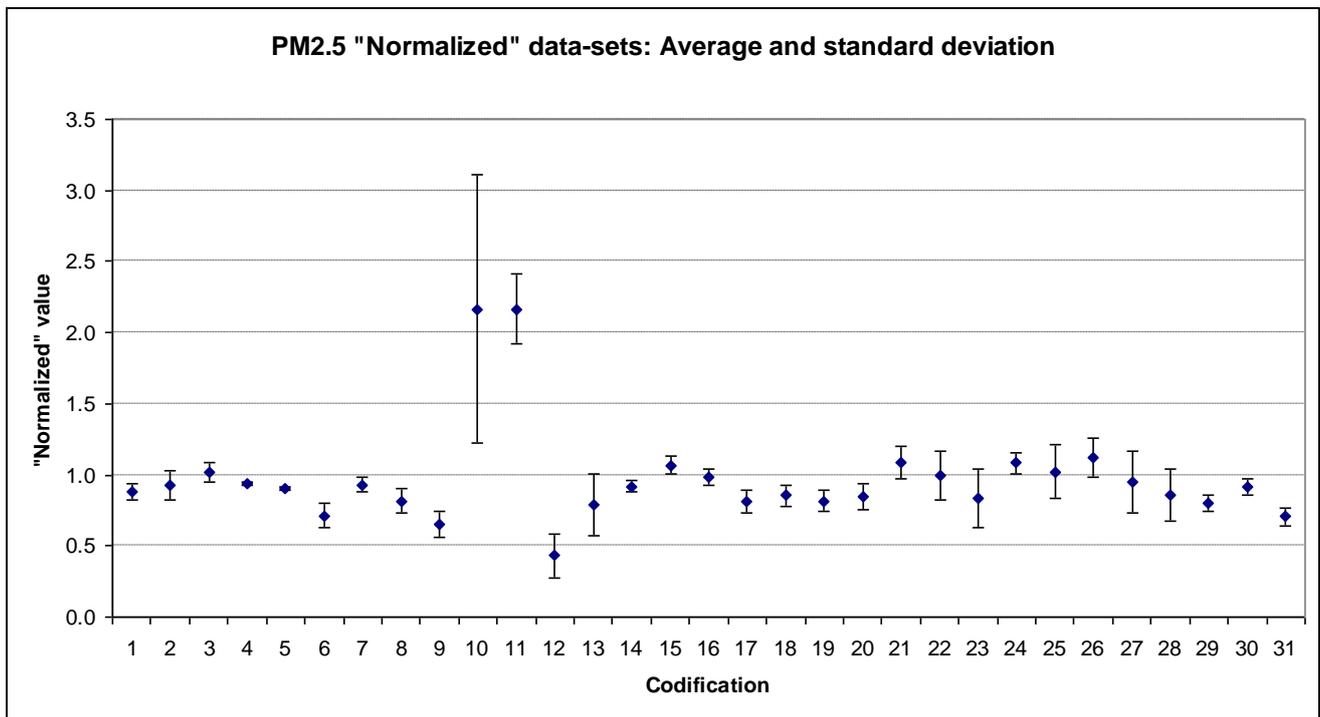
Based on the reproducibility standard deviation found after censoring, the relative uncertainty of PM10 measurement results from this study is estimated to be 14%. Using a coverage factor of 2, which for the number of datasets available represents a confidence interval of 95%, the relative expanded uncertainty is 28%. For an overall mean of reference values of $32.2 \mu\text{g}/\text{m}^3$, this means an absolute expanded uncertainty of $9 \mu\text{g}/\text{m}^3$.

5.1.2 Calculations for PM2.5

5.1.2.1 Averages and standard deviation

For PM2.5, 31 data-sets were evaluated. The averages of the “normalized” data-sets range from 0.43 to 2.17, their standard deviations from 0.01 to 0.94; an overview is given in figure 19.

Figure 19: “Normalized” data-sets for PM2.5: Average and standard deviation of each participant

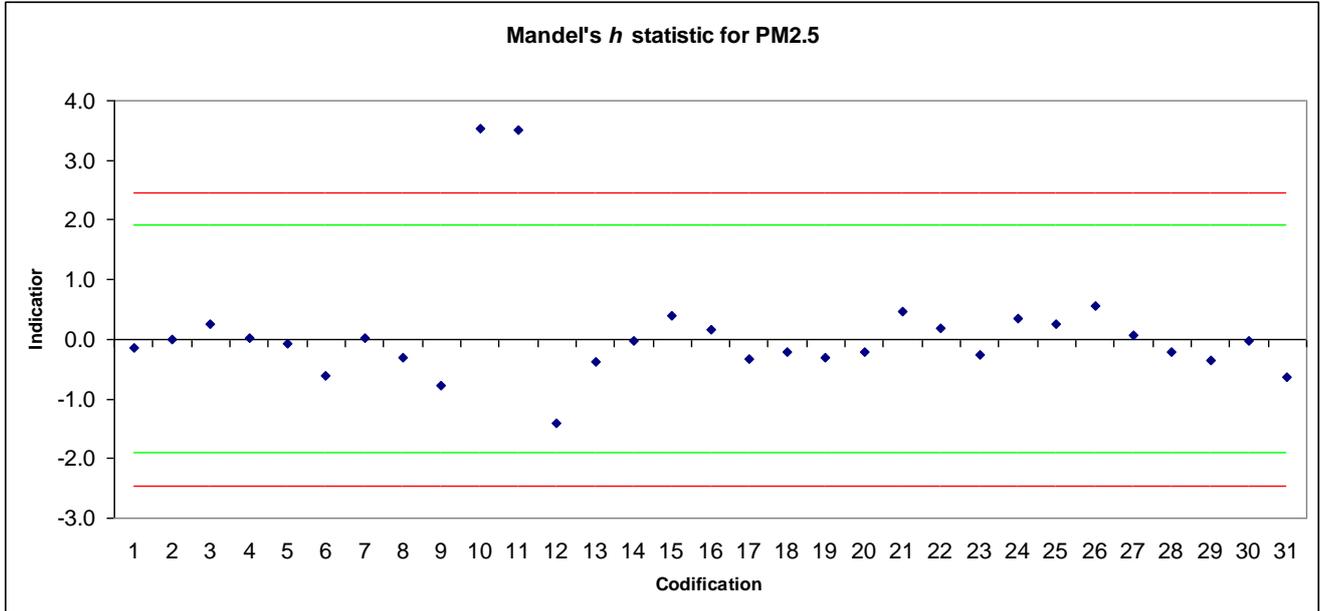


The majority of the averages fall within the interval 0.5-1.5. Data-sets 10 and 11 present an average well above the rest while data-set 12 is the only one below the mentioned interval. In addition to the anomalous average data-set 10 presents also a considerable data spread.

5.1.2.2 Mandel's h and k statistics

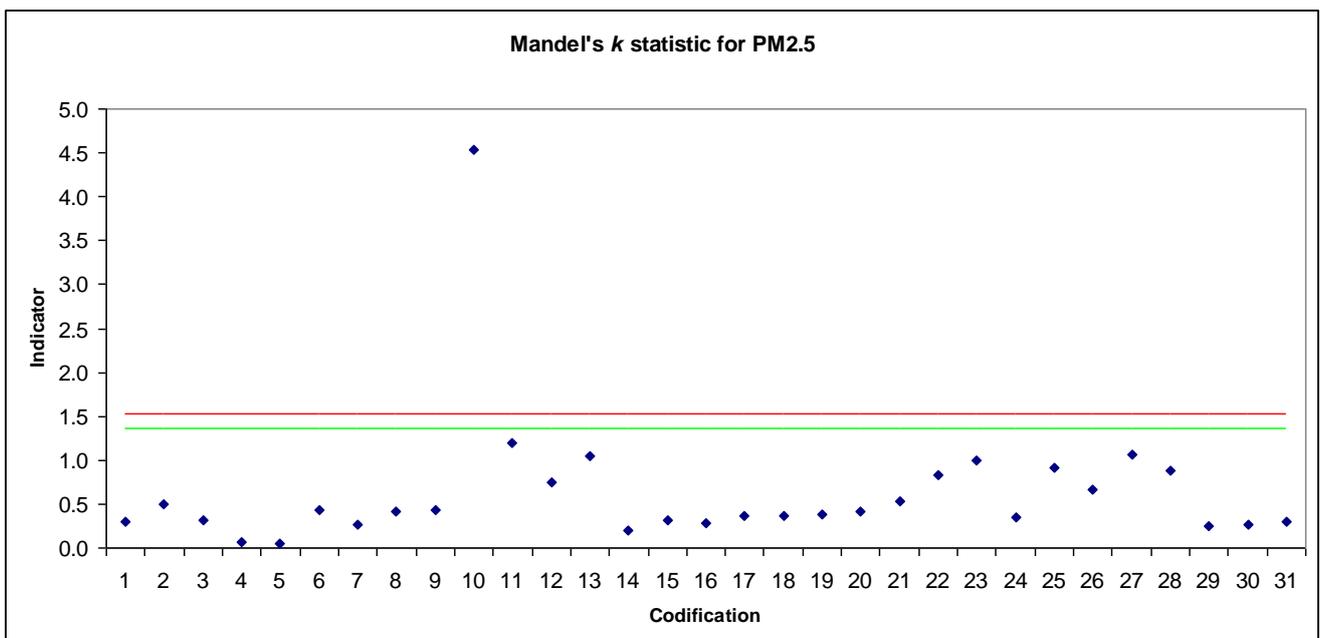
A description of the adopted methodology is given in chapter 5.1.1.2. Two data-sets, 10 and 11, exceed even the 1% level for Mandel's h statistic. An overview of the mentioned statistic for each data-set is given in figure 20.

Figure 20: Mandel's h statistic for PM2.5 with Critical Values for the 5% (green) and 1% (red) significance level



Data-set 10 exceeds even the 1% level of significance for the Mandel k test. An overview of the mentioned statistic for all PM2.5 data-sets is given in Figure 21.

Figure 21: Mandel's k statistic for PM2.5 with Critical Values for the 5% (green) and 1% (red) significance level



5.1.2.3 Grubbs outlier test

A Grubbs outlier test for one maximum or minimum observation was performed with all 31 data-sets. Starting G_{\max} (3.5250) was higher than the 5% (2.924) and 1% (3.253) critical values [6] for Grubbs' test ($p = 31$). The test identified data-sets 10 and 11 as outliers for one maximum observation and data-set 12 as straggler for one minimum observation.

5.1.2.4 Cochran test

Within laboratory variances were assessed using Cochran test performed with all 31 data-sets (consisting of an average of 12 data each). Eliminating two doubtful data-sets (10,11) improved the result from a starting value of 0.6636 to a lowest value of 0.1241, but still higher than the Critical Value for the Cochran test interpolated from tables: 0.105 at the 1% and 0.093 at the 5% level of significance ($p = 29$ and $n = 12$) [12].

5.1.2.5 Summary of consistency and outlier tests

Mandel's h statistic pointed out the lack of between lab consistency for data-sets 10 and 11, also in agreement with the preliminary interpretation of figure 19. Mandel's k statistic signalled the lack of within lab consistency for data-set 10 which is coherent with the visual data spread resulting from figure 19. The Grubbs test identifies the data-sets 10 and 11 as outliers for maximum observations and 12 as a straggler for minimum observations. Differences in within laboratory variances appeared to be relevant as revealed by statistics above the critical level in the Cochran test too.

To summarize all PM2.5 measurements, the grand mean, median, repeatability and reproducibility (both expressed as standard deviation) were calculated for all data-sets (uncensored) and a reduced amount of data-sets (censored) with suspect data-sets code 10, 11 and 12 eliminated. Table 12 presents the consensus values in detail.

Table 12: PM2.5 consensus values for uncensored and censored data-sets

| | uncensored | censored |
|---------------------|------------|----------|
| number of data-sets | 31 | 28 |
| grand mean | 0.926 | 0.903 |
| median | 0.90 | 0.90 |
| repeatability | 0.186 | 0.113 |
| reproducibility | 0.328 | 0.163 |

Based on the reproducibility standard deviation found after censoring, the relative uncertainty of PM2.5 measurement results from this study is estimated to be 16%. Using a coverage factor of 2, which for the number of datasets available represents a confidence interval of 95%, the relative expanded uncertainty is 33%. For an overall mean of reference values of $22.3 \mu\text{g}/\text{m}^3$, this means an absolute expanded uncertainty of $7.2 \mu\text{g}/\text{m}^3$.

5.1.3 Differentiation between samplers and automatic analyzers

In order to obtain information on possible effects of the method of measurement used, the ISO 5725 part 2 statistics have been applied to the three main groups of methods:

- Manual gravimetric methods using low-volume samplers
- Manual gravimetric methods using high-volume samplers
- Automatic analyzers.

The results obtained are presented in tables 13 and 14. As “censored” is understood, that data-sets were either identified as questionable by statistical analysis (see chapter 5.1.1 and 5.1.2) or consist of ≤ 10 daily averages.

Table 13: PM10 results differentiated by method

| | LVS | | HVS | | Autom. analyzer | |
|--------------------|-------------------|-----------------|-------------------|-----------------|------------------------|-----------------|
| | <i>uncensored</i> | <i>censored</i> | <i>uncensored</i> | <i>censored</i> | <i>uncensored</i> | <i>censored</i> |
| Number of datasets | 29 | 18 | 13 | 11 | 37 | 33 |
| Mean | 0,986 | 0,966 | 0,957 | 0,932 | 0,947 | 0,931 |
| Median | 0,966 | 0,962 | 0,947 | 0,940 | 0,924 | 0,915 |
| Repeatability | 0,154 | 0,065 | 0,108 | 0,096 | 0,104 | 0,098 |
| Reproducibility | 0,185 | 0,102 | 0,144 | 0,119 | 0,170 | 0,154 |

Table 14: PM2.5 results differentiated by method

| | LVS | | HVS | | Autom. analyzer | |
|--------------------|-------------------|-----------------|-------------------|-----------------|------------------------|-----------------|
| | <i>uncensored</i> | <i>censored</i> | <i>uncensored</i> | <i>censored</i> | <i>uncensored</i> | <i>censored</i> |
| Number of datasets | 16 | 10 | 3 | 2 | 12 | 10 |
| Mean | 1,009 | 0,932 | 0,912 | 0,910 | 0,832 | 0,876 |
| Median | 0,926 | 0,925 | 0,907 | 0,903 | 0,822 | 0,872 |
| Repeatability | 0,233 | 0,082 | 0,041 | 0,042 | 0,132 | 0,133 |
| Reproducibility | 0,405 | 0,147 | 0,041 | 0,042 | 0,227 | 0,192 |

When considering censored results only it is found that all methods slightly underestimate the reference values, with underestimations being less for PM10. Reproducibility standard deviations for methods with sufficient datasets (excluding HVS for PM2.5) are better for LVS and HVS for PM10, and LVS for PM2.5 when compared to automatic analyzers. When using reproducibility standard deviations as indicators for uncertainties, the relative uncertainties for results obtained by application of low-volume sampling are 10% for PM10 and 15% for PM2.5, and 12% for results for PM10 measured by applying high-volume sampling. Relative expanded uncertainties are thus in the range of 20 to 30%. When expressed at the level of the limit value, the relative expanded uncertainties are 13-15% for PM10 (LVS/HVS), and 26% for PM2.5 (LVS, taking the annual average target value for PM2.5).

5.2 Orthogonal regression and correlation analysis

In addition to the correlation coefficient between participants and reference in each data-set, orthogonal regression using the excel template for the Equivalence field-test of the Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods [5], was calculated. For both regression outputs and correlation coefficients, the minimum, maximum and median give generally better results for PM10 compared to PM2.5. Around 90% of the PM10 data-sets show $R^2 \geq 0.90$ while only 75% of PM2.5 data-sets have $R^2 \geq 0.90$. For PM10, data-sets code 4 and 66 present the lowest correlation factors (0.023 and 0.171 respectively), being linked to bad regression parameters too. For PM2.5, data-set code 11 presents the lowest correlation coefficient (0.086) linked to the worst regression parameters. This confirms the findings of the evaluations made in 5.1. In the following all delivered data are reported for the sake of completeness even though there are certain data-sets in which the number of daily averages is clearly too small for any statistical treatment. Detailed information on the regression output parameters, the correlation coefficient (R^2) and the associated amount of data (n) for each data-set is given in table 15 for PM10 and table 16 for PM2.5.

Table 15: Regression outputs and correlation coefficients for PM10 data-sets

| Country | Codification | Laboratory | Instrument | Regression output | | | | n | R ² |
|---------|--------------|------------|-------------------|-------------------|------------------|-------------|------------------|----|----------------|
| | | | | slope b | uncertainty of b | intercept a | uncertainty of a | | |
| ES | 1 | ISCIII | Derenda A | 0.87 | 0.02 | 0.52 | 0.71 | 13 | 0.996 |
| | 2 | ISCIII | Derenda B | 0.85 | 0.02 | 0.92 | 0.76 | 7 | 0.996 |
| | 3 | AdM | Teom 1400 | 1.32 | 0.05 | -2.77 | 2.21 | 13 | 0.984 |
| PT | 4 | IdA | Tecora | 7.04 | 0.49 | -188.62 | 16.16 | 13 | 0.023 |
| | 5 | IdA | Andersen | 0.93 | 0.16 | 1.38 | 5.35 | 13 | 0.687 |
| | 6 | IdA | Env. 101 | 0.92 | 0.10 | -5.17 | 3.45 | 14 | 0.850 |
| SI | 7 | EPA SI | Derenda | 0.93 | 0.23 | 7.76 | 8.73 | 8 | 0.630 |
| | 8 | EPA SI | Teom 1400 | 0.87 | 0.12 | 5.25 | 4.12 | 14 | 0.780 |
| | 9 | EIMV | Tecora | 1.23 | 0.06 | -0.31 | 2.23 | 13 | 0.970 |
| | 10 | Anhovo | Tecora | 1.05 | 0.06 | 0.20 | 2.02 | 14 | 0.962 |
| | 11 | EIMV | Andersen | 1.35 | 0.13 | -4.45 | 4.60 | 8 | 0.940 |
| AT | 12 | UBA AT | Digitel | 0.95 | 0.02 | 0.31 | 1.19 | 12 | 0.995 |
| | 13 | LR OOe | Digitel | 0.95 | 0.02 | -0.25 | 0.82 | 12 | 0.997 |
| | 14 | UBA AT | FDMS | 0.96 | 0.03 | -0.07 | 1.65 | 12 | 0.990 |
| | 15 | LR OOe | FDMS | 1.04 | 0.03 | -6.64 | 1.55 | 12 | 0.992 |
| | 16 | LR Stmk. | Digitel | 0.82 | 0.04 | 1.55 | 2.07 | 12 | 0.978 |
| | 17 | LR Stmk. | FH 62 IR | 0.86 | 0.07 | 4.31 | 3.64 | 12 | 0.939 |
| CZ | 18 | CHMI | FH95 Nitrocell. | 0.91 | 0.03 | 0.73 | 0.74 | 14 | 0.987 |
| | 19 | CHMI | FH95 glass | 0.99 | 0.02 | -2.94 | 0.41 | 14 | 0.996 |
| | 20 | CHMI | Derenda LVS Seq | 0.98 | 0.02 | -1.84 | 0.50 | 14 | 0.995 |
| | 21 | CHMI | Derenda Hvol B | 0.94 | 0.06 | 1.91 | 1.36 | 14 | 0.957 |
| | 22 | CHMI | Derenda Hvol A | 0.91 | 0.04 | 1.34 | 0.88 | 14 | 0.981 |
| | 23 | CHMI | MCZ/Andersen | 0.80 | 0.04 | 4.14 | 1.09 | 14 | 0.963 |
| | 24 | CHMI | FH 62 IR | 0.92 | 0.03 | -0.56 | 0.61 | 14 | 0.991 |
| DE | 25 | LANUV | Digitel 4 | 1.04 | 0.02 | -1.55 | 0.62 | 13 | 0.996 |
| | 26 | LANUV | Digitel 37 | 1.02 | 0.03 | -1.58 | 1.03 | 13 | 0.988 |
| | 27 | HLUG | Leckel Seq | 1.04 | 0.02 | -0.62 | 0.45 | 13 | 0.998 |
| | 28 | HLUG | Sharp | 1.22 | 0.07 | -6.04 | 2.25 | 13 | 0.958 |
| | 29 | HLUG | FH62 IR | 0.94 | 0.04 | -2.89 | 1.28 | 13 | 0.977 |
| DK | 30 | NERI | SM 200 | 1.00 | 0.08 | -5.38 | 3.70 | 10 | 0.953 |
| | 31 | NERI | Teom 1400 | 0.74 | 0.04 | -0.84 | 2.06 | 11 | 0.966 |
| SE | 32 | ITM | Leckel Seq | 1.12 | 0.02 | -4.65 | 1.79 | 12 | 0.997 |
| | 33 | IVL | sampler A | 1.52 | 0.52 | -4.06 | 23.88 | 3 | 0.878 |
| | 34 | IVL | sampler B | 1.32 | 0.21 | 0.25 | 9.58 | 3 | 0.975 |
| | 35 | EHAS | Teom 1400 | 1.22 | 0.04 | -6.45 | 3.10 | 14 | 0.989 |
| | 36 | EHAS | FDMS | 1.32 | 0.03 | -3.21 | 3.10 | 10 | 0.994 |
| FI | 37 | FMI | FH62 IR_632 | 0.88 | 0.10 | 1.80 | 1.47 | 14 | 0.856 |
| | 38 | FMI | FH62 IR_280 | 0.89 | 0.08 | 1.93 | 1.22 | 14 | 0.902 |
| EE | 39 | EERC | Digitel container | 0.83 | 0.07 | 0.09 | 0.80 | 12 | 0.938 |
| | 40 | EERC | Digitel MobLab | 0.85 | 0.06 | -0.70 | 0.73 | 12 | 0.950 |
| | 41 | EERC | FH62 IR container | 0.75 | 0.07 | 2.32 | 0.80 | 12 | 0.925 |
| | 42 | EERC | FH62 IR MobLab | 1.07 | 0.09 | 1.88 | 1.14 | 12 | 0.923 |
| NL | 43 | RIVM | Leckel Seq | 1.03 | 0.01 | -1.63 | 0.48 | 14 | 0.998 |
| NL/BE | 44 | VMM | Leckel Seq | 1.06 | 0.01 | -0.30 | 0.47 | 13 | 0.999 |
| NL | 45 | RIVM | FH62 IR | 1.17 | 0.03 | -1.62 | 1.10 | 14 | 0.994 |
| | 46 | GGD | Derenda seq LV | 1.02 | 0.03 | -4.82 | 0.74 | 3 | 0.999 |
| BE | 47 | VMM | Leckel Seq | 1.05 | 0.04 | 1.19 | 1.20 | 14 | 0.987 |
| | 48 | Issep | SW126 gravimetr. | 0.98 | 0.02 | -3.40 | 0.81 | 14 | 0.993 |
| | 49 | Issep | SW129 gravimetr. | 0.94 | 0.04 | -1.87 | 1.45 | 13 | 0.978 |
| BE/NL | 50 | RIVM | Leckel Seq | 1.01 | 0.04 | 0.79 | 1.21 | 14 | 0.985 |
| BE | 51 | VMM | ESM BOR801 | 1.08 | 0.13 | -0.56 | 4.51 | 14 | 0.819 |
| | 52 | VMM | Teom 1400 | 0.74 | 0.12 | 10.04 | 4.19 | 14 | 0.701 |
| | 53 | VMM | FDMS | 0.90 | 0.06 | -2.54 | 2.18 | 11 | 0.954 |
| | 54 | Issep | SW126 beta | 0.93 | 0.03 | -3.04 | 1.14 | 14 | 0.985 |
| | 55 | Issep | SW129 beta | 1.00 | 0.03 | -5.31 | 1.20 | 13 | 0.987 |
| | 56 | Issep | Env.101_33 | 0.78 | 0.05 | 1.86 | 1.83 | 14 | 0.943 |
| | 57 | Issep | Env.101_78 | 0.76 | 0.06 | 0.15 | 2.00 | 13 | 0.937 |
| | 58 | Issep | Grimm 180 | 0.95 | 0.06 | -1.87 | 1.92 | 14 | 0.958 |
| BE/NL | 59 | GGD | Derenda seq LV | 1.01 | 0.05 | -1.34 | 1.73 | 9 | 0.982 |
| FR | 60 | Ineris | Partisol | 0.98 | 0.05 | -1.11 | 0.87 | 14 | 0.973 |
| | 61 | EDM | Env.101 | 0.87 | 0.08 | 0.98 | 1.50 | 14 | 0.899 |
| | 62 | Ineris | FDMS 9032 | 0.91 | 0.04 | 0.03 | 0.70 | 14 | 0.980 |
| | 63 | Ineris | FDMS 15702 | 0.90 | 0.04 | 1.28 | 0.83 | 14 | 0.971 |
| | 64 | Airparif | FDMS | 0.87 | 0.04 | 0.86 | 0.76 | 14 | 0.974 |
| IE | 65 | EPA | FDMS | 0.80 | 0.02 | 2.82 | 0.43 | 17 | 0.988 |
| | 66 | DCC | Partisol | 0.46 | 0.32 | 4.46 | 8.41 | 6 | 0.171 |
| GB | 67 | AEA | Partisol emfab | 0.96 | 0.05 | -0.70 | 1.28 | 9 | 0.979 |
| | 68 | BV | Partisol quartz | 1.20 | 0.08 | -1.81 | 1.99 | 9 | 0.966 |
| | 69 | BV | Partisol emfab | 1.06 | 0.04 | -2.43 | 1.06 | 9 | 0.988 |
| | 70 | NPT | FDMS | 1.00 | 0.05 | 3.06 | 1.95 | 7 | 0.898 |
| IT | 71 | Ispra | Tecora | 1.02 | 0.03 | -3.62 | 1.41 | 15 | 0.985 |
| | 72 | Arpa | Zambelli | 1.16 | 0.13 | -6.23 | 5.18 | 15 | 0.842 |
| | 73 | Arpa | Tecora | 0.89 | 0.04 | 1.48 | 1.71 | 15 | 0.972 |
| | 74 | Arpa | SM200 | 0.91 | 0.05 | 2.04 | 2.20 | 15 | 0.954 |
| | 75 | Arpa | FDMS | 1.00 | 0.07 | -7.31 | 2.72 | 14 | 0.949 |
| HU | 76 | HMS | Digitel | 0.92 | 0.02 | 0.01 | 1.05 | 14 | 0.994 |
| | 77 | HMS | FH62 IR | 0.92 | 0.04 | -2.25 | 2.33 | 14 | 0.971 |
| | 78 | MDV | FH62 IR | 0.89 | 0.03 | 0.54 | 1.35 | 13 | 0.991 |
| SK | 79 | SHMU | FDMS | 0.93 | 0.04 | -3.19 | 0.73 | 14 | 0.982 |

| | | | | | |
|--------|------|------|---------|-------|-------|
| Min | 0.46 | 0.01 | -188.62 | 0.41 | 0.023 |
| Max | 7.04 | 0.52 | 10.04 | 23.88 | 0.999 |
| Median | 0.95 | 0.04 | -0.56 | 1.39 | 0.975 |

Table 16: Regression outputs and correlation coefficients for PM2.5 data-sets

| Country | Codification | Laboratory | Instrument | Regression output | | | | n | R ² |
|---------|--------------|------------|-------------------|-------------------|------------------|-------------|------------------|----|----------------|
| | | | | slope b | uncertainty of b | intercept a | uncertainty of a | | |
| ES | 1 | ISCI | Derenda | 0.84 | 0.05 | 0.56 | 0.98 | 12 | 0.965 |
| PT | 2 | IdA | Tecora | 0.81 | 0.11 | 1.28 | 1.51 | 13 | 0.796 |
| SI | 3 | EPA SI | Leckel Seq | 0.93 | 0.07 | 2.05 | 1.76 | 14 | 0.931 |
| AT | 4 | UBA AT | Digitel | 1.01 | 0.03 | -3.33 | 1.35 | 3 | 0.999 |
| | 5 | LR OOe | Digitel | 0.91 | 0.01 | -0.14 | 0.51 | 12 | 0.998 |
| CZ | 6 | CHMI | Leckel SEQ | 0.79 | 0.03 | -1.07 | 0.50 | 13 | 0.989 |
| | 7 | CHMI | Derenda | 0.99 | 0.02 | -0.90 | 0.39 | 14 | 0.995 |
| | 8 | CHMI | FH 62 IR | 0.89 | 0.05 | -1.27 | 0.92 | 14 | 0.967 |
| DK | 9 | NERI | Teom 1400 | 0.74 | 0.06 | -2.47 | 1.81 | 11 | 0.947 |
| SE | 10 | IVL | sampler A | 4.42 | 0.69 | -27.60 | 9.80 | 9 | 0.789 |
| | 11 | IVL | sampler B | 25.10 | 7.14 | -455.10 | 141.83 | 3 | 0.086 |
| | 12 | EHAS | Teom 1400 | 0.22 | 0.03 | 3.49 | 1.04 | 14 | 0.826 |
| EE | 13 | EERC | FH62 IR | 0.53 | 0.09 | 1.41 | 0.70 | 13 | 0.719 |
| NL | 14 | GGD | Derenda seq LV | 0.95 | 0.03 | -0.95 | 1.28 | 8 | 0.992 |
| BE | 15 | VMM | Leckel SEQ Whatm. | 1.18 | 0.03 | -1.84 | 0.55 | 13 | 0.995 |
| | 16 | VMM | Leckel SEQ Pall | 1.08 | 0.02 | -1.57 | 0.51 | 14 | 0.994 |
| | 17 | Issep | SW126 gravimetr. | 0.94 | 0.03 | -2.20 | 0.60 | 14 | 0.989 |
| | 18 | Issep | SW129 gravimetr. | 0.99 | 0.03 | -2.35 | 0.68 | 13 | 0.989 |
| | 19 | Issep | SW126 beta | 0.96 | 0.03 | -2.45 | 0.65 | 14 | 0.988 |
| | 20 | Issep | SW129 beta | 1.02 | 0.02 | -2.88 | 0.47 | 13 | 0.995 |
| | 21 | Issep | Grimm 180 | 1.12 | 0.07 | -0.64 | 1.54 | 14 | 0.950 |
| | 22 | VMM | ESM | 1.27 | 0.12 | -5.25 | 2.57 | 14 | 0.891 |
| BE/NL | 23 | GGD | Derenda seq LV | 0.94 | 0.22 | -2.62 | 4.77 | 10 | 0.576 |
| FR | 24 | Airparif | FDMS | 0.98 | 0.06 | 0.72 | 0.79 | 14 | 0.796 |
| GB | 25 | BV | Partisol emfab | 0.90 | 0.12 | 0.90 | 1.36 | 9 | 0.873 |
| | 26 | NPT | Partisol | 1.21 | 0.11 | -0.96 | 1.32 | 14 | 0.898 |
| | 27 | BV | FDMS | 1.50 | 0.19 | -5.73 | 2.25 | 14 | 0.794 |
| IT | 28 | Arpa | Zambelli | 0.70 | 0.21 | 3.21 | 5.18 | 7 | 0.627 |
| | 29 | Arpa | SM200 | 0.92 | 0.08 | -2.81 | 1.98 | 7 | 0.963 |
| HU | 30 | MDV | Digitel | 0.90 | 0.03 | 0.15 | 1.51 | 14 | 0.986 |
| | 31 | MDV | FH62 IR | 0.79 | 0.03 | -3.11 | 1.45 | 14 | 0.846 |

| | | | | | | |
|--------|-------|------|---------|--------|--|-------|
| Min | 0.22 | 0.01 | -455.10 | 0.39 | | 0.086 |
| Max | 25.10 | 7.14 | 3.49 | 141.83 | | 0.999 |
| Median | 0.94 | 0.05 | -1.27 | 1.32 | | 0.950 |

5.3 Distinction of data measured by National Reference Laboratories and Local Networks

To verify if the quality of data measured by National Reference Laboratories distinguishes significantly from the quality of data measured by local networks, all data sets, independently from the used measurement technique, were split into a comparison of NRLs vs. JRC and a comparison of local networks vs. JRC.

To provide an overview of the spread of single measurements with respect to the Reference Values, the relative differences of the daily averages were plotted separately for NRLs and local networks. Some of the biggest spreads (> ±50 %) are linked to low data capture (SE, IE) indicating a technical/analytical problem, or to a measurement campaign with low PM concentration levels (EE). Figures 22 - 25 illustrate the spread split into PM10/PM2.5 and NRL/local network. To identify possible trends in relation to the used instrumentation, results are plotted in three different colours: Blue for LVS, pink for HVS and black for automatic analyzers.

