Framework plan for the development of monitoring of particulate matter in EECCA

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ABSTRACT

Monitoring and assessment of population exposure to particulate matter (PM2.5 and PM10) is a prerequisite of an effective health-related air quality management. To facilitate development of this monitoring in the Member States, and in particular in the countries of eastern Europe, Caucasus and Central Asia, this technical paper summarizes principles of PM monitoring and presents practical guidelines on essential steps to be taken in a country initiating PM monitoring. The cost-effectiveness of the system and its operation in countries with limited financial resources and limited expertise are assumed when the recommendations are formulated.

Keywords

ENVIRONMENTAL MONITORING - METHODS
AIR POLLUTANTS, ENVIRONMENTAL
AIR - STANDARDS
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Content

Executive Summary

Air quality assessment has an important role in health-oriented air quality management. This paper shows paths to providing air quality managers, control authorities and the public with relevant data. It focuses on one part of the broader process of monitoring, assessing, controlling and managing air quality, showing technical ways for monitoring and assessing air quality. It discusses a wide range of conditions that should be considered when monitoring is established. The paper provides general principles of the monitoring programme, which have to be adjusted to local conditions and needs.

Health aspects
The evidence concerning links between ambient concentrations of PM10 and PM2.5 with a wide range of health effects has grown considerably in the recent decade. Both short term (24-hour mean) exposure and long-term (annual mean) exposures influence population health and must be addressed by pollution reduction strategies.

PM fractions to be monitored
Due to their health significance, both fractions (PM10 and PM2.5) have to be monitored.
PM monitoring has to be conducted to:

- Assess PM concentration in a certain area;
- Assess PM concentration time pattern and trend over a longer period in selected locations;
- Understand spatial distribution and composition of the PM in the city;
- Link PM concentration with the emission sources.

Spatial distribution of PM concentration
Differences in PM sources, its atmospheric transport, chemical behaviour of PM10 and PM2,5 (and the precursor gases) result in different distribution of PM in various areas. The concentration field of PM2.5 is less variable than that of PM10. This means that a description of population exposure to PM2.5 requires fewer monitoring sites than the number of PM10 measurement sites necessary to describe PM10 distribution. For the assessment of regional background PM10 and PM2.5 concentrations EMEP modelling and monitoring results could be taken into account, where available.

Selecting region(s) within a state
The set-up of PM monitoring is a complex process, and includes gathering local experiences and resources. Therefore it is recommended that countries start the monitoring in one or two cities. This should include the capital city as the biggest population centre as well as densely populated areas where indicative measurements and/or modelling results have identified the highest air pollution burden, and the network should be expanded to other locations gradually.

Site selection
Proper selection of monitor's location is crucial for the reliability of the collected data and their usefulness in air quality management. Both theoretical and practical aspects must be considered. To prepare the base for site selection a large number of preparatory tasks must be implemented.

This requires the involvement of various experts with extensive professional experience in various areas as well as a significant amount of coordinating work.

Establishing the network

To control the PM exposure of population of a big city, the PM10 monitoring should be undertaken at least at:

- Two urban residential sites and
- One industrial site, and
- One traffic site.

In one of the urban residential sites where the PM10 is monitored, PM2.5 should also be measured.

If the resources are limited, it is better to establish one station less and assure high quality measurements in the remaining stations.

Timing

Site selection and establishing the network is a step by step procedure, which may take several years. During the preparatory work and establishing of the network, local specialists must be trained and capacities of the local teams to run the monitoring must be built. External expertise is necessary in the initial phase of the monitoring to ensure the generation of usable data.

Methods for monitoring

Three different methods for PM monitoring exist, each using different kinds of equipment. Each method has its advantages and disadvantages, therefore a combination of various methods is recommended. The gravimetric method is necessary to fulfil the control task (maintenance of a limit/target value), but to fulfil the reporting requirements (daily information) a continuous automatic monitor has to be used.

1 Background

Recently accumulated scientific evidence indicate that the current levels of air pollution in European cities cause significant damage to health, increasing mortality, shortening life expectancy of all population by almost a year, increasing morbidity, and affecting the healthy development of children. In recognition of these risks, the 5th Ministerial Conference on "Environment for Europe" (Kiev, May 2003), adopted an environmental strategy, calling for the optimization of air quality standards a key action and requesting WHO Regional Office for Europe to facilitate the implementation of this action. Also the Fourth Ministerial Conference on Environment and Health, held in Budapest in 2004, requested WHO Regional Office for Europe to assist the Member States of eastern Europe, Caucasus and Central Asia (EECCA) in strengthening their capacities to reduce the health risks of exposures to environmental hazards.

The urgent need for harmonization of the national air quality regulations as well as the monitoring and control systems of the EECCA countries with WHO guidelines was recognized by the WHO meeting "Air Quality and Health in EECCA", St. Petersburg, 13-14 October 2003. The meeting also recommended developing a comprehensive air quality assessment and management strategy, and emphasized the need to address pollutants most relevant to human health, including particulate matter (PM10 and PM2.5); See the report from the meeting in English http://www.euro.who.int/document/E82809.pdf or in Russian http://www.euro.who.int/document/e82809r.pdf

Following these recommendations and to assist the EECCA countries in their efforts to reduce the health impacts of air pollution, the WHO Regional Office for Europe organized a consultation meeting in Moscow, on 30-31 May 2005[1]. Its main objective was to agree on an action plan to harmonize national air quality regulations with WHO Air Quality Guidelines. The elements of the General Strategy and Action Plan to reduce negative impacts of air pollution on health were discussed, and a practical approach was proposed to implement the plan in the EECCA countries.

Workshop participants agreed that the need to update their national strategies taking into account the workshop recommendations should be the subject of thorough discussions at their institutions. The decisions will require the involvement of the ministry of health, ministry of of the environment and, in some countries, other agencies, such as hydrometeorology. National Environment and Health Action Plan (NEHAP) committees could provide a convenient forum for such discussion and the preparation of decisions for governmental approval. In some countries, the current updating and revision of the NEHAP provides a convenient opportunity, allowing specifying activities relevant to the implementation of the political commitments made at the Fourth Ministerial Conference on Environment and Health in Budapest.

Development and implementation of PM monitoring is necessary to assess the magnitude of the impacts of air pollution on health and to plan rational, cost-effective measures for air quality improvement. To assist the EECCA countries in harmonized development of PM monitoring, the workshop recommended renewing the mandate of the present WHO working group. The

[1] Workshop report available at http://www.euro.who.int/Document/AIQ/health_basis_AQ.pdf, Russian version http://www.euro.who.int/document/aiq/health_basis_aq_r.pdf

Working Group would be used as a consultative forum, with its first task to formulate a framework plan for development of PM monitoring in the EECCA countries.

Following the Working Group recommendations, this paper formulates such a framework plan. It gives guidance, mainly technical, for PM monitoring and assessment. Due to the well recognized health impacts of respirable particulate matter, and due to the need to develop PM monitoring recommended by the WHO workshops, the paper focuses on the assessment of ambient concentrations of PM10 and PM2.5. The main conclusions of the Working Group meeting in Moscow are summarized and the main characteristics of PM are described as well a brief summary of health effects of PM, followed by the presentation of the strategy and procedures for PM monitoring. General principles and issues related to PM monitoring are presented in sections 3 and 4, and recommendations specific for EECCA are presented in sections 5 and 6.

1.1 Main conclusions of the consultation meeting in Moscow

The main conclusions reached at the Consultative Meeting in Moscow, which provide the basis for the PM monitoring framework plan are summarised below.

1. The key pollutants to be addressed by national strategies of the EECCA countries in the future are: **particulate matter (PM10 and PM2.5**), **NO_x, SO_2 and ozone (O_3).** In special situations (e.g. depending on the kind or proximity of the source) further pollutants, or their groups, can be added to the list for local monitoring and control (e.g. certain volatile organic compounds, VOCs).

2. Besides the need to control the gaseous pollutants due to their specific health relevance, the monitoring and control of these compounds is also essential in management of particulate matter because they are precursors for secondarily formed particulate matter.