Figure 22: Relative deviations from PM10 Reference Value for NRL (blue: LVS, pink: HVS, black: automatic analyzers)

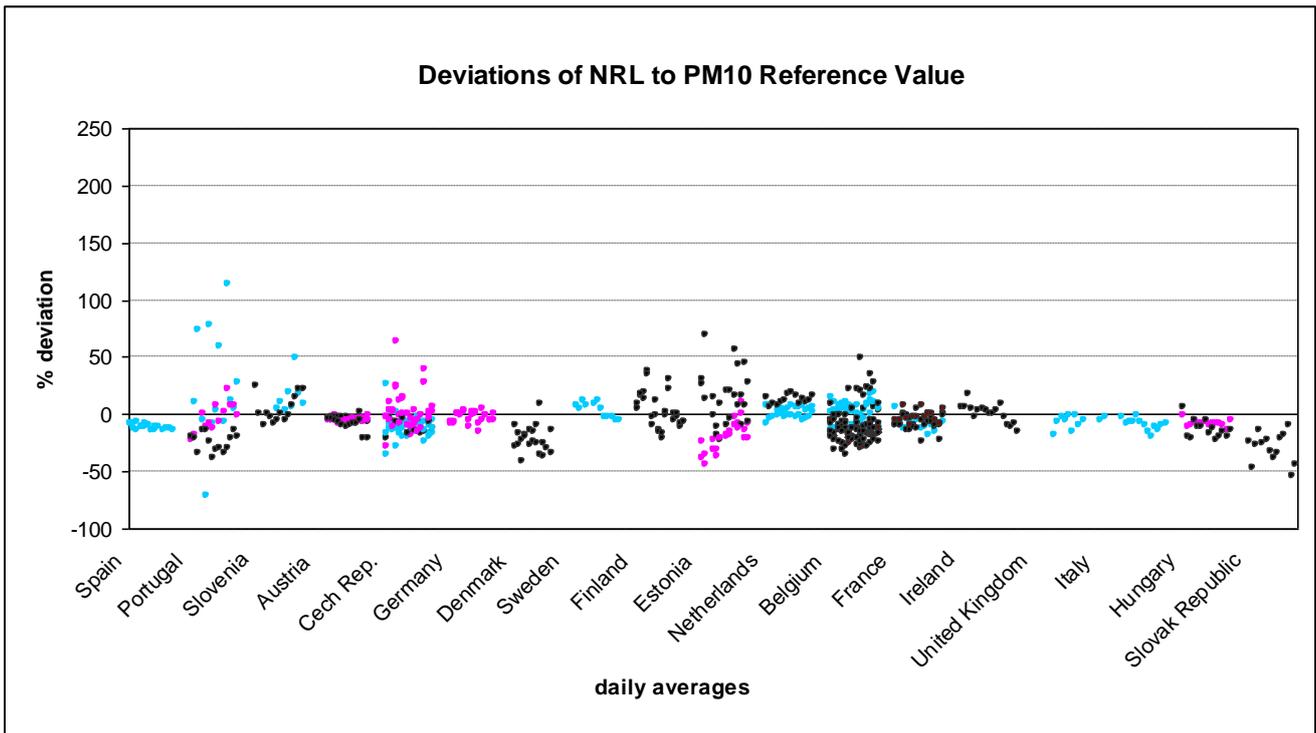


Figure 23: Relative deviations from PM10 Reference Value for local networks (blue: LVS, pink: HVS, black: automatic analyzers)

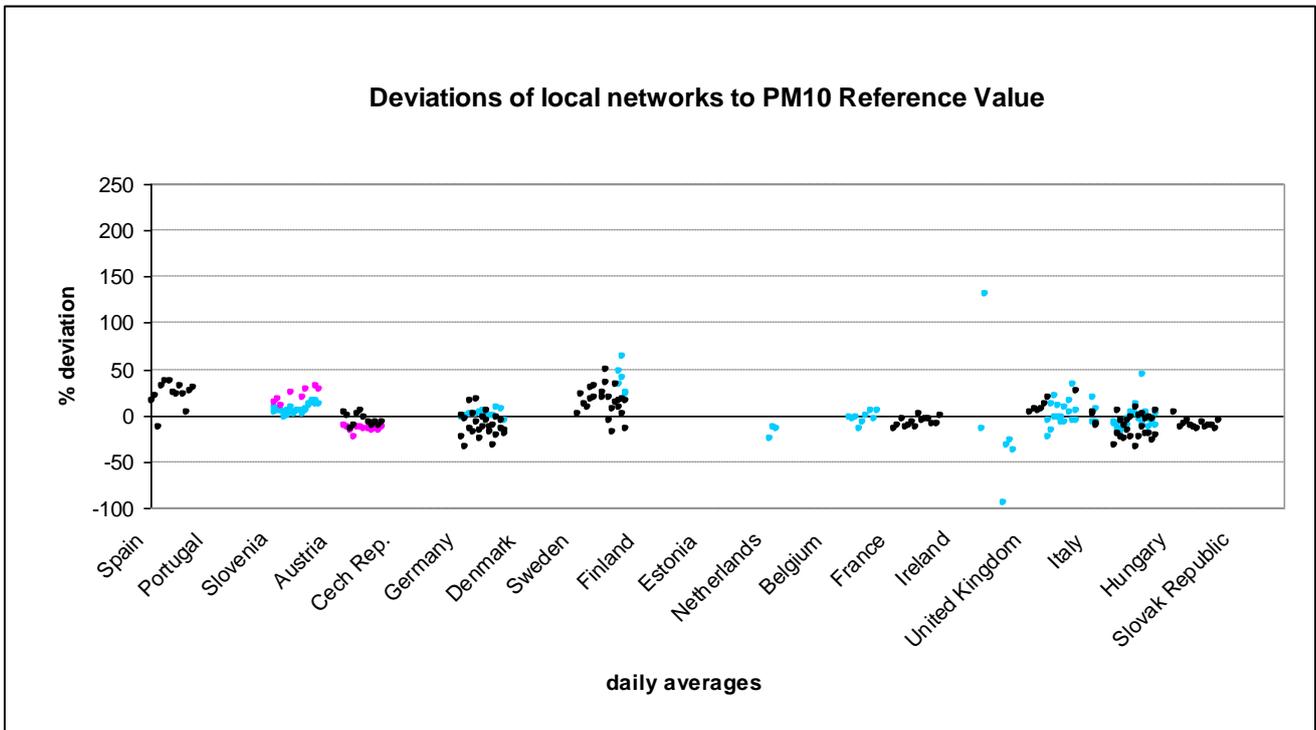


Figure 24: Relative deviations from PM2.5 Reference Value for NRL (blue: LVS, pink: HVS, black: automatic analyzers)

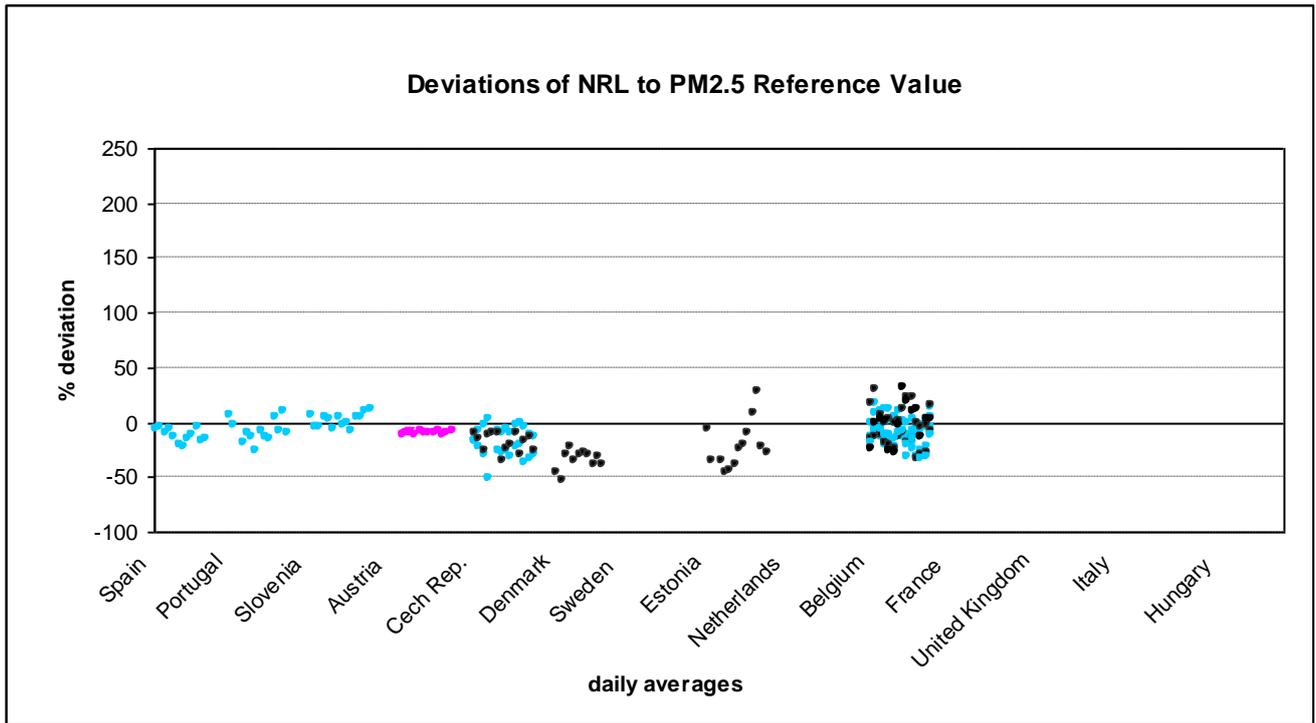
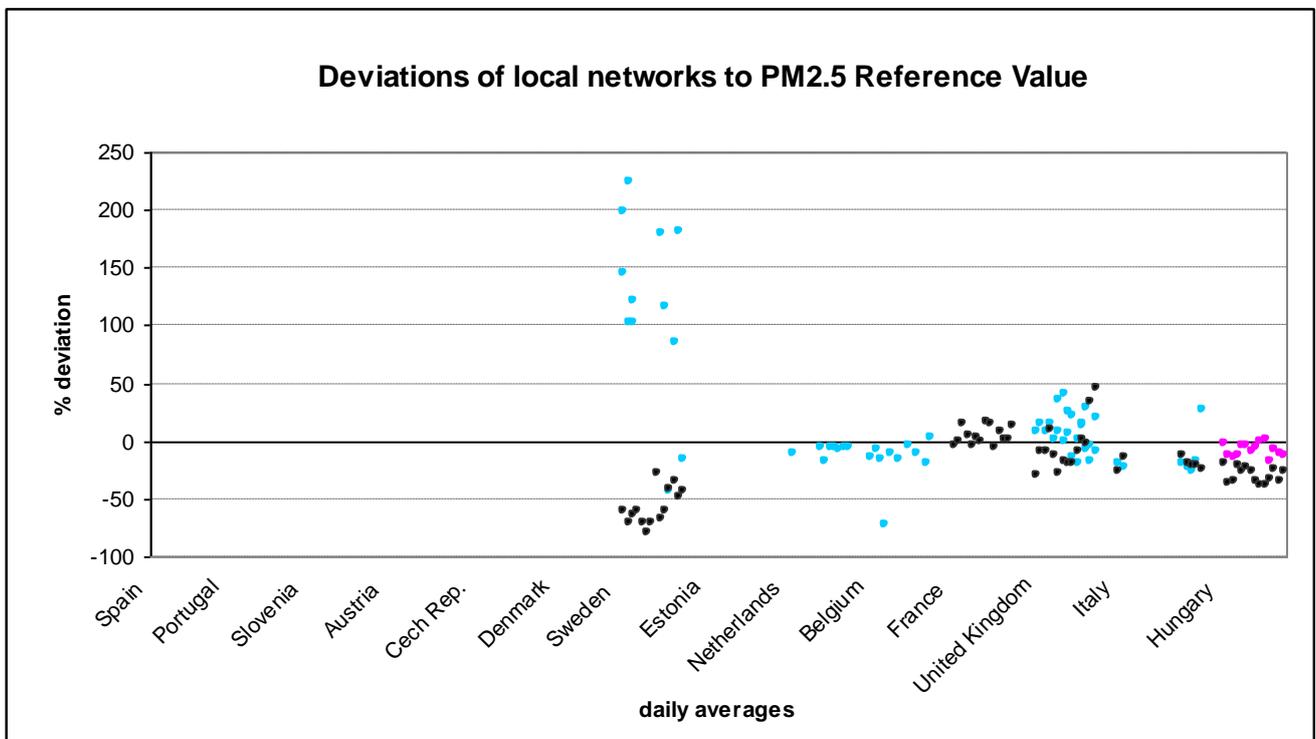


Figure 25: Relative deviations from PM2.5 Reference Value for local networks (blue: LVS, pink: HVS, black: automatic analyzers)



A summary of these relative deviations was done using “normalized” data (ratios) between values reported by

NRLs/local networks respectively and the Reference Values (as described in chapter 3.3.3). The averages and standard deviations of the ratios were calculated for the two types of laboratories. On average, for both PM10 and PM2.5, NRLs are measuring lower values than local networks. Regarding PM10, the reproducibility standard deviation is very similar for both types of laboratories, but differs considerably for PM2.5 with the NRLs performing better than local networks. Table 17 gives the ratios, reproducibility standard deviation and number of data-sets in detail.

Table 17: Ratios for PM10 and PM2.5 for all laboratories and separated into NRL and local networks; the number of data sets is given in parentheses

| | all laboratories average (n) | all laboratories s(R) | NRL average (n) | NRL s(R) | Local Networks average (n) | Local Networks s(R) |
|-------|---------------------------------|--------------------------|--------------------|-------------|----------------------------------|---------------------------|
| PM10 | 0.962 (79) | 0.17 | 0.947 (54) | 0.16 | 1.000 (25) | 0.19 |
| PM2.5 | 0.926 (31) | 0.33 | 0.891 (18) | 0.15 | 0.984 (13) | 0.50 |

Where:

- s(R) is the standard deviation (reproducibility) of the ratios
- n is the number of data sets

Further, for PM10 parametric and non-parametric tests were performed, all of them resulting in a p-value <0.025 thus indicating that data measured by NRLs are significantly different from data measured by local networks. Details of these tests can be found in Annex 8.

Further calculations in this report will not distinguish anymore between NRLs and local networks.

5.4 Compliance with Data Quality Objective (DQO) of European Directive

One of the goals of this project was to understand if routine PM measurements performed in the European Member States comply with the DQO for ambient air quality assessment given in Annex I of the European Directive 2008/50/EC. The DQO for PM10 and PM2.5 is given as 25% at the Limit Value (LV). The LV is 50 $\mu\text{g}/\text{m}^3$ for PM10 as a 24 h average, while for PM2.5 a target value of 25 $\mu\text{g}/\text{m}^3$ is given as annual average. Regarding PM2.5, the target value was considered as a daily average in the following calculations thus allowing also comparison to a "DQO" as for PM10. This has to be considered when PM2.5 data is interpreted.

5.4.1 Relative differences from reference values

To compare data to the DQO at the LV / target value the following procedure was applied:

Only data pairs where the Reference Value was higher than LV-25% ($\geq 37.5 \mu\text{g}/\text{m}^3$ for PM10 and $\geq 18.75 \mu\text{g}/\text{m}^3$ for PM2.5) were compared to the DQO. The relative difference of each single daily average measured by a participant to the corresponding Reference Value was calculated. Their deviations from the DQO are shown in Figure 26 (PM10) and Figure 27 (PM2.5). To identify possible trends in relation to the used instrumentation, results are plotted in different colours. From a visual point of view it looks that automatic analyzers give worse results than gravimetric methods. The few PM2.5 LVS data (SE) with a deviation > 100% result from a particular instrument type with low data capture.

Figure 26: Deviations from the reference value for PM10 at the level of the DQO (blue: LVS, pink: HVS, black: automatic analyzers). The space between red lines represents the interval of compliance with DQO (+/- 25%)

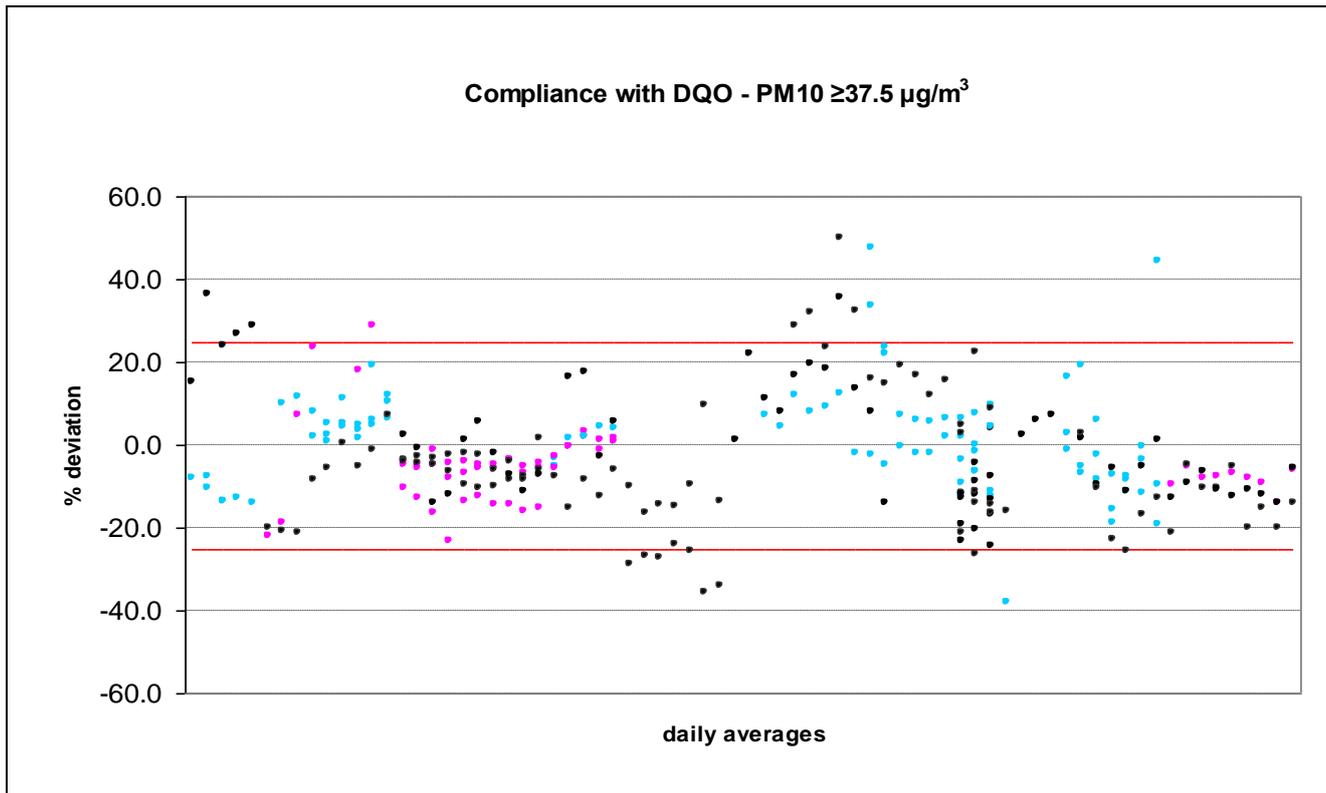
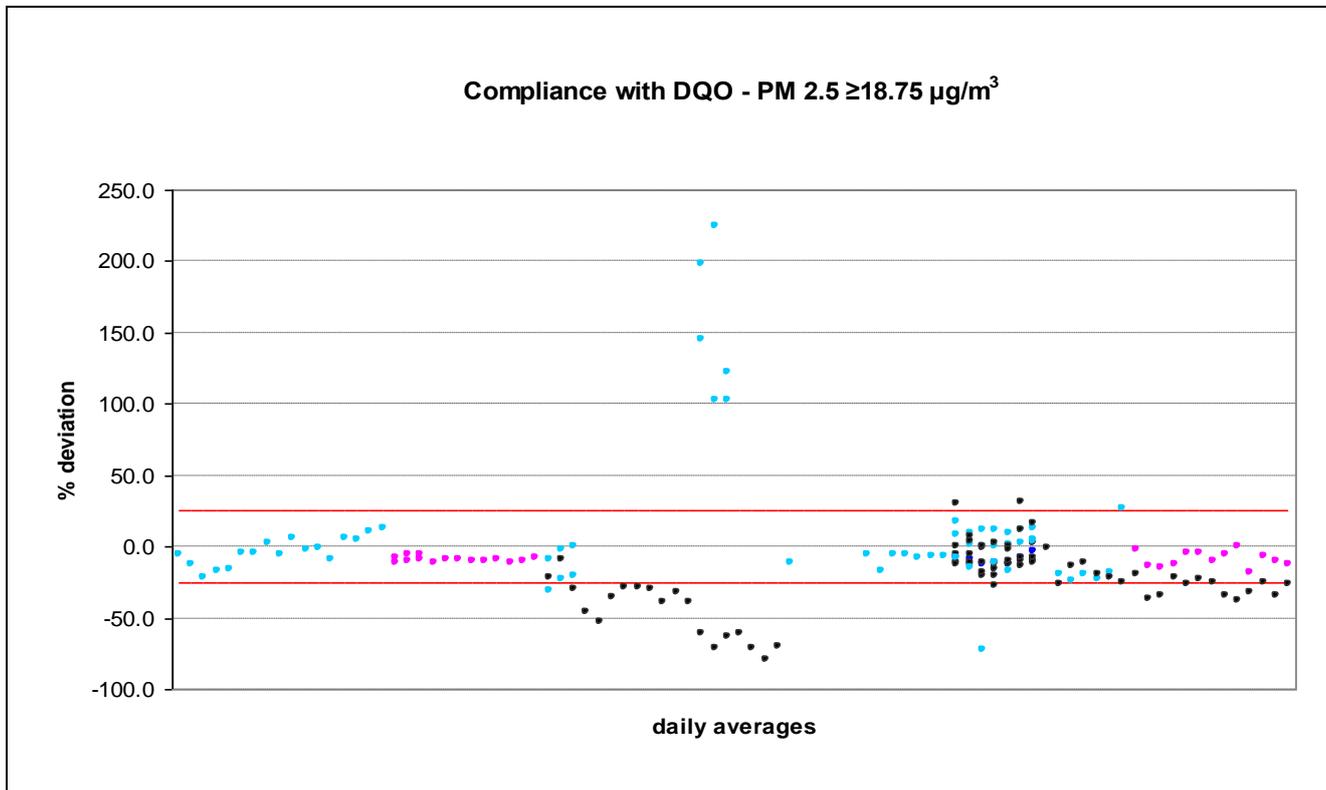


Figure 27: Deviations from the reference value for PM2.5 at the level of the "DQO" under the assumption that the target value is a 24h and not an annual average (blue: LVS, pink: HVS, black: automatic analyzers). The space between red lines represents the interval of compliance with DQO (+/- 25%)



Summarizing the compliance with the DQO, 7.1 % of the considered PM10 measurements exceed the DQO. For PM2.5, 23.8 % of the considered measurements exceed the “DQO”. Table 18 summarizes the exceedances of the DQO and allows comparing them to exceedances in case that all data, independent from their concentration level, had been taken into account.

Table 18: Exceedances of the DQO (PM2.5 under the assumption that the target value is a 24h and not an annual average)

| | sum of daily averages | sum of daily avg.>DQO | % of daily avg.>DQO |
|--------------------|-----------------------|-----------------------|---------------------|
| PM10 all data | 975 | 103 | 10.6 |
| PM10>LV | 294 | 21 | 7.1 |
| PM2.5 all data | 365 | 94 | 25.8 |
| PM2.5>target value | 172 | 41 | 23.8 |

Further, for PM10 parametric and non-parametric tests were performed to find out if LVS behave differently from HVS and automatic analyzers respectively. All tests between LVS and HVS showed a p-value >0.025 thus confirming that differences are not significant. However, all tests between LVS and automatic samplers indicated that differences are significant. Details of these tests can be found in Annex 8.

5.4.2 Calculation of uncertainty at the limit value

The uncertainties for PM10 at the LV and for PM2.5 at the “Target Value” (assumed to be a 24 h average) have been calculated using the Excel template for the Equivalence field test of the “Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods” [5]. For the demonstration of equivalence the cited guide requires at least 40 data pairs and at least 20% of data shall be greater than the upper assessment threshold specified for annual limit values (28 µg/m³ for PM10 and 17 µg/m³ for PM2.5) [2]. Demonstrating equivalence was not the objective of the present QA/QC program, therefore less data pairs are available for each campaign. This imposes caution in the interpretation of results. Notwithstanding the limitations accruing from the reduced number of data pairs for each single campaign, this exploratory estimation has been carried out to give a general picture of the situation in Europe taking advantage of the uniqueness of this database in which an overwhelming number of different instruments in different sites and conditions were compared against the same reference samplers.

To optimize the calculations, only data-sets with >10 data pairs and more than 20% of data greater than the upper assessment threshold have been taken into account. Consequently 53 (out of 79) data-sets for PM10 and 19 (out of 31) data-sets for PM2.5 were calculated. One third of the PM10 and half of the PM2.5 data-sets exceed the uncertainty at the LV (“target Value”) according to this exploratory estimation. The result for PM2.5 is linked to the low PM2.5 “Target Value” (25 µg/m³) compared to the PM10 LV (50 µg/m³). Looking at the type of instrument, for both size fractions the automatic analyzers perform worse than the gravimetric methods thus confirming the findings in 5.4.1. However, at the time of the performance of the comparisons it is highly likely that only few networks have used experimental correction factors based on the approach given in [5].

Table 19 gives a summary for PM10, table 20 for PM2.5. Detailed information for each data-set can be found in Annex 6.

Table 19: Exceedances of expanded uncertainty at the LV for PM10

| Type of instrument | Total data-sets | Data-sets exceeding U at LV | % of data-sets exceeding U at LV |
|--------------------|-----------------|-----------------------------|----------------------------------|
| Low Vol | 18 | 3 | |
| High Vol | 10 | 2 | |
| Automatic | 25 | 12 | |
| Sum | 53 | 17 | 32.1% |

Table 20: Exceedances of expanded uncertainty at the "target value" for PM2.5

| Type of instrument | Total data-sets | Data-sets exceeding U at "Target Value" | % of data-sets exceeding U at "Target Value" |
|--------------------|-----------------|---|--|
| Low Vol | 9 | 4 | |
| High Vol | 2 | 0 | |
| Automatic | 8 | 6 | |
| Sum | 19 | 10 | 52.6% |

When comparing these results to those from 5.4.1 it is observed that the percentages "failure" are much higher. This is due to the fact that in the approach described in 5.4.1 single daily averages with a concentration in the range of the LV are compared to the DQO, however in 5.4.2 data-sets (containing usually 14 daily averages of all concentration ranges) are used to calculate exceedances of the DAQ. Hence in the latter case a few daily averages with high deviations can discriminate a whole data set.

5.5 Gravimetric methods: Influence of filter material and sampler type on PM measurement

To find out if the used filter material and the type of sampler (manufacturer) have an influence on the quality of the measured data, in a first step all PM10 and PM2.5 data were separated by these two criteria and plotted against the DQO. The used filter materials were quartz, glass, cellulose nitrate or Teflon (PTFE or Teflon-coated glass fibre also called Emfab).

Looking at the graphs it is difficult to identify clear trends regarding sampler type and the used filter material. However, it is obvious that some LVS data-sets suffer from poor repeatability: Tecora quartz (PT) and Partisol glass (IE) of the PM10 and IVL "unknown" (SE) of the PM2.5 results.

Figure 28 and 29 present, separated into PM10 and PM2.5, the relative deviations from the Reference Value for LVS; Figure 30 and 31 present the same results for HVS. In case information of a participant could not be retrieved it is labelled as "unknown".

Figure 28: PM10 LVS deviation from reference value split by filter material and sampler type (manufacturer). Colour indicates sampler type and symbol denotes filter material.

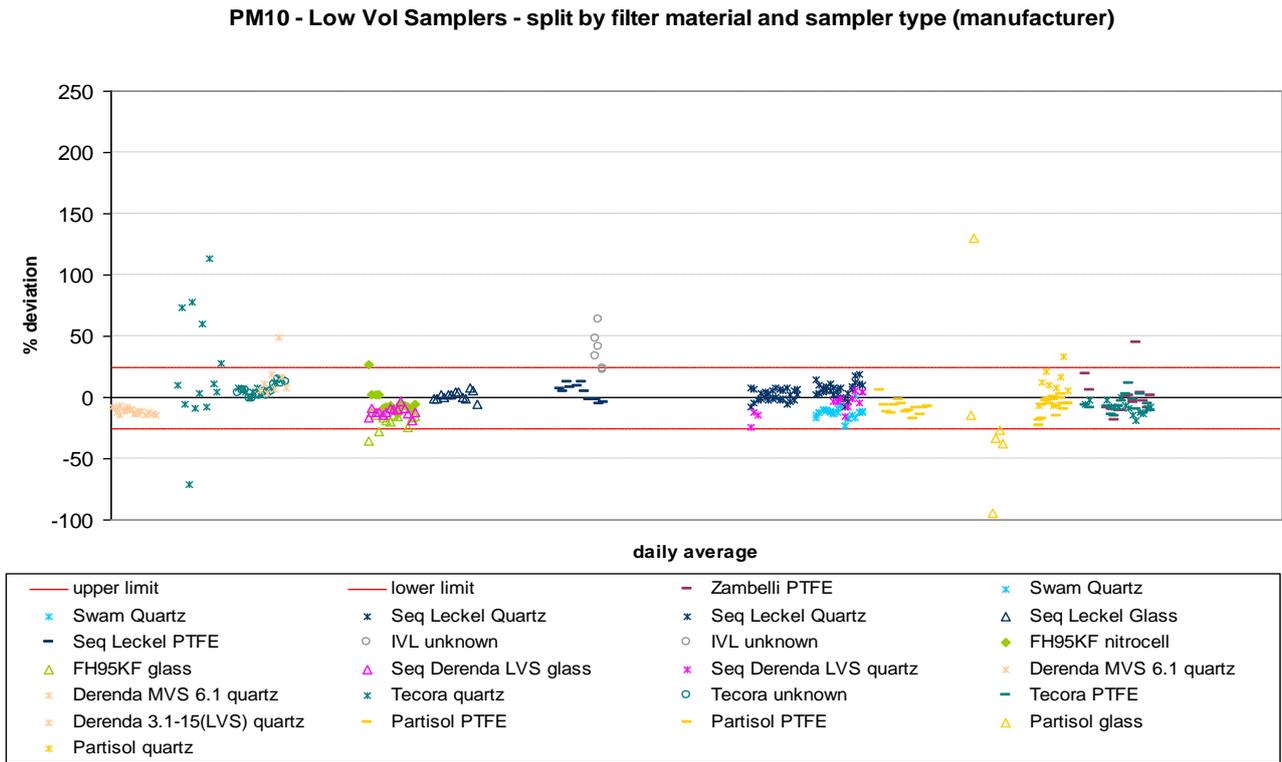


Figure 29: PM2.5 LVS deviation from reference value split by filter material and sampler type (manufacturer). Colour indicates sampler type and symbol denotes filter material.

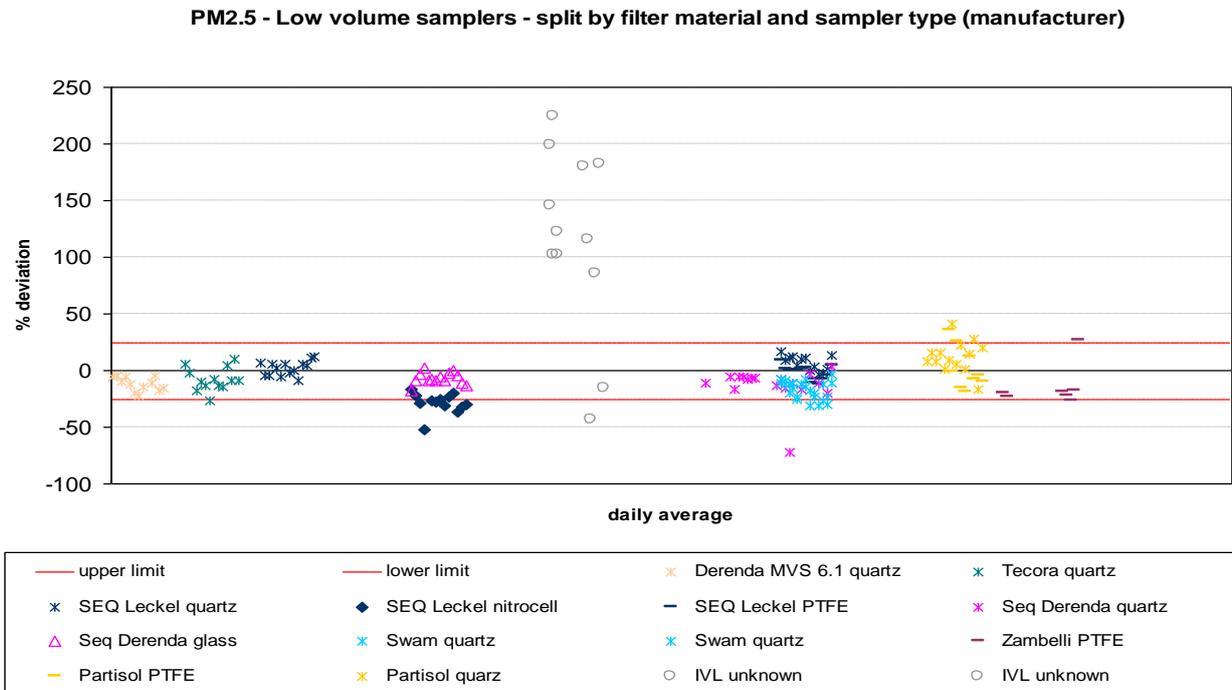


Figure 30: PM10 HVS deviation from reference value split by filter material and sampler type (manufacturer). Colour indicates sampler type and symbol denotes filter material.

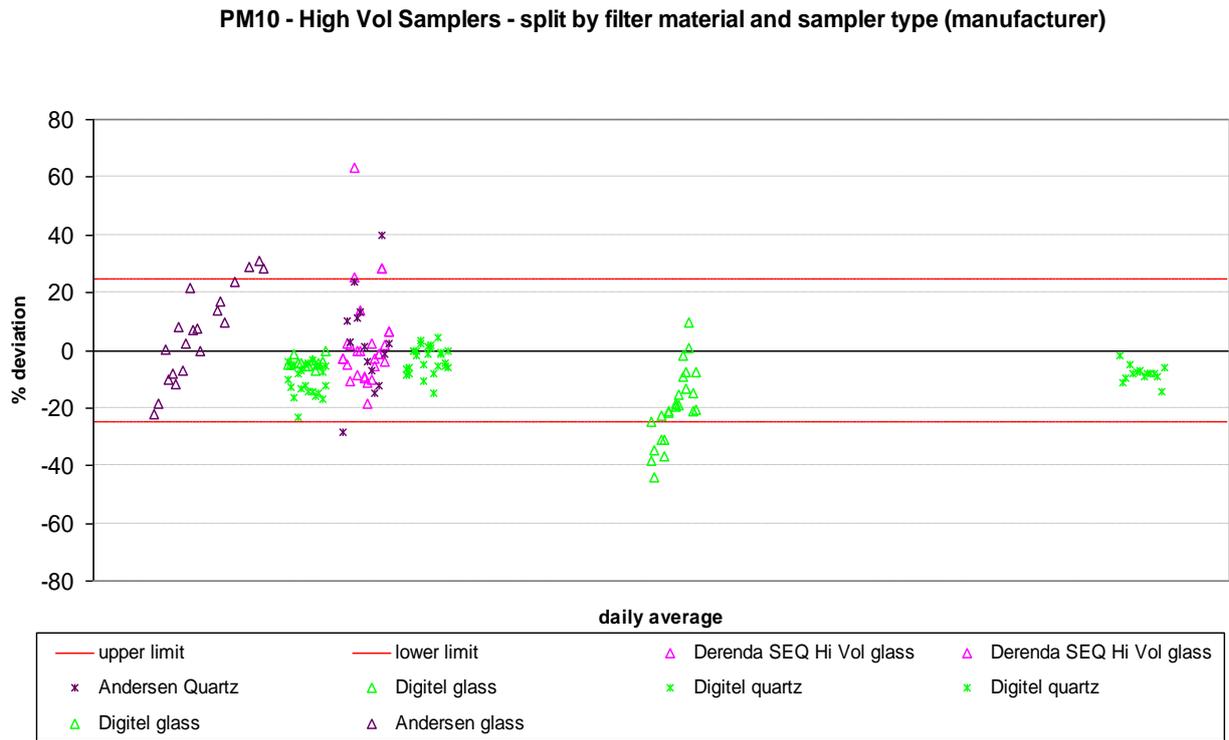
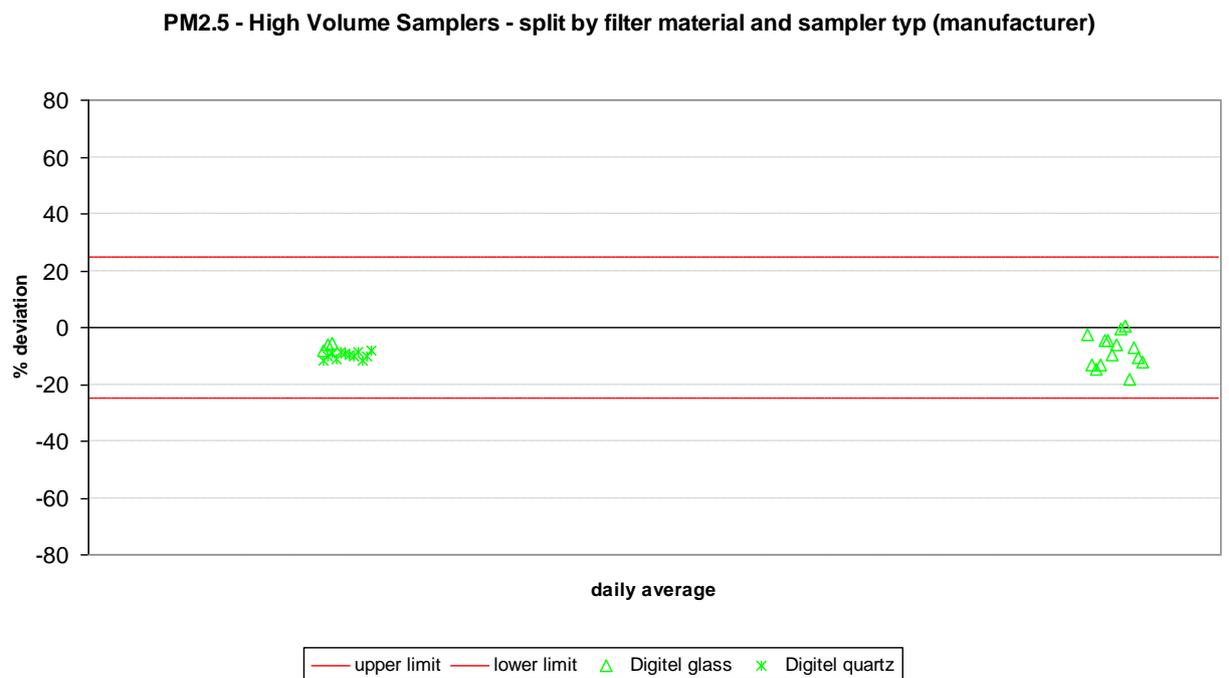


Figure 31: PM2.5 HVS deviation from reference value split by filter material and sampler type (manufacturer). Colour indicates sampler type and symbol denotes filter material.



In a second step, limited to the PM10 results, Analysis of Variance (ANOVA) was used for the same purposes as above. Data sets, where the filter material was not specified by the participant, were omitted.

Regarding LVS, results obtained with instruments from Derenda, Thermo, Partisol and Zambelli are not significantly different. The value of information produced by Zambelli (1 instrument), Thermo and FAI (2 instruments each) is limited. Leckel and Tecora instruments produced on average the highest results and show a significant difference to most of the other sampler types. However, Leckel (together with FAI) has the smallest spreads of all types, even though it was used with three different filter materials. Zambelli and Thermo show already bigger spreads. The two above mentioned data sets with poor repeatability (PT and IE) are mainly responsible for the biggest spreads, observed for Tecora and Partisol samplers and quartz and glass filter material. The median of measurements with quartz filter material, also used for the Reference Value, shows a ratio of almost 1. Glass however, tends to produce the lowest results and shows significant differences to quartz and Teflon filter materials. Cellulose nitrate shows the lowest spread for filter material, but it was used by one sampler only thus limiting the value of information.

Regarding HVS, measurement results obtained from Digital tend to be the lowest and show a significant difference to Andersen and Derenda. The filter materials used, glass and quartz, produced similar results and do not show a significant difference from each other.

Details of these tests can be found in Annex 8.

5.6 Discussion on applied correction factors for automatic analyzers

In 2005, when this project was launched, a common practise in EU - Member States was to correct the values of automatic analyzers using a coefficient as described in DIR1999/50/EC and EN 12341 (ETC Technical Paper 2005/6 [14]). Hence another goal of this program was to identify how such factors are influencing the measurement results.

During all measurement campaigns were produced a total of 37 datasets of PM10 measured with automatic analyzers, 15 of which included corrected data. In most of the cases this factor was constant all the year long, but also season-depending factors and the combination of a factor plus an offset were used. In 10 cases the application of a correction factor improved the results with respect to the DQO, in 3 cases the results remained unchanged and in 2 cases the results worsened; Table 21 shows a summary of the effect of correction factors on PM10 data quality. Details can be found in Annex 3.

Table 21: Influence of correction factors on PM10 data quality

| Country | Institution | Analyzer | Correction factor | Change of result |
|---------|-------------|---------------------------------|-----------------------------|------------------|
| ES | AdM | Teom 1400 AB | 1.1 | worsened |
| PT | IdA | Environnement MP 101 | 1.1 | improved |
| SI | EPA | Teom 1400 | 1.03 (summer) 1.24 (winter) | equal |
| AT | LR Stmk. | Eberline FH 62 IR | 1.3 | improved |
| CZ | CHMI | FH 62 IR | 1.3 | improved |
| DE | HLUG | FH 62 IR | 1.18 | improved |
| EE | EERC | Thermo ESM FH 62 IR (container) | 1.15 | improved |
| | | Thermo ESM FH 62 IR (mob lab) | 1.15 | worsened |
| NL | RIVM | Thermo FH 62 IR | 1.17 + 2.7 | equal |
| BE | VMM | ESM Andersen | 1.37 | improved |
| | | Teom 1400 | 1.47 | improved |
| BE | ISSeP | Environnement MP 101 sn 33 | 1.08 | improved |
| | | Environnement MP 101 sn 78 | 1.08 | improved |
| HU | HMS | FH 62 IR | 1.1 | improved |
| | MDV | FH 62 IR | 1.1 | equal |

During all measurement campaigns were produced a total of 12 PM2.5 - datasets measured with automatic analyzers, 3 of which included corrected data. In all cases this factor was constant all the year long and improved the results with respect to the DQO; Table 22 shows a summary of the effects of correction factors on PM2.5 data quality. Details for each participant applying a correction factor can be found in Annex 3.

Table 22: Influence of correction factors on PM2.5 data quality

| Country | Institution | Analyzer | Correction factor | Change of result |
|---------|-------------|---------------------------------|-------------------|------------------|
| CZ | CHMI | FH 62 IR | 1.3 | improved |
| EE | EERC | Thermo ESM FH 62 IR (container) | 1.15 | improved |
| HU | MDV | FH 62 IR | 1.31 | improved |

5.7 Automatic methods: Influence of sampling temperature and instrument type on PM measurement

To evaluate whether the sampling temperature and the type of analyzer (manufacturer) have an influence on the quality of measurements, in a first step all PM₁₀ and PM_{2.5} data from automatic monitors were split using these two criteria and plotted against the DQO. Sampling temperature differs considerably between the participants. Either the sampling line was not heated at all, surrounded by sheath air, equipped with a dynamic heating system (maintaining the temperature always a few degrees above ambient and/or regulating the heating as a function of the relative humidity), or heated with a constant temperature between 30 and 50 degrees Celsius.

In general terms analyzers with higher sampling temperatures are expected to measure lower values than analyzers without heating. But in fact the distribution, especially for PM₁₀, shows no obvious dependency on sampling temperatures. This means that other parameters like calibration, applied correction factors or data expressed at standard conditions instead of ambient are overlapping with the influence of the sampling line temperature.

Figure 32 and 33 visualize the relative deviations from the Reference Value for PM₁₀ and PM_{2.5} respectively.

Figure 32: PM₁₀ automatic analyzers deviation from reference value split by sampling temperature and instrument type. Colour indicates type of analyzer and symbol denotes sampling temperature.

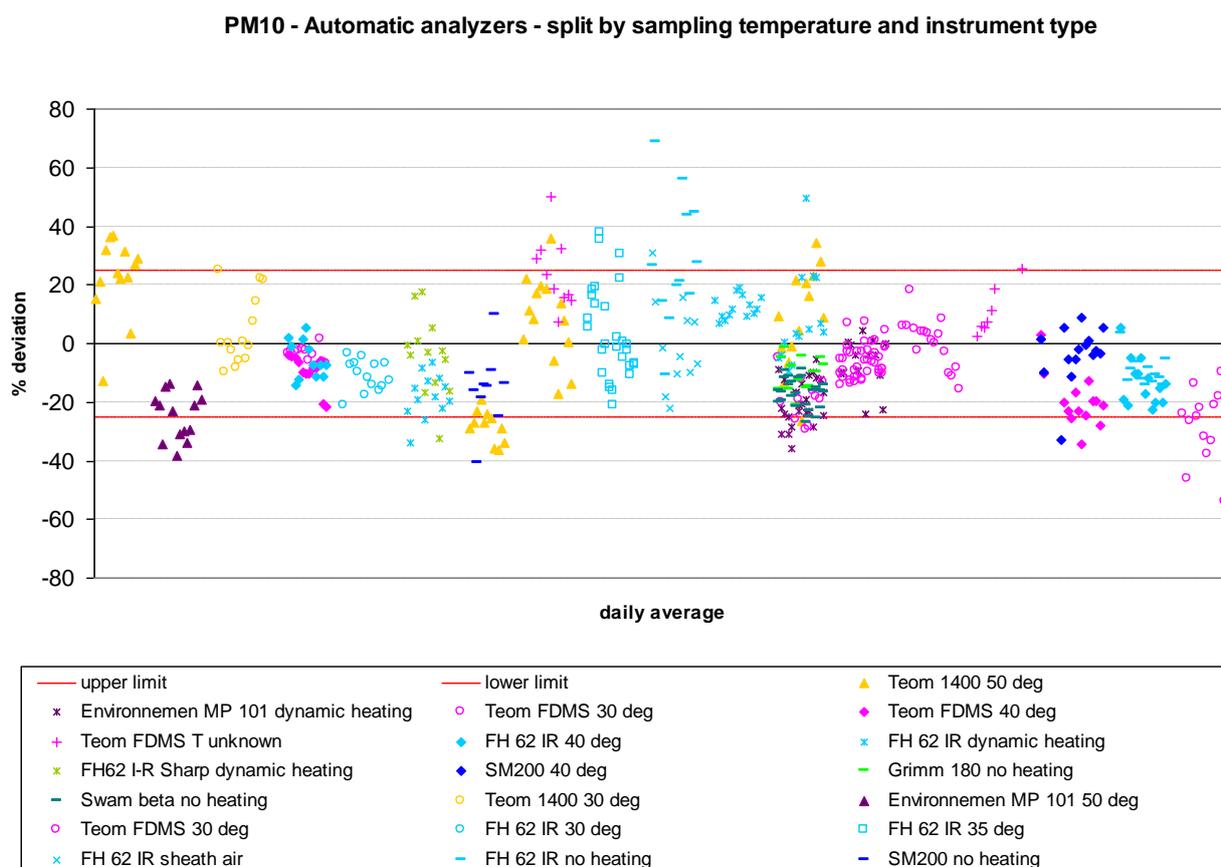
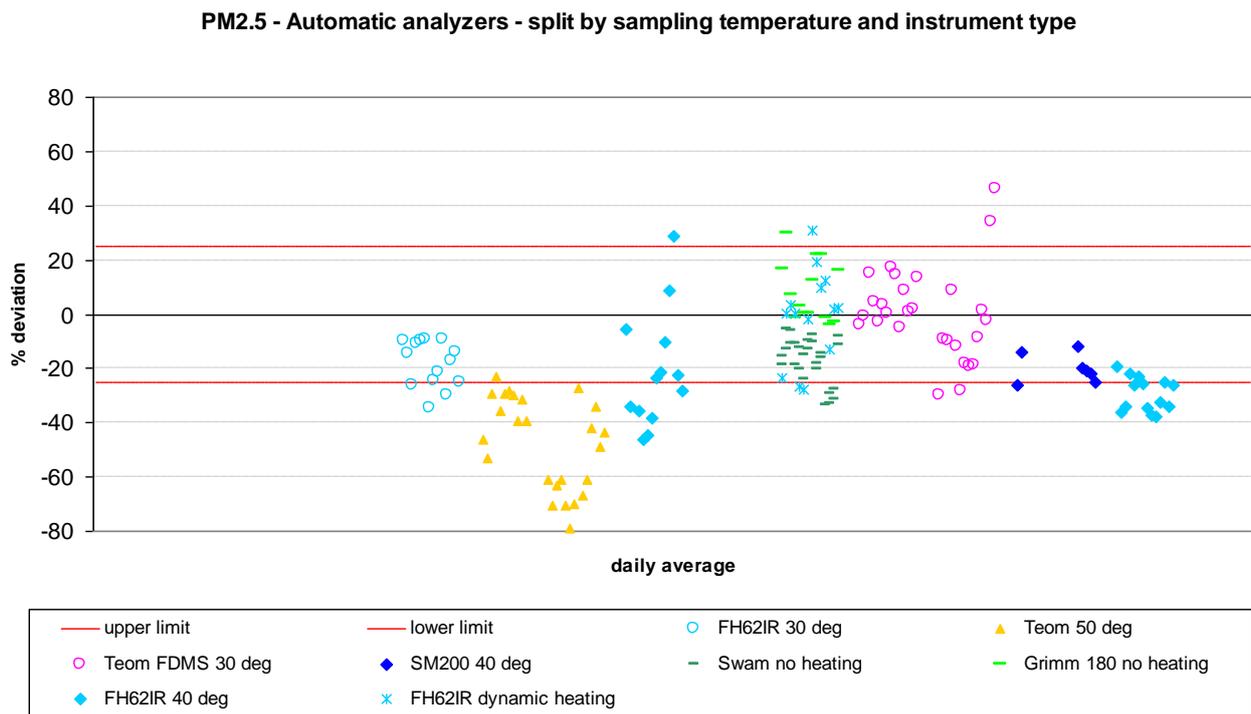


Figure 33: PM2.5 automatic analyzers deviation from reference value split by sampling temperature and instrument type. Colour indicates type of analyzer and symbol denotes sampling temperature.



In a second step, limited to the PM10 results, Analysis of Variance (ANOVA) was used for the same purposes as above. Data sets, where the sampling temperature was not specified by the participant, were omitted.

Regarding the instrument type, FH62 shows the biggest spread of all instruments, what can be explained by the highest number of instruments (19). Teom instruments produced on average the highest results with a ratio of >1, even most of the Teom instruments were used with a sampling temperature of 50°C. Environnement and Swam (two instruments used by the same laboratory only) produced the lowest averages. Only one instrument was used for the types Sharp and Grimm thus limiting the value of information. Regarding the sampling temperature, it is again evident that other factors are overlapping its influence on the measurement results. Otherwise it cannot be explained that data obtained with a sampling temperature of 50°C are higher than most of the data obtained with lower sampling temperatures.

Details of these tests can be found in Annex 8.

5.8 Expression of data with consideration of applied pressure and temperature conditions

Directive 2008/50/EC [2] provides that PM sampling volume refers to ambient conditions in terms of temperature and atmospheric pressure at the date of measurement. The same directive defines the reference method for PM10 as EN 12341 [3] and for PM2.5 as EN 14907 [4]. Regarding the sampling volume conditions, EN 14907 is in line with the directive; however EN 12341 uses reference conditions of 273 K and 101.3 kPa to express the PM10 concentrations.

Most of the participants expressed their data at ambient conditions as foreseen in the directive, but, probably as

a consequence of the different conditions given in the two European standards, it occurred that some participants expressed data at reference conditions. In addition, applied reference conditions differ in the used reference temperature. In this report participants' data were used as delivered. This means that deviations between Reference and participant values might result from normalisation of conditions by the participant. Table 23 (PM10) and table 24 (PM2.5) present an overview of all participants using normalised instead of ambient conditions.

Table 23: Applied conditions different from ambient in terms of temperature and atmospheric pressure for PM10

| country | institution | instrument | reference conditions |
|----------------|--------------------|-------------------|-----------------------------|
| ES | AdM | Teom 1400 AB | 101.3 kPa / 293 K |
| SI | EPA SI | Teom 1400 | 101.3 kPa / 293 K |
| | EIMV | Tecora | 101.3 kPa / 273 K |
| | | Andersen | 101.3 kPa / 273 K |
| DK | NERI | Opsis | 101.3 kPa / 273 K |
| SE | EHAS | Teom 1400 | 101.3 kPa / 298 K |
| FR | AIRPARIF | Teom FDMS | 101.3 kPa / 293 K |
| HU | MDV | FH 62 IR | 101.3 kPa / 293 K |
| SK | SHMU | Teom FDMS | 101.3 kPa / 293 K |

Table 24: Applied conditions different from ambient in terms of temperature and atmospheric pressure for PM2.5

| country | institution | instrument | reference conditions |
|----------------|--------------------|-------------------|-----------------------------|
| SE | EHAS | Teom 1400 | 101.3 kPa / 298 K |
| FR | AIRPARIF | Teom FDMS | 101.3 kPa / 293 K |
| HU | MDV | FH 62 IR | 101.3 kPa / 293 K |
| | | Digitel DHA 80 | 101.3 kPa / 293 K |

5.9 Discussion on uncertainties

5.9.1 Individual participants

Each participant of a measurement campaign was asked to express the uncertainty of the reported results. 12 participants expressed an uncertainty for their PM10 measurements and 3 participants for their PM2.5 measurements. They are listed in table 25 for PM10 and table 26 for PM2.5.

Table 25: Combined uncertainties for PM10

| Country | Institution | Sampler/Analyzer | Combined uncertainty u_c |
|---------|-------------|--------------------------|--|
| ES | ISCI | Derenda MVS 6.1 | 4% (will be adopted to EN14907) |
| SI | EIMV | Tecora Low Vol | 5% |
| AT | LR OOe | Digitel High Vol | 2.50% |
| DE | LANUV | Digitel High Vol | 2.25 $\mu\text{g}/\text{m}^3$ at 40 $\mu\text{g}/\text{m}^3$ |
| | HLUG | FH 62 IR | 11 - 22% |
| | | FH 62 IR sharp | 9% |
| NL | RIVM | Leckel SEQ 47/50 | ca. 4% |
| | | Thermo FH 62 I-R | 8.30% |
| | GGD | Leckel SEQ 47/50 | 3% |
| BE | VMM | Derenda SEQ Low Vol | 2.15% (partly calculated) |
| | | Leckel SEQ 47/50 | only between sampler u |
| | | ESM Andersen | 11.06% |
| | | Teom 1400 | 13.72% |
| | | Teom FDMS | 8.78% |
| FR | EDM | FAI Beta data | 2.35% |
| | | Environnement MP 101 | 6% |
| | AIRPARIF | Environnement MP101M-RST | 6 - 7.5% at 50 $\mu\text{g}/\text{m}^3$ |
| IT | Ispira | Teom FDMS | 9% at 50 $\mu\text{g}/\text{m}^3$ |
| | | Tecora Low Vol | 0.8 $\mu\text{g}/\text{m}^3$ at 50 $\mu\text{g}/\text{m}^3$ |

Table 26: Combined uncertainties for PM2.5

| Country | Institution | Sampler/Analyzer | Combined uncertainty u_c |
|---------|-------------|---------------------|-----------------------------------|
| AT | LR OOe | Digitel High Vol | 2.50% |
| NL | GGD | Derenda SEQ Low Vol | 2.15% (partly calculated) |
| FR | AIRPARIF | Teom FDMS | 9% at 50 $\mu\text{g}/\text{m}^3$ |

For laboratories expressing an uncertainty, the E_n - numbers could be calculated (as described in chapter 3.3.2) according to ISO/IEC guide 43-1 [7]. In case an uncertainty was declared only for values above a certain PM concentration, the following procedure has been applied: 25% was subtracted from this stated PM concentration and only data above this "limit" were taken into consideration for the calculation of the E_n - numbers. For PM10, calculations were done for each data-set with JRC sequential sampler A and JRC sequential sampler B independently; a total amount of 500 E_n - numbers were calculated. For PM2.5 only one JRC sampler was available resulting in 30 E_n - numbers. Even if the amount of PM2.5 E_n - numbers is quite low, it seems more difficult to get satisfactory results (≤ 1) for this size fraction. A summary of E_n - numbers is given in table 27. All detailed E_n - numbers can be found in Annex 5.

Table 27: Summary of E_n - numbers for PM10 and PM2.5

| | n of E_n - numbers | n of E_n - numbers >1 | % non satisfactory results |
|-------|----------------------|-------------------------|----------------------------|
| PM10 | 500 | 191 | 38,2 |
| PM2.5 | 30 | 15 | 50,0 |

5.9.2 Uncertainties based on grouped results

Reproducibility standard deviations found by applying ISO 5725 statistics (see 5.1) can be used as estimators of the uncertainties of grouped results for participants considered.

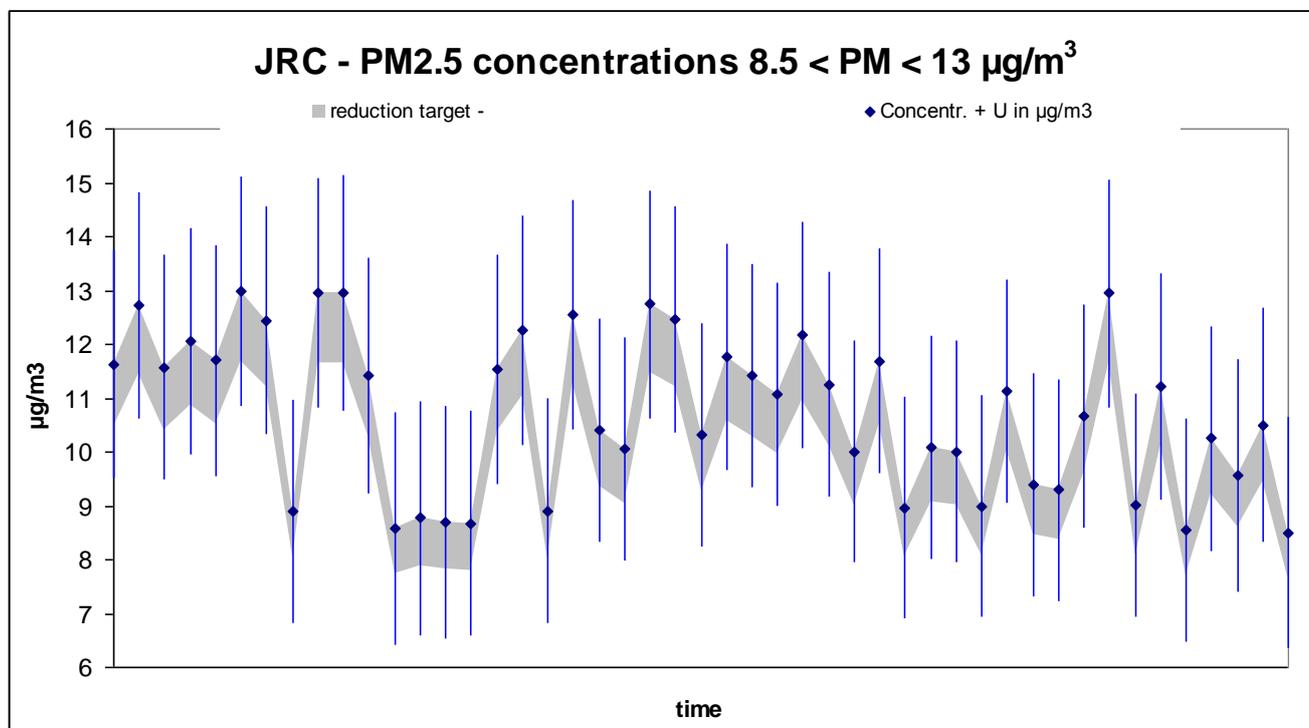
When considering all results after removal of outliers, the relative expanded uncertainties (95% confidence) for PM10 and PM2.5 grouped results are 28% and 33%, respectively. For PM10 uncertainties for NRL and local networks are comparable; for PM2.5 the uncertainty for local networks is considerably higher than that for NRL.

When examining results differentiated by method it is found that LVS and HVS give comparable uncertainties for PM10; automatic analyzers always give higher results.

5.9.3 PM2.5 uncertainties at low concentration level

Directive 2008/50/EC [2] requires the EU member states to calculate for PM2.5 an Average Exposure Index, a three calendar year running annual mean concentration of several sampling points in urban background locations. This mean value, depending on its concentration, is linked to an exposure reduction target. Whilst for concentrations $\leq 8.5 \mu\text{g}/\text{m}^3$ the reduction target is still 0%, for concentrations from >8.5 to $<13 \mu\text{g}/\text{m}^3$ it is already 10%, corresponding to $1.1 \mu\text{g}/\text{m}^3$ on average. Even if the limited length of the monitoring campaigns does not allow the estimation of a PM2.5 annual mean uncertainty, it was considered informative to compare the PM2.5 uncertainty of 24 h means of the Reference Value with the reduction target in the concentration range <8.5 to $<13 \mu\text{g}/\text{m}^3$. For that purpose, due to the lack of a second PM2.5 reference sampler, the uncertainty was calculated with an $u_{\text{field}} = 1 \mu\text{g}/\text{m}^3$ as foreseen in EN 14907 [4] leading to an expanded uncertainty ($k=2$) of $2.12 \mu\text{g}/\text{m}^3$ on average (field blank uncertainty excluded). In the latest revision of EN 14907, the expanded uncertainty, including a contribution for field blank effects, would be $2.5 \mu\text{g}/\text{m}^3$ for a 1-year average (Hafkenscheid, Th., personal communication). This estimation is comparable with those obtained in a four years survey in an urban background site with PM2.5 mass average of $8.0 \mu\text{g}/\text{m}^3$, where the long term propagated uncertainty ($k=1$) in mass measurements was $1.28 \mu\text{g}/\text{m}^3$ (Dutton et al., 2009)[13]. Consequently it looks challenging to clearly distinguish a 10 % reduction of the PM2.5 Average Exposure Index from its associated uncertainty. Figure 34 illustrates all PM2.5 Reference Values and expanded uncertainties in the concentration range >8.5 to $<13 \mu\text{g}/\text{m}^3$ measured during the run of all 18 measurement campaigns.

Figure 34: PM2.5 Reference Values in the range >8.5 to $<13 \mu\text{g}/\text{m}^3$ with expanded uncertainties and associated reduction targets. The blue vertical bars indicate the expanded uncertainties whilst the gray field shows the reduction target.



5.10 Investigation of field blanks

EN 14907 requires the use of field blanks which are weighed before and after a measurement campaign in the same way as filters used for sampling. In case the blank mass differs by more than 40 µg for LVS, the reason shall be investigated.

During all campaigns (apart from Madrid, where the available field blank had to be used instead of a damaged sampling-filter) field blanks are available for the reference values. During the run of the project, the amount of filed blanks varied from 2 to 8 filters per campaign such to get an idea about their repeatability. Further investigations were carried out to check whether filters exposed in a sampler inside the air conditioned mobile laboratory (PM10) behave differently from filters exposed in samplers placed outside (PM2.5, PM1) the mobile laboratory. Considering all field blanks together it was observed that 56% of the 110 field blanks exceeded the limit of 40 µg. In addition, a tendency of filters exposed in samplers outside the mobile laboratory to behave worse (62.5% exceedances) than filters exposed in samplers inside the mobile laboratory (46% of exceedances) was observed. In table 28 are listed the masses of all field blanks.

Table 28: JRC filed blanks in µg with data >40 µg marked in red

| measurement site | PM1 (no.67) | PM2.5 (no.68/66) | PM10 A (no.64) | PM10 B (no.65) |
|------------------------|-------------|------------------|----------------|----------------|
| <i>Lisbon</i> | 14 | | | 15 |
| <i>Ljubljana</i> | 78 | 86 | 48 | 38 |
| <i>Graz</i> | 31 | 4 | 11 | 16 |
| <i>Prag</i> | 36 | 52 | 13 | 19 |
| <i>Wiesbaden</i> | -25 | -165 | -118 | |
| <i>Copenhagen</i> | 41 | 11 | 35 | 48 |
| | 54 | 33 | 50 | 57 |
| <i>Stockholm</i> | 78 | 69 | 15 | 33 |
| | 73 | 68 | 9 | 21 |
| <i>Helsinki</i> | 26 | 20 | 17 | |
| | 21 | 0 | 7 | -22 |
| <i>Tallinn</i> | 60 | 59 | 73 | 74 |
| | 62 | 62 | 55 | 61 |
| <i>Biest-Houtakker</i> | 32 | 45 | 18 | 27 |
| | 53 | 55 | 26 | 91 |
| <i>Borgerhout</i> | 22 | 4 | 12 | 12 |
| | | 13 | 23 | 28 |
| <i>Paris</i> | 70 | 39 | | 70 |
| <i>Dublin</i> | 28 | 54 | 11 | 18 |
| | 34 | 18 | 28 | 37 |
| <i>Port Talbot</i> | 73 | 49 | 28 | 44 |
| | 74 | 54 | 37 | 49 |
| | 117 | 134 | 96 | 89 |
| <i>Milan</i> | 68 | 52 | 55 | 41 |
| | 64 | 38 | 34 | 47 |
| <i>Budapest</i> | 340 | 331 | 274 | 292 |
| | 333 | 342 | 317 | 307 |
| <i>Bratislava</i> | 282 | 306 | 263 | 279 |
| | 310 | 285 | 288 | 299 |

None of the participants subtracted field blanks from their measurement results; the same is valid for the Reference Values with the exception of the campaigns in Budapest and Bratislava. During these two campaigns the field blank masses increased so much that their average contribution to the mass concentration reached

5.75 $\mu\text{g}/\text{m}^3$ in Budapest and 5.23 $\mu\text{g}/\text{m}^3$ in Bratislava. For Bratislava this led in the worst case to an influence of 50% on PM10 and 62% on PM2.5 results. A comparison of the gravimetric value to the JRC - Teom FDMS confirmed for both campaigns the influence of the filter matrix on the gravimetric results. Linear trend lines were calculated for both the gravimetric result and the gravimetric result minus the field blank against the FDMS. Whilst the slopes remained constant, the intercept changed in a magnitude comparable to field blank contribution to the mass concentration: 5.93 vs. 5.75 $\mu\text{g}/\text{m}^3$ in Budapest and 4.22 vs. 5.23 $\mu\text{g}/\text{m}^3$ in Bratislava. Such confirms the same increase in mass for filters used for sampling. Investigations after the measurement campaigns identified single boxes to contain unstable quartz filter material. However, the problem could not be linked to a whole batch – number. An experiment carried out at JRC revealed that quartz filters from suspect boxes increased their mass significantly (>200 μg within 14 days) when exposed outdoor in a Seq – sampler (identical to the ones used in the QA/QC programme). However, exposing quartz filters from the same boxes in the balance room or even in a Seq – sampler placed indoor did not change their mass significantly (1 μg and - 27 μg respectively within 14 days). Therefore the increase in mass of field blanks could not be foreseen during the weighing of the blank filters before these measurement campaigns. Flushing a field blank from Budapest with particle free air for 24 h did not reduce its mass; this implies that the mass increase due to storage of loaded filters may be approximated by the mass increase of the field blank. However, heating a field blank from Budapest to the same temperature to which sample is exposed in TEOM-FDMS (30° C) for 24 h removed almost all of the mass gained during its exposure (259 out of 342 μg removed). The good agreement between the gravimetric-TEOM regression intercept with the mass observed in the blanks plus the removal of such mass from the filters by heating, strongly suggest that adsorption of semi volatiles (or humidity) on filter matrix could have lead to the observed anomalous behaviour of the filters in Budapest and Bratislava all coming from the same boxes. Consequently, taking into account the exceptionality of these circumstances, the field blanks for Budapest and Bratislava were subtracted from the measurement results and an additional term, derived from the standard deviation of the field blanks, was added to calculate the uncertainty contribution for u_{mass} . For Budapest, figure 35 shows a scatter plot and the trend line - equation of the FDMS against the gravimetric result without subtracting the field blank, Figure 36 after subtraction of the field blank. Figure 37 and 38 show the same for Bratislava.

Figure 35: Budapest PM10: Gravimetric result without subtraction of field blank vs. FDMS

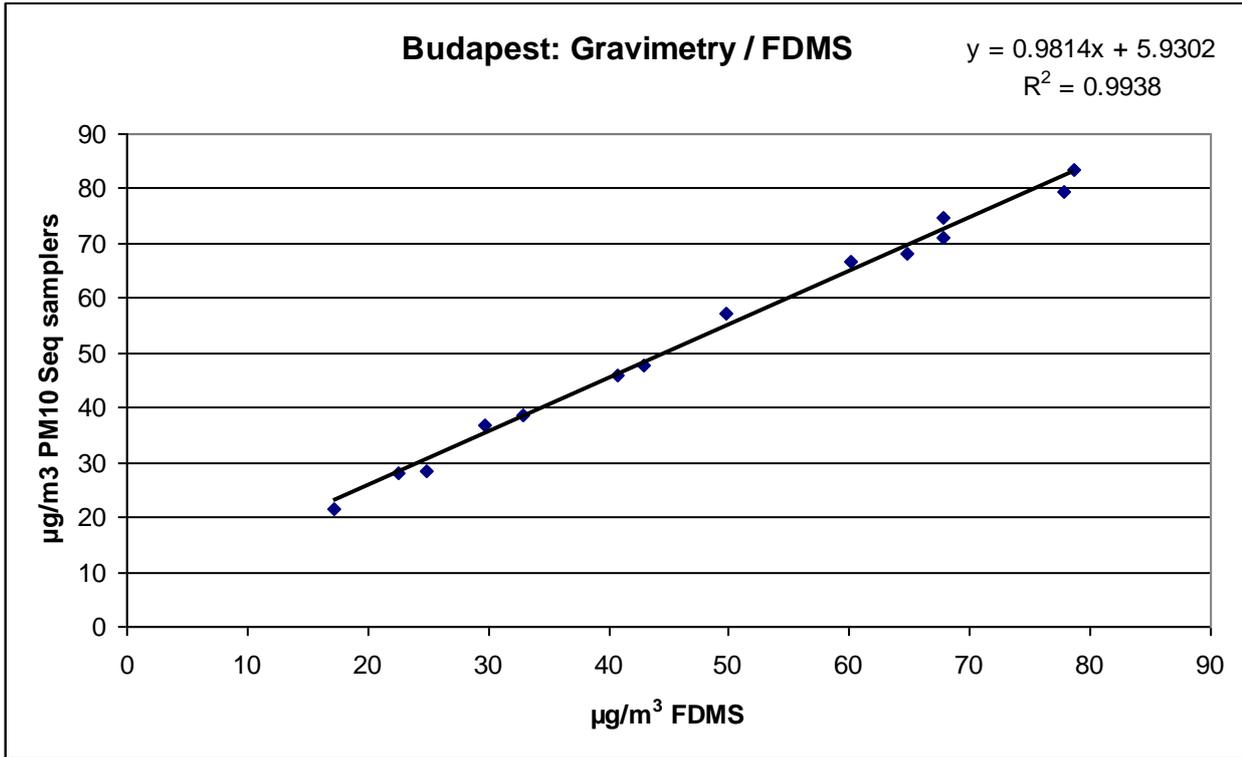


Figure 36: Budapest PM10: Gravimetric result after subtraction of field blank vs. FDMS

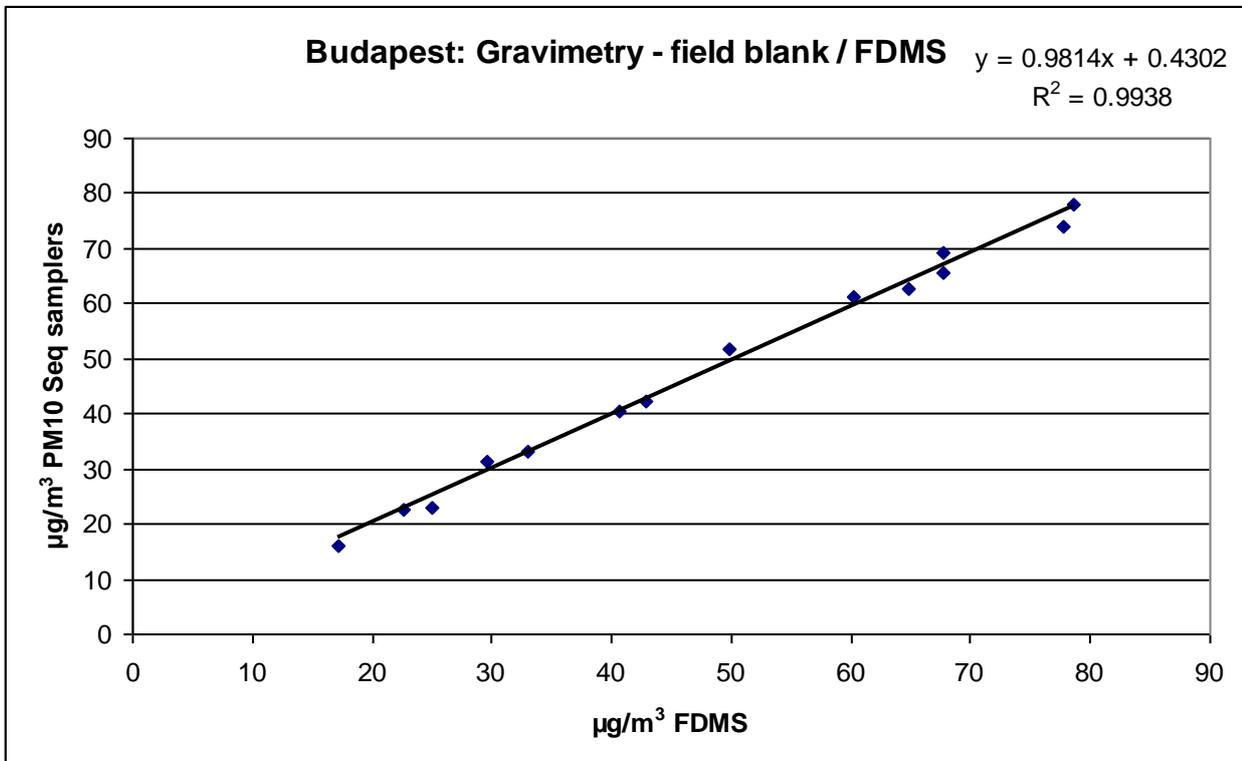


Figure 37: Bratislava PM10: Gravimetric result without subtraction of field blank vs. FDMS