3. **The WHO Air quality guidelines** should be used as a primary reference in assessment of health relevance of the pollutants included in the strategy.

4. Both the amount of the **emissions** of the pollutant (or its precursors) as well as **ambient concentrations** of the key pollutants should be monitored and assessed against specified targets.

5. The strategy should define the responsibilities of various sectors involved both in the pollution generating activities (industry, energy production, transport, agriculture, domestic sector) as well as of the pollution monitoring and control agencies.

6. The Consultative Meeting in Moscow further agreed that the **number of monitoring stations** should depend on the size of the city, ideally with one monitoring station per 200,000-300,000 inhabitants. The countries should gradually develop PM10/PM2.5 monitoring networks, allowing for training, building expertise and personnel capacities, preferably starting with 2 - 4 stations in one (capital) city, so that at this early stage various pollution levels will also allow analysis of the variability of the pollution within the city area.

7. Quality assurance and quality control (QA/QC) shall be established as one of the key elements of the PM monitoring system.

1.2 What is particulate matter (PM)?

Particulate matter is an air pollutant consisting of a mixture of solid and liquid particles suspended in the air. These suspended particles vary in size, composition and origin. Particles are often classified by their aerodynamic properties because: (a) these properties govern the transport and removal of particles from the air; (b) they also govern their deposition within the respiratory system and (c) they are associated with the chemical composition and sources of particles. These properties are conveniently summarized by the aerodynamic diameter, that is the size of a unit-density sphere with the same aerodynamic characteristics. Particles are sampled and described by their mass concentration ($\mu g/m^3$) on the basis of their aerodynamic diameter, usually called simply the particle size. Other important parameters are number concentration and surface area.

The most commonly used size fractions are:

- TSP (total suspended particulates) comprises all airborne particles
- PM10 is used for particles with an aerodynamic diameter less than 10 µm
- PM2.5 is used for particles with an aerodynamic diameter less than 2.5 µm
- Coarse fraction (between 2.5 and 10 µm)
- Ultrafine particle is used for particles with an aerodynamic diameter less than 0,1 µm
- BS (Black Smoke): has been widely used as indicator for the 'blackness' of aerosols (and therefore as a surrogate for soot). The definition is linked to a monitoring method used to measure BS. Monitoring is based on an optical method.

1.3 Health Effects of PM

The evidence on airborne PM and public health is consistent in showing adverse health effects at exposures experienced by urban populations in cities throughout the world, in both developed and developing countries[2]. A WHO analysis of impacts of PM exposure on health in big cities of the world concluded that close to 800,000 premature deaths per year can be attributed to PM exposure[3]. Similar analysis conducted in support of the European Commission's programme "Clean air for Europe" estimated that close to 290,000 premature deaths per year can be attributed to PM from anthropogenic sources in all European Union countries[4]. This exposure reduces average life expectancy by approximately one year. The range of effects is broad, affecting the respiratory and cardiovascular systems and extending to children and adults, and to a number of large, susceptible groups within the general population. The risk for various outcomes has been shown to increase with exposure and there is little evidence to suggest a threshold below which no adverse health effects would be anticipated. The epidemiological evidence shows adverse effects of particles after both short-term (days) and long-term (years) exposures.

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[2] *Air quality guidelines for Europe. Second Edition*. Copenhagen, WHO Regional Office for Europe, 2000 (WHO Regional Publications. European series No 91) http://www.euro.who.int/air/activities/20050223_4; Russian translation

[3] Cohen A. et al. "Mortality impacts of urban air pollution," in *Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors*, M. Ezzati et al., eds., World Health Organization, Geneva, pp. 1353-1434 (2004)

[4] Watkiss P et al. CAFE CBA: Baseline analysis 2000 to 2020. Didcot. AEA Technology Environment., 2005 http://europa.eu.int/comm/environment/air/cafe/activities/pdf/cba_baseline_results2000_2020.pdf

Most of the epidemiological studies showing adverse health effects of PM used PM10 mass concentration as an indicator of exposure level. The coarse fraction of PM10 (i.e. the particles between 2.5 and 10 µm in size) is linked with respiratory morbidity. However, the strongest links between mortality due to cardiovascular diseases and long term exposures to PM were observed for PM2.5 concentration, and not for the larger particles. Therefore, the reduction of exposure to PM10 and PM2.5 is recommended as the necessary measure to reduce the risk of a wide range of health effects. Particles larger than PM10 stay in the upper parts of the respiratory tract and do not therefore affect morbidity and mortality. Based on the conclusions of health related studies, the management of air quality should focus on reducing population exposure to PM2.5 and PM10. This requires assessment of PM2.5 and PM10 concentrations. The monitoring of concentration of total suspended particulate matter, TSP, (including particles larger than PM10) is less suitable for effective support for health-oriented air quality management.

2 Strategy of PM Monitoring: general principles

2.1 Introduction

Since the late 1990s, substantial experience of monitoring and assessing PM10 has been accumulated in Europe due to the introduction of legally binding standards and norms, but there is less experience and information available on PM2.5. This imbalance is also reflected in this draft of the framework plan. In the light of health-related WHO evaluations, it is recommended to use PM2.5, as well as PM10 for assessing exposure to PM and its health risks. In the currently discussed update of the European Union air quality directive, a reduction of population exposure to PM2.5 is proposed. In the United States, the air quality standard applies to PM2.5 but the coarse fraction PM(2.5-10) is also controlled.

The general aim of an air quality management strategy is prevention and reduction of the negative impacts on human health (and the environment as a whole) caused by air pollutants, especially by particulate matter (PM). To protect human health, the population exposure to PM should be reduced, prevented or if possible avoided.

The goal of the assessment is to provide the air quality management process with relevant data through a proper characterization of the PM levels, its spatial and temporal patterns, and composition. It uses monitoring and/or modelling programmes and projection of future air quality associated with alternative strategies.

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In line with the General Strategy for reducing the negative impacts of air pollution on health in the EECCA countries, the General Action Plan guarantees in a more precise and technical way a consistent derivation of the process of monitoring, assessing, controlling and managing air quality. The main purpose of this paper is to specify all conditions necessary for PM monitoring. However, to assure consistency of the monitoring with all the air quality management system, various other issues have to be considered when the monitoring is planned.

There are various reasons why monitoring is conducted but the ultimate objective is the assessment of population exposure to PM in ambient air. This assessment allows planning pollution abatement strategy for effectively reducing the exposure and, therefore, negative health impacts of the pollution. Basic principles are described in “Monitoring Ambient Air Quality for

Health Impact Assessment", WHO Regional Publications, European Series, no. 85, 1999 (available both in English and Russian).

The strategy of PM monitoring should always be seen in connection with an assessment. To be able to perform this assessment some important aspects have to be considered:

- In many countries, regulation concerning chemical composition of PM10 applies only to selected compounds located on the PM2.5 fraction.
- "Particulate matter" cannot be described by a chemical formula such as "sulfur dioxide = SO_2" and can't be described by a physical or chemical property. The most essential properties are the particle size, the chemical composition and as a result of both, the mass.
- PM can be emitted directly to the air (so called primary particles) or be formed in the atmosphere as "secondary particles" from gases such as NO_x, SO_2 and NH_3 (ammonia).
- PM can be caused locally or regionally or can be transported over long distances.

Monitoring mass concentration of PM10, even combined with PM2.5, may be insufficient for understanding the pollution sources. So the task will involve determining what further investigation will be necessary. For example the chemical composition allows conclusions about the contributions of different emitter groups and thus, indirectly, which part of these contributions is caused by local or regional sources or is transported from far away. This knowledge is essential in choosing the most effective emission reduction strategy.

Further attention has to be given to the fact that:

- Emission data and meteorological/topographical data should be available for planning the monitoring.
- The usual time resolution for PM data (specified in existing standards in many countries and also the EC limit value) is 24 hours, the calendar day.
- Due to the size fraction process, PM data are usually reported at ambient temperature and pressure, which is different from the practice applied for gaseous pollutants.

2.2 General principles of PM monitoring

The PM assessment leads to the compilation of data on the concentrations over various ranges of time and space. Meaningful comparison of such data, from different sites and/or different times, is only possible if the monitoring data are of good quality, represent the same variable and are presented in the same way. This is only possible if agreed common methods are used for all issues.