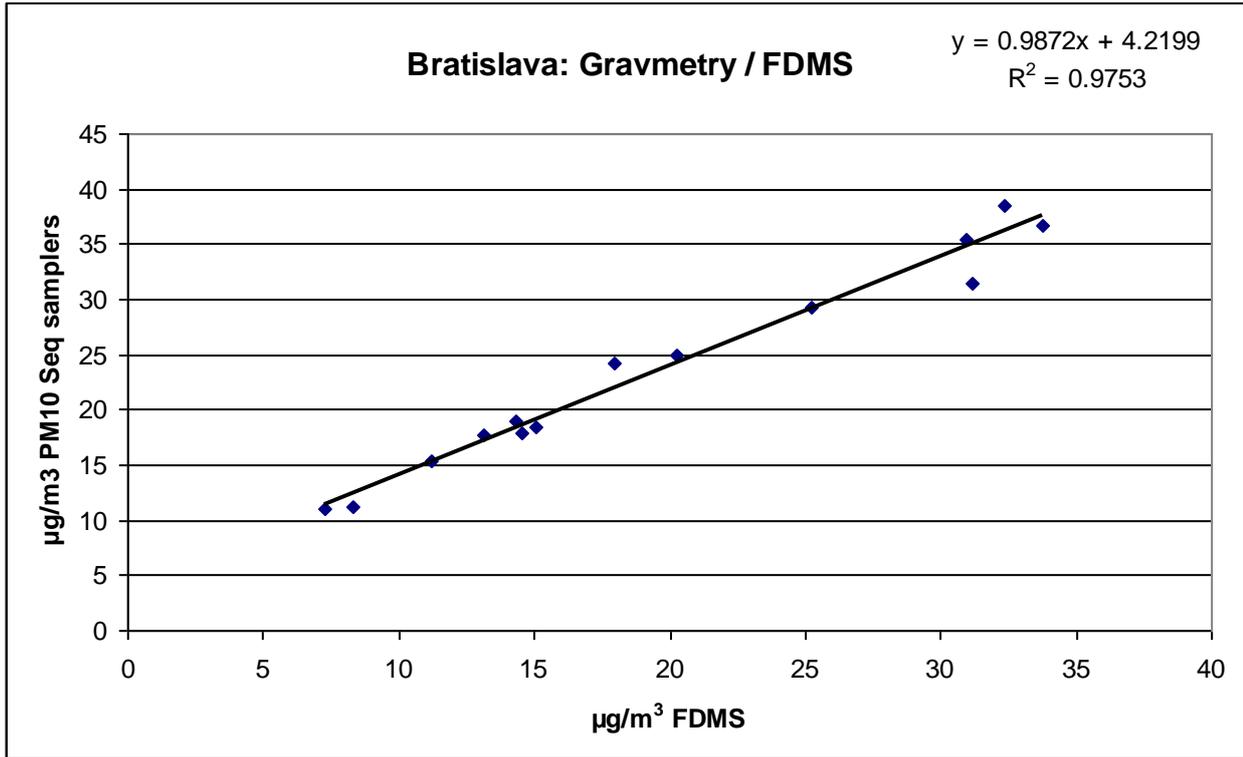
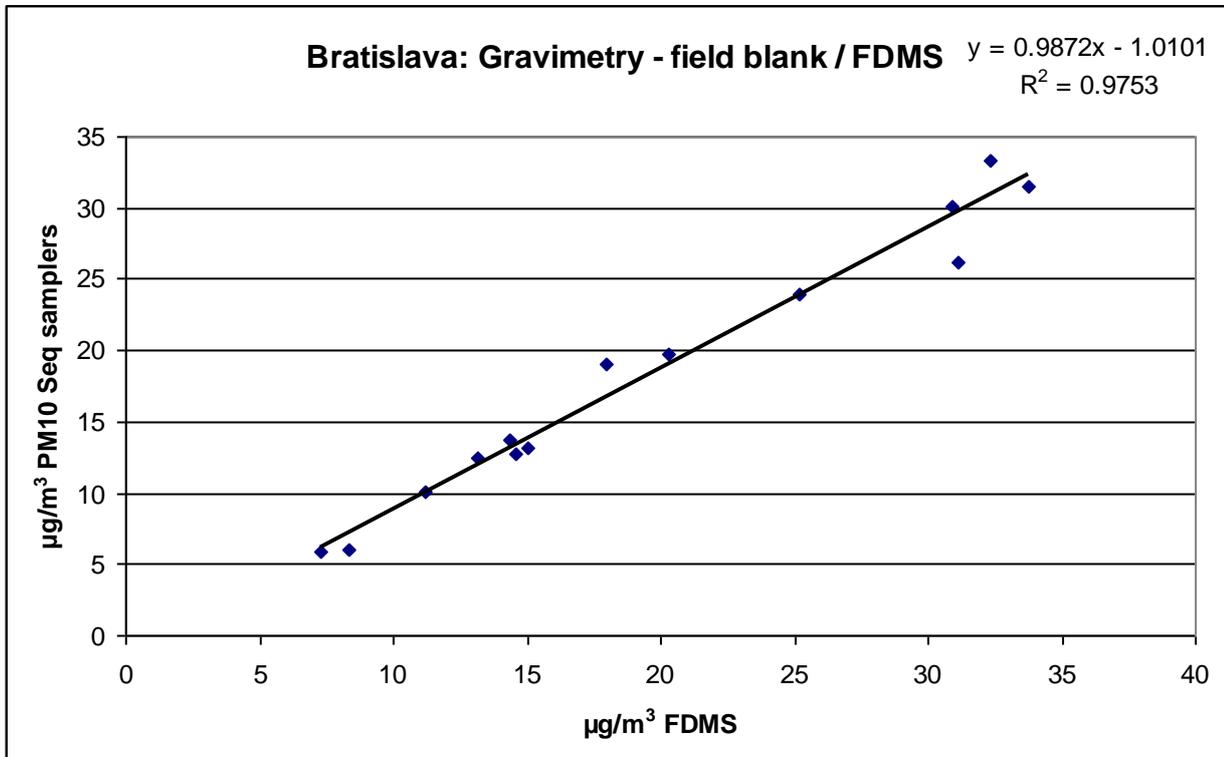


Figure 38: Bratislava PM10: Gravimetric result after subtraction of field blank vs. FDMS



6. Conclusions

With reference to the objectives of the study (see chapter “summary”) the following conclusions can be drawn:

The methodology applied by the JRC has been shown to yield robust reference values. These have been further used for comparison with results obtained by National Reference Laboratories (NRL) and local networks.

A total of 79 datasets have been obtained for PM10, of which 54 are from NRL. For PM2.5 a total of 31 datasets have been obtained, of which 18 are from NRL. For PM10 6 datasets can be marked as suspect when applying ISO 5725 statistics; for PM2.5 3 datasets are suspect.

When using all data supplied, National Reference Laboratories are found to underestimate the Reference Values for PM10 by 5.3% with a reproducibility standard deviation of 16%. Local networks were found, on average, to almost exactly reproduce the Reference Values with a reproducibility standard deviation of 19%. For PM2.5 the underestimation of the Reference Values by National Reference Laboratories increased to about 11%, whereas the average of the local networks was 1.6% lower. However, the reproducibility of the local networks was considerably worse (50% vs. 15% for the National Reference Laboratories). On a whole, these findings indicate that – within the uncertainties associated with the measurements – the average results of National Reference Laboratories and local networks agree with the JRC Reference Values.

For assessment of compliance with the uncertainty data quality objectives of Directive 2008/50/EC both uncertainties of individual results and uncertainties of grouped results have been considered. Of individual PM10 measurements, 7.1% did not comply with the Data Quality Objective at the limit value given in Directive 2008/50/EC; of individual PM2.5 measurements 23.8% did not comply with the Data Quality Objective at the target value given in EU Directive 2008/50/EC. Deviations could not be directly attributed to specific parameters like filter material, sampling temperature or instrumentation type as too many variables are influencing the measurement results.

Around one third of the PM10 and half of the PM2.5 measurements exceed the required uncertainty at the limit respectively target value, with automatic analyzers performing worse than the gravimetric methods. The expectancy for these fractions would be 5%.

When considering relative uncertainties of grouped results based on reproducibility standard deviations after removal of outliers these are 28% (95% confidence) for PM10 and 33% (95% confidence) for PM2.5. For reference methodologies the uncertainties are lower than for automatic analyzers, which may partly be attributed to the use of default correction factors instead of factors derived from equivalence tests. The average findings are higher than the required uncertainty of 25% (95% confidence). For PM2.5 these findings will have consequences for the establishment of the reduction in the Average Exposure Indicator.

These findings indicate that at the time of the study problems have existed in meeting the uncertainty data quality objectives of 2008/50/EC. Meanwhile, it is expected that uncertainties of results for automatic analyzers will have decreased as a result of equivalence testing. However, also uncertainties for reference methodologies

are relatively high, showing a need for reduction of possible variations in methodologies existing at the time of this study.

Almost half of all users of automatic analyzers have used correction factors for the results obtained by the analyzers. The use of correction factors generally improves their results.

Furthermore, the following findings have been reported:

- When comparing low-volume sampling to high-volume sampling, results for low-volume sampling are generally found to be higher. For high-volume sampling, no difference can be found between results obtained using quartz-fibre or glass-fibre filters (the two mostly used filter types), however for low-volume sampling results obtained using quartz-fibre filters are higher.
- A considerable fraction of the field blanks examined during this study exceeds of the criterion given in EN 14907, with levels of up to $6 \mu\text{g}/\text{m}^3$. The reason for this phenomenon requires further investigation.

7. References

- 1 1999/30/EC - Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (L 163, 29.06.1999)
- 2 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. OJ L152/1 of 11.6.2008
- 3 EN 12341:1998: Air Quality – Determination of the PM10 fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods, European Standard, CEN, Brussels
- 4 EN 14907:2005: Ambient air quality – Standard gravimetric measurement method for the determination of the PM2,5 mass fraction of suspended particulate matter, European Standard, CEN, Brussels
- 5 Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods
<http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf>
- 6 ISO 5725-2:1994(E): Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method, Geneva (CH)
- 7 ISO/IEC guide 43-1:1997(E): Proficiency testing by interlaboratory comparisons –Part 1: Development and operation of proficiency testing schemes, Geneva (CH)
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- 10 Putaud et al, Atmospheric Environment 44 (2010) 1308-1320
- 11 <http://www.statistics4u.info>
- 12 <http://www.watpon.com>
- 13 Dutton S. J., Schauer J.J., Vedal S ., Hannigan M. P, 2009. Atmospheric Environment 43 (2009) 1136–1146
- 14 ETC Technical paper 2005/6 PM10 measurement methods and correction factors in AirBase 2004 status report

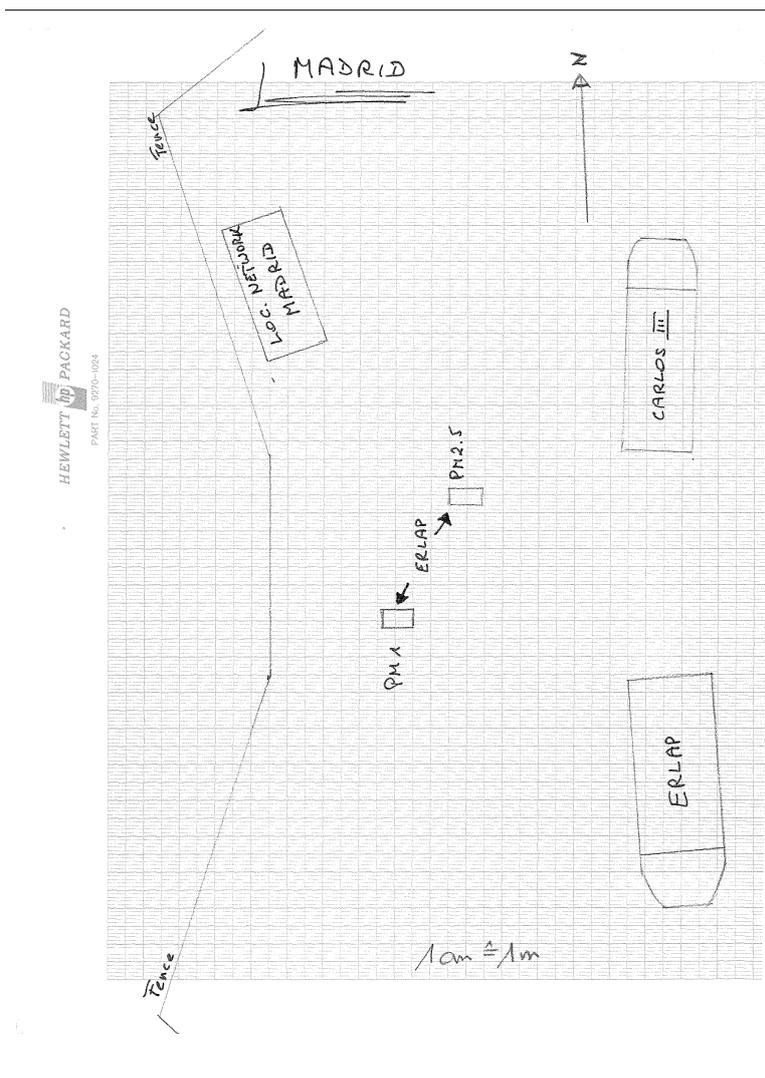
ANNEX 1: Description of measurement sites

Spain (Madrid):

Location: On a crossing of major roads next to a huge park and residential area

Sampling: Free of local obstacles

Prevailing/local sources: Traffic

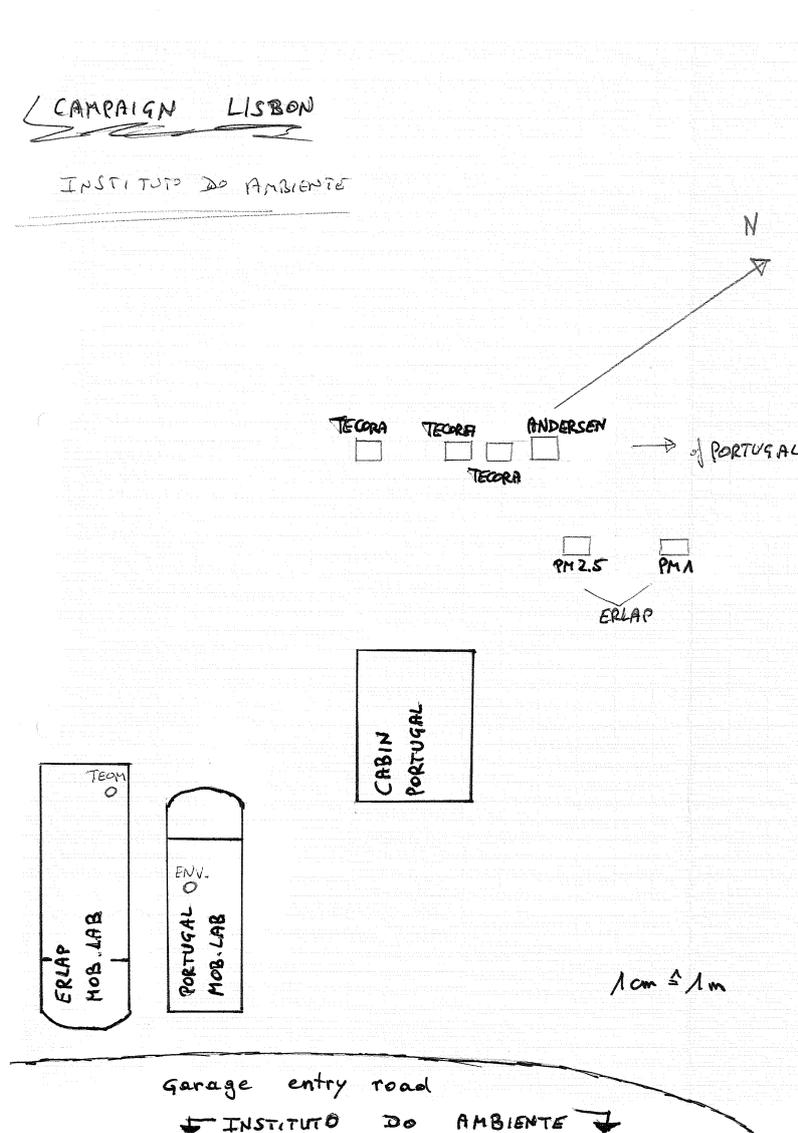


Portugal (Amadora):

Location: Next to "Istituto do Ambiente" in a residential area west of Lisbon

Sampling: Free of local obstacles

Prevailing/local sources: Residential combustion, traffic, sea salt

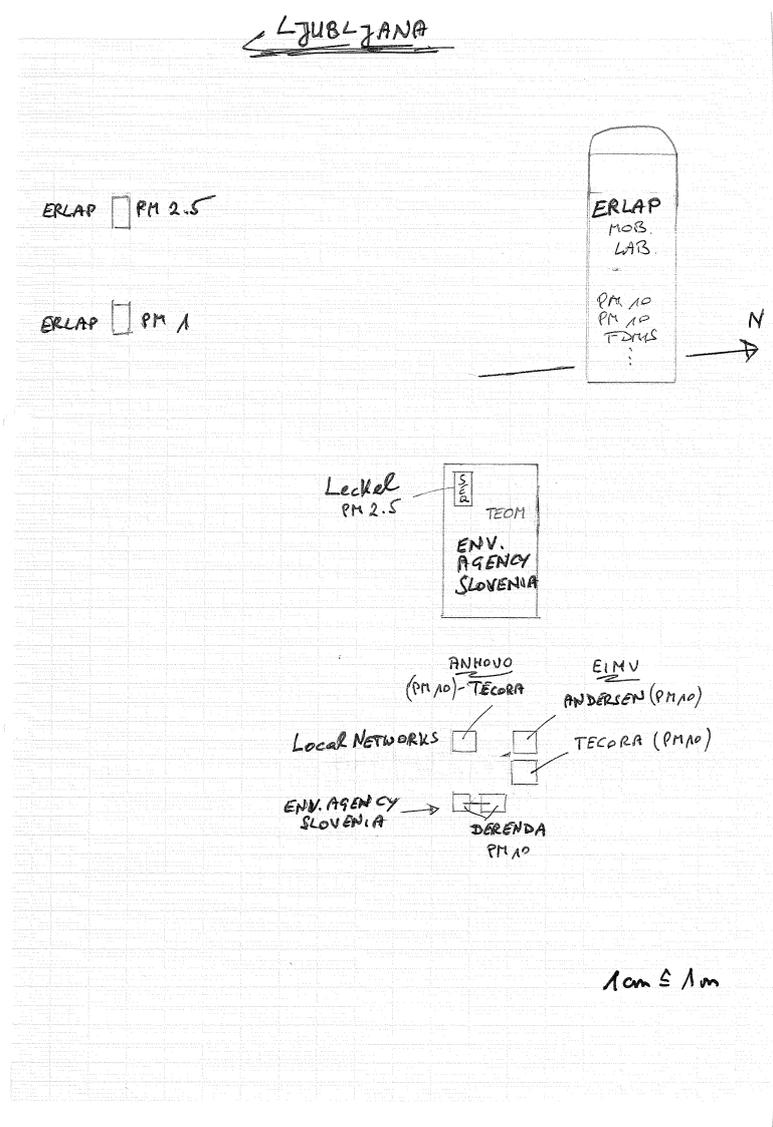


Slovenia (Ljubljana):

Location: Courtyard next to EPA in residential area

Sampling: Free of local obstacles

Prevailing/local sources: Residential combustion, traffic

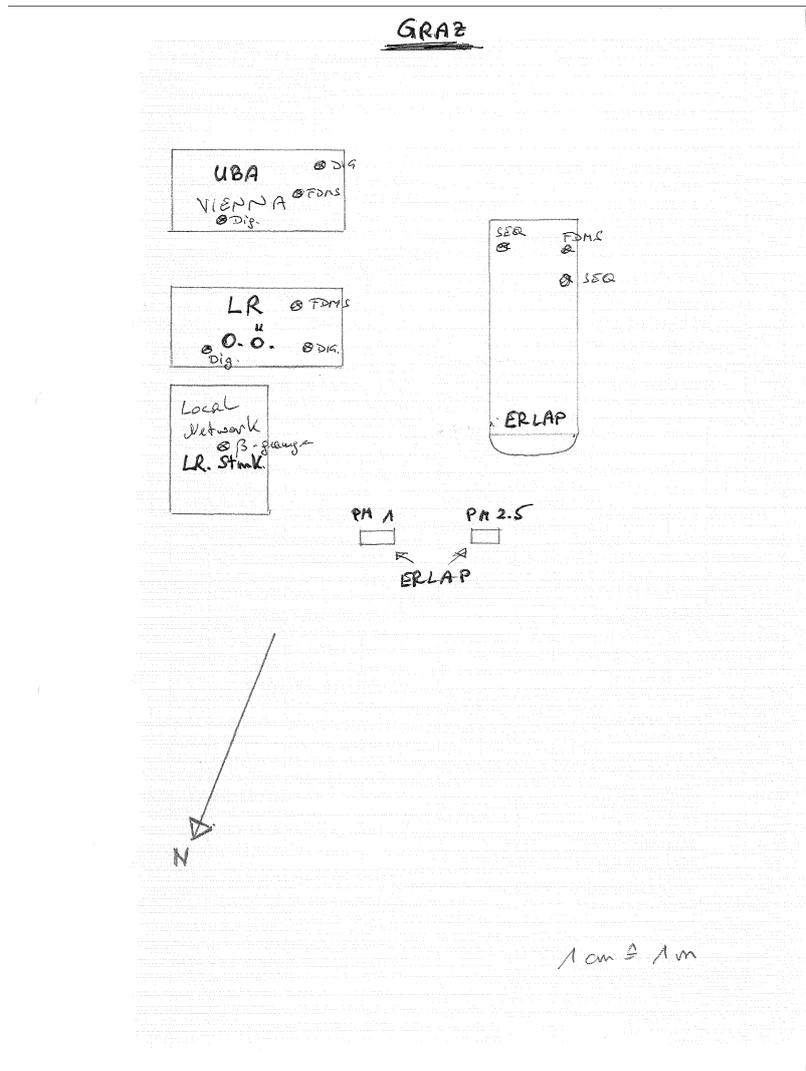


Austria (Graz):

Location: Residential area in the south of the city, single houses, fields

Sampling: Free of local obstacles

Prevailing/local sources: Residential combustion, traffic, carpentry (300 m distance), secondary aerosol and silicate are dominant

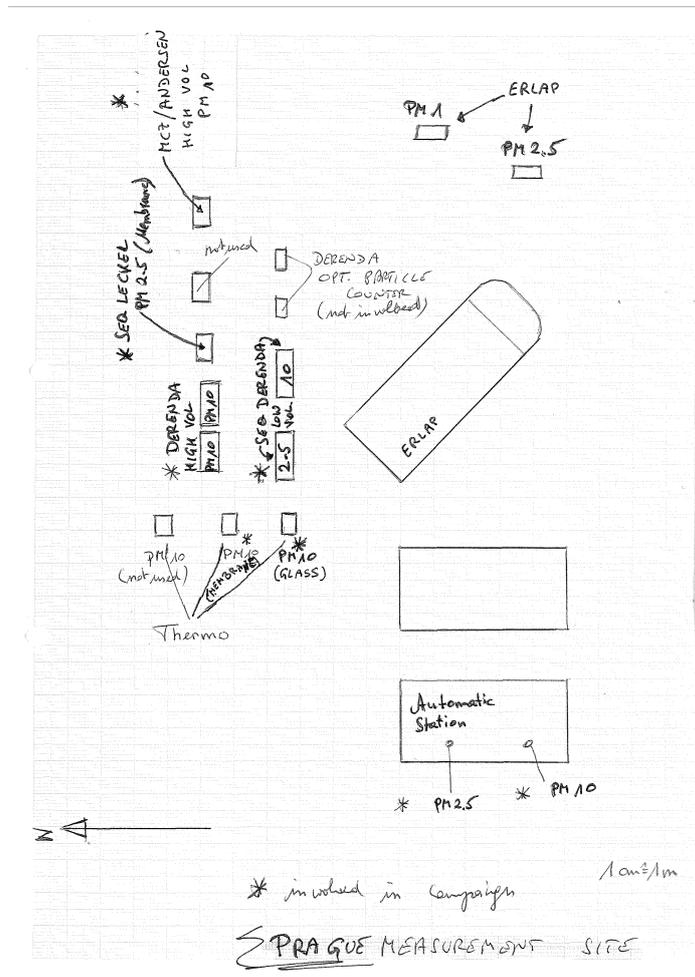
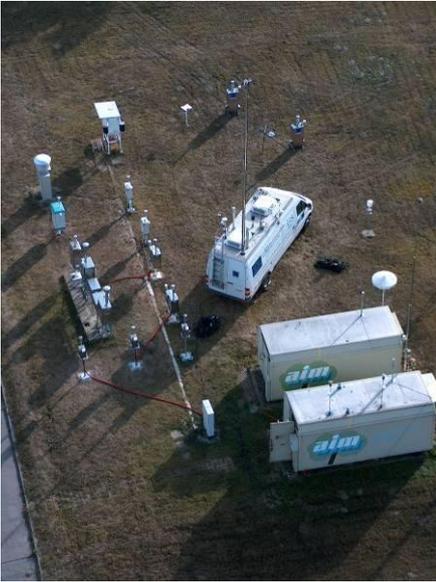


Czech Republic (Prague):

Location: Residential area in the south of the city next to the CHMI, fields

Sampling: Free of local obstacles

Prevailing/local sources: Residential combustion, traffic

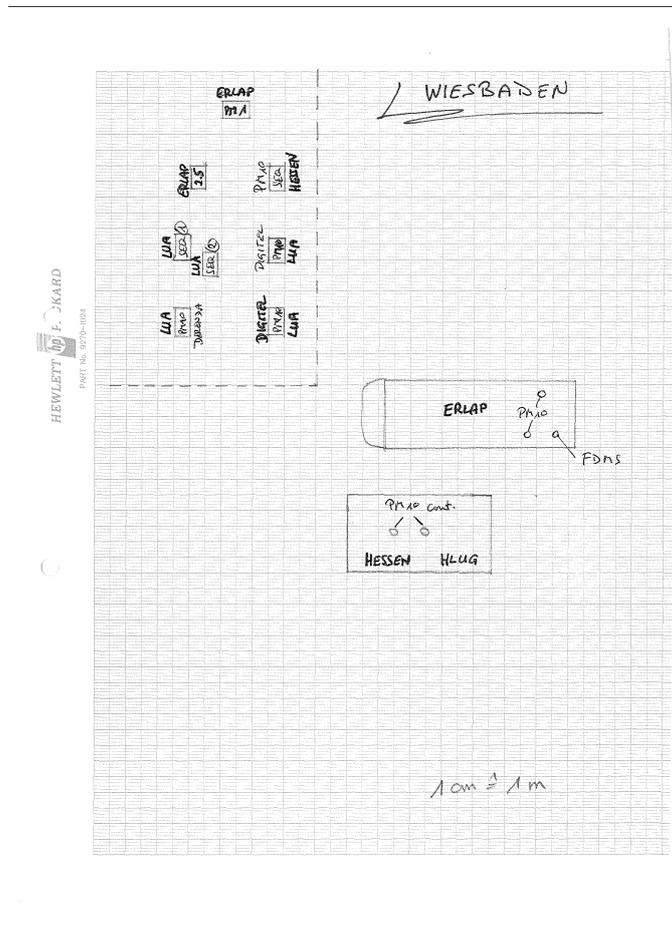


Germany (Wiesbaden):

Location: Courtyard next to the HLUG in Biebrich – south Wiesbaden, residential and industrial area (chemical industry, cement works) in the vicinity

Sampling: Free of local obstacles

Prevailing/local sources: Residential combustion, traffic, industry



Denmark (Copenhagen):

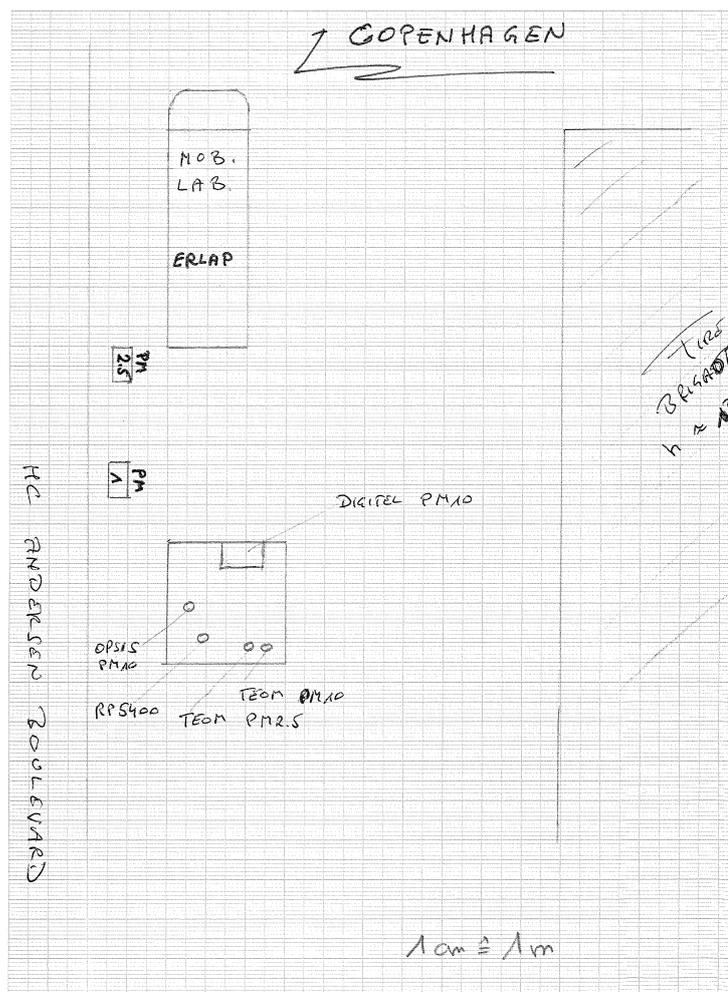
Location: Along a major road in the city centre

Sampling: Free of local obstacles but buildings to the north-east of the measurement site

Prevailing/local sources: Traffic



HEWLETT
PACKARD
P. KARD
PART No. 0220-024

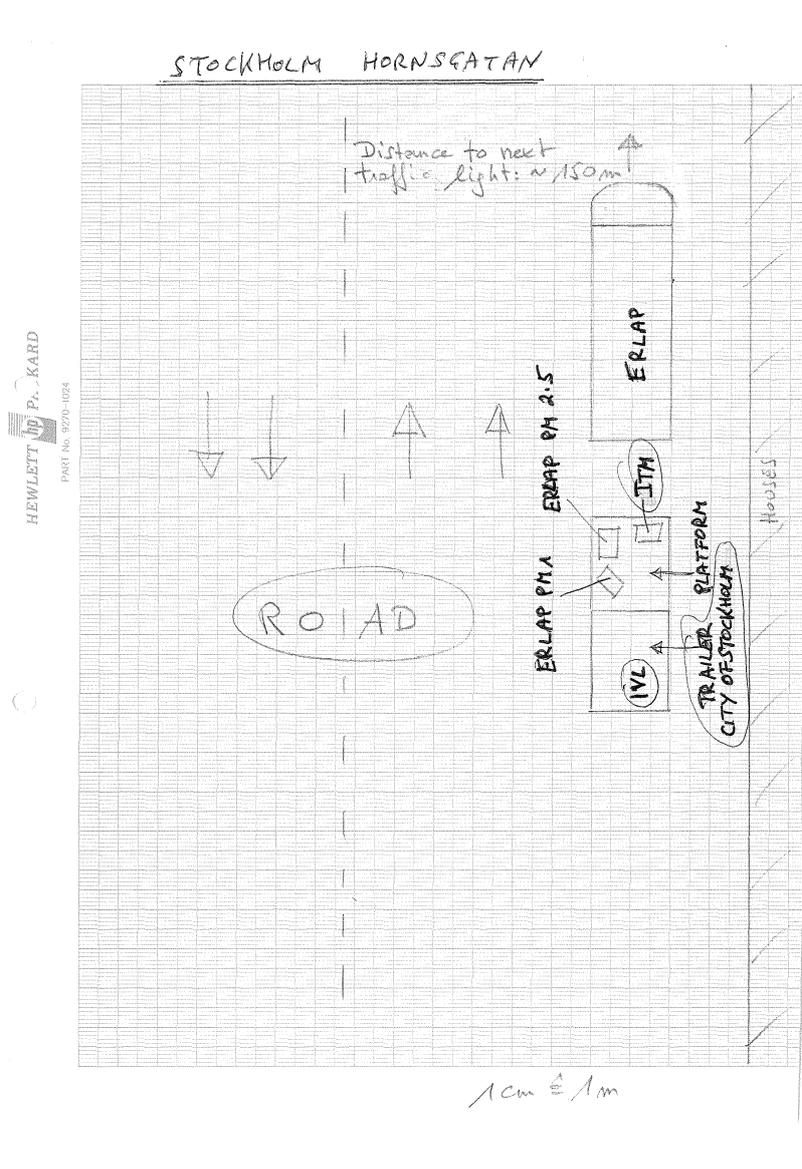


Sweden (Stockholm):

Location: Kerb-site in the city centre

Sampling: Buildings to both sides of the road

Prevailing/local sources: Traffic

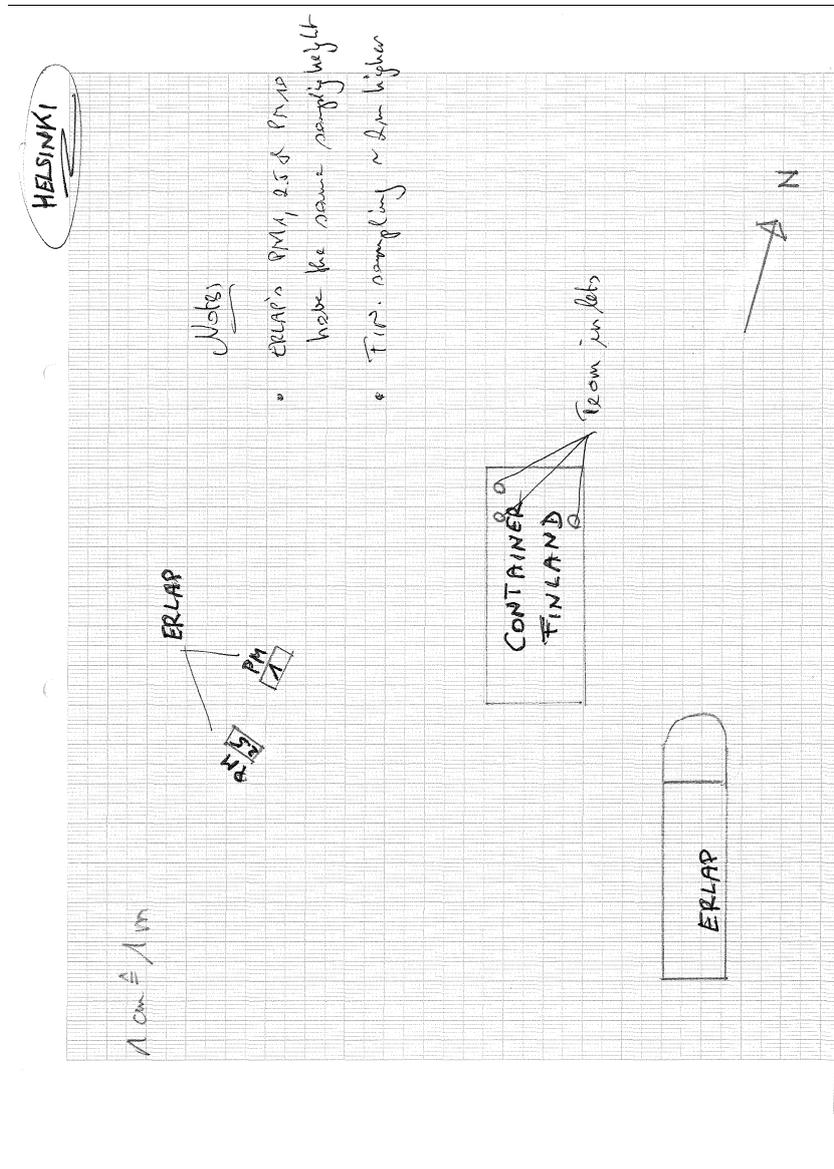


Finland (Helsinki):