The results of the various existing methods for monitoring PM10 differ systematically, and each of the methods has advantages and disadvantages, which need to be considered in network design. Annex A provides basic information about the different methods.

This paper divides the methods into gravimetric (measuring directly the mass of collecting PM on a filter and, subsequently, weighting the collected PM mass on a precise scale) and continuous methods, which assess the mass of PM indirectly. Gravimetric methods may be divided into devices, which require a manual change of filters, and those with automatic filter changer. In principle all three methods can be used to monitor either TSP or PM10, PM2.5 or PM1 concentration. The selected type of air inlet determines the size of particles measured. In addition, gravimetric method is applied in so-called "dichotomous configuration", where particles of different size: PM2.5 (fine PM) and PM10-2.5 (coarse fraction) are collected on separate filters.

The following paragraphs provide an overview of the various available methods of PM monitoring, summarizing the main features of each method. The selection of the equipment will be the responsibility of local authorities, who can follow the recommendations given in chapter 4 of this paper.

2.2.1 Monitoring of PM10

Table 1 groups the methods of PM monitoring into the main categories. The coding used in the table will be applied in the further text.

Table 1: Overview of methods of PM monitoring

Monitoring method	Type of equipment	Quality	Comments
A - Manual sampling and gravimetry	A1 - Low volume (Kleinfiltergerät) A2 – High volume (Anderson)	Reference method*)	Requires manual filter change every day. Online data transfer NOT possible
B - Automatic filter changer with gravimetry	B1 - Digitel B2 – Partisol B3 – Leckel	Gravimetric equivalence method **)	Automatic change of filters Online data transfer NOT possible
C - Continuous automatic monitor	C1 – ß-attenuation C2 –Tapered Element Oscillating Microbalance (TEOM) C3 – other monitors	Continuous monitor with local correction factor **), ***)	Online data transfer possible

*) According to EU norm EN 12341
**) According a report given in http://europa.eu.int/comm/environment/air/pdf/equivalence_report2.pdf
***) see Annex B

Table 1 indicates that many combinations of methods and types of equipment are possible in a single network. It depends on the network's task, as to which combination will be optimal. *As indicated, equipment A demonstrates the highest level of "seriousness", equipment C the least*. But there is no single equipment type, which provides all desirable information; there are still advantages and disadvantages to each combination. The operation of manual equipment is the most labour-intensive method, requiring very high skills and efforts to maintain consistent quality of the measurements. Therefore, equipment A is not recommended for routine monitoring. The planning group must find a practical solution between the precision of the data from monitoring and fulfilling the entire range of monitoring tasks. Some information will need to be collected with additional, not routine, activities.

Table 2 shows the adequate equipment for different tasks of monitoring. For fulfilling the control task, equipment B (equivalent to the reference method, labour intensive) has to be used, to fulfil the reporting requirements (daily information) one needs current data so that a continuous automatic monitor is necessary, (equipment C). Equipment C with a higher time resolution than the reference method can be an advantage for those cases when, additional to gravimetric method, the hourly (short-term) variation of the concentration is of interest.

When starting a programme of emission reduction in highly polluted areas, less demanding equipment (C) will fulfil the need to “observe the trend in CCEEA countries” because the decrease of concentration can be readily registered by such equipment.

To fulfil the different tasks given in table 2, primarily PM monitoring has to be done, but in some cases additional information is necessary (see last column).

At monitoring stations near industry, near traffic and in larger highly polluted areas there might be a need to determine the contribution of specific emission sources to the high pollution level. In these cases the source oriented approach is the most effective one: the analysis of the chemical composition of the PM10 mass, see paragraph 4.2.2. Co-location of equipment B and C will be needed to determine the local correction factor.

Table 2: Equipment for different tasks of routine PM10 monitoring

Tasks	Type of equipment	Additional requirements	Additional equipment / parameter
a) Control: Compliance with limit values, target values (including Preliminary Assessment)	B – Gravimetry; automatic filter changer B1 - Digitel B2 – Partisol B3 – Leckel	* Weighing room with temperature and humidity control * Balance of higher sensitivity	* Composition of PM10: well equipped chemical laboratory * C – Continuous automatic monitor * Meteorological data * Emission data
b) Daily information to the public c) Observation of trend and time pattern	C - Continuous automatic monitor C1 – ß-attenuation C2 – TEOM C3 - other	* Additional expertise to identify the local correction factor necessary	* Meteorological data * Emission data

If chemical analyses of the composition of PM10 mass are necessary, equipment B has to sample with different types of filter:

- Glass fibre filter (and some kind of quartz fibre filter) for the routine determination of the mass;
- Quartz fibre filter for the chemical analysis of some species;
- Teflon filter for full chemical analysis.

Having in mind that chemical analyses were undertaken to learn something about the composition of the PM10 mass (and not for controlling one species if its limit/target value is exceeded) approximately one analysis each week is acceptable. It is necessary to compile a sampling plan in advance, because on those days on which chemical analyses should be undertaken, a quartz fibre (or Teflon) filter has to be used instead of the cheaper glass fibre filter.

When establishing the sampling plan, one should have in mind a frequency of chemical analyses that enables not only insight to be gained on the weekly behaviour of PM10 concentration but also in the composition. Therefore a statistical distribution between the weekdays should exist. This can be reached only by using an uneven number of days. To avoid the influence of a weekly pattern of emission, do not use the frequency of every seventh day! Table 3 gives as an example the frequency of every fifth day.

Another possibility is to concentrate the chemical analyses at a time period when weather conditions cause high PM concentration, such as during inversion or at a specific occasion of higher emission (e.g. during winter when power plants work with higher capacity).

If the monitoring programme of PM includes analyses of chemical composition of particulate samples then the monitoring strategy and applied methodology including quality assurance programme of EMEP (European Monitoring and Evaluation of Pollutants) should be consulted[5].

Table 3: Example for a plan for monitoring of chemical composition of PM10
(Q = quartz filter to be used)

Week	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
1st	Q					Q	
2nd				Q			
3rd		Q					Q
4th					Q		
5th			Q				
∑	1	1	1	1	1	1	1

Only with a continuous automatic monitor (equipment C) with its high time resolution (e.g. 1 hour) can one learn about the time variation of the ambient air concentration and can uncover, in combination with meteorological data, mainly wind direction, explanations for specific situations causing high pollution episodes.

2.2.2 Monitoring of PM2.5

In principle the methods for monitoring PM2.5 are the same as given in table 1 for PM10. In a first approximation the same kind of equipment can be used, only the air inlet has to be constructed for a cut-off at 2.5 µm.

The reference method is given in EN 14907. Reference sampling methods are:

- High volume sampler (30 m^3/h) with given size-selected air inlet (like Digitel)
- Low volume sampler (2,3 m^3/h) with given size-selected air inlet (like Leckel).

[5] http://www.nilu.no/projects/ccc/monitoring_strategy/

2.2.3 Monitoring of coarse fraction (PM10-2.5)

Beside the equipments monitoring either the PM10 or PM2.5 fraction there is also equipment available that uses the principle of Dichotomous configuration which allows simultaneous sampling of the fine fraction (PM2.5) and the coarse fraction (particles between 2.5 and 10 µm aerodynamic diameter) on the gravimetric basis. After weighing the filters the mass concentration of the fine fraction (C_f) and the mass concentration of the coarse fraction (C_c) are known. The sum of both gives the PM10-concentration (C_t).

$C_t = C_f + C_c$

It can be seen as an advantage that with only one device two PM-fractions can be given (doubled amount of work for weighing!) but it can also be a disadvantage that no filter exists for the PM10-fraction for the analysis of the chemical composition.

It isn't known if this sampler has completed an equivalence test.

2.2.4 Conclusions:

Principally the method should be chosen which has the highest level of appropriateness for a given task. For the control task (compliance with limit/target value) the gravimetric method has to be used, but for additional information requiring higher time resolution than 24 hours, a continuous automatic monitor has to be used. Such a combination of methods is necessary because the results of both methods differ systematically; this is an important disadvantage of PM monitoring in comparison to the measurement of gaseous compounds.

2.3 Quality assurance and quality control

The implementation of quality assurance and quality control (QA/QC) system is essential for assuring confidence in one's own monitoring data, to make them comparable in time and between various locations, and to make them comparable with data of other institutions within the country and abroad.

2.3.1 Principles of quality assurance and quality control

In principle, there are four different levels of harmonization for a monitoring method; the higher the harmonisation level the less quality, and accuracy activities are needed during practical monitoring work. All four levels have to be taken into consideration. European Union countries have agreed to adopt the highest levels of PM monitoring harmonization (level 4 or 3).

1. *A method by common agreement*. The weakest possibility. This means that a group of experts declares one monitoring method as the chosen method for working in practice for a specific monitoring task. This approach itself can not guarantee the method compatibility to another method, or data compatibility.

2. *A standardized method* (for example ISO). The chemical or physical reactions and detection methods are prescribed in a standard. Since air quality assessment needs high comparability of data, an agreement should be reached, not only on harmonization of monitoring methods and on the reliability of measuring results by verification of their quality and accuracy, but also on harmonization of data handling and evaluation.

3. *Equivalent method*. It is possible to use any method if one can demonstrate that this method produces equivalent results or shows consistent relationship to the reference method. (Countries / institutions using such a method must undertake studies to show comparability with the reference method!).

4. *Reference method.* The measurement principles of the reference method are laid down in the specific Directives. The measurement method is defined in the European Standards (EN). The Directives set requirements for the reference method regarding time resolution, data quality objectives and their application. The requirements for the data quality objectives vary with the concentration level.

For PM10, the reference is the manual gravimetric method, the equivalent method an automated filter changer. Both are discussed in EN12341. The European norm EN12341 covers only gravimetric methods in its discussion of equivalence and does not deal with equivalence of commonly employed automated systems such as β-attenuation or oscillating mass balance methods (TEOM). The use of continuous automatic monitors will provide a relationship to the reference method through inter-comparison measurements.

For PM2.5 the reference method is defined in EN14907. It is a manual gravimetric method using single filters. The norm also gives procedures for determining whether non-reference measurement methods (like other manual gravimetric or gravimetric automatic monitoring methods) are equivalent to this reference method.

Table 4: Technical requirements and QA/QC issues for the different methods

Type of equipment	Requirements	QA/QS issues
A - Manual sampling and gravimetry A1 - Low volume (Kleinfiltergerät) A2 - High volume (Anderson)	Weighing room Balance of higher sensitivity Well trained personal	Temperature and humidity control in the weighing room Volume control
B - Automatic filter changer B1 - Digitel B2 – Partisol B3 - Leckel	Weighing room Balance with higher sensibility Well trained personal	Temperature and humidity control in the weighing room Volume control
C - Continuous automatic monitor C1 – ß-Absorption C2 – tapered oscillation… C3 - …..	Air conditioned monitoring station Online data transfer possible Local correction factor (of different “quality”)	Volume control

Quality control has to start as soon as a measuring method is selected; the different levels of harmonization of a monitoring method are given above. Therefore one needs to specify required performance criteria such as precision, repeatability, reproducibility and correctness of the

measurements. Specifications are also needed with regard to the daily measurement procedures, which also could be changing in time, if necessary. Data quality objectives must be given also in regard to the minimum data capture (data completeness) and time coverage.
The aim of all these procedures must be a complete quality assurance and quality control programme (QA/QC) that allows starting with any agreed measuring method and ending with methods comparable with the reference method.

Table 4 summarizes technical conditions and QA/QC activities necessary when the different methods are applied. Equipment A and equipment B can run either within a monitoring station (shelter, container) or outdoors, without any "weather protection". Installation inside a shelter or container has the advantage for maintenance and filter change independent of weather conditions. The storage conditions of the filters are defined especially during hot summer days. The reliability of instruments protected from weather is higher during severe and cold weather. These statements are valid for both PM10 and PM2.5 monitoring.

2.3.2 Quality issues in the different methods of PM monitoring

The fact that there exist three different methods for PM monitoring has its advantages but also its disadvantages. The main problem is unequal level of harmonization of various methods.

At present non-gravimetric methods in use do not produce results equivalent to the reference method under all conditions. In practice gravimetric methods yield higher concentration data than continuous automatic monitors. This is due to the necessity of heating the continuous automatic monitors, resulting in a loss of more volatile parts of PM.

In the EU, the main purpose of PM10 monitoring is compliance with the EU standards. Therefore it was necessary not only to achieve a harmonization of methods but a harmonization on a high level. Preparatory work for PM10 monitoring has been done during the past few years to get an agreement on the different problems related to the PM10 monitoring. As a result of these discussions, only the reference and equivalent methods (level 4 and 3) can be used for compliance monitoring, i.e. only:

- Manual sampling and gravimetry (the reference method per definition);
- Automatic filter changer and gravimetry (the equivalent method).

Because the reference method is very laborious, it is used very rarely in the existing networks. Since several studies have demonstrated that the equipment with automatic filter changer (B) produces equivalent results to the reference method, it is widely used for compliance checking.

Besides PM10 monitoring for compliance purposes, it is also necessary to gather PM concentration data of a higher time resolution than 24 hours. Therefore a continuous automatic monitor has to be used. However, this equipment produces data that does not fit into the hierarchy of harmonization. All efforts showing equivalency have failed. The only way out of this problem is to run an automatic filter changer in parallel to a continuous automatic monitor for a period of time during winter and summer each. In this way one receives the so called "local correction factor". This correction factor depends on the monitoring site (high/low proportion of secondary aerosols), the season (high/low temperature) and the type of instrument. This means that there is no one general correction factor.

Some basic conditions for carrying out this inter comparison are given in the EC Report "Guidance to Member States on PM10 monitoring and intercomparisons with the reference method"; http://europa.euint/comm/environment/air/ambient.htm#1 Report 2001. Based on this EC report, annex B summarizes information on the approach to generate the local correction factor for PM10 monitoring (how to randomize data from continuous automatic monitors in gravimetric equivalent data). In the last few years, a lot of data from comparison studies have been evaluated. Also, new developments and improvements in the field of automatic continuous monitoring (mainly reducing the losses of volatile material) have taken place. According to this combined knowledge, it should be sufficient to establish the local correction factor at one selected site, and to transfer it to another site(s) of the same type of micro-environment within the region. It depends principally on the size of the region, the differences between monitoring sites and types of equipment used, how many intercomparison measurements have to be undertaken. Intercomparison measurements at 10 – 20 % of stations of each type (monitoring site and type of equipment) should be sufficient at the start of the monitoring.

For monitoring PM2.5, the equipment listed in table 1 for PM10 monitoring can be used but with changed air inlet. That means that all problems arising with different methods and different levels of harmonization specific for PM10 monitoring still exist, in principle, for PM2.5 monitoring. Consequently, also for PM2.5 monitoring the equivalency of the equipment with automatic filter changer to the reference method has to be shown and "local correction" factors for continuous automatic monitors have to be established.

It is difficult to predict whether the problems of poor equivalency and consistency with local correction factors will increase or diminish when changing from PM10 to PM2.5. On the one hand, slight deviations of the samplers from the ideal PM2.5 cut-off point will result in lower mass changes, as PM2.5 is close to the minimum of the particle mass distribution, whereas the PM10 cut-off point is close to the maximum of the coarse mode. On the other hand the overall PM mass decreases by about one third when going from PM10 to PM2.5, and the portion of secondary semi-volatile aerosols which is predominantly in the fine mode increases.

2.3.3 Documentation

Documentation of the decisions, procedures and data is one of the crucial components of the monitoring system. Development of the documentation system costs time and effort (and money) but using it in practice brings a lot of benefits, in particular providing the possibility to verify and correct data.

Documentation has to include records of:

- Site-selection procedures. Sites should be fully documented at the classification stage by photographs of the surrounding area and a detailed map. Sites should be reviewed at regular intervals with repeated documentation to ensure that selection criteria remain valid over time;
- QA/QC processes (of daily, weekly, monthly, …. activities);
- Data handling (methods of data transfer, storage, assessment, reporting until printing).