Location: On a hill in the periphery, next to FMI and university campus, fields

Sampling: Free of obstacles

Prevailing/local sources: Domestic heating, traffic, long range transport, sea salt

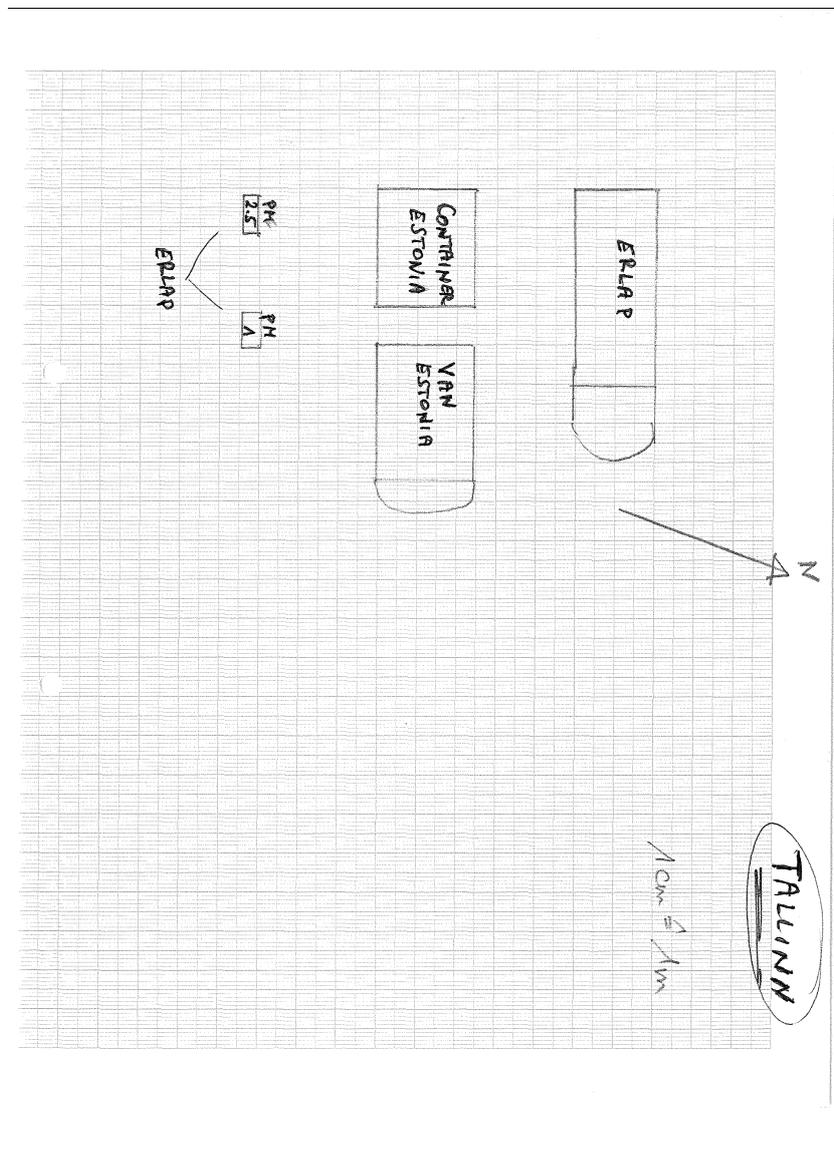


Estonia (Tallinn):

Location: In the west of the city in a court/park area surrounded by apartment buildings

Sampling: Free of obstacles

Prevailing/local sources: Domestic heating, traffic

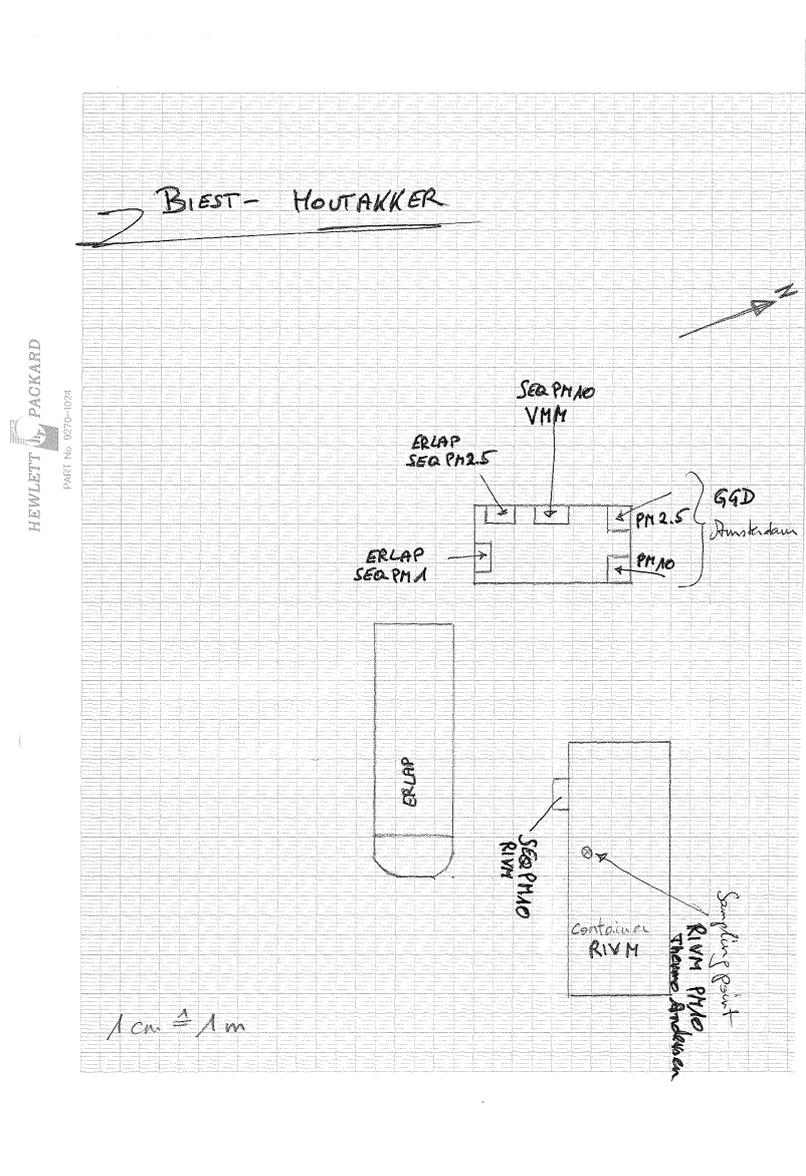


Netherlands (Biest - Houtakker):

Location: Around 10 km east of Tilburg, in the middle of fields and along a channel

Sampling: Free of obstacles

Prevailing/local sources: Agriculture

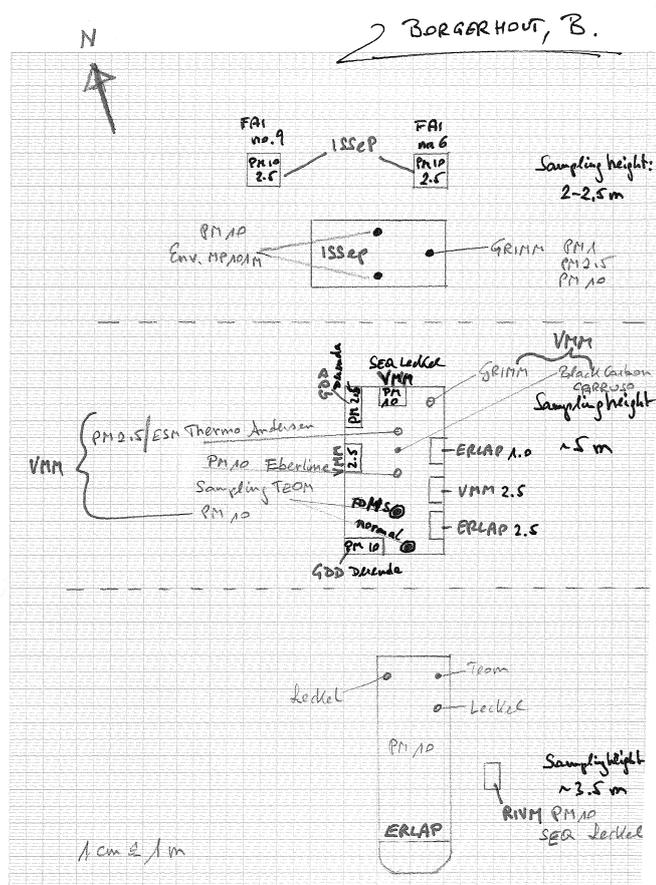


Belgium (Borgerhout):

Location: Suburb in the east of Antwerp, close to a school court and a major road

Sampling: Building in the east close to the measurement site

Prevailing/local sources: Traffic, loose terrain of schoolyard

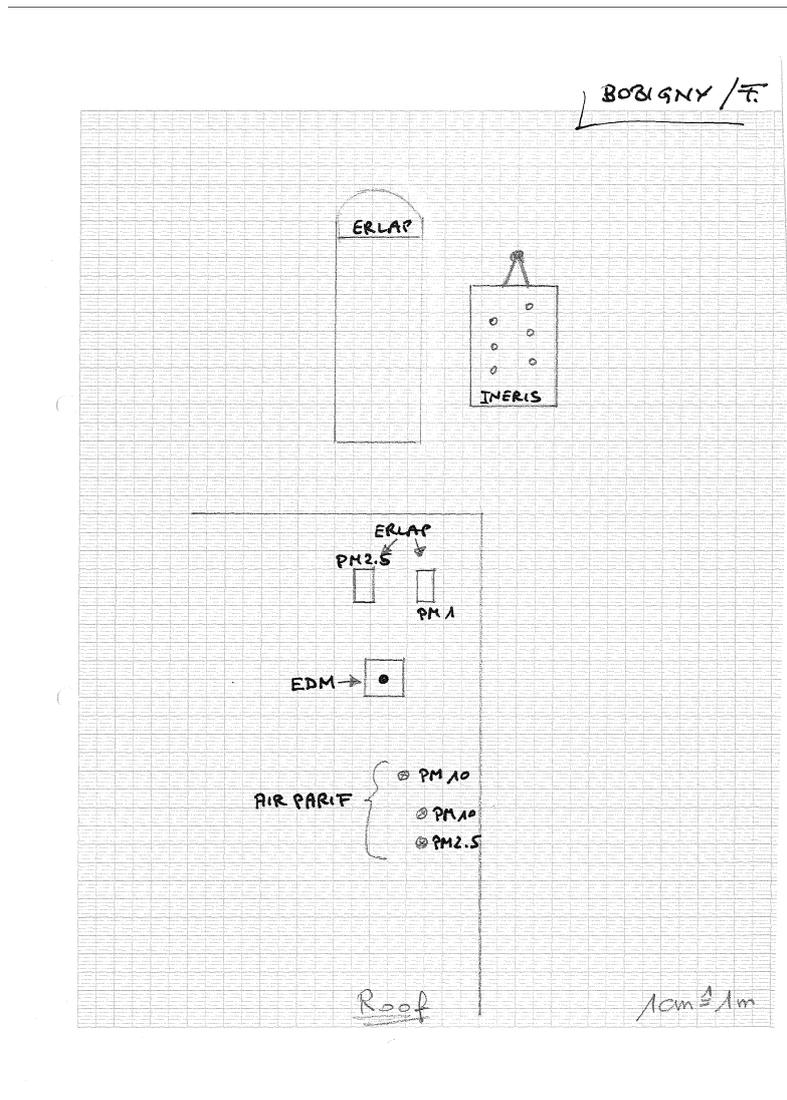


France (Bobigny):

Location: Suburb in the east of Paris, open park area

Sampling: Free of obstacles

Prevailing/local sources: Domestic heating

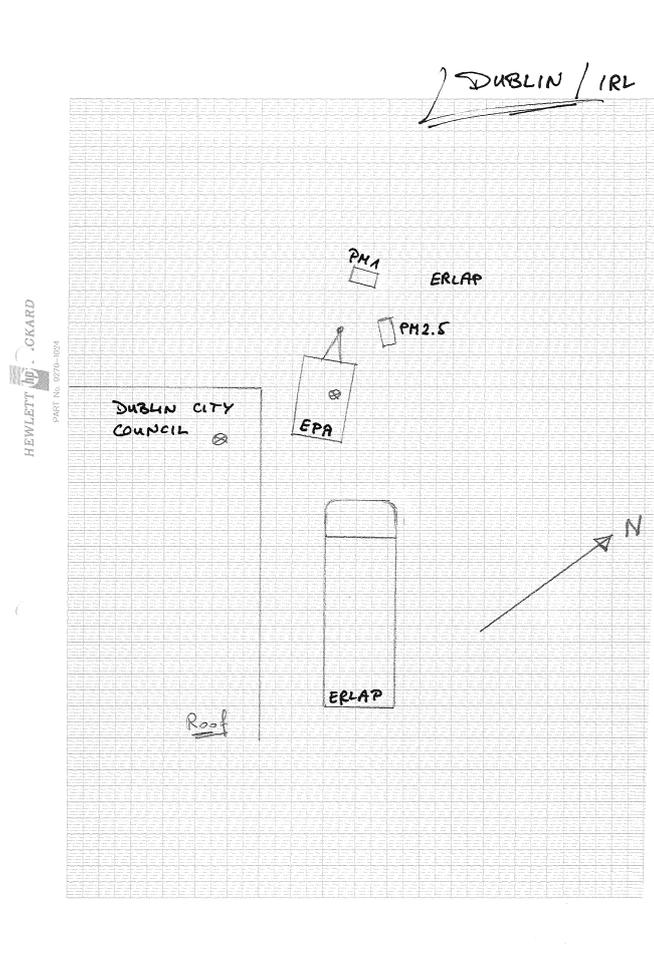


Ireland (Dublin):

Location: Suburb in the west of the city, open park area

Sampling: Free of obstacles

Prevailing/local sources: Domestic heating

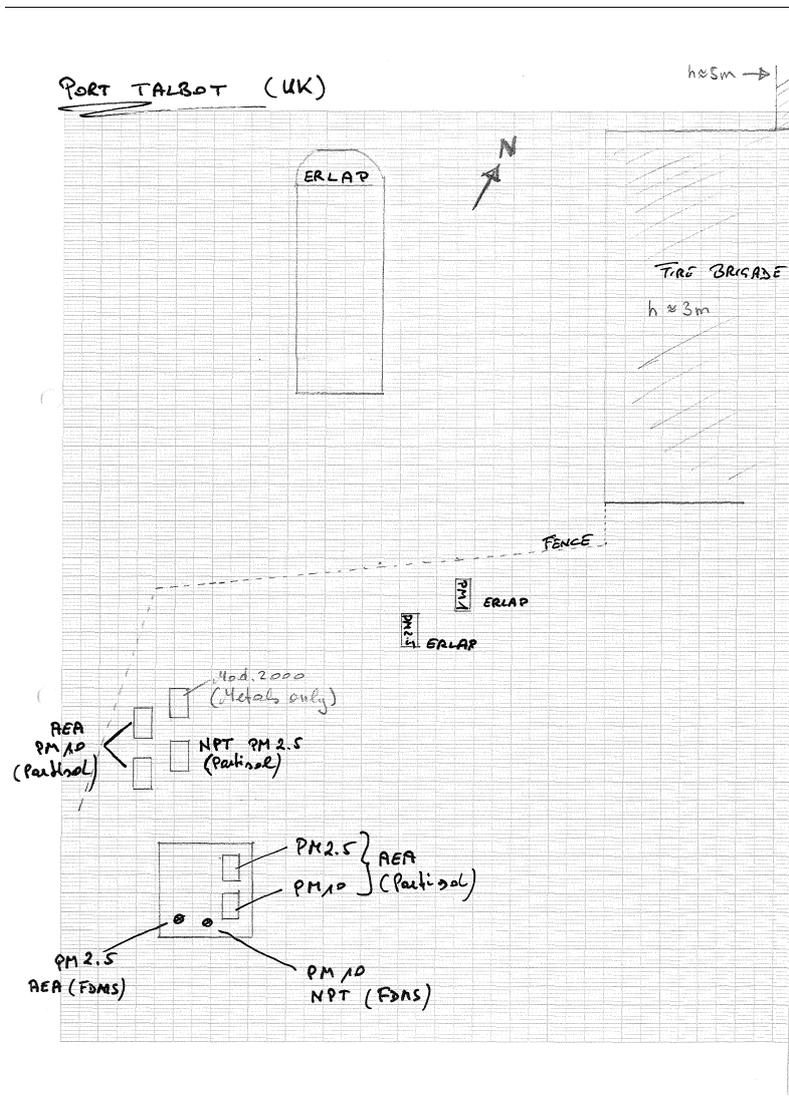


United Kingdom (Port Talbot/Wales):

Location: Suburb in the east of the city, next to single houses, railway and steel plant, close to the sea

Sampling: Free of obstacles

Prevailing/local sources: Steel plant, domestic heating, sea salt

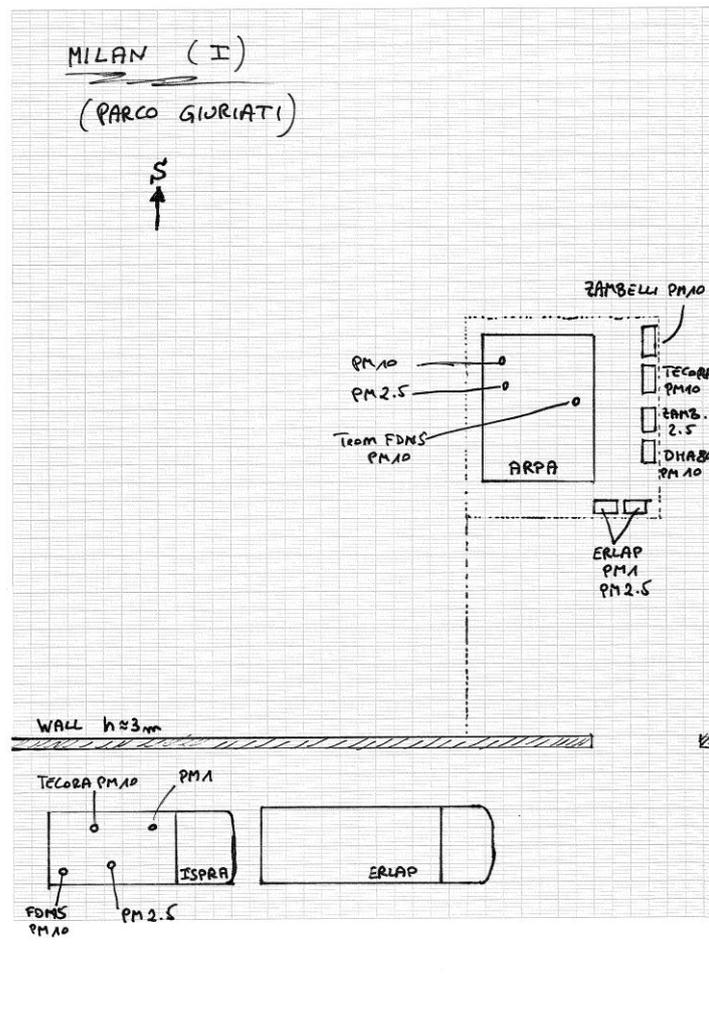


Italy (Milan)

Location: Parco Giuriati in the east of the city next to a sport yard and university campus

Sampling: Free of obstacles apart from some small but high trees

Prevailing sources: Domestic heating, traffic

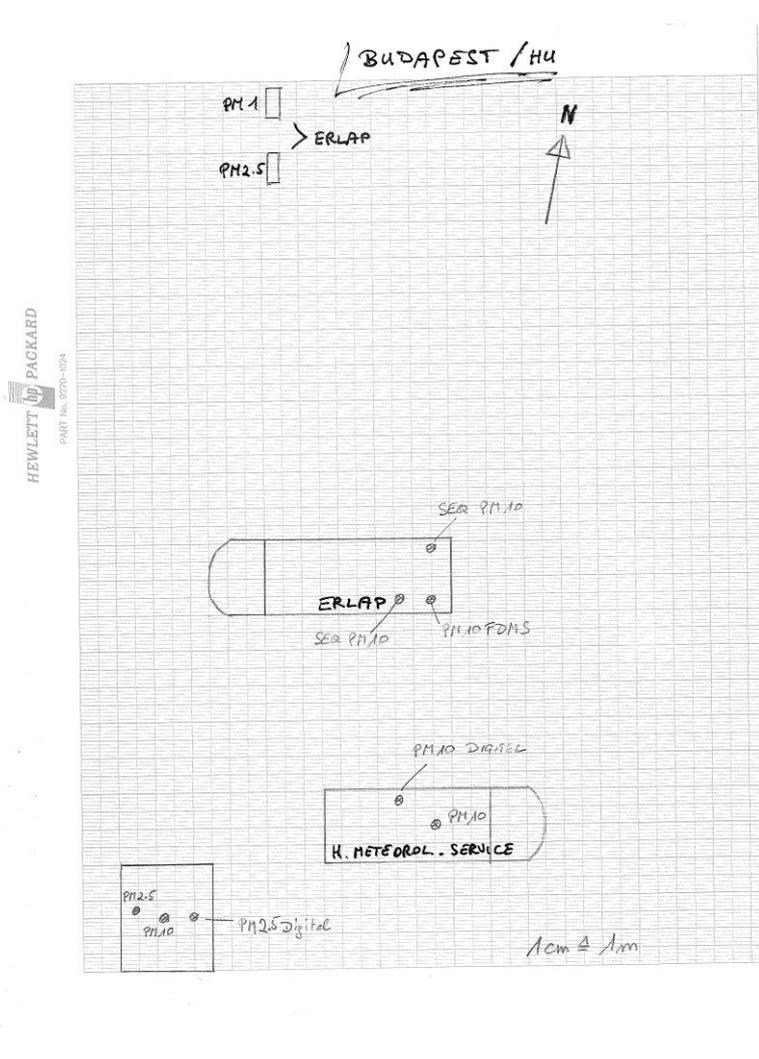


Hungary (Budapest)

Location: Meteorological observatory in the eastern suburb of the city

Sampling: Free of obstacles

Prevailing sources: Domestic heating, traffic

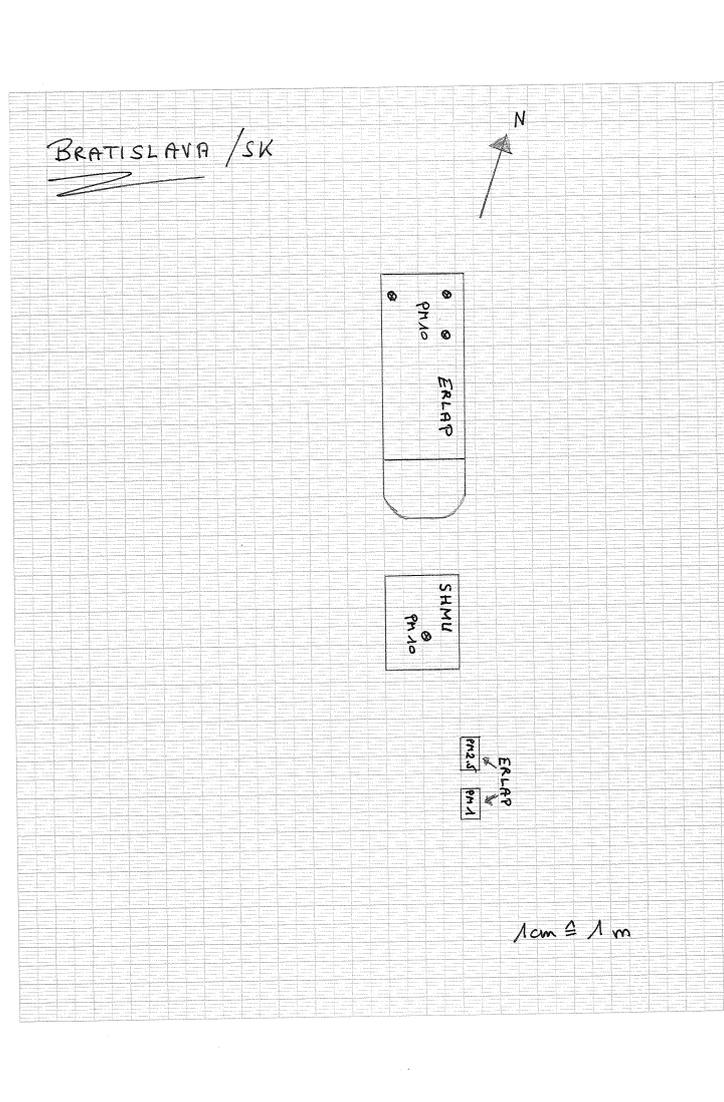


Slovakia (Bratislava)

Location: Next to a footpath on an open field surrounded by apartment buildings, suburb in the south of the city

Sampling: Free of obstacles

Prevailing sources: Domestic heating, traffic



ANNEX 2: Inlets

Type 1: Derenda new (2.3m³/h)



Type 2: Derenda old (2.3m³/h)



Type 3: Leckel SEQ (2.3m³/h)



Type 4: Tecora I (1m³/h)



Type 5: Tecora II (2.3m³/h)



Type 6: Andersen (68m³/h)



Type 7: Digital (1m³/h)



Type 8: Digital High Vol (30m³/h)



Type 9: Teom I (1m³/h)



Type 10: Teom II (1m³/h)



Type 11: Leckel modified (2.3m³/h)



Type 12: FAI PM2.5 & PM10 (2.3m³/h)



Type 13: Derenda High Vol ($30\text{m}^3/\text{h}$)



Type 14: Digital ($2.3\text{m}^3/\text{h}$)



Type 15: Grimm TSP (72 l/h)



Type 16: IVL (18 l/min)

No picture available

Type 17: Aquaria PM 2.5 ($1\text{m}^3/\text{h}$)



Type 18: Aquaria PM 10 ($1\text{m}^3/\text{h}$)



Type 19: Teom PM 1 ($1\text{m}^3/\text{h}$)



Type 20: Unitec ($2.3\text{m}^3/\text{h}$)



Type 21: Zambelli PM 2.5 ($1\text{m}^3/\text{h}$)



Type 22: Zambelli PM 10 ($1\text{m}^3/\text{h}$)



Type 23: Thermo PM10 / PM2.5 ($1\text{m}^3/\text{h}$)



ANNEX 3: Details of applied correction factors

PM10 data in $\mu\text{g}/\text{m}^3$:

| JRC | | Ayuntamiento de Madrid | | | |
|------------------|---------------------------|------------------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 54.44 | 57.07 | 4.83 | 62.78 | 15.31 | |
| 30.63 | 33.74 | 10.17 | 37.11 | 21.19 | |
| 12.79 | 10.15 | -20.66 | 11.17 | -12.73 | |
| 19.22 | 23.04 | 19.88 | 25.34 | 31.86 | |
| 37.96 | 47.05 | 23.95 | 51.76 | 36.34 | |
| 33.16 | 41.22 | 24.32 | 45.34 | 36.76 | |
| 40.55 | 45.69 | 12.66 | 50.26 | 23.93 | |
| 35.93 | 39.85 | 10.90 | 43.84 | 21.99 | |
| 29.09 | 34.80 | 19.61 | 38.28 | 31.57 | |
| 33.71 | 37.58 | 11.47 | 41.34 | 22.62 | |
| 20.47 | 19.21 | -6.17 | 21.13 | 3.22 | |
| 61.95 | 71.50 | 15.41 | 78.65 | 26.95 | |
| 70.99 | 83.13 | 17.10 | 91.44 | 28.82 | |
| 69.15 | 77.11 | 11.51 | 84.82 | 22.67 | |
| Median: | | 12.09 | | 23.30 | |
| Min: | | -20.66 | | -12.73 | |
| Max: | | 24.32 | | 36.76 | |
| Data within DQO: | | 14 | | 8 | |

| JRC | | Instituto do Ambiente | | | |
|------------------|---------------------------|-----------------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 39.78 | 29.00 | -27.10 | 31.90 | -19.81 | |
| 45.06 | 32.42 | -28.06 | 35.66 | -20.87 | |
| 28.47 | 17.00 | -40.28 | 18.70 | -34.31 | |
| 35.84 | 27.83 | -22.34 | 30.62 | -14.57 | |
| 32.19 | 25.25 | -21.55 | 27.78 | -13.71 | |
| 23.66 | 16.50 | -30.25 | 18.15 | -23.28 | |
| 36.78 | 20.67 | -43.81 | 22.73 | -38.19 | |
| 28.80 | 18.08 | -37.21 | 19.89 | -30.93 | |
| 25.18 | 16.00 | -36.45 | 17.60 | -30.09 | |
| 33.19 | 19.92 | -39.99 | 21.91 | -33.99 | |
| 25.16 | 16.17 | -35.75 | 17.78 | -29.33 | |
| 46.07 | 33.00 | -28.37 | 36.30 | -21.21 | |
| 32.65 | 25.42 | -22.16 | 27.96 | -14.37 | |
| 24.86 | 18.25 | -26.58 | 20.08 | -19.24 | |
| Median: | | -29.31 | | -22.24 | |
| Min: | | -43.81 | | -38.19 | |
| Max: | | -21.55 | | -13.71 | |
| Data within DQO: | | 3 | | 8 | |

| JRC | | EPA of the Republic of Slovenia | | | |
|------------------|---------------------------|---------------------------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 24.9 | 30.15 | 21.23 | 31.05 | 24.87 | |
| 29.7 | 28.85 | -2.75 | 29.72 | 0.17 | |
| 30.9 | 27.04 | -12.43 | 27.85 | -9.81 | |
| 21.0 | 20.42 | -2.80 | 21.04 | 0.11 | |
| 28.0 | 26.47 | -5.33 | 27.26 | -2.49 | |
| 40.4 | 35.91 | -11.10 | 36.99 | -8.43 | |
| 40.9 | 37.40 | -8.48 | 38.52 | -5.74 | |
| 38.7 | 37.78 | -2.45 | 38.91 | 0.48 | |
| 43.5 | 39.94 | -8.09 | 41.13 | -5.33 | |
| 42.8 | 41.11 | -3.93 | 42.35 | -1.05 | |
| 42.2 | 36.55 | -13.45 | 45.32 | 7.32 | |
| 28.9 | 26.63 | -7.87 | 33.02 | 14.25 | |
| 28.2 | 27.75 | -1.48 | 34.41 | 22.16 | |
| 29.5 | 28.96 | -1.96 | 35.91 | 21.57 | |
| Median: | | -4.63 | | 0.14 | |
| Min: | | -13.45 | | -9.81 | |
| Max: | | 21.23 | | 24.87 | |
| Data within DQO: | | 14 | | 14 | |

| JRC | | LR Steiermark | | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| | 26.92 | | 35.00 | | |
| | 31.77 | | 41.30 | | |
| 54.4 | 42.77 | -21.38 | 55.60 | 2.21 | |
| 63.1 | 48.15 | -23.71 | 62.60 | -0.83 | |
| 73.4 | 48.54 | -33.91 | 63.10 | -14.08 | |
| 61.3 | 41.46 | -32.35 | 53.90 | -12.05 | |
| 46.4 | 36.15 | -22.10 | 47.00 | 1.27 | |
| 39.3 | 31.85 | -18.92 | 41.40 | 5.41 | |
| 46.1 | 34.77 | -24.57 | 45.20 | -1.93 | |
| 52.1 | 37.15 | -28.66 | 48.30 | -7.26 | |
| 75.0 | 51.31 | -31.58 | 66.70 | -11.05 | |
| 53.7 | 38.31 | -28.73 | 49.80 | -7.34 | |
| 33.4 | 22.77 | -31.85 | 29.60 | -11.40 | |
| 27.9 | 19.85 | -28.78 | 25.80 | -7.41 | |
| Median: | | -28.69 | | -7.30 | |
| Min: | | -33.91 | | -14.08 | |
| Max: | | -18.92 | | 5.41 | |
| Data within DQO: | | 5 | | 12 | |

| JRC | | | CHMI | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 8.63 | 5.22 | -39.47 | 6.79 | -21.31 | |
| 19.03 | 14.11 | -25.86 | 18.34 | -3.62 | |
| 21.90 | 15.59 | -28.80 | 20.27 | -7.44 | |
| 11.10 | 7.97 | -28.18 | 10.37 | -6.63 | |
| 16.82 | 11.65 | -30.76 | 15.14 | -9.99 | |
| 19.57 | 14.37 | -26.57 | 18.68 | -4.54 | |
| 16.93 | 10.75 | -36.53 | 13.97 | -17.49 | |
| 18.82 | 12.78 | -32.12 | 16.61 | -11.76 | |
| 32.63 | 21.53 | -34.00 | 27.99 | -14.21 | |
| 54.61 | 38.88 | -28.80 | 50.55 | -7.44 | |
| 31.11 | 20.04 | -35.59 | 26.05 | -16.27 | |
| 9.78 | 6.40 | -34.57 | 8.32 | -14.94 | |
| 23.26 | 16.70 | -28.21 | 21.71 | -6.68 | |
| 17.01 | 11.44 | -32.72 | 14.88 | -12.54 | |
| Median: | | -31.44 | | -10.87 | |
| Min: | | -39.47 | | -21.31 | |
| Max: | | -25.86 | | -3.62 | |
| Data within DQO: | | 0 | | 14 | |

| JRC | | | HLUG | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 23.0 | 15.00 | -34.68 | 17.70 | -22.93 | |
| 16.1 | 9.00 | -44.15 | 10.62 | -34.10 | |
| 44.4 | 32.00 | -27.99 | 37.76 | -15.03 | |
| 30.6 | 21.00 | -31.41 | 24.78 | -19.07 | |
| 42.5 | 33.00 | -22.28 | 38.94 | -8.29 | |
| 31.9 | 20.00 | -37.29 | 23.60 | -26.01 | |
| 41.8 | 31.00 | -25.92 | 36.58 | -12.59 | |
| 44.0 | 35.00 | -20.46 | 41.30 | -6.14 | |
| 26.0 | 18.00 | -30.72 | 21.24 | -18.25 | |
| 13.4 | 10.00 | -25.44 | 11.80 | -12.02 | |
| 10.6 | 7.00 | -33.84 | 8.26 | -21.93 | |
| 16.6 | 12.00 | -27.60 | 14.16 | -14.57 | |
| 16.2 | 11.00 | -31.90 | 12.98 | -19.64 | |
| Median: | | -30.72 | | -18.25 | |
| Min: | | -44.15 | | -34.10 | |
| Max: | | -20.46 | | -6.14 | |
| Data within DQO: | | 2 | | 11 | |

| JRC | | | Estonian Env. Research Centre (container) | | |
|------------------|---------------------------|-----------------|---|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 7.0 | 7.98 | 14.01 | 9.17 | 31.11 | |
| 6.5 | 6.42 | -0.84 | 7.39 | 14.03 | |
| 4.4 | 3.28 | -25.56 | 3.78 | -14.39 | |
| 7.9 | 6.78 | -14.34 | 7.80 | -1.49 | |
| 8.3 | 5.92 | -28.64 | 6.81 | -17.94 | |
| 23.1 | 15.68 | -32.09 | 18.03 | -21.91 | |
| 13.4 | 10.47 | -22.02 | 12.04 | -10.33 | |
| 20.5 | 17.04 | -16.91 | 19.60 | -4.45 | |
| 7.8 | 7.84 | 0.69 | 9.01 | 15.80 | |
| 9.2 | 8.60 | -6.41 | 9.88 | 7.63 | |
| 9.8 | 7.64 | -21.74 | 8.79 | -10.00 | |
| 7.3 | 6.77 | -6.57 | 7.79 | 7.44 | |
| 11.4 | 9.25 | -19.18 | 10.64 | -7.06 | |
| Median: | | -16.91 | | -4.45 | |
| Min: | | -32.09 | | -21.91 | |
| Max: | | 14.01 | | 31.11 | |
| Data within DQO: | | 10 | | 12 | |

| JRC | | | Estonian Env. Research Centre (mob lab) | | |
|------------------|---------------------------|-----------------|---|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 7.0 | 7.69 | 9.86 | 8.84 | 26.34 | |
| 6.5 | 9.51 | 46.83 | 10.94 | 68.86 | |
| 4.4 | 4.37 | -0.82 | 5.03 | 14.06 | |
| 7.9 | 7.85 | -0.78 | 9.03 | 14.10 | |
| 8.3 | 6.43 | -22.59 | 7.39 | -10.98 | |
| 23.1 | 21.76 | -5.75 | 25.02 | 8.38 | |
| 13.4 | 13.99 | 4.18 | 16.09 | 19.81 | |
| 20.5 | 21.62 | 5.39 | 24.86 | 21.20 | |
| 7.8 | 10.56 | 35.61 | 12.14 | 55.95 | |
| 9.2 | 11.48 | 24.99 | 13.20 | 43.73 | |
| 9.8 | 9.91 | 1.52 | 11.40 | 16.74 | |
| 7.3 | 9.11 | 25.69 | 10.48 | 44.55 | |
| 11.4 | 12.71 | 11.06 | 14.62 | 27.72 | |
| Median: | | 5.39 | | 21.20 | |
| Min: | | -22.59 | | -10.98 | |
| Max: | | 46.83 | | 68.86 | |
| Data within DQO: | | 10 | | 7 | |

| JRC | | | RIVM | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 18.17 | 15.52 | -14.58 | 20.86 | 14.80 | |
| 32.56 | 27.39 | -15.86 | 34.75 | 6.74 | |
| 31.56 | 27.21 | -13.77 | 34.54 | 9.44 | |
| 33.06 | 28.11 | -14.97 | 35.59 | 7.65 | |
| 32.21 | 27.92 | -13.31 | 35.37 | 9.81 | |
| 35.80 | 31.88 | -10.94 | 40.00 | 11.74 | |
| 36.32 | 34.36 | -5.39 | 42.90 | 18.13 | |
| 46.47 | 45.03 | -3.09 | 55.39 | 19.19 | |
| 40.11 | 37.70 | -6.01 | 46.81 | 16.69 | |
| 26.32 | 22.24 | -15.51 | 28.72 | 9.11 | |
| 26.41 | 23.30 | -11.79 | 29.96 | 13.43 | |
| 34.25 | 30.03 | -12.32 | 37.84 | 10.47 | |
| 67.86 | 62.56 | -7.82 | 75.89 | 11.83 | |
| 73.19 | 70.09 | -4.23 | 84.71 | 15.74 | |
| Median: | | -12.05 | | 11.79 | |
| Min: | | -15.86 | | 6.74 | |
| Max: | | -3.09 | | 19.19 | |
| Data within DQO: | | 14 | | 14 | |

| JRC | | | VMM - ESM Andersen | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 28.38 | 19.71 | -30.55 | 27.00 | -4.86 | |
| 37.48 | 26.28 | -29.90 | 36.00 | -3.96 | |
| 36.88 | 27.01 | -26.76 | 37.00 | 0.33 | |
| 37.40 | 24.82 | -33.64 | 34.00 | -9.09 | |
| 30.26 | 20.44 | -32.46 | 28.00 | -7.47 | |
| 33.79 | 25.55 | -24.38 | 35.00 | 3.59 | |
| 50.64 | 37.96 | -25.05 | 52.00 | 2.68 | |
| 48.95 | 43.80 | -10.53 | 60.00 | 22.57 | |
| 24.07 | 26.28 | 9.17 | 36.00 | 49.56 | |
| 26.65 | 20.44 | -23.30 | 28.00 | 5.08 | |
| 22.72 | 20.44 | -10.03 | 28.00 | 23.27 | |
| 17.14 | 15.33 | -10.58 | 21.00 | 22.51 | |
| 23.43 | 18.25 | -22.13 | 25.00 | 6.69 | |
| 41.39 | 31.39 | -24.17 | 43.00 | 3.88 | |
| Median: | | -24.28 | | 3.74 | |
| Min: | | -33.64 | | -9.09 | |
| Max: | | 9.17 | | 49.56 | |
| Data within DQO: | | 8 | | 13 | |

| JRC | | | VMM - Teom 1400 | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 28.38 | 21.09 | -25.69 | 31.00 | 9.23 | |
| 37.48 | 25.17 | -32.85 | 37.00 | -1.29 | |
| 36.88 | 21.77 | -40.97 | 32.00 | -13.22 | |
| 37.40 | 23.81 | -36.34 | 35.00 | -6.42 | |
| 30.26 | 20.41 | -32.55 | 30.00 | -0.86 | |
| 33.79 | 27.89 | -17.45 | 41.00 | 21.35 | |
| 50.64 | 36.05 | -28.81 | 53.00 | 4.65 | |
| 48.95 | 24.49 | -49.97 | 36.00 | -26.46 | |
| 24.07 | 19.73 | -18.04 | 29.00 | 20.48 | |
| 26.65 | 21.09 | -20.86 | 31.00 | 16.34 | |
| 22.72 | 19.05 | -16.15 | 28.00 | 23.27 | |
| 17.14 | 15.65 | -8.72 | 23.00 | 34.17 | |
| 23.43 | 20.41 | -12.91 | 30.00 | 28.02 | |
| 41.39 | 30.61 | -26.04 | 45.00 | 8.72 | |
| Median: | | -25.87 | | 8.98 | |
| Min: | | -49.97 | | -26.46 | |
| Max: | | -8.72 | | 34.17 | |
| Data within DQO: | | 6 | | 11 | |

| JRC | | | ISSeP - MP 101 sn 33 | | |
|------------------|---------------------------|-----------------|------------------------|-----------------|--|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % | |
| 28.38 | 24.00 | -15.43 | 25.92 | -8.67 | |
| 37.48 | 27.00 | -27.97 | 29.16 | -22.21 | |
| 36.88 | 30.00 | -18.65 | 32.40 | -12.14 | |
| 37.40 | 26.00 | -30.48 | 28.08 | -24.92 | |
| 30.26 | 20.00 | -33.90 | 21.60 | -28.62 | |
| 33.79 | 26.00 | -23.04 | 28.08 | -16.89 | |
| 50.64 | 37.00 | -26.94 | 39.96 | -21.10 | |
| 48.95 | 39.00 | -20.33 | 42.12 | -13.96 | |
| 24.07 | 18.00 | -25.22 | 19.44 | -19.24 | |
| 26.65 | 22.00 | -17.43 | 23.76 | -10.83 | |
| 22.72 | 19.00 | -16.36 | 20.52 | -9.66 | |
| 17.14 | 15.00 | -12.49 | 16.20 | -5.49 | |
| 23.43 | 19.00 | -18.92 | 20.52 | -12.43 | |
| 41.39 | 32.00 | -22.69 | 34.56 | -16.51 | |
| Median: | | -21.51 | | -15.23 | |
| Min: | | -33.90 | | -28.62 | |
| Max: | | -12.49 | | -5.49 | |
| Data within DQO: | | 9 | | 13 | |

JRC

ISSeP - MP 101 sn 78

| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
|-----------------|---------------------------|-----------------|------------------------|-----------------|
| 28.38 | | | | |
| 37.48 | 24.00 | -35.97 | 25.92 | -30.85 |
| 36.88 | 26.00 | -29.49 | 28.08 | -23.85 |
| 37.40 | 24.00 | -35.83 | 25.92 | -30.70 |
| 30.26 | 18.00 | -40.51 | 19.44 | -35.75 |
| 33.79 | 26.00 | -23.04 | 28.08 | -16.89 |
| 50.64 | 36.00 | -28.92 | 38.88 | -23.23 |
| 48.95 | 36.00 | -26.46 | 38.88 | -20.58 |
| 24.07 | 17.00 | -29.37 | 18.36 | -23.72 |
| 26.65 | 19.00 | -28.69 | 20.52 | -22.99 |
| 22.72 | 15.00 | -33.96 | 16.20 | -28.68 |
| 17.14 | 14.00 | -18.33 | 15.12 | -11.79 |
| 23.43 | 19.00 | -18.92 | 20.52 | -12.43 |
| 41.39 | 29.00 | -29.94 | 31.32 | -24.33 |

Median:

Min:

Max:

Data within DQO:

| |
|--------|
| -29.37 |
| -40.51 |
| -18.33 |
| 3 |

| |
|--------|
| -23.72 |
| -35.75 |
| -11.79 |
| 9 |

JRC

Hungarian Meteorological Institute - FH62 IR

| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
|-----------------|---------------------------|-----------------|------------------------|-----------------|
| 22.67 | 21.75 | -4.03 | 23.93 | 5.57 |
| 31.14 | 22.87 | -26.56 | 25.16 | -19.21 |
| 51.48 | 36.95 | -28.23 | 40.64 | -21.06 |
| 62.31 | 53.83 | -13.62 | 59.21 | -4.98 |
| 60.91 | 49.55 | -18.66 | 54.50 | -10.53 |
| 77.86 | 63.43 | -18.54 | 69.77 | -10.39 |
| 73.63 | 63.55 | -13.69 | 69.90 | -5.06 |
| 32.94 | 24.86 | -24.52 | 27.35 | -16.97 |
| 15.90 | 12.73 | -19.95 | 14.00 | -11.94 |
| 22.22 | 15.60 | -29.80 | 17.16 | -22.78 |
| 42.01 | 30.53 | -27.33 | 33.58 | -20.06 |
| 40.04 | 30.94 | -22.74 | 34.03 | -15.02 |
| 68.96 | 50.19 | -27.22 | 55.21 | -19.94 |
| 65.44 | 51.25 | -21.67 | 56.38 | -13.84 |

Median:

Min:

Max:

Data within DQO:

| |
|--------|
| -22.21 |
| -29.80 |
| -4.03 |
| 9 |

| |
|--------|
| -14.43 |
| -22.78 |
| 5.57 |
| 14 |

JRC

MDV Hungary - FH62 IR

| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
|-----------------|---------------------------|-----------------|------------------------|-----------------|
| 22.67 | 21.36 | -5.76 | 23.50 | 3.67 |
| 31.14 | | | | |
| 51.48 | 40.73 | -20.89 | 44.80 | -12.98 |
| 62.31 | 51.55 | -17.28 | 56.70 | -9.01 |
| 60.91 | 51.73 | -15.08 | 56.90 | -6.59 |
| 77.86 | 63.00 | -19.08 | 69.30 | -10.99 |
| 73.63 | 58.73 | -20.24 | 64.60 | -12.26 |
| 32.94 | 25.73 | -21.89 | 28.30 | -14.08 |
| 15.90 | 13.27 | -16.52 | 14.60 | -8.17 |
| 22.22 | 17.55 | -21.05 | 19.30 | -13.15 |
| 42.01 | 34.09 | -18.84 | 37.50 | -10.73 |
| 40.04 | 32.09 | -19.86 | 35.30 | -11.85 |
| 68.96 | 53.82 | -21.96 | 59.20 | -14.16 |
| 65.44 | 56.18 | -14.14 | 61.80 | -5.56 |

Median:

Min:

Max:

Data within DQO:

| |
|--------|
| -19.08 |
| -21.96 |
| -5.76 |
| 13 |

| |
|--------|
| -10.99 |
| -14.16 |
| 3.67 |
| 13 |

PM2.5 data in $\mu\text{g}/\text{m}^3$:

| JRC | | | CHMI | |
|------------------|---------------------------|-----------------|------------------------|-----------------|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
| 5.90 | 4.09 | -30.73 | 5.31 | -9.94 |
| 13.81 | 9.06 | -34.39 | 11.78 | -14.71 |
| 15.41 | 8.78 | -43.02 | 11.42 | -25.93 |
| 7.87 | 5.40 | -31.33 | 7.02 | -10.73 |
| 12.96 | 8.98 | -30.71 | 11.68 | -9.92 |
| 16.31 | 11.36 | -30.35 | 14.77 | -9.45 |
| 15.11 | 7.62 | -49.57 | 9.91 | -34.45 |
| 16.03 | 9.32 | -41.84 | 12.12 | -24.39 |
| 25.19 | 15.27 | -39.39 | 19.85 | -21.20 |
| 46.83 | 32.05 | -31.56 | 41.66 | -11.02 |
| 25.35 | 13.69 | -46.01 | 17.80 | -29.81 |
| 6.79 | 4.32 | -36.46 | 5.61 | -17.40 |
| 16.26 | 10.75 | -33.84 | 13.98 | -13.99 |
| 14.69 | 8.44 | -42.55 | 10.98 | -25.31 |
| Median: | | -35.42 | | -16.05 |
| Min: | | -49.57 | | -34.45 |
| Max: | | -30.35 | | -9.45 |
| Data within DQO: | | 0 | | 10 |

| JRC | | | Estonian Env. Research Centre (container) | |
|------------------|---------------------------|-----------------|---|-----------------|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
| 3.9 | 3.21 | -17.65 | 3.69 | -5.30 |
| 4.3 | 2.44 | -42.84 | 2.81 | -34.27 |
| 6.8 | 3.79 | -44.09 | 4.36 | -35.70 |
| 7.1 | 3.35 | -53.06 | 3.85 | -46.02 |
| 15.0 | 7.19 | -51.95 | 8.27 | -44.74 |
| 7.1 | 3.83 | -46.18 | 4.41 | -38.10 |
| 6.7 | 4.47 | -33.62 | 5.14 | -23.66 |
| 12.5 | 8.56 | -31.71 | 9.85 | -21.47 |
| 4.5 | 3.50 | -21.98 | 4.03 | -10.27 |
| 4.2 | 4.01 | -5.51 | 4.61 | 8.67 |
| 4.5 | 5.05 | 11.95 | 5.80 | 28.74 |
| 5.1 | 3.42 | -32.56 | 3.94 | -22.44 |
| 6.7 | 4.15 | -37.56 | 4.78 | -28.20 |
| Median: | | -33.62 | | -23.66 |
| Min: | | -53.06 | | -46.02 |
| Max: | | 11.95 | | 28.74 |
| Data within DQO: | | 4 | | 6 |

| JRC | | | MDV Hungary - FH62 IR | |
|------------------|---------------------------|-----------------|------------------------|-----------------|
| Reference value | without correction factor | Difference in % | with correction factor | Difference in % |
| 20.46 | 12.60 | -38.44 | 16.50 | -19.35 |
| 29.10 | 14.12 | -51.47 | 18.50 | -36.43 |
| 50.43 | 25.34 | -49.75 | 33.20 | -34.17 |
| 60.33 | 35.95 | -40.41 | 47.10 | -21.93 |
| 59.80 | 33.74 | -43.58 | 44.20 | -26.08 |
| 76.01 | 44.58 | -41.35 | 58.40 | -23.17 |
| 72.19 | 41.07 | -43.11 | 53.80 | -25.47 |
| 30.84 | 15.34 | -50.25 | 20.10 | -34.82 |
| 14.24 | 6.79 | -52.28 | 8.90 | -37.49 |
| 20.38 | 9.69 | -52.44 | 12.70 | -37.69 |
| 41.37 | 21.37 | -48.34 | 28.00 | -32.32 |
| 33.77 | 19.31 | -42.82 | 25.30 | -25.09 |
| 52.34 | 26.34 | -49.68 | 34.50 | -34.08 |
| 58.60 | 32.98 | -43.72 | 43.20 | -26.28 |
| Median: | | -46.03 | | -29.30 |
| Min: | | -52.44 | | -37.69 |
| Max: | | -38.44 | | -19.35 |
| Data within DQO: | | 0 | | 3 |

ANNEX 4: All “normalized” data-sets

PM10 codification and Mandel’s *h* and *k* statistics

| Codification | Laboratory | Instrument | Measurement day | | | | | | | | | | | | | | | | | mean | s | n | Mandel | | | |
|--------------|------------|------------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----|----|------|-------|-------|--------|-------|--------|-------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | | | | 18 | 19 | h | k |
| 1 | ISCIH | Derenda MVS 6.1 (LVS) A | 0.918 | 0.914 | 0.860 | 0.885 | 0.922 | 0.905 | 0.863 | 0.891 | 0.894 | 0.860 | 0.879 | 0.872 | 0.859 | | | | | | | 0.886 | 0.023 | 13 | -0.547 | 0.167 |
| 2 | ISCIH | Derenda MVS 6.1 (LVS) B | | 0.882 | 0.938 | 0.885 | 0.896 | 0.905 | 0.863 | 0.863 | | | | | | | | | | | | 0.890 | 0.026 | 7 | -0.520 | 0.189 |
| 3 | AdM | Teom 1400 | 1.153 | 1.212 | 0.873 | 1.319 | 1.363 | 1.368 | 1.239 | 1.220 | 1.316 | 1.226 | 1.032 | 1.270 | 1.288 | | | | | | | 1.221 | 0.138 | 13 | 1.869 | 0.994 |
| 4 | IdA | Tecora Low Vol | | 1.099 | 1.730 | 0.943 | 0.286 | 1.778 | 0.911 | 1.035 | 1.597 | 0.928 | 2.138 | 1.115 | 1.043 | 1.273 | | | | | | 1.221 | 0.481 | 13 | 1.868 | 3.462 |
| 5 | IdA | Andersen High Vol | 0.781 | 0.813 | | 1.003 | 0.896 | 0.921 | 0.882 | 1.080 | 0.928 | 1.023 | 1.217 | 1.071 | 1.075 | 0.995 | | | | | | 0.976 | 0.121 | 13 | 0.099 | 0.872 |
| 6 | IdA | Environnemen MP 101 | 0.802 | 0.791 | 0.657 | 0.854 | 0.863 | 0.767 | | 0.618 | 0.691 | 0.699 | 0.660 | 0.707 | 0.788 | 0.856 | 0.808 | | | | | 0.754 | 0.081 | 14 | -1.498 | 0.586 |
| 7 | EPA SI | Derenda 3.1-15(LVS) | | | | | | | | 1.052 | 1.110 | 1.036 | 1.192 | 1.066 | 1.488 | 1.172 | 1.083 | | | | | 1.150 | 0.147 | 8 | 1.353 | 1.061 |
| 8 | EPA SI | Teom 1400, std...c/corr.fact | 1.249 | 1.002 | 0.902 | 1.001 | 0.975 | 0.916 | 0.943 | 1.005 | 0.947 | 0.990 | 1.073 | 1.142 | 1.222 | 1.216 | | | | | | 1.041 | 0.119 | 14 | 0.572 | 0.853 |
| 9 | EIMV | Tecora | 1.079 | 1.070 | 1.047 | 1.004 | 1.040 | 1.081 | 1.025 | 1.051 | 1.049 | 1.062 | 1.121 | 1.161 | 1.150 | | | | | | | 1.072 | 0.047 | 13 | 0.795 | 0.335 |
| 10 | Anhovo | Tecora | 1.037 | 1.055 | 1.055 | 0.984 | 0.988 | 1.022 | 1.007 | 1.044 | 1.015 | 1.048 | 1.105 | 1.139 | 1.111 | 1.121 | | | | | | 1.052 | 0.050 | 14 | 0.649 | 0.357 |
| 11 | EIMV | Andersen | 1.138 | 1.167 | 1.097 | | | 1.236 | | | | 1.182 | 1.288 | | 1.308 | 1.283 | | | | | 1.212 | 0.078 | 8 | 1.804 | 0.559 | |
| 12 | UBA AT | Digitel | | | 0.950 | 0.952 | 0.989 | 0.955 | 0.958 | 0.944 | 0.945 | 0.966 | 0.931 | 0.956 | 0.961 | 0.995 | | | | | | 0.959 | 0.018 | 12 | -0.026 | 0.131 |
| 13 | LROOe | Digitel | | | 0.960 | 0.945 | 0.952 | 0.920 | 0.931 | 0.951 | 0.953 | 0.966 | 0.947 | 0.944 | 0.927 | 0.947 | | | | | | 0.945 | 0.013 | 12 | -0.123 | 0.096 |
| 14 | UBA AT | Teom FDMS | | | 0.964 | 0.971 | 0.970 | 0.976 | 0.981 | 0.974 | 0.941 | 0.961 | 0.922 | 1.016 | 0.935 | 0.932 | | | | | | 0.962 | 0.026 | 12 | -0.001 | 0.186 |
| 15 | LROOe | Teom FDMS | | | 0.962 | 0.956 | 0.953 | 0.937 | 0.904 | 0.895 | 0.899 | 0.914 | 0.917 | 0.940 | 0.792 | 0.783 | | | | | | 0.904 | 0.059 | 12 | -0.417 | 0.424 |
| 16 | LR Stmk. | Digitel | | | 0.897 | 0.871 | 0.837 | 0.767 | 0.865 | 0.877 | 0.854 | 0.856 | 0.841 | 0.850 | 0.831 | 0.877 | | | | | | 0.852 | 0.033 | 12 | -0.794 | 0.235 |
| 17 | LR Stmk. | FH 62 IR | | | 1.022 | 0.992 | 0.859 | 0.879 | 1.013 | 1.054 | 0.981 | 0.927 | 0.890 | 0.927 | 0.886 | 0.926 | | | | | | 0.946 | 0.064 | 12 | -0.114 | 0.461 |
| 18 | CHMI | FH95KF (nitrocell) | 1.265 | 1.027 | 1.019 | 1.018 | 0.911 | 0.927 | 0.929 | 0.911 | 0.863 | 0.949 | 0.938 | 0.925 | 0.899 | 0.945 | | | | | | 0.966 | 0.098 | 14 | 0.029 | 0.708 |
| 19 | CHMI | FH95KF (glass) | 0.642 | 0.874 | 0.860 | 0.720 | 0.838 | 0.810 | 0.797 | 0.852 | 0.847 | 0.950 | 0.911 | 0.756 | 0.828 | 0.839 | | | | | | 0.823 | 0.078 | 14 | -1.002 | 0.560 |
| 20 | CHMI | Derenda SEQ Low Vol | 0.831 | 0.911 | 0.880 | 0.878 | 0.852 | 0.875 | 0.911 | 0.904 | 0.904 | 0.969 | 0.909 | 0.861 | 0.808 | 0.879 | | | | | | 0.884 | 0.040 | 14 | -0.565 | 0.286 |
| 21 | CHMI | Derenda SEQ Hi Vol B | 0.970 | 1.026 | 1.019 | 1.633 | 0.995 | 1.141 | 0.906 | 0.815 | 1.026 | 0.971 | 0.986 | 1.284 | 1.019 | 1.066 | | | | | | 1.061 | 0.194 | 14 | 0.715 | 1.411 |
| 22 | CHMI | Derenda SEQ Hi Vol A | 0.970 | 0.952 | 0.892 | 1.255 | 0.912 | 0.998 | 0.906 | 0.889 | 0.897 | 0.945 | 0.986 | 1.283 | 0.959 | 1.066 | | | | | | 0.993 | 0.127 | 14 | 0.226 | 0.911 |
| 23 | CHMI | MCZ/Andersen Hi Vol | 0.716 | 1.103 | 1.028 | 1.238 | 1.114 | 1.133 | 1.011 | 0.963 | 0.932 | 0.852 | 0.878 | 1.396 | 0.987 | 1.021 | | | | | | 1.027 | 0.169 | 14 | 0.464 | 1.215 |
| 24 | CHMI | FH62IR | 0.787 | 0.964 | 0.926 | 0.934 | 0.900 | 0.955 | 0.825 | 0.882 | 0.858 | 0.926 | 0.837 | 0.851 | 0.933 | 0.875 | | | | | | 0.889 | 0.053 | 14 | -0.524 | 0.381 |
| 25 | LANUV | Digitel 4 | 0.936 | 0.939 | 0.997 | 0.999 | 1.033 | 0.950 | 1.013 | 1.017 | 0.920 | 0.947 | 0.988 | 0.946 | 0.999 | | | | | | | 0.976 | 0.037 | 13 | 0.099 | 0.266 |
| 26 | LANUV | Digitel 37 | 0.913 | 0.918 | 0.997 | 0.984 | 1.021 | 0.893 | 0.987 | 1.009 | 0.851 | 1.046 | 0.992 | 0.953 | 0.940 | | | | | | | 0.962 | 0.056 | 13 | -0.002 | 0.405 |
| 27 | HLUG | SEQ Leckel | 0.986 | 0.993 | 1.017 | 1.004 | 1.020 | 1.027 | 1.045 | 1.039 | 0.998 | 0.993 | 1.075 | 1.058 | 0.946 | | | | | | | 1.015 | 0.034 | 13 | 0.384 | 0.247 |
| 28 | HLUG | FH62 I-R Sharp | 0.993 | 0.962 | 1.163 | 1.009 | 1.178 | 0.834 | 0.970 | 1.054 | 0.870 | 0.678 | 0.973 | 0.947 | 0.836 | | | | | | | 0.959 | 0.135 | 13 | -0.022 | 0.975 |
| 29 | HLUG | FH62 I-R | 0.771 | 0.659 | 0.850 | 0.809 | 0.917 | 0.740 | 0.874 | 0.939 | 0.817 | 0.880 | 0.781 | 0.854 | 0.804 | | | | | | | 0.823 | 0.076 | 13 | -1.006 | 0.544 |
| 30 | NERI | SM200 | 0.899 | 0.836 | 0.593 | 0.812 | 0.858 | 0.852 | 0.905 | 1.097 | 0.748 | | 0.865 | | | | | | | | | 0.846 | 0.127 | 10 | -0.834 | 0.912 |
| 31 | NERI | Teom | 0.711 | 0.732 | 0.768 | 0.807 | 0.728 | 0.759 | 0.744 | 0.642 | 0.635 | 0.708 | 0.661 | | | | | | | | | 0.718 | 0.054 | 11 | -1.762 | 0.388 |
| 32 | ITM | SEQ Leckel | | | 1.072 | 1.045 | 1.122 | 1.081 | | 1.093 | 1.123 | 1.044 | 0.982 | 0.980 | 0.978 | 0.948 | 0.950 | | | | | 1.035 | 0.065 | 12 | 0.524 | 0.467 |
| 33 | IVL | IVL 10 A | | | | | | | | | | | | | 1.474 | 1.634 | 1.221 | | | | | 1.443 | 0.208 | 3 | 3.467 | 1.498 |
| 34 | IVL | IVL10 B | | | | | | | | | | | | | 1.336 | 1.407 | 1.238 | | | | | 1.327 | 0.085 | 3 | 2.630 | 0.613 |
| 35 | EHAS | Teom | 1.013 | 1.220 | 1.114 | 1.081 | 1.170 | 1.195 | | 1.186 | 1.357 | 0.940 | 0.826 | 1.138 | 1.079 | 1.006 | 0.860 | | | | | 1.085 | 0.146 | 14 | 0.883 | 1.047 |
| 36 | EHAS | FDMS | | | | | 1.290 | 1.320 | | 1.237 | 1.499 | 1.188 | 1.074 | 1.326 | 1.159 | 1.169 | 1.150 | | | | | 1.241 | 0.122 | 10 | 2.012 | 0.876 |
| 37 | FMI | FH-62 IR 632 | 1.054 | 1.163 | 1.193 | 1.379 | 0.899 | 0.995 | 0.857 | 0.790 | 0.983 | 1.305 | 0.952 | 0.976 | 0.892 | 0.926 | | | | | | 1.026 | 0.173 | 14 | 0.460 | 1.244 |
| 38 | FMI | FH-62 IR 280 | 1.084 | 1.180 | 1.134 | 1.353 | 0.974 | 1.124 | 0.850 | 0.838 | 1.018 | 1.221 | 1.006 | 0.997 | 0.921 | 0.930 | | | | | | 1.045 | 0.146 | 14 | 0.597 | 1.054 |
| 39 | EERC | Digitel Container | 0.753 | 0.651 | | 0.775 | 0.689 | 0.790 | | 0.804 | 0.847 | 0.981 | 0.922 | 1.098 | 0.854 | 0.924 | | | | | | 0.841 | 0.126 | 12 | -0.875 | 0.906 |
| 40 | EERC | Digitel Mob.Lab. | 0.615 | 0.557 | | 0.687 | 0.632 | 0.782 | | 0.815 | 0.811 | 0.911 | 0.869 | 1.006 | 0.790 | 0.793 | | | | | | 0.772 | 0.130 | 12 | -1.368 | 0.933 |

PM2.5 codification and Mandel's *h* and *k* statistics

| Codification | Laboratory | Instrument | Measurement day | | | | | | | | | | | | | | | | | mean | s | n | Mandell | | | | | | | | |
|--------------|------------|----------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---|---------|----|---|-------|-------|-------|--------|--------|-------|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | | | | 18 | 19 | h | k | | | | | |
| 1 | ISCI | Derenda MVS 6.1 (LVS) | 0.942 | 0.954 | 0.902 | 0.946 | 0.873 | 0.796 | 0.782 | 0.851 | 0.884 | 0.950 | 0.825 | 0.844 | | | | | | | | | | | | 0.879 | 0.061 | 12 | -0.137 | 0.294 | |
| 2 | IdA | Tecora | 1.058 | 0.980 | | 0.819 | 0.897 | 0.871 | 0.733 | 0.924 | 0.866 | 0.855 | 1.049 | 0.916 | 1.097 | 0.909 | | | | | | | | | | | 0.921 | 0.103 | 13 | -0.018 | 0.495 |
| 3 | EPA SI | Seq Leckel | 1.071 | 0.954 | 0.956 | 1.051 | 1.023 | 0.942 | 1.055 | 0.975 | 0.995 | 0.913 | 1.054 | 1.048 | 1.108 | 1.124 | | | | | | | | | | | 1.019 | 0.064 | 14 | 0.261 | 0.311 |
| 4 | UBA AT | Digitel | | | 0.920 | 0.941 | 0.944 | | | | | | | | | | | | | | | | | | | 0.935 | 0.013 | 3 | 0.022 | 0.063 | |
| 5 | LROOe | Digitel | | | 0.881 | 0.900 | 0.908 | 0.891 | 0.913 | 0.907 | 0.904 | 0.900 | 0.914 | 0.886 | 0.899 | 0.921 | | | | | | | | | | | 0.902 | 0.012 | 12 | -0.072 | 0.057 |
| 6 | CHMI | Seq Leckel LVS | 0.834 | 0.783 | 0.709 | 0.480 | | 0.736 | 0.724 | 0.741 | 0.690 | 0.768 | 0.795 | 0.628 | 0.674 | 0.695 | | | | | | | | | | | 0.712 | 0.089 | 13 | -0.611 | 0.428 |
| 7 | CHMI | Seq Derenda LVS | 0.822 | 0.914 | 0.968 | 1.027 | 0.906 | 0.926 | 0.907 | 0.945 | 0.910 | 0.980 | 0.997 | 0.954 | 0.890 | 0.871 | | | | | | | | | | | 0.930 | 0.053 | 14 | 0.007 | 0.258 |
| 8 | CHMI | FH62IR | 0.901 | 0.853 | 0.741 | 0.893 | 0.901 | 0.906 | 0.656 | 0.756 | 0.788 | 0.907 | 0.702 | 0.826 | 0.860 | 0.747 | | | | | | | | | | | 0.817 | 0.085 | 14 | -0.314 | 0.409 |
| 9 | NERI | Teom | 0.539 | 0.467 | 0.705 | 0.773 | 0.645 | 0.709 | 0.717 | 0.704 | 0.606 | 0.683 | 0.605 | | | | | | | | | | | | | 0.650 | 0.089 | 11 | -0.786 | 0.431 | |
| 10 | IVL | IVL 2.5 A | 2.985 | 3.249 | 2.220 | | | | | | 2.801 | 2.159 | 0.565 | 1.857 | 2.817 | 0.848 | | | | | | | | | | | 2.167 | 0.940 | 9 | 3.518 | 4.537 |
| 11 | IVL | IVL 2.5 B | 2.452 | 2.022 | 2.021 | | | | | | | | | | | | | | | | | | | | | | 2.165 | 0.248 | 3 | 3.513 | 1.199 |
| 12 | EHAS | Teom | 0.389 | 0.293 | 0.367 | 0.389 | 0.293 | 0.213 | 0.299 | 0.727 | 0.333 | 0.391 | 0.582 | 0.657 | 0.513 | 0.562 | | | | | | | | | | | 0.429 | 0.154 | 14 | -1.414 | 0.742 |
| 13 | EERC | Thermo FH 62 I-R Container | 0.947 | 0.657 | | 0.643 | 0.540 | 0.553 | 0.619 | 0.763 | 0.785 | 0.897 | 1.087 | 1.287 | 0.776 | 0.718 | | | | | | | | | | | 0.790 | 0.217 | 13 | -0.389 | 1.047 |
| 14 | GGD | Seq Derenda Low Vol | | 0.887 | | | | | | 0.940 | 0.828 | 0.948 | 0.948 | 0.923 | 0.936 | 0.935 | | | | | | | | | | | 0.918 | 0.041 | 8 | -0.026 | 0.199 |
| 15 | VMM | Seq Leckel (Whatman) | | 1.172 | 1.093 | 1.113 | 1.119 | 1.043 | 1.095 | 1.113 | 0.997 | 1.028 | 0.962 | 0.983 | 1.016 | 1.132 | | | | | | | | | | | 1.067 | 0.065 | 13 | 0.396 | 0.316 |
| 16 | VMM | Seq Leckel (Pall) | 0.998 | 1.088 | 1.009 | 1.002 | 1.005 | 0.999 | 1.015 | 1.019 | 0.891 | 0.927 | 0.881 | 0.919 | 0.959 | 1.050 | | | | | | | | | | | 0.983 | 0.060 | 14 | 0.158 | 0.289 |
| 17 | Issep | Sw126 Grav. | 0.829 | 0.889 | 0.875 | 0.800 | 0.844 | 0.770 | 0.877 | 0.861 | 0.689 | 0.763 | 0.684 | 0.874 | 0.698 | 0.893 | | | | | | | | | | | 0.810 | 0.077 | 14 | -0.332 | 0.371 |
| 18 | Issep | Sw.129 Grav. | 0.857 | 0.923 | 0.915 | 0.878 | 0.892 | 0.741 | 0.877 | 0.926 | 0.823 | 0.803 | | 0.732 | 0.767 | 0.962 | | | | | | | | | | | 0.854 | 0.074 | 13 | -0.209 | 0.359 |
| 19 | Issep | Sw126 Beta | 0.846 | 0.872 | 0.890 | 0.812 | 0.799 | 0.759 | 0.871 | 0.898 | 0.815 | 0.855 | 0.666 | 0.707 | 0.722 | 0.920 | | | | | | | | | | | 0.817 | 0.078 | 14 | -0.314 | 0.374 |
| 20 | Issep | Sw.129 Beta | 0.812 | 0.943 | 0.938 | 0.892 | 0.877 | 0.849 | 0.903 | 0.921 | 0.795 | 0.840 | | 0.669 | 0.688 | 0.885 | | | | | | | | | | | 0.847 | 0.087 | 13 | -0.228 | 0.421 |
| 21 | Issep | Grimm 180 | 1.167 | 1.301 | 1.072 | 0.988 | 1.028 | 1.001 | 1.005 | 1.122 | 1.220 | 1.221 | 0.989 | 0.961 | 0.968 | 1.159 | | | | | | | | | | | 1.086 | 0.112 | 14 | 0.450 | 0.538 |
| 22 | VMM | ESM BXR801 | 0.763 | 1.001 | 1.032 | 1.005 | 0.731 | 0.722 | 0.982 | 1.311 | 1.193 | 1.099 | 1.124 | 0.872 | 1.020 | 1.023 | | | | | | | | | | | 0.991 | 0.172 | 14 | 0.181 | 0.828 |
| 23 | GGD | Seq Derenda Low Vol | 0.862 | 0.925 | 0.848 | 0.273 | 0.885 | | 0.833 | | 0.963 | | 0.892 | | 0.801 | 1.035 | | | | | | | | | | | 0.832 | 0.207 | 10 | -0.272 | 1.001 |
| 24 | Airparif | Teom FDMS | 0.960 | 0.993 | 1.151 | 1.046 | 0.969 | 1.035 | 1.002 | 1.174 | 1.146 | 0.951 | 1.086 | 1.006 | 1.020 | 1.134 | | | | | | | | | | | 1.048 | 0.077 | 14 | 0.346 | 0.369 |
| 25 | BV | Partisol Emfab | | | | | | 1.356 | 0.987 | 1.259 | 0.850 | 0.811 | 1.127 | 0.924 | 0.959 | 0.902 | | | | | | | | | | | 1.019 | 0.188 | 9 | 0.261 | 0.906 |
| 26 | NPT | Partisol | 1.079 | 1.153 | 1.081 | 1.156 | 1.017 | 1.085 | 1.415 | 1.057 | 1.224 | 1.011 | 1.149 | 1.279 | 0.831 | 1.199 | | | | | | | | | | | 1.124 | 0.138 | 14 | 0.558 | 0.665 |
| 27 | BV | Teom FDMS | 0.702 | 0.907 | 0.904 | 1.090 | 0.882 | 0.717 | 0.818 | 0.806 | 0.812 | 0.911 | 1.011 | 0.974 | 1.339 | 1.464 | | | | | | | | | | | 0.952 | 0.219 | 14 | 0.071 | 1.057 |
| 28 | ARPA | Zambelli | 0.802 | 0.764 | | | | | | | | | | | | | 0.811 | 0.774 | 0.738 | 0.818 | 1.263 | | | | | 0.853 | 0.183 | 7 | -0.211 | 0.884 | |
| 29 | ARPA | SM200 | 0.740 | 0.860 | | | | | | | | | | | | | 0.883 | 0.803 | 0.791 | 0.783 | 0.750 | | | | | 0.801 | 0.053 | 7 | -0.357 | 0.256 | |
| 30 | MDV | DHA 80 | 0.975 | 0.868 | 0.853 | 0.870 | 0.956 | 0.953 | 0.902 | 0.938 | 0.997 | 1.004 | 0.817 | 0.927 | 0.893 | 0.879 | | | | | | | | | | | 0.916 | 0.057 | 14 | -0.031 | 0.274 |
| 31 | MDV | FH 62 IR | 0.806 | 0.636 | 0.658 | 0.781 | 0.739 | 0.768 | 0.745 | 0.652 | 0.625 | 0.623 | 0.677 | 0.749 | 0.659 | 0.737 | | | | | | | | | | | 0.704 | 0.063 | 14 | -0.634 | 0.304 |