2.3.4 Conclusions

- In principle, four levels of harmonization for monitoring methods exist; the higher the harmonization level, the fewer quality and accuracy activities are needed as the practical work begins.

- For air pollutants such as PM10, for which standards or target values are given, one of the two highest harmonization levels are obligatory in the EU.
- It will be an advantage for EECCA countries (saving time, personal resources and money) to develop PM monitoring using experiences from the EU and adopting the reference method (manual sampling and gravimetry) as well as the equivalence method (automatic filter changer and gravimetry) instead of developing another reference method or work on a lower harmonization level by a method of common agreement.
- The continuous automatic monitor is out of this "gravimetry hierarchy" of EU-harmonization. However, its deployment is necessary to fulfil some tasks of the monitoring. In so doing, one has to run the continuous automatic monitor for certain time periods parallel to a gravimetry method to generate the "local correction factor". This comparison procedure has to be undertaken at each site individually.

2.4 Network issues

Monitoring the population's exposure to an air pollutant requires gathering concentration data in several locations in centres of population, i.e. mostly in big cities and in other densely populated areas. Monitoring on different sites makes it possible to assess exposure and can be combined with modelling and other exposure assessment methods. The main purpose of this section is to present the main issues to be considered when designing the network in a large city, such as a capital city.

The design of a network consists of several steps, in which information of the different issues has to be collected to support decision making. If the required information is not available, it should be gradually collected. The following information is necessary for design of the PM monitoring network:

- plan of the area;
- spatial distribution of industries (specifying type, technologies potentially causing significant pollution emissions and available emission control, including height of the stacks etc. allowing assessment of whether the emissions will affect the local pollution levels);
- emission data from all significant point sources and major diffused sources;
- location and size of major traffic flows;
- topographical and meteorological data relevant to dispersion on emissions and of pollution transport phenomena;
- spatial distribution of the population living in this area;
- basic characteristic of the population in various areas, including health status, age distribution etc. (the latter can be indicated by location of hospitals, schools, houses for elderly etc.).

All information about pollution concentrations observed over previous years or any observation about nature damage could be helpful.

When starting with the design of a PM network the main questions will be:

- Does a pollution monitoring network already exist in the city? If yes, is it appropriate for PM monitoring or is it possible to re-design it, extending it to include PM monitoring?

- Is the existing network appropriate for the control of compliance of limit/target values?
- Is the existing network appropriate to assess the trend in PM concentrations, defined as an urgent task for the networks to be created in the EECCA countries?

These questions can be answered in the first evaluation, which includes the evaluation of the capacities of the existing, or modified, network in relation to the spatial distribution of industries and traffic, existing emission data and information on population distribution.

This evaluation can conclude that the network:

- Is appropriate for PM monitoring, i.e. that the existing stations can be used as the PM10 monitoring sites, or
- Must be re-designed, i.e. one or more existing stations should be moved by a few hundred metres or a new monitoring station should be set up.

If no network exists, the location of the new monitors should be decided following the guidelines as strictly as possible. This should result in the best design and the best results.

The use of an air quality model can be very helpful in selecting the monitor's location. Air quality models are used to establish a relationship between emissions and air quality in a given area. The contribution of the emission of a single source to pollutant concentration at ground level can be assessed with a relatively simple model. However, the models necessary to evaluate the concentration field over the whole urban area are highly sophisticated, particularly for particulate matter and especially in complex terrain. Whenever the model is used, the model results must be compared with measured data. Data from measurements are also often used as input data for model calibration and validation.

It can be assumed that monitoring will start in highly polluted areas with high population density. In such areas, the monitoring has to be undertaken:

- In an urban residential area ;
- In an urban area with significant diffused industrial sources;
- Near busy streets or in street canyons.

In each highly polluted area, traffic will be an additional emission source. The PM levels depend strongly on the immediate surroundings of the road. Highest PM levels are observed in street canyons with rows of connected buildings on both sides. The polluted area can be situated in a continental flat region, in a mountainous region, at the seashore, or can be influenced by a desert. All these conditions will affect the selection of location of the monitor.

To protect the whole population in the area of interest (and to receive comparable PM data from different cities) a harmonization of the types of PM monitoring sites is necessary. The PM monitoring should follow these macro-scale objectives:

- To provide data for the areas where the highest concentrations occur to which the population is likely to be exposed for a period which is significant in relation to the averaging period relevant for health impacts (24-hour or annual average).
- To provide data on levels in other areas which are representative of the exposure of the general population.

For practical purposes, the number of monitoring sites is usually lower than precise exposure assessment would require. Therefore the few available monitoring stations should be located at such sites where one can be sure to monitor as much as possible of the pollution burden.

When running a monitoring station, some terms of reference also have to be considered, on the vicinity of the site, see “Micro-scale Conditions” in the report from the WHO Consultation in Moscow.

When assessing the contribution of a large industrial plant to the pollution, it might be difficult to select the optimal location for the PM10 monitor, if only one device is available. The site where short-term high peaks of pollution can be registered may be different from the site where high long-term average concentration occurs. The first location may be preferable when PM monitoring is used for assessment of pollution abatement actions undertaken in the plant. The second location may be more appropriate for assessing human exposure, and its trends.

In conclusion, and following the macro-scale conditions, one PM10 monitoring site has to be located near each of the existing hot spots, and at least one has to be situated in a suburban residential area. Furthermore, if available resources allow, one more monitoring site should be established outside of the urban area at a rural background site. The comparison of data “inside the urban area” and “outside” can help to understand air pollution behaviour over the urban area, even when only PM10 mass concentration data are available. Even more useful would be gathering of chemical composition data, at least during the summer or winter (the local relevant meteorological months) in these two stations because they will show possible different origins of the pollution much more clearly. The examination of both these two data sets will make it easier to find a suitable abatement strategy for the region of interest than the data of the urban region alone.

For better understanding the variation of the PM concentration, SO_2 and NO_x should be monitored as well, in at least one suburban residential site. This is independent from the concern of direct health effects of these gases, requiring their monitoring.

When PM is monitored in a region with a pollution pattern that is not well understood, it is advisable to use a continuous automatic monitor (equipment C) at one site (in particular a site influenced by industry) to gain insight into the short-term variation of PM10 concentration during the day. The assessment of the impact of the individual sources on pollution level will be more efficient when meteorological data, at least wind direction, is available.

The number of monitoring sites will always be a compromise between the required coverage of the area, representative enough to show the improvement of air quality – and (always limited) budget. To determine the minimum number of sampling points to assess compliance with limit/target values in an area of interest where measurements are conducted and where the monitoring is the sole source of information on air quality, the following factors have to be considered:

1. The number of inhabitants (starting optimally with one station for an area between 200,000 and 300,000 inhabitants and increasing the number of stations with increasing number of inhabitants; this is the approach taken in the European Union.
2. Type of urban area:
    - Without any big point sources or significant diffused sources;
    - With one big point source (in this case one station has to be situated at the point where the highest contribution of this source is expected and a second site in that direction where contribution of this point source to the PM levels is unlikely);
    - With one significant diffuse source (in this case one station has to be situated at the point where the highest contribution of the sources is expected and a second

site in that direction where contribution of these sources to the PM levels is unlikely);
   - Dominated by point sources (in this case the number should be calculated taking into account emission densities, the likely distribution patterns of ambient air pollution and the potential exposure of the population);
   - Traffic dominated;
3. The mix of one pollutant of different sources.

When starting PM10 monitoring, only the number of inhabitants (point 1) is of relevance for the determination of the number of monitoring sites. Points 2) and 3) give guidance on how the given number of monitoring sites will be split up between the different types of urban area. By choosing the sites of PM monitoring in this way it can be expected that the network will cover the relevant emissions sources.

In most cities, the area with high pollution levels is much smaller than the populated area for which measures have to be taken. Therefore it is necessary to collect data of a greater area than the urban area. Sometimes emission data are necessary for the whole territory of the country.