ANNEX 5: En – numbers for participants with reported uncertainty

En – numbers for PM10

| Country | Measurement day | En - number between JRC sampler A / participant and JRC sampler B / participant | | | | | | | | | |
|---------|-----------------|---|------|------------------|------|-----------------|------|-------------|------|------------|------|
| ES | | ISCIII Derenda A | | ISCIII Derenda B | | | | | | | |
| | | A | B | A | B | | | | | | |
| | 1 | 0.99 | 0.81 | | | | | | | | |
| | 2 | 1.12 | 0.62 | 1.47 | 0.97 | | | | | | |
| | 3 | 1.30 | 0.70 | 0.74 | 0.12 | | | | | | |
| | 4 | 1.10 | 0.94 | 1.10 | 0.94 | | | | | | |
| | 5 | 0.92 | 0.72 | 1.21 | 1.02 | | | | | | |
| | 6 | 1.21 | 0.76 | 1.21 | 0.76 | | | | | | |
| | 7 | 1.52 | 1.51 | 1.52 | 1.51 | | | | | | |
| | 8 | 1.44 | 0.87 | 1.76 | 1.19 | | | | | | |
| | 9 | 1.22 | 0.94 | | | | | | | | |
| | 10 | 1.53 | 1.47 | | | | | | | | |
| | 11 | 1.25 | 0.95 | | | | | | | | |
| | 12 | 1.58 | 1.37 | | | | | | | | |
| | 13 | 1.75 | 1.55 | | | | | | | | |
| 14 | 1.85 | 1.15 | | | | | | | | | |
| SI | | EIMV Tecora | | | | | | | | | |
| | | A | B | | | | | | | | |
| | 1 | 1.67 | 1.75 | | | | | | | | |
| | 2 | 1.59 | 1.69 | | | | | | | | |
| | 3 | 1.49 | 1.53 | | | | | | | | |
| | 4 | 0.96 | 1.19 | | | | | | | | |
| | 5 | 1.43 | 1.43 | | | | | | | | |
| | 6 | 1.77 | 1.74 | | | | | | | | |
| | 7 | 1.41 | 1.37 | | | | | | | | |
| | 8 | 1.52 | 1.61 | | | | | | | | |
| | 9 | 1.56 | 1.51 | | | | | | | | |
| | 10 | 1.59 | 1.63 | | | | | | | | |
| | 11 | 2.03 | 2.04 | | | | | | | | |
| | 12 | 2.33 | 2.28 | | | | | | | | |
| 13 | 2.33 | 2.17 | | | | | | | | | |
| AT | | LR OOe. Digitel | | | | | | | | | |
| | | A | B | | | | | | | | |
| | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | 0.76 | 0.30 | | | | | | | | |
| | 4 | 0.88 | 0.60 | | | | | | | | |
| | 5 | 0.86 | 0.48 | | | | | | | | |
| | 6 | 1.23 | 0.96 | | | | | | | | |
| | 7 | 0.95 | 0.79 | | | | | | | | |
| | 8 | 0.81 | 0.36 | | | | | | | | |
| | 9 | 0.87 | 0.30 | | | | | | | | |
| | 10 | 0.63 | 0.26 | | | | | | | | |
| | 11 | 0.82 | 0.67 | | | | | | | | |
| | 12 | 0.87 | 0.59 | | | | | | | | |
| | 13 | 0.96 | 0.68 | | | | | | | | |
| 14 | 0.62 | 0.46 | | | | | | | | | |
| DE | | Lanuv Digitel 4 | | Lanuv Digitel 37 | | HLUG Leckel Seq | | HLUG FH62IR | | HLUG Sharp | |
| | | A | B | A | B | A | B | A | B | A | B |
| | 1 | | | | | 0.14 | 0.10 | 0.66 | 0.65 | 0.05 | 0.03 |
| | 2 | | | | | 0.02 | 0.08 | 1.09 | 1.11 | 0.17 | 0.20 |
| | 3 | 0.06 | 0.01 | 0.06 | 0.01 | 0.13 | 0.20 | 0.41 | 0.39 | 0.73 | 0.77 |
| | 4 | 0.02 | 0.01 | 0.11 | 0.08 | 0.01 | 0.06 | 0.53 | 0.52 | 0.03 | 0.06 |
| | 5 | 0.19 | 0.35 | 0.10 | 0.26 | 0.10 | 0.30 | 0.23 | 0.18 | 0.76 | 0.85 |
| | 6 | 0.36 | 0.29 | 0.72 | 0.65 | 0.20 | 0.30 | 0.80 | 0.77 | 1.04 | 0.97 |
| | 7 | 0.01 | 0.22 | 0.22 | 0.01 | 0.30 | 0.57 | 0.36 | 0.29 | 0.24 | 0.08 |
| | 8 | 0.14 | 0.14 | 0.07 | 0.07 | 0.38 | 0.38 | 0.15 | 0.15 | 0.27 | 0.27 |
| | 9 | | | | | 0.12 | 0.16 | 0.46 | 0.54 | 0.66 | 0.83 |
| | 10 | | | | | 0.04 | 0.13 | 0.26 | 0.33 | 1.78 | 1.87 |
| | 11 | | | | | 0.79 | 0.06 | 0.41 | 0.75 | 0.16 | 0.38 |
| | 12 | | | | | 0.41 | 0.45 | 0.38 | 0.36 | 0.28 | 0.24 |
| 13 | | | | | 0.09 | 0.71 | 0.42 | 0.64 | 0.66 | 1.10 | |

| NL | RIVM Leckel Seq | | RIVM FH62IR | | GGD Derenda Seq | |
|----|-----------------|------|-------------|------|-----------------|------|
| | A | B | A | B | A | B |
| 1 | 1.01 | 0.58 | 0.60 | 0.82 | 2.96 | 2.49 |
| 2 | 0.52 | 0.46 | 0.35 | 0.37 | 1.76 | 1.69 |
| 3 | 0.30 | 0.23 | 0.48 | 0.51 | 2.01 | 1.92 |
| 4 | 0.14 | 0.18 | 0.41 | 0.40 | | |
| 5 | 0.02 | 0.02 | 0.51 | 0.51 | | |
| 6 | 0.29 | 0.16 | 0.58 | 0.63 | | |
| 7 | 0.19 | 0.04 | 0.85 | 0.92 | | |
| 8 | 0.22 | 0.10 | 0.87 | 1.00 | | |
| 9 | 0.40 | 0.07 | 0.76 | 0.89 | | |
| 10 | 0.39 | 0.12 | 0.35 | 0.59 | | |
| 11 | 0.73 | 0.44 | 0.61 | 0.74 | | |
| 12 | 0.38 | 0.45 | 0.56 | 0.53 | | |
| 13 | 0.43 | 0.05 | 0.54 | 0.69 | | |
| 14 | 0.17 | 0.29 | 0.77 | 0.82 | | |

| BE | VMM ESM Andersen | | VMM Teom | | VMM FDMS | | Issep Sw 126 beta | | Issep Sw 129 beta | | Issep Env.33 | | Issep Env.78 | | RIVM Leckel Seq | | GGD Derenda Seq | |
|----|------------------|------|----------|------|----------|------|-------------------|------|-------------------|------|--------------|------|--------------|------|-----------------|------|-----------------|------|
| | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B |
| 1 | 0.19 | 0.24 | 0.32 | 0.28 | 0.24 | 0.29 | 1.81 | 1.86 | 2.32 | 2.36 | 0.61 | 0.68 | | | 0.28 | 0.17 | | |
| 2 | 0.16 | 0.19 | 0.03 | 0.06 | 1.26 | 1.30 | 2.55 | 2.58 | 2.15 | 2.18 | 1.91 | 1.95 | 2.88 | 2.91 | 0.41 | 0.33 | | |
| 3 | 0.12 | 0.09 | 0.44 | 0.63 | | | 1.23 | 1.76 | 0.87 | 1.42 | 0.79 | 1.15 | 1.91 | 2.29 | 0.78 | 0.26 | | |
| 4 | 0.32 | 0.54 | 0.15 | 0.33 | | | 1.53 | 2.08 | 1.17 | 1.73 | 2.02 | 2.41 | 2.68 | 3.07 | 0.86 | 0.32 | | |
| 5 | 0.29 | 0.40 | 0.01 | 0.07 | | | 2.02 | 2.23 | 1.41 | 1.64 | 2.42 | 2.59 | 3.24 | 3.39 | 0.65 | 0.38 | | |
| 6 | 0.17 | 0.13 | 0.64 | 0.62 | 1.74 | 1.78 | 2.69 | 2.72 | 2.10 | 2.14 | 1.36 | 1.40 | 1.36 | 1.40 | 0.32 | 0.24 | 0.31 | 0.39 |
| 7 | 0.14 | 0.09 | 0.18 | 0.14 | 1.20 | 1.27 | 1.57 | 1.70 | 1.60 | 1.73 | 1.85 | 1.94 | 2.08 | 2.17 | 0.29 | 0.15 | 0.44 | 0.59 |
| 8 | 0.84 | 0.79 | 1.23 | 1.29 | 0.69 | 0.78 | 1.45 | 1.62 | 1.13 | 1.30 | 1.12 | 1.23 | 1.78 | 1.89 | 0.09 | 0.08 | 0.11 | 0.30 |
| 9 | 1.37 | 1.53 | 0.52 | 0.68 | 2.12 | 1.74 | 2.52 | 1.90 | 3.17 | 2.53 | 1.69 | 1.25 | 2.10 | 1.64 | 1.02 | 0.48 | 1.90 | 1.29 |
| 10 | 0.05 | 0.37 | 0.38 | 0.62 | 2.19 | 1.65 | 3.26 | 2.34 | 3.03 | 2.12 | 1.10 | 0.51 | 2.19 | 1.54 | 0.74 | 0.05 | 1.35 | 0.47 |
| 11 | 0.71 | 0.91 | 0.58 | 0.74 | 1.11 | 0.78 | 1.95 | 1.34 | | | 0.89 | 0.48 | 2.53 | 2.04 | 0.38 | 0.88 | 0.34 | 0.22 |
| 12 | 0.64 | 0.89 | 0.79 | 0.98 | 1.21 | 0.79 | 1.60 | 0.95 | 2.46 | 1.78 | 0.57 | 0.11 | 1.00 | 0.51 | 0.61 | 1.15 | 0.13 | 0.71 |
| 13 | 0.14 | 0.39 | 0.69 | 0.86 | 1.31 | 0.94 | 2.00 | 1.34 | 2.60 | 1.92 | 1.13 | 0.67 | 1.13 | 0.67 | 0.71 | 1.24 | 0.78 | 0.15 |
| 14 | 0.12 | 0.20 | 0.25 | 0.32 | 0.85 | 0.73 | 2.07 | 1.78 | 2.41 | 2.11 | 1.48 | 1.30 | 2.29 | 2.10 | 0.37 | 0.59 | 0.45 | 0.70 |

| IT | Ispra Tecora | |
|----|--------------|------|
| | A | B |
| 1 | 1.01 | 1.08 |
| 2 | 0.61 | 0.36 |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | 1.56 | 1.25 |
| 10 | 1.56 | 1.34 |
| 11 | 0.11 | 0.08 |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | 3.65 | 3.71 |

En – numbers for PM2.5

| Country | Measurement day | En - number between JRC / participant |
|---------|-----------------|---------------------------------------|
| AT | | LR OOe. Digitel |
| | 1 | |
| | 2 | |
| | 3 | 1.44 |
| | 4 | 1.28 |
| | 5 | 1.24 |
| | 6 | 1.40 |
| | 7 | 1.03 |
| | 8 | 0.94 |
| | 9 | 1.04 |
| | 10 | 1.22 |
| | 11 | 1.15 |
| | 12 | 1.37 |
| | 13 | 0.93 |
| 14 | 0.68 | |
| NL | | GGD Derenda Seq |
| | 1 | |
| | 2 | 1.05 |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 7 | |
| | 8 | 0.68 |
| | 9 | 2.00 |
| | 10 | 0.47 |
| | 11 | 0.45 |
| | 12 | 0.80 |
| | 13 | 0.90 |
| 14 | 0.91 | |
| BE | | GGD Derenda Seq |
| | 1 | 0.90 |
| | 2 | 0.72 |
| | 3 | 1.72 |
| | 4 | 7.65 |
| | 5 | 0.99 |
| | 6 | |
| | 7 | 1.91 |
| | 8 | |
| | 9 | 0.18 |
| | 10 | |
| | 11 | 0.62 |
| | 12 | |
| | 13 | 1.09 |
| 14 | 0.31 | |

ANNEX 6: Uncertainty at the LV for PM10 and “target value” for PM2.5 for data-sets with n>10 and a minimum of 20% of data greater upper assessment threshold of annual limit value (exceedances in red).

PM10:

| country | codification | laboratory | instrument | relative uncertainty at the LV | n |
|---------|--------------|------------|------------------|--------------------------------|----|
| | | | | % | |
| ES | 1 | ISCI | Derenda A | 11.85 | 13 |
| | 3 | AdM | Teom 1400 | 27.11 | 13 |
| PT | 4 | | Tecora | 250.48 | 13 |
| | 5 | IdA | Andersen | 9.66 | 13 |
| SI | 6 | | Env. 101 | 19.44 | 14 |
| | 8 | EPA SI | Teom 1400 | 6.88 | 14 |
| | 9 | EIMV | Tecora | 22.98 | 13 |
| AT | 10 | Anhovo | Tecora | 5.76 | 14 |
| | 12 | UBA | Digitel | 4.32 | 12 |
| | 14 | | FDMS | 4.30 | 12 |
| | 13 | LR OOe | Digitel | 5.47 | 12 |
| CZ | 15 | | FDMS | 9.13 | 12 |
| | 16 | LR Stmk. | Digitel | 15.28 | 12 |
| | 17 | | FH 62 IR | 8.40 | 12 |
| | 18 | CHMI | FH95 Nitrocell. | 7.44 | 14 |
| | 19 | | FH95 glass | 6.80 | 14 |
| | 20 | | Derenda LVS Seq | 5.50 | 14 |
| DE | 21 | | Derenda Hvol B | 5.10 | 14 |
| | 22 | | Derenda Hvol A | 7.33 | 14 |
| | 23 | | MCZ/Andersen | 12.61 | 14 |
| | 24 | | FH 62 IR | 9.13 | 14 |
| | 25 | Lanuv | Digitel 4 | 1.57 | 13 |
| | 26 | | Digitel 37 | 2.74 | 13 |
| | 27 | HLUG | Leckel Seq | 2.83 | 13 |
| | 28 | | Sharp | 11.51 | 13 |
| DK | 29 | | FH62 IR | 11.83 | 13 |
| | 31 | Neri | Teom 1400 | 27.63 | 11 |
| SE | 32 | ITM | Leckel Seq | 6.66 | 12 |
| | 35 | EHAS | Teom 1400 | 14.69 | 14 |
| NL | 43 | RIVM | Leckel Seq | 0.64 | 14 |
| | 45 | | FH62 IR | 14.17 | 14 |
| NL/BE | 44 | VMM | Leckel Seq | 5.77 | 13 |
| BE | 47 | VMM | Leckel Seq | 7.96 | 14 |
| | 51 | | ESM BOR801 | 12.06 | 14 |
| BE/NL | 52 | | Teom 1400 | 10.56 | 14 |
| | 53 | | FDMS | 15.99 | 11 |
| | 48 | Issep | SW126 gravimetr. | 8.66 | 14 |
| | 49 | | SW129 gravimetr. | 10.34 | 13 |
| | 54 | | SW126 beta | 12.96 | 14 |
| | 55 | | SW129 beta | 10.73 | 13 |
| | 56 | | Env.101_33 | 19.01 | 14 |
| | 57 | | Env.101_78 | 24.48 | 13 |
| IT | 58 | | Grimm 180 | 9.02 | 14 |
| | 50 | RIVM | Leckel Seq | 2.96 | 14 |
| HU | 71 | Ispra | Tecora | 6.41 | 15 |
| | 72 | Arpa | Zambelli | 14.07 | 15 |
| | 73 | | Tecora | 8.68 | 15 |
| | 74 | | SM200 | 7.62 | 15 |
| | 75 | | FDMS | 15.61 | 14 |
| SK | 76 | HMS | Digitel | 8.52 | 14 |
| | 77 | | FH62 IR | 14.32 | 14 |
| SK | 78 | MDV | FH62 IR | 10.66 | 13 |
| | 79 | SHMU | FDMS | 13.36 | 14 |

PM2.5:

| country | codification | laboratory | instrument | relative uncertainty at the target value | n |
|---------|--------------|------------|--------------------|--|----|
| | | | | % | |
| ES | 1 | ISCIII | Derenda | 13.88 | 12 |
| PT | 2 | IdA | Tecora | 14.05 | 14 |
| SI | 3 | EPA | Leckel Seq | 4.61 | 14 |
| AT | 5 | LR OOe | Digitel | 10.05 | 12 |
| CZ | 6 | CHMI | Leckel SEQ | 25.32 | 14 |
| | 7 | | Derenda | 4.41 | 14 |
| | 8 | | FH 62 IR | 16.95 | 14 |
| DK | 9 | Neri | Teom 1400 | 37.32 | 11 |
| SE | 12 | EHAS | Teom 1400 | 64.56 | 14 |
| BE | 22 | VMM | ESM | 15.72 | 14 |
| | 15 | | Leckel SEQ Whatman | 10.37 | 13 |
| | 16 | | Leckel SEQ Pall | 1.61 | 14 |
| | 17 | Issep | SW126 gravimetr. | 14.67 | 14 |
| | 18 | | SW129 gravimetr. | 10.40 | 13 |
| | 19 | | SW126 beta | 13.68 | 14 |
| | 20 | | SW129 beta | 9.97 | 13 |
| | 21 | | Grimm 180 | 12.28 | 14 |
| HU | 30 | MDV | Digitel | 12.08 | 14 |
| | 31 | | FH62 IR | 34.58 | 14 |

ANNEX 7: Speciation of PM10 filters

Analysis of the chemical composition was carried out on selected PM10 filters with the aim of investigating the coherence of the PM chemical composition compared with sites distinctive features and to explain differences between sites. Concentrations of major ions (Chloride, Nitrate, Sulphate, Sodium, Ammonium, Potassium, Magnesium and Calcium) were measured by ion chromatography while elements (Magnesium, Aluminium, Potassium, Calcium, Titanium, Vanadium, Chromium, Manganese, Iron, Zinc, Arsenic, Cadmium, Antimony, Lead, Nickel and Copper) were determined by ICP-MS. Where available, organic and elemental carbon, measured with on-line thermal-optical transmittance method with RT-quartz protocol (Sunset inc.), were also considered.

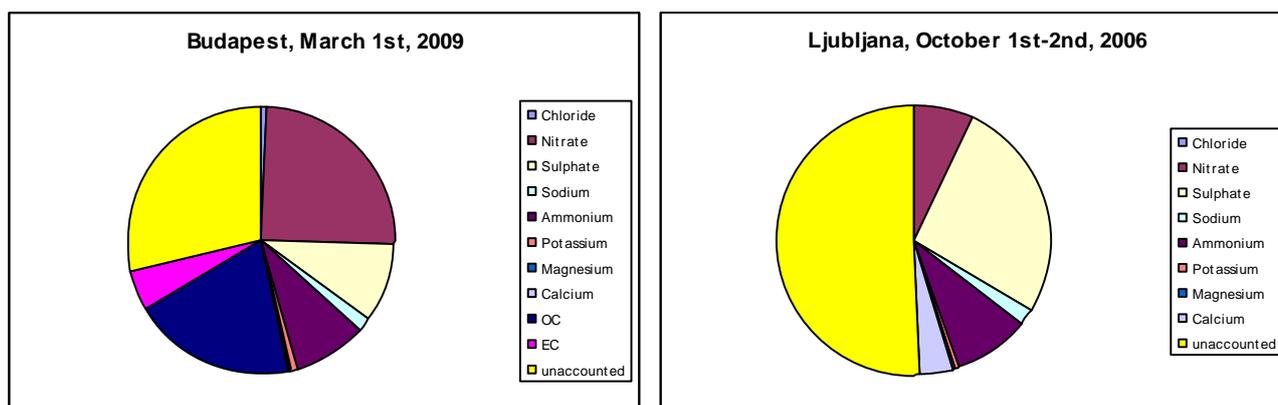
Among ions the content of nitrate and sulphate is the most relevant variable to explain the differences between sites. Samples from Budapest differ from all the others due to their high content in either ammonium nitrate or ammonium sulphate. In certain cases like Ljubljana sulphate is always more relevant than nitrate (maybe linked to a local source of SO₂), in other cases like Bratislava nitrate seems to be more relevant (figure A7.1).

Certain measurement sites like Borgerhout and Port Talbot show different patterns on different days, depending on the wind direction and wind speed (figure A7.2). Samples from Lisbon and partly Port Talbot (May 1st, 2008) present appreciable concentrations of sodium chloride which has been interpreted as contribution of sea salt. In the latter case this has a major influence on the ratio PM2.5/PM10: 0.32 with wind coming from the sea (prevailing wind-direction WSW on May 1st, 2008) or 0.70 with wind coming from inland (prevailing wind-direction E on May 3rd, 2008). On certain days (e.g. April 28th, 2008) the influence of the steel plant close to the measurement site in Port Talbot is evident due to the higher content of iron in the samples (figure A7.3).

Ion concentrations in samples from Stockholm (traffic site) are dominated by sodium chloride and have low concentrations of both nitrate and sulphate. This is considered to reflect the influence of re-suspension of road salting connected to the use of studded tires. In Copenhagen however, apart from sodium chloride also nitrate and sulphate are relevant. Madrid, a measurement site with an evident influence of traffic source, shows a significant amount of Calcium (a component of earth crustal material) and EC (figure A7.4).

Examples of these analyses are presented in the following figures:

Figure A7.1 Chemical composition in selected samples of PM10 from Budapest, Ljubljana and Bratislava



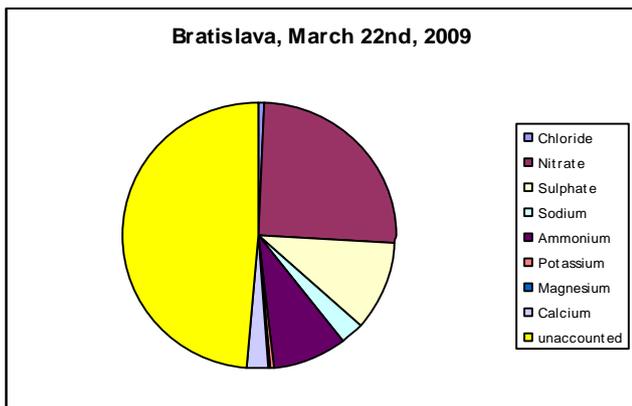


Figure A7.2 Chemical composition in selected samples of PM10 from Borgerhout, Port Talbot and Lisbon.

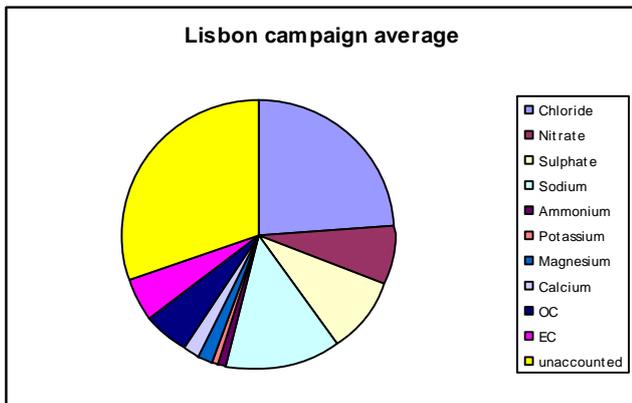
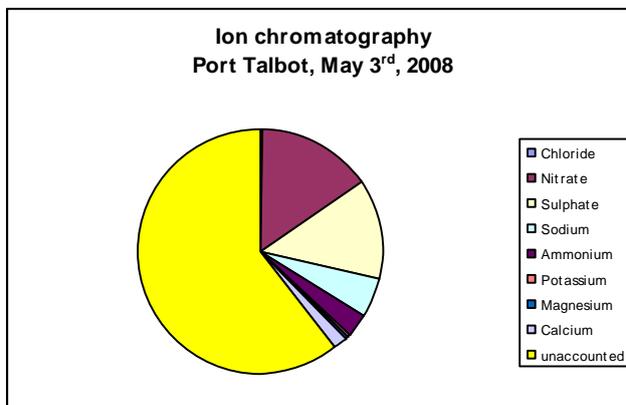
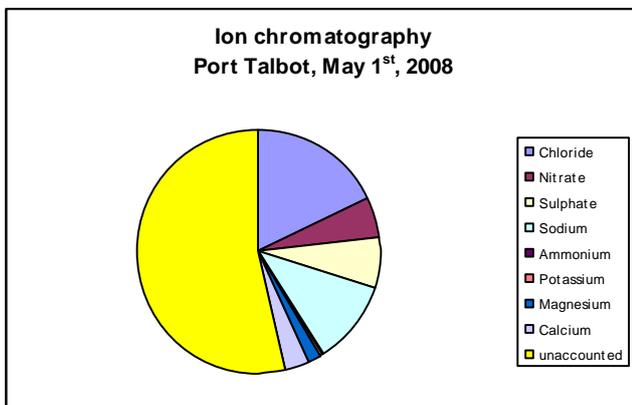
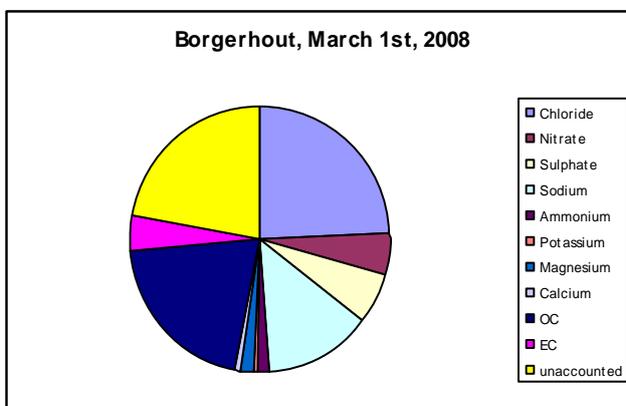
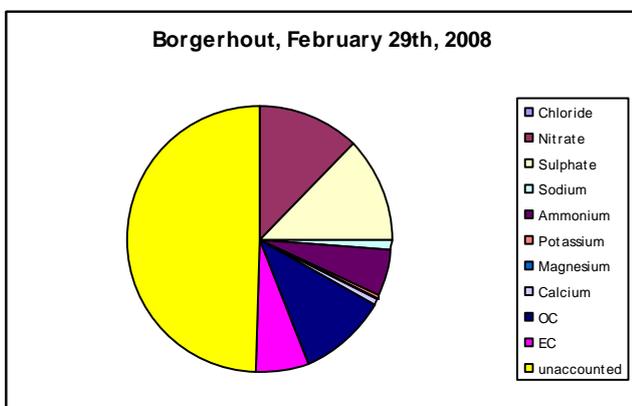


Figure A7.3 Day to day variability in the chemical composition in PM10 from Port Talbot

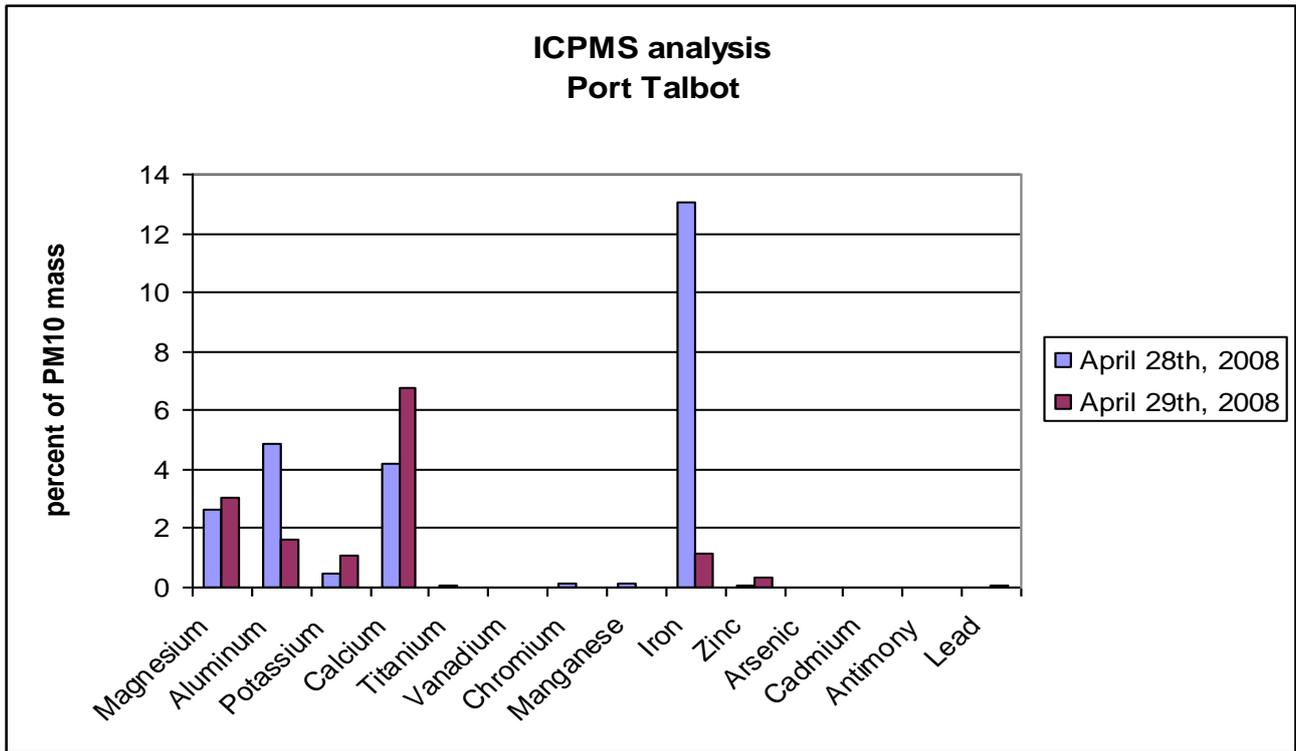
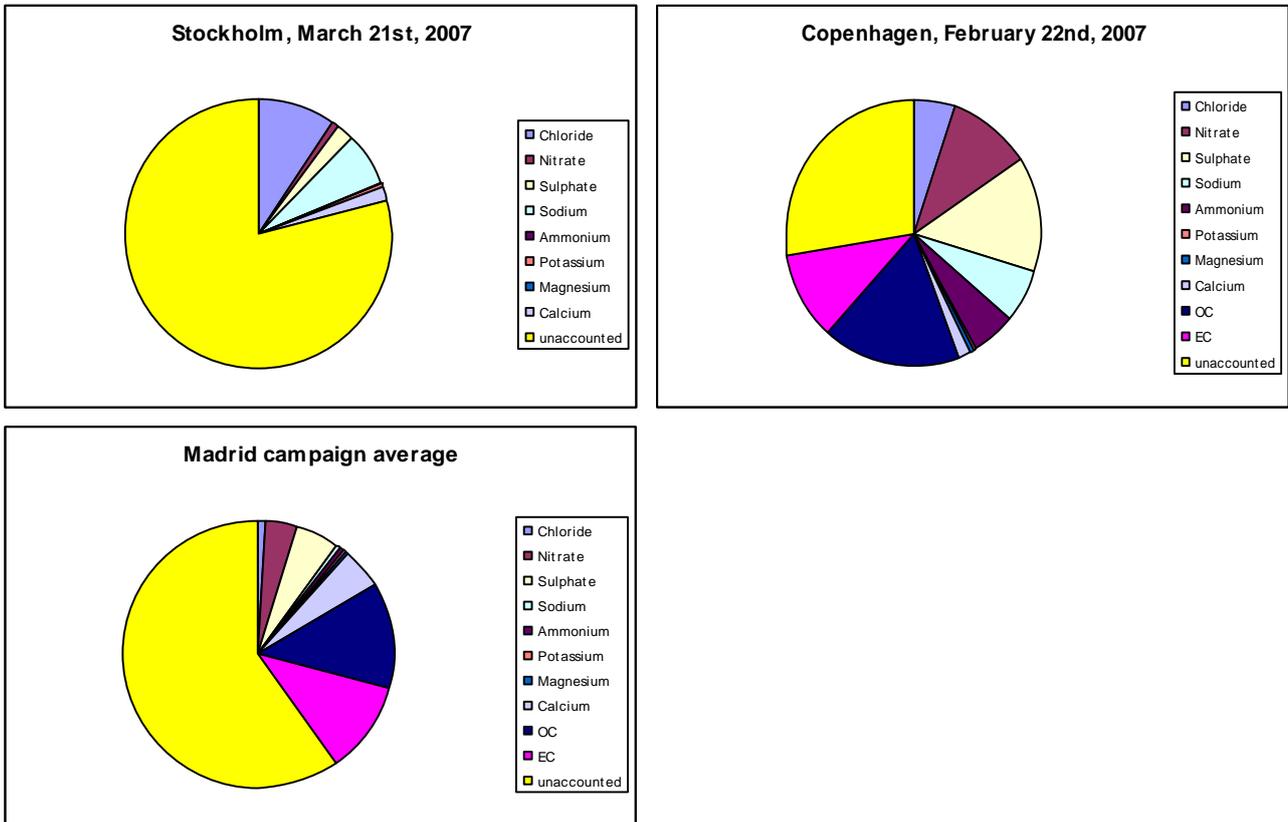


Figure A7.4 Chemical composition in selected samples of PM10 from Stockholm, Copenhagen and Madrid



ANNEX 8: Parametric, non-parametric tests and ANOVA for PM10 (significant p-values in red)

Differences between NRL and LOCAL NETWORKS (only for campaigns with both type of laboratories)

Parametric

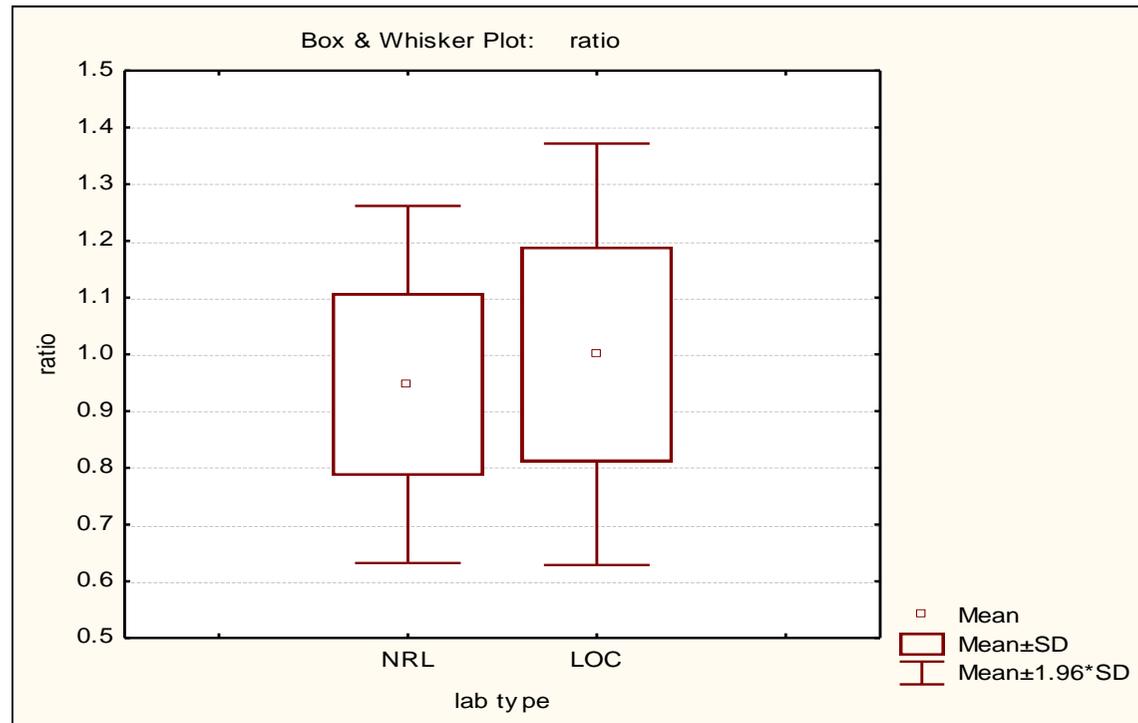
| | Mean NRL | Mean LOC | t-value | df | p | Valid N NRL | Valid N LOC | Std.Dev. NRL | Std.Dev. LOC | F-ratio Variances | p Variances |
|-------|----------|----------|-----------|-----|----------|-------------|-------------|--------------|--------------|-------------------|-------------|
| ratio | 0.944017 | 1.000131 | -4.997811 | 702 | 0.000001 | 434 | 270 | 0.108201 | 0.189507 | 3.067549 | 0.000000 |

Non parametric

| Wald-Wolfowitz | Valid N NRL | Valid N LOC | Mean NRL | Mean LOC | Z | p-level | Z adjstd | p-level | No. of Runs | No. of ties |
|----------------|-------------|-------------|----------|----------|----------|----------|----------|----------|-------------|-------------|
| ratio | 434 | 270 | 0.944017 | 1.000131 | -2.62413 | 0.008687 | 2.584251 | 0.009760 | 301 | 0 |

| Kolmogorov S mirnov | Max Neg Differnc | Max Pos Differnc | p-level | Mean NRL | Mean LOC | Std.Dev. NRL | Std.Dev. LOC | Valid N NRL | Valid N LOC |
|---------------------|------------------|------------------|----------|----------|----------|--------------|--------------|-------------|-------------|
| ratio | -0.212221 | 0.023622 | p < .001 | 0.944017 | 1.000131 | 0.108201 | 0.189507 | 434 | 270 |

| U test (rank) | Rank Sum NRL | Rank Sum LOC | U | Z | p-level | Z adjusted | p-level | Valid N NRL | Valid N LOC |
|---------------|--------------|--------------|----------|----------|----------|------------|----------|-------------|-------------|
| ratio | 141801.0 | 106359.0 | 47406.00 | -4.26252 | 0.000020 | -4.26252 | 0.000020 | 434 | 270 |



Differences between LVS and HVS (only for campaigns with both type of instruments)

Parametric

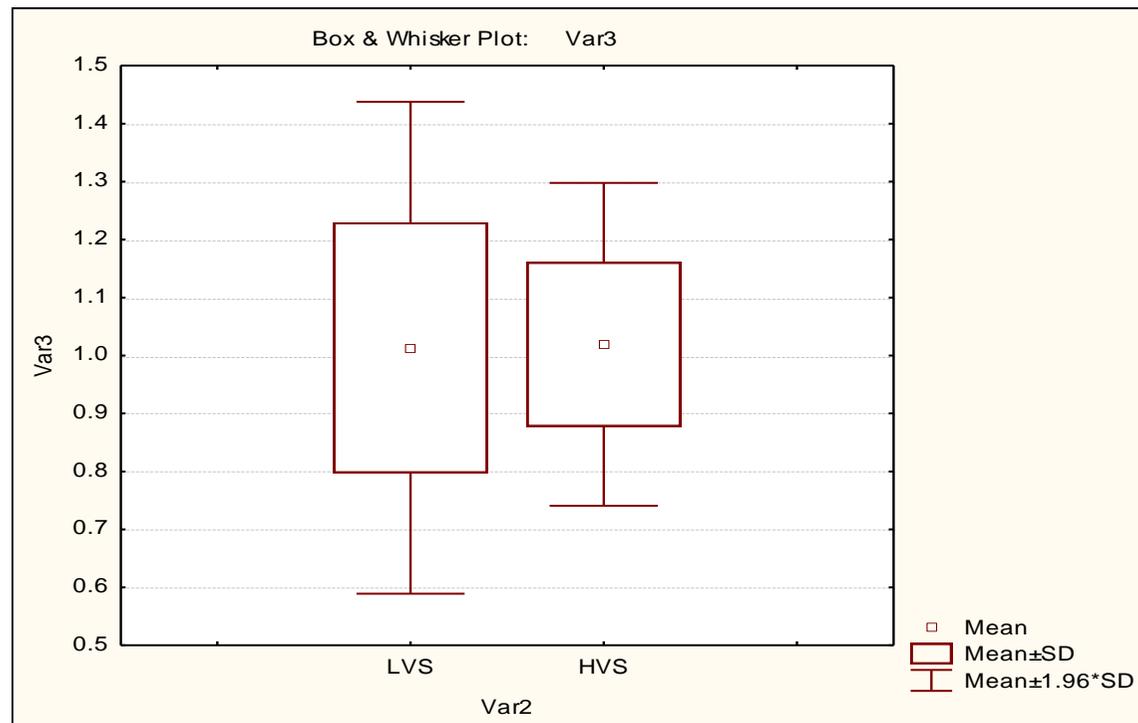
| | Mean LVS | Mean HVS | t-value | df | p | Valid N LVS | Valid N HVS | Std.Dev. LVS | Std.Dev. HVS | F-ratio Variances | p Variances |
|-------|----------|----------|-----------|-----|----------|-------------|-------------|--------------|--------------|-------------------|-------------|
| ratio | 1.013300 | 1.019253 | -0.221440 | 190 | 0.824988 | 103 | 89 | 0.216450 | 0.142111 | 2.319846 | 0.000070 |

Non parametric

| Wald-Wolfowitz | Valid N LVS | Valid N HVS | Mean LVS | Mean HVS | Z | p-level | Z adjstd | p-level | No. of Runs | No. of ties |
|----------------|-------------|-------------|----------|----------|----------|----------|----------|----------|-------------|-------------|
| ratio | 103 | 89 | 1.013300 | 1.019253 | -1.08969 | 0.275849 | 1.016946 | 0.309180 | 89 | 0 |

| Kolmogorov S mirnov | Max Neg Differnc | Max Pos Differnc | p-level | Mean LVS | Mean HVS | Std.Dev. LVS | Std.Dev. HVS | Valid N LVS | Valid N HVS |
|---------------------|------------------|------------------|---------|----------|----------|--------------|--------------|-------------|-------------|
| ratio | -0.142140 | 0.126868 | p > .10 | 1.013300 | 1.019253 | 0.216450 | 0.142111 | 103 | 89 |

| U test (rank) | Rank Sum LVS | Rank Sum HVS | U | Z | p-level | Z adjusted | p-level | Valid N LVS | Valid N HVS |
|---------------|--------------|--------------|----------|-----------|----------|------------|----------|-------------|-------------|
| ratio | 9783.000 | 8745.000 | 4427.000 | -0.407580 | 0.683582 | -0.407580 | 0.683582 | 103 | 89 |



Differences between LVS and AUTOMATIC (only for campaigns with both type of instruments)

Parametric (t-test)

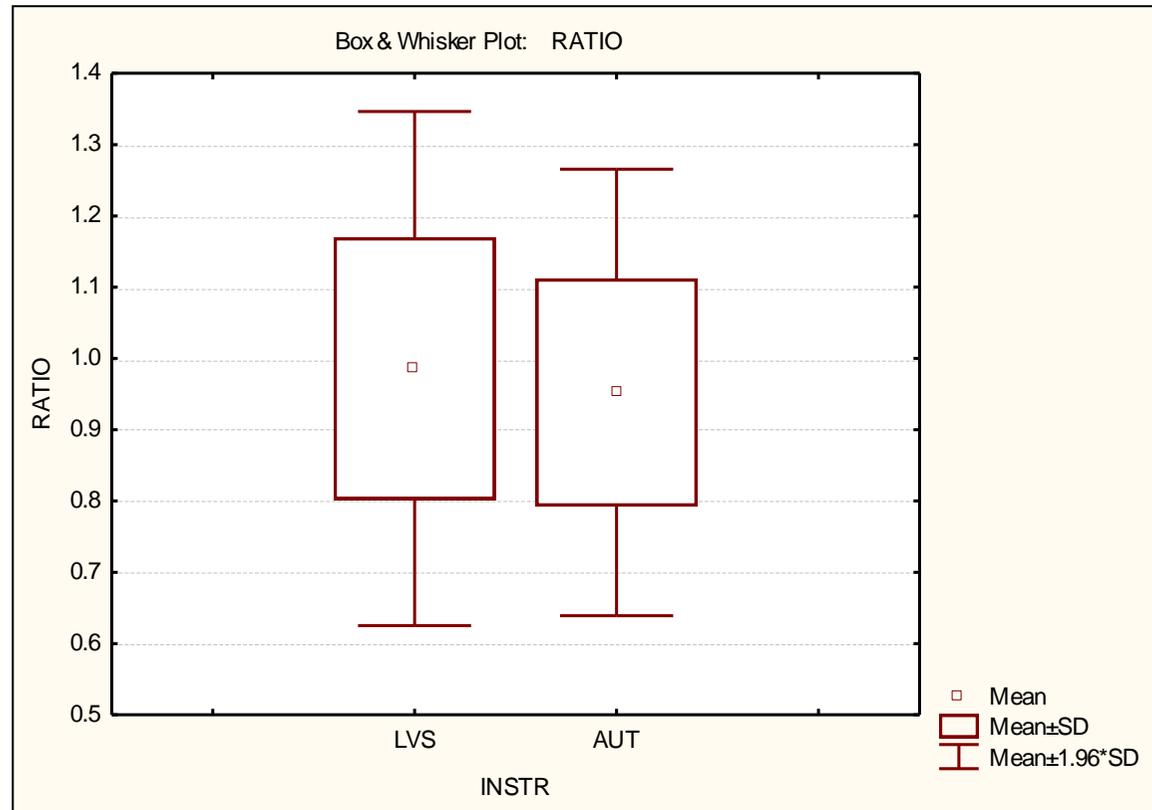
| | Mean LVS | Mean AUT | t-value | df | p | Valid N LVS | Valid N AUT | Std.Dev. LVS | Std.Dev. AUT | F-ratio Variances | p Variances |
|-------|----------|----------|----------|-----|----------|-------------|-------------|--------------|--------------|-------------------|-------------|
| ratio | 0.985791 | 0.952285 | 2.503066 | 660 | 0.012553 | 327 | 335 | 0.184025 | 0.159804 | 1.326110 | 0.010491 |

Non parametric

| Wald-Wolfowitz | Valid N LVS | Valid N AUT | Mean LVS | Mean AUT | Z | p-level | Z adjstd | p-level | No. of Runs | No. of ties |
|----------------|-------------|-------------|----------|----------|----------|----------|----------|----------|-------------|-------------|
| ratio | 327 | 335 | 0.985791 | 0.952285 | -4.27537 | 0.000019 | 4.236473 | 0.000023 | 277 | 0 |

| Kolmogorov S mirnov | Max Neg Differn | Max Pos Differn | p-level | Mean LVS | Mean AUT | Std.Dev. LVS | Std.Dev. AUT | Valid N LVS | Valid N AUT |
|---------------------|-----------------|-----------------|----------|----------|----------|--------------|--------------|-------------|-------------|
| ratio | -0.069670 | 0.173782 | p < .001 | 1 | 0.952285 | 0 | 0 | 327.000000 | 335.000000 |

| U test (rank) | Rank Sum LVS | Rank Sum AUT | U | Z | p-level | Z adjusted | p-level | Valid N LVS | Valid N AUT |
|---------------|--------------|--------------|----------|----------|----------|------------|----------|-------------|-------------|
| ratio | 116349.0 | 103104.0 | 46824.00 | 3.230894 | 0.001234 | 3.230895 | 0.001234 | 327 | 335 |



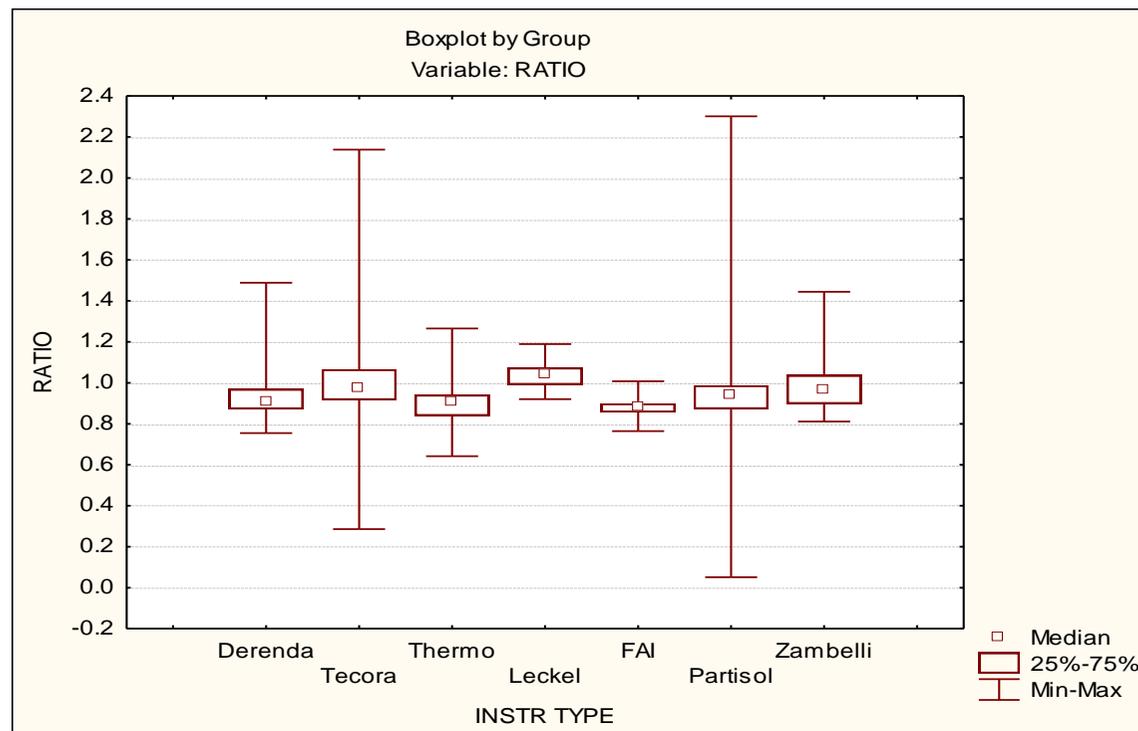
Differences between sampler type and filter material for LVS (median, 25 and 75 percentile and min-max)

Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: INSTRUMENT TYPE

Kruskal-Wallis test: H (6, N= 307) =99.69777 p =0.000

| | Derenda R:117.65 | Tecora R:175.23 | Thermo R:94.679 | Leckel R:222.39 | FAI R:68.074 | Partisol R:135.77 | Zambelli R:163.40 |
|----------|------------------|-----------------|-----------------|-----------------|--------------|-------------------|-------------------|
| Derenda | | 0.014085 | 1.000000 | 0.000000 | 0.374164 | 1.000000 | 1.000000 |
| Tecora | 0.014085 | | 0.001854 | 0.048229 | 0.000005 | 0.516799 | 1.000000 |
| Thermo | 1.000000 | 0.001854 | | 0.000000 | 1.000000 | 1.000000 | 0.326364 |
| Leckel | 0.000000 | 0.048229 | 0.000000 | | 0.000000 | 0.000002 | 0.381962 |
| FAI | 0.374164 | 0.000005 | 1.000000 | 0.000000 | | 0.033372 | 0.017931 |
| Partisol | 1.000000 | 0.516799 | 1.000000 | 0.000002 | 0.033372 | | 1.000000 |
| Zambelli | 1.000000 | 1.000000 | 0.326364 | 0.381962 | 0.017931 | 1.000000 | |

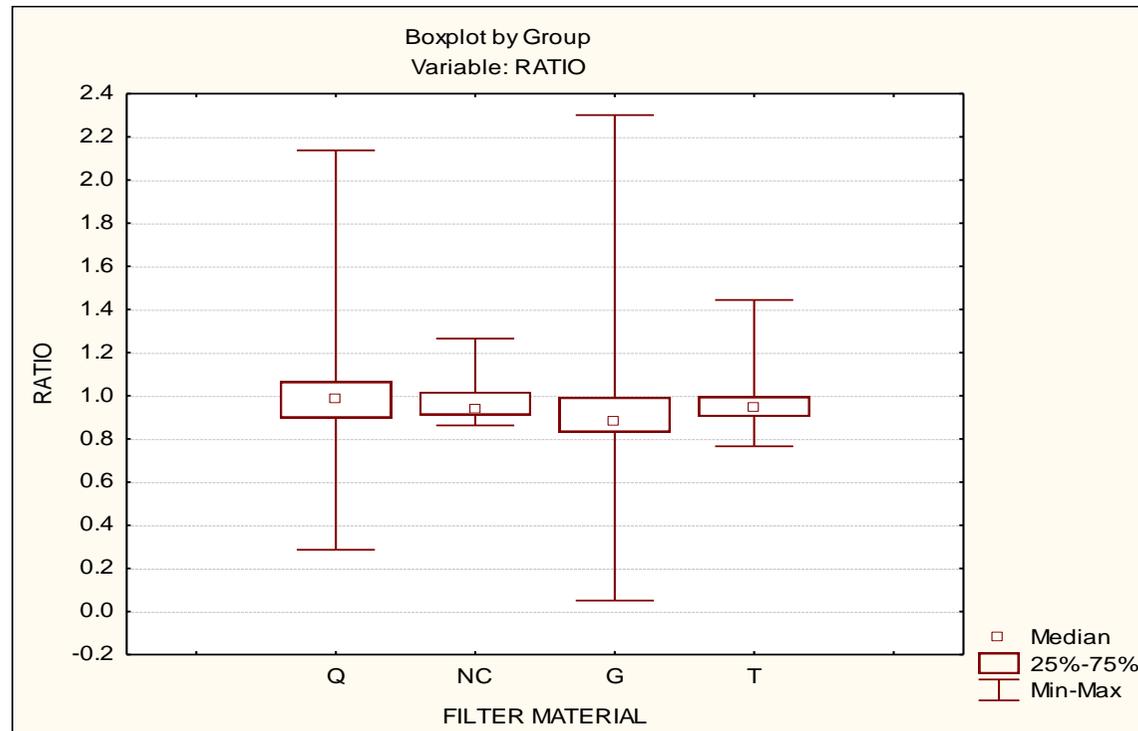


Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: FILTER MATERIAL

Kruskal-Wallis test: $H(3, N=307) = 25.46788$ $p = .0000$

| | Q R:172.26 | NC R:149.79 | G R:99.532 | T R:146.96 |
|----------------------|------------|-------------|------------|------------|
| Quartz (Q) | | 1.000000 | 0.000004 | 0.242290 |
| Nitro cellulose (NC) | 1.000000 | | 0.377858 | 1.000000 |
| Glass (G) | 0.000004 | 0.377858 | | 0.025060 |
| Teflon (T) | 0.242290 | 1.000000 | 0.025060 | |



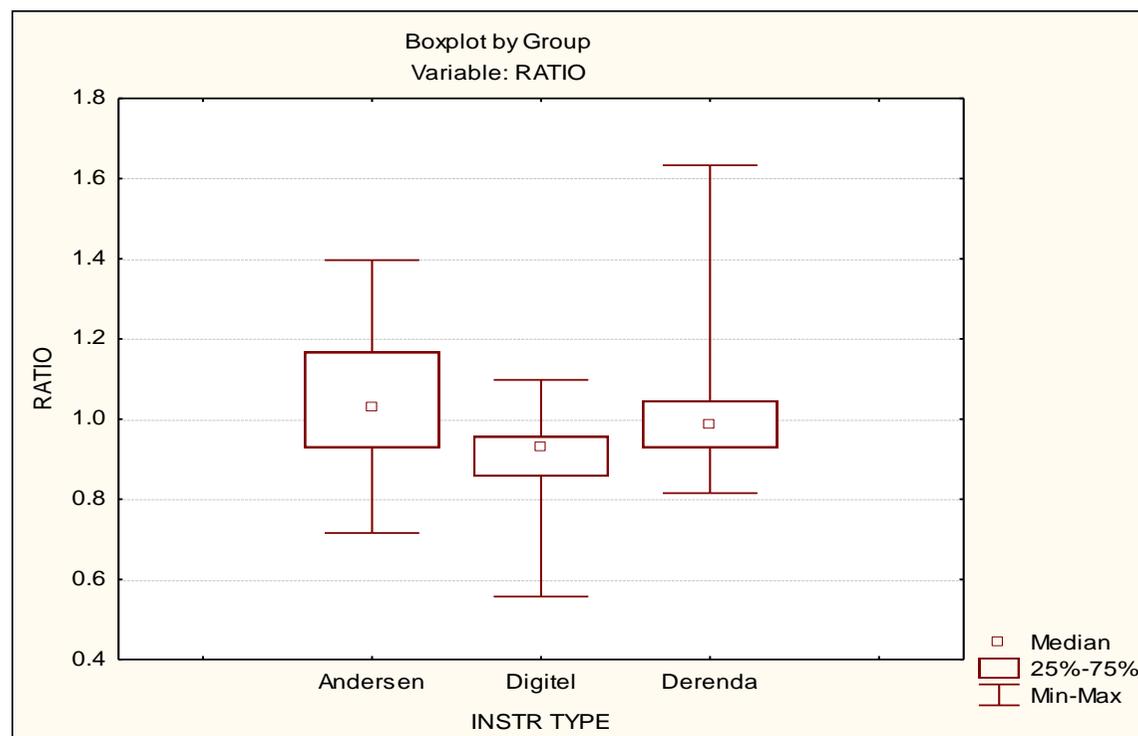
Differences between sampler type and filter material for HVS (median, 25 and 75 percentile and min-max)

Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: INSTRUMENT TYPE

Kruskal-Wallis test: $H(2, N=163) = 32.34319$ $p = .0000$

| | Andersen R:111.89 | Digitel R:65.430 | Derenda R:103.82 |
|----------|-------------------|------------------|------------------|
| Andersen | | 0.000002 | 1.000000 |
| Digitel | 0.000002 | | 0.000426 |
| Derenda | 1.000000 | 0.000426 | |

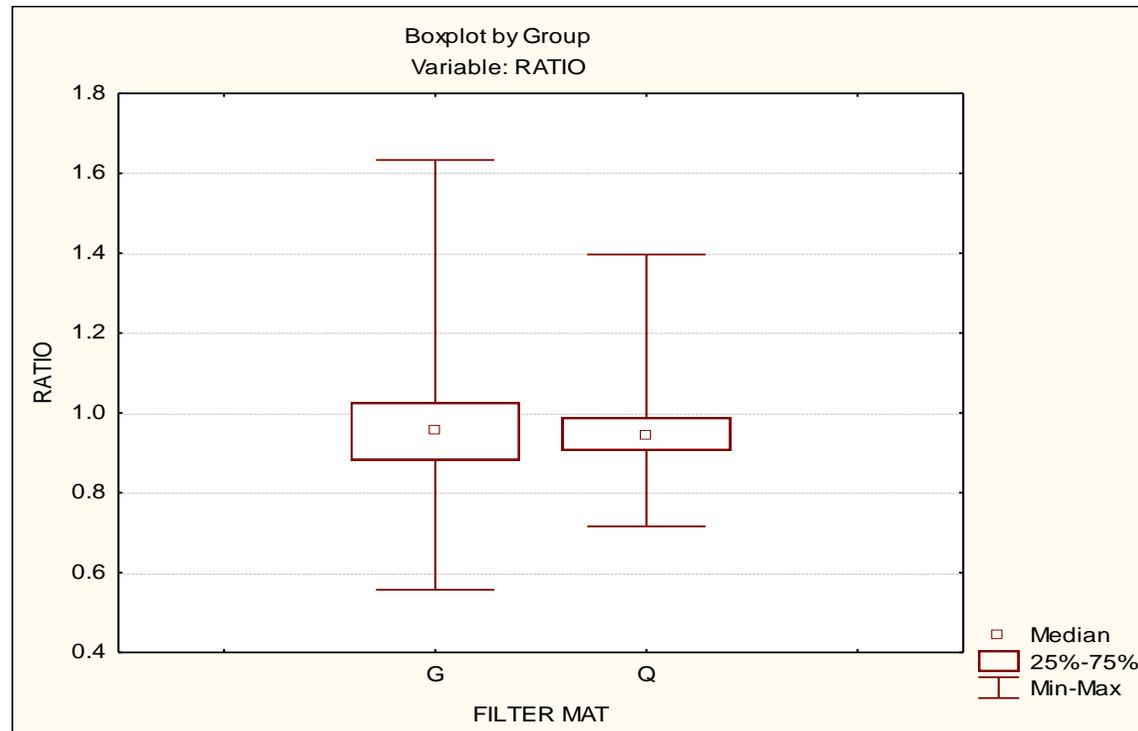


Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: FILTER MAT

Kruskal-Wallis test: $H(1, N=163) = .6409999$ $p = .4233$

| | G R:84.835 | Q R:78.910 |
|------------|------------|------------|
| Glass (G) | | 0.423349 |
| Quartz (Q) | 0.423349 | |



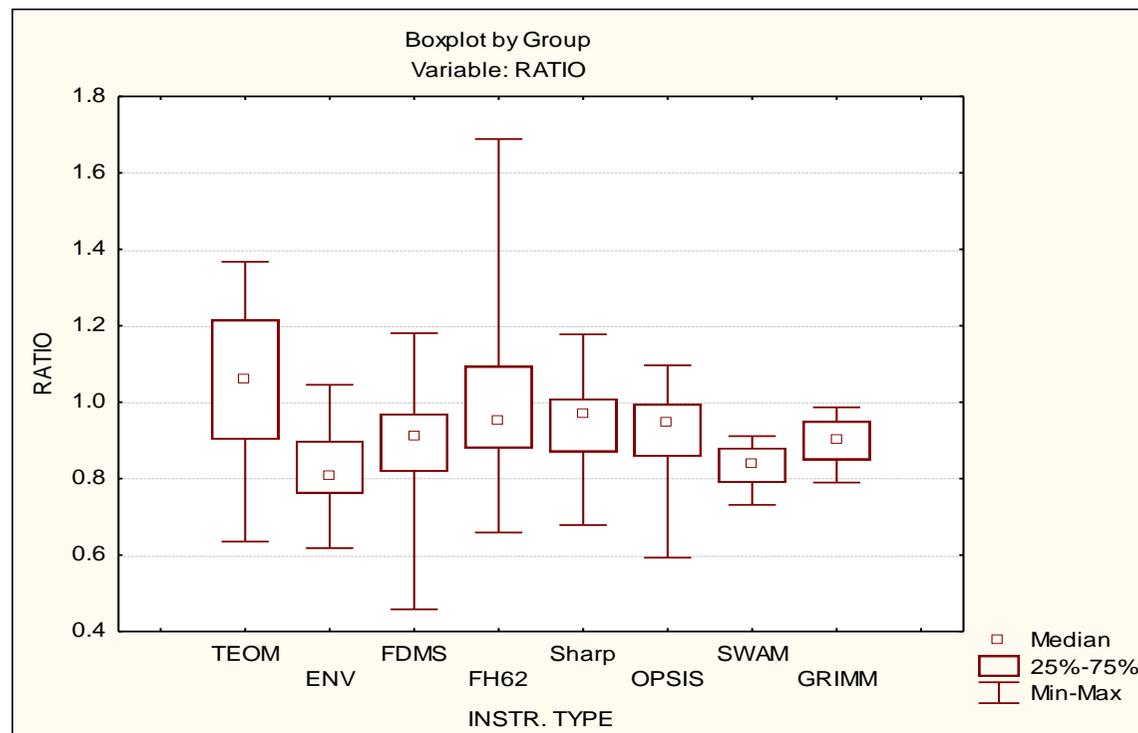
Differences between instrument type and sampling temperature for automatic analyzers (median, 25 and 75 percentile and min-max)

Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: INSTRUMENT TYPE

Kruskal-Wallis test: H (7, N= 468) =91.93672 p =.0000

| | TEOM R:310.70 | ENV R:132.04 | FDMS R:212.09 | FH62 R:278.19 | Sharp R:269.15 | OPSIS R:236.08 | SWAM R:120.54 | GRIMM R:202.21 |
|---------------|---------------|--------------|---------------|---------------|----------------|----------------|---------------|----------------|
| TEOM | | 0.000000 | 0.000051 | 1.000000 | 1.000000 | 0.526295 | 0.000000 | 0.179373 |
| ENVIRONNEMENT | 0.000000 | | 0.007502 | 0.000000 | 0.028297 | 0.039925 | 1.000000 | 1.000000 |
| FDMS | 0.000051 | 0.007502 | | 0.001893 | 1.000000 | 1.000000 | 0.040826 | 1.000000 |
| FH62 | 1.000000 | 0.000000 | 0.001893 | | 1.000000 | 1.000000 | 0.000001 | 1.000000 |
| Sharp | 1.000000 | 0.028297 | 1.000000 | 1.000000 | | 1.000000 | 0.031732 | 1.000000 |
| OPSIS | 0.526295 | 0.039925 | 1.000000 | 1.000000 | 1.000000 | | 0.058342 | 1.000000 |
| SWAM | 0.000000 | 1.000000 | 0.040826 | 0.000001 | 0.031732 | 0.058342 | | 1.000000 |
| GRIMM | 0.179373 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | |

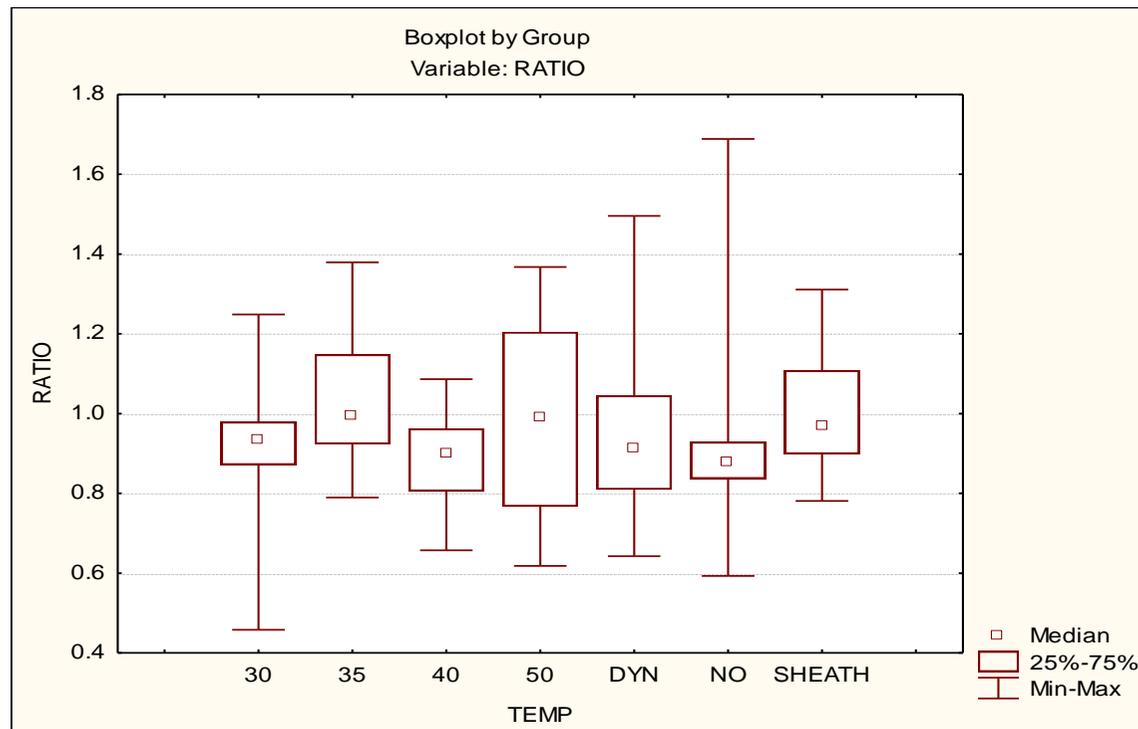


Multiple Comparisons p values (2-tailed)

Independent (grouping) variable: TEMPERATURE

Kruskal-Wallis test: $H(6, N = 468) = 21.01871$ $p = .0018$

| | 30 R:236.56 | 35 R:317.68 | 40 R:207.36 | 50 R:251.86 | DYN R:233.23 | NO R:201.85 | SHEATH R:292.08 |
|--------|-------------|-------------|-------------|-------------|--------------|-------------|-----------------|
| 30°C | | 0.087091 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 35°C | 0.087091 | | 0.006071 | 0.649555 | 0.077441 | 0.002247 | 1.000000 |
| 40°C | 1.000000 | 0.006071 | | 1.000000 | 1.000000 | 1.000000 | 0.958872 |
| 50°C | 1.000000 | 0.649555 | 1.000000 | | 1.000000 | 0.587520 | 1.000000 |
| DYN | 1.000000 | 0.077441 | 1.000000 | 1.000000 | | 1.000000 | 1.000000 |
| NO | 1.000000 | 0.002247 | 1.000000 | 0.587520 | 1.000000 | | 0.666183 |
| SHEATH | 1.000000 | 1.000000 | 0.958872 | 1.000000 | 1.000000 | 0.666183 | |



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Abstract

To harmonize PM measurements in the European Union, the JRC together with the AQUILA Network of National Air Quality Reference Laboratories organized a PM QA/QC program.

From 2006 – 2009, the JRC, equipped with a mobile laboratory, measured in 18 Member States, for a duration of two weeks each, PM₁₀ and PM_{2.5} in parallel to measurement sites of local networks and to the National Reference Laboratories.

The main goals of the project were to find out to which degree PM measurements performed in the Member States agree with the requirements of the relevant EU directive and how correction factors for automatic analyzers were applied.

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