2.4.1 Conclusions:

- PM Monitoring has to start in highly polluted areas, with pollution caused by different sources.
- Monitoring stations have to be situated always at the highest polluted sites of each region.
- The data collected by the network should be sufficient to determine exposure of the population living in the area covered by the network to PM.

3 Procedure of PM monitoring

3.1 Regional Planning

Assessment and prevention of the population's exposure to pollution should be the challenge of the highest level of responsibility within each country. However, depending on the country administration structure, a network can be planned on a national, regional or local scale. In each case, there should be a clearly defined group at state governmental level which assures harmonization of all the monitoring requirements, including its QA/QC, and which is responsible for preparation of reports and evaluations based on the monitoring data, and also for training personnel.

The monitoring programme has to be adjusted to regional/local needs, conditions and regulations. It must be feasible for implementation but, even with the limited resources and funding, the programme must meet the basic requirements summarized in the previous sections of this paper. The planning, and duration of the preparatory process for the network development, will be shorter if more, and better, initially required data is available. In particular, the data related to the sources of PM emission are important. Preparatory work consists of:

- gathering of all available data;

- analysis of the local situation;
- initial selection of locations for monitoring;
- starting PM monitoring.

Both PM10 and PM2.5 concentrations need to be assessed. However, due to the greater PM10 (spatial) variability, the PM network will need to measure PM10 in all locations, and in few of those locations also PM2.5 will be monitored simultaneously.

3.2 Preparatory work

3.2.1 Pilot project

To design the network, it could be wise to start with a pilot project to gain a good understanding of the spatial distribution of PM concentration and to identify the areas with the highest concentration. The work on the pilot project often has to start without ambient air concentration data. The air quality must then be based on first estimations of the emission of single sources and different optical observations, e.g. identification of locations with nature damage.

During the pilot project, the monitoring should be undertaken mainly at fixed sites, to assess trends. A few mobile monitoring stations (monitors moved from one location to another) can be used for preliminary assessment. The equipment to be used will include mostly gravimetric samplers with automatic filter changer, accompanied by a continuous automatic monitor.

When equipment is limited or the area of interest is too large, one can consider whether the area of interest could be divided into two or three sub-areas, and if so, how. These sub-areas will be assessed with the available equipment one after the other. Therefore monitoring will start with a delay of one year in each sub-area. If doing this, it will be wise to run one device with an automatic filter changer at one fixed site from sub-area 1 during the measurement periods in sub-area 2 and 3. The pilot project should be limited to one year in each area.

In areas where PM10 data are already available, the planning will be more efficient.

The pilot project is essential to gather information about the spatial and temporal patterns of PM concentration field. The evaluation of all gathered monitoring data, together with the emission data and meteorological/topographical allows detailed design of the network to start. This analysis gives the first information about the emission sources (under concrete meteorological conditions) contributing mostly to the PM concentration at a distinct monitoring site. The improvement of the assessment can provide the chemical composition of PM10.

The data collected in the pilot project will be also the basis for:

- The decision on whether the sites chosen will remain in the network and whether for one or the other site the preparatory work has to continue for one more year.
- The necessary evaluation of the preliminary assessment. Preliminary assessment means comparing the situation with limit/target values.

At this time one must also start to check the potential for reducing emissions contributing to the PM concentrations. This is the most essential question because very often the emission source(s) that contribute the most to the observed concentration will be located outside the area of the city.

Sometimes a substantial part of the concentration will be due to the transport of pollution from neighbouring areas or even from remote areas.

3.2.2 Source/receptor relationship

In each area, the contribution of various sources to total emissions will be different. The main PM sources may be domestic heating, traffic, and specific industries like steel mills or cokeries.. The local distribution of the emitters in connection with topographic and meteorological conditions cause specific ambient air concentrations with variation over the year, the weeks and over the 24 hours of a day.

Knowledge about the chemical composition of PM allows conclusions to be arrived at, about the contributions of different emitter groups. It also, indirectly, indicates what fraction of pollution is caused by local or regional sources, or is transported from far away. This knowledge helps in the preparatory phase when choosing the best site for PM monitoring and is essential to choose the most effective emission reduction strategy.

Table 5: Components, their sources and most suitable analytical method

Components	Sources/Formation	Analytical methods
Anions: sulphate, nitrate, ammonium	All main SO_2 and NO_x sources such as domestic heating, power generation, metallurgic processes, traffic, … agricultural activities → secondary component arising from chemical reactions during atmospheric transportation In some regions: a small amount can be a primary component that arises from sea salt or mineral matter such as gypsum	Ion chromatography
Elemental carbon	So called black smoke (soot) is formed during combustion of fossil fuels (coal, oil, natural gas) and biomass fuels	Thermo optical method corrected for charring
Organic carbon	Originates partly directly from traffic (tail pipe emission) and combustion sources, and as a secondary pollutant as a product of oxidation of volatile organic compounds (VOCs). Most of them are highly toxic; some of these components can be considered as tracer components, like benzo(a)pyren	Thermo optical method corrected for charring
Trace metals: lead, cadmium, mercury, nickel, chromium, zinc, manganese…	Generated by metallurgical processes like steel making, or out of additives/impurities of industrial used products, from impurities or additives of fuels and also from mechanical abrasion processes (during vehicle motion and break and tyre wear)	ICP-MS or GF-AAS
Minerals: aluminium, silicon, iron, calcium	Crustal materials (rock and soil); arise from quarrying, construction and demolition work, from wind driven dusts (mainly found in the coarse PM fraction)	ICP-MS
Trace organic compounds	Very large number of individual organic compounds. Arising directly from fuel combustion processes. Generated by traffic and solvents: aromatic compounds like benzene and toluene. From vegetation, especially conifers and heathers: monoterpenes. Additional secondary organic compounds can be found.	ICP-MS
Water	Some water soluble components like ammonium sulphates, ammonium nitrates and sodium chloride take up water from the atmosphere	
Sodium chloride	Sea salt	Ion chromatography
All compounds	Specific for industrial branches in the given area	

Table 5 summarizes the main components of PM10 and their main sources. The overview shows the groups of components, which can be analyzed by one analytical method.

Most of these components are of anthropogenic origin. Some are emitted in geogenic or biogenic processes. The chemical analysis data in connection with the local emission data and meteorological data allows conclusions to be come to, on which emitter contributes and to what extent, to the concrete situation at this monitoring site. The different kinds of industries within the area and their different technologies in combination with the local emission data have to be examined to learn which components has to be analyzed. An initial screening will be necessary to be sure that no important component is missing. Experience shows that the arithmetic sum of the concentration figures of all components will be less than the mass concentration itself. In most cases, the difference cannot be attributed to any of the specific sources / compounds.

When considering the availability of a local laboratory to participate in the chemical analysis of PM10 samples, the regional planning group will need to answer the following questions:

- Does a chemical laboratory with suitable equipment exist in the city/region/country?
- In which field of chemical analyses does experience exist?
- What kind of intra-laboratory comparisons have been undertaken?
- What kind of inter-laboratory national comparison has been undertaken?
- What kind of inter laboratory comparison with a European laboratory has been undertaken?

If the laboratory exists and its procedures satisfy at least the requirements of national inter-laboratory comparison tests, the regional planning group may decide to conduct the analysis of chemical composition of PM there. If such a laboratory is not easily available, or cannot be established in the initial stages of monitoring, it might be more cost-effective to use an external laboratory that routinely performs similar analyses.

4 Plan to establish PM monitoring in EECCA

Based on the general principles presented in the previous chapters, this chapter provides a short compilation of the minimum desirable activities necessary to initiate PM monitoring in EECCA countries.

Why monitoring PM?
The main goal of PM monitoring is observation of human exposure and verification of air quality compliance with limit/target values (if they have been set in the country). This information is essential for assessment of the magnitude of burden to health caused by PM exposure.
Additionally, the monitoring provides information about:

- PM concentration at selected sites, and their trend in time;
- Spatial distribution of PM in the city;
- Composition of PM in the city;
- A link of PM concentration with the emission sources.

To gather PM10 data that are comparable within a country and within all EECCA countries, it is essential to harmonize the PM monitoring. The harmonization requires a lot of preparatory work, is time consuming, and needs budgetary and personal resources, but is an essential requirement if the data are to be reliable. Such reliable monitoring data show in a direct way the magnitude of human exposure and identifies the most effective emission reduction strategies. The first priority of the generation of PM monitoring data should be to support abatement strategies.

4.1 Preparatory work in EECCA

A structured, harmonized approach applied by all EECCA countries could be based on their own discussion, expertise and developmental work, or could use experience gathered by the EU countries in the recent years, developing the methods currently applied in the EU. The latter approach is recommended, since it is less expensive, does not require substantial research capacities and will save several years that would otherwise be necessary for preparation of the methods. Furthermore, the PM10 data collected in EECCA according to the European norm (EN 12341) will be comparable with the results of monitoring conducted in all EU countries.

Quick generation of data in a few selected locations is necessary to start assessment of PM concentration trend. It will support the initial actions aiming at emission reduction. Therefore, instead of waiting several years for the data while all infrastructure necessary for comprehensive PM monitoring is built, it would be advisable to start operating at least one continuous automatic monitor for observing the PM10 trend as soon as possible. At this initial period, when the local correction factor will be not available, a default correction factor recommended for the EU countries (=1.3) will be used to transform the results from the automatic monitor to the gravimetric equivalent data (only for a strictly limited period of say, 3 years). These results will be used for the network planning and for information to the public.

As the second step, the infrastructure should be developed for the introduction of gravimetric measurements, allowing the monitoring of PM10 with a method of a higher harmonization level (equivalent or reference). This gravimetric equipment, together with the continuous automatic monitor, will be used for the pilot project.

If the monitoring of TSP is conducted in a region, the network will need to be quickly re-organized to accommodate for the proper PM10 monitoring. However, the TSP monitoring should also be carried out during the planning period and reorganization of the network, and, if possible, the data should be collected simultaneously. This would allow the development of an understanding of the approximate relationship between TSP measured with the old methodology and the newly gathered PM10 data.

In industrialised areas where little or no abatement strategy has been conducted, high concentrations of SO_2 in ambient air are often accompanied by high PM concentration. Therefore, as a first approach one can check if sites with high SO_2 concentration fulfil the main requirements of a PM10 monitoring site, and use them for the pilot project.

4.2 Selection of monitoring method and equipment

Considering that each of PM10/PM2.5 monitoring method has its advantages and disadvantages, using the experience of EU countries in selecting the approach to harmonized monitoring will significantly reduce the costs and effort in establishment PM monitoring in EECCA countries. Consequently, it is recommended to use:

- Gravimetric equipment as reference method, and
- Automatic filter changer as gravimetric equivalence method (equipment as given in table 1).

For additional measurements and description of changes of PM concentration in time, automatic monitors must be used.

Furthermore, the following approach is recommended:

- The gravimetric equivalence method should be a preferred method for the PM monitoring.
- Considering the need for gradual development of the network, capacity building and gathering of experiences, the most practical approach is to start by operating a gravimetric equivalence method for PM10 monitoring in at least one site in the area of interest.
- At the other (few) sites, the PM10 monitoring should be conducted with continuous automatic monitor(s). An expert should set the local correction factor.
- Until harmonized PM10 monitoring equipment is available, operation of the presently available and used equipment (even TSP monitoring) should continue.
- A further option is monitoring the coarse fraction of PM (PM10-PM2.5) and PM2.5 simultaneously at one site with a Dichotomous sequential sampler.

The PM monitoring equipment must be installed in a container, and not in a building, since the air inlet of PM equipments must be upright and direct. This is different to monitoring gaseous compounds, where a curved air inlet pipe can be used.

4.3 Sites of the monitoring stations

The experience of many countries shows that it is more efficient to monitor PM in fewer areas with an adequate PM method instead of more areas with an inadequate method. Therefore, it is recommended:

1. To start PM monitoring in one or two cities, including the capital as a biggest population centre;
2. To gather quickly first data for those cities;
3. To gain experience, build capacities and start using this data for air quality management and policymaking.
4. To extend the network to other cities only after the initial experience is available.

The planning group should make the first selection of monitoring sites within the area of interest based on its knowledge of local specific conditions and data. For assessing population exposure to PM10 in a big city, the monitoring should be started at least in the following sites:

- Two urban residential sites;
- One industrial site, and
- One traffic site.

In at least at one of the urban residential sites where the PM10 data are collected, also PM2.5 concentration should be measured. Furthermore, when thinking in advance about establishing necessary abatement strategies, it can be very helpful to establish additional PM10 monitoring at a rural background station.

When the PM monitoring starts in a city, there is usually less equipment available then necessary. The practical cases presented below indicate the priorities in locating the available monitors to gather information on PM concentration, finding the most useful system for assessment of population exposure in the city and characterizing the PM.

4.3.1 Case 1: if only automatic filter changers are available.

Equipment available	Type of PM10 site	Type of PM2.5 site
1 automatic filter changer	Urban residential site	
2 automatic filter changers	* Urban residential site * Industrial site	
3 automatic filter changers	* Urban residential site * Industrial site	Urban residential site
3 automatic filter changers	* Urban residential site * Industrial site * Traffic site	

A manual sampling device is less expensive than an automatic filter changer. However, in manual equipment the filter has to be changed every day at midnight to receive a 24-hour sample over the calendar day. This is not practical, increases the risks of having missing data and makes it difficult to maintain consistent quality of the measurements. This is the reason why its deployment is not recommended for the routine monitoring network.

Monitoring at traffic sites has less priority at the beginning of the monitoring. The measurements in those locations are more difficult and their results depend significantly on the micro-scale characteristics of the traffic site (distance from the road, location in the street canyon, its dimensions, shape and orientation in relation to the wind direction). PM concentrations at traffic locations are not, generally, representative of population exposure. Measurements at a few traffic sites should start when PM data from at least one year's monitoring in all the other site types are available.

4.3.2 Case 2: If an additional continuous automatic PM10 monitor is available.

Number of automatic filter changers available	Automatic filter changer at:	Additional continuous automatic monitor at:
1 automatic filter changer	Urban residential site	Industrial site
2 automatic filter changers	* Urban residential site * Industrial site	Industrial site
3 automatic filter changers	* Urban residential site * Industrial site * Traffic site	1st year industrial site (2nd year traffic site)

The continuous automatic monitor should be operated at the same time period(s) as the PM10 monitor with automatic filter changer to get information about the time variation. The data of the continuous automatic monitor must be corrected with the local correction factor. If the impact of the daily/weekly time variation of traffic on pollution levels is to be assessed, it can be detected very easily and less expensively by CO monitoring.

4.3.3 Case 3: If three different types of equipment are available

A dichotomous sampler measures the mass of two size fractions of PM simultaneously - PM2.5 and (PM10 minus PM2.5) – and by arithmetic addition of both mass figures, the mass of PM10. This is a major advantage of this sampler. However, its serious disadvantage is that there is no one sample of PM10 for chemical analyses of PM10.

There is no information available about the equivalency of dichotomous samplers with the reference ones. Consequently, they cannot be used for testing the compliance with EU limit/target values, and are also not recommended to be used for this purpose in EECCA. However, a dichotomous sampler can be used for preliminary assessment of PM and is a good choice for the equipment to be transferred from one site to another after completing one year'spreliminary assessment.

Equipment	Case 3a	Case 3b
1 dichotomous sampler	Urban residential site	Industrial site
1 automatic filter changer (PM10)	Industrial site	Urban residential site
1 continuous monitor (PM10)	Industrial site	Industrial site

The dichotomous sampler is very appropriate for the observation of population exposure because it provides concentration data for both interesting PM fractions. This information can be collected in Case 3a. However, it could also be very efficient to run the dichotomous sampler in a region with various sources of industrial emissions (including chemical industries), alone or in connection with a continuous monitor. This method, presented as Case 3b, facilitates characteristics of the emissions from the industry.

4.4 Equipment

The equipment necessary for PM monitoring is a collective term and it includes:

- The PM monitoring devices as well as all operational materials (in particular filters) and additional equipment to install, protect and operate in the monitors;
- The equipment for the laboratory and workshop necessary to adjust, repair and control the monitors; spare parts for outside monitoring as well as devices for chemical analyses.

When using an automatic filter changer for PM monitoring in a network the following equipment must be available:

- Container;
- Weighing room with temperature and humidity control;
- Balance of higher sensitivity;
- Air flow meter.

If the monitoring starts only with a continuous automatic monitor, the demands for the laboratory equipment are lower, since only a flow meter will be needed. However, as soon as possible, the gravimetric monitor with automatic filter changer should be also deployed for identifying the local correction factor.

The equipment for chemical analyses will vary according to the compounds to be evaluated. Table 5 lists the types of equipment needed, and its selection should be based on the local conditions and emission sources. Early in the network planning process, it should be determined whether the network should build its own capacities for chemical analysis, or if they can be outsourced to an external (sometimes foreign) laboratory. The arguments concerning the required experience of the laboratory and quality of its analyses presented in section 3.2.2 should be considered in developing this decision.

4.5 Reporting and communication

The basic purpose of the monitoring is to support air quality policies and management with reliable, clear and comprehensive information abut the air pollution concentration, its spatial and temporal patterns, population exposure to outdoor air pollution and their relation to the pollution sources. This is done through regular reports presented to the decision makers and the public. At the early stages of the network operation, the annual report should be prepared. In further steps, these should be supplemented by monthly reports. A clear, simple outline of a standard report should be planned in advance, and adjusted based on the users' comments on the initial reports. The reports must present the characteristics of the monitoring locations (residential, industrial, traffic) and interpret the data to allow assessment of population exposure in the area covered by the monitoring. If the local limit or target values are specified, they should be used as a reference facilitating the interpretation of the monitoring results. Results from local modelling, linking the concentrations with individual emission sources or their groups (e.g. traffic, big point sources etc.) will provide further information essential for planning and evaluation of pollution reduction actions.

Reliable current, "on line" data on PM levels cannot be produced, in contrast to such information available for some gaseous compounds. The data from continuous automatic monitors must be corrected by local correction factor before their use but such a correction factor is estimated for longer periods (set of one-day measurements) and is not reliable for very short periods (hours). Only approximate real time daily information, to be communicated by telephone, teletext or web can be reported, e.g. in a form of indicator, but not a precise concentration number. The results of a more reliable gravimetric method with automatic filter changer are available only after the filters are collected and weighted, and the delay in data availability ranges from a few days to few weeks.

All collected data, as well as other relevant information, should be promptly communicated between all groups involved in air quality assessment in the area covered by the monitoring network. It will be the responsibility of the network management to assure such communication between specialists with different knowledge and functions in the network. Swift, direct communication is necessary to guarantee the success of coordination of work within and between various groups involved in the network operation. It also enhances the ability to find relevant data in due time.

4.6 Human resources and institution infrastructure

Planning, developing and operating the PM monitoring network require dedicated commitment of work time of various experts and decision makers. A dedicated institution with a permanent staff and highly educated specialists must be the core of the network operation. Some of the planning and operation tasks may be performed by other institutions or independent experts, but working with clearly defined (contractual, if necessary) commitment and tasks. The responsibility of the personnel involved will be:

Step 1: To plan the network;

Step 2: To assure its development according to the plan; solve the practical problems emerging during the network installation and initial operation;

Step 3: To operate the network including regular reporting and periodic network review.

The inputs of experts with different expertise are necessary for the different tasks. Step 1 requires the contributions of academic or research institutions, strengthening the expertise of the core team and advising local authorities responsible for the network establishment. External (also foreign) expertise may be very useful at this stage providing the benefits of practical experiences of network development in other cities /countries. Personnel involved in steps 2 and 3 should primarily belong to the local institution(s) and be well trained in technical and laboratory procedures required during network installation and operation. They must be trained before the start of the system operation (either locally or in the other existing networks using the same equipment) and trained regularly during the routine work to assure consistent quality of the monitoring results.

4.7 Time schedule

The schematic plan presented below is based on practical experience of network development in European cities. The time needed for each task is approximate and may differ between cities/countries according to the local conditions and decisions regarding the desired level of harmonization of the network to be achieved by a certain deadline. A gradual, stepwise approach is proposed, allowing measuring progress in the establishment of the network and assuring its stable methodological basis.

The following development phases can be specified:

1. Planning phase;
2. Preparatory working phase;
3. Establishing the network;
4. Running the network
5. (Re-planning).

Initial planning phase 1 is the most relevant one, should start at the beginning of the project and includes anticipatory planning for all the steps. However, further planning is necessary during the whole process, adjusting the general plans according to the accumulated experience and data.

The planning phase 1 should result in decisions taken at a very high level of responsibility, and determine the basic requirements for the network. It must specify:

- Air quality criteria to be used by the network (limit, target or standard value);

- Type of reference method and equivalence method(s), i.e. level of network harmonization;
- Organizational setup and responsibilities;
- The financial resources.

While planning phase 1 is obligatory for the entire city or even for a country, preparatory work means looking into the local and regional situations and bringing together all necessary local information. The main activities are well known but the amount of work required depends on the quality and availability of the necessary documents as well as on the experience of the involved personnel.

Table 6: Activities during the preparatory work and establishing the network

Step	Activities	Date after time ZERO	Duration
1	Training workshop for personnel leading in network preparation	Immediately	2-4 days
2	Collecting (as far as possible) all necessary, available information, mainly data about human exposure to air pollution, emission data and meteorological and topographic data	Immediately	0,5 – 1 year
3	Generate missing information (includes creation of an emission inventory, if not yet available)	Immediately	Few days up to 3 years
4	Analyze collected data, combine information, develop first conclusions about site selection	Immediately	0,5 – 1 year
5	Decision about types of monitoring stations and their number	Month 6	Few days
6	Decision about the types of equipment to be used	Month 6	1 month
7	Decision if weighing of the filters will be done at the own laboratory / core institution (special air conditioned weighing room needed) or by an external laboratory.	Immediately	Few days
8	Planning, installation, test runs	During first months	Few days / weeks
9	Design of data transfer from the container to the central office, data processing, analysis and storage	Immediately	1-3 months
10	Work out tender conditions, take decisions, order equipment gradually, accept delivery date	Month 7	Up to 7 months
11	Initial planning of the network (desk exercise)	Month 7	Few days
12	Inspection of potential locations and feed back to step 11	Month 7	Depends on number of sites
13	Possible necessary revision of the planned network (step 11)	Month 8	Few days / weeks
14	Getting necessary permissions for building up a monitoring station (external property, bus bar of electricity, telephone connections)	Month 8	Up to 6 months
15	Built up infrastructure (after step 12 is successful) for running a container at the selected site (place wires under the ground, putting up a fence if necessary)	Not later than month 14	Up to 3 weeks per site
16	Accept delivery of equipment, make first runs of the monitors at the office of the supplier or at the central office	Not later than month 14	1 month
17	Installation and test of the whole equipment for the PM monitoring site by site	Not later than month 14 for the first site	1 month
18	First training for monitor operators becoming a technical specialist for ongoing servicing	Not later than month 14 (immediately after step 16)	Few days for each monitor type
19	First training for calibration the monitors	Not later than month 14	1 week for 3 types

Table 6 provides an overview of the main activities during the preparatory phase and network establishment (phases 2 and 3). It shows the sequence of the activities and roughly indicates duration of each step, but not the workload, which may depend on the local conditions. It also shows the date when activity has to start. The end of planning phase 1 is time "ZERO" for starting the preparatory work. The transition from preparatory work to establishing the network is smooth and can be seen in between steps 10 and 11, i.e. about half year after the start of preparatory phase.

The optimistic overview shows that the first monitoring station can work after 15 months of starting the preparatory phase. It is realistic to say that if no problems occur at delivering and getting all necessary permissions for the first monitoring site, each further monitoring site will enter in a routine operation in the following 6 months. The work load in network preparation is similar if only PM10 or if both PM10 and PM2.5 is to be monitored at one or the other site of the network.

Running the network means ongoing servicing of all monitors and equipment to receive PM data, and all other relevant data, on a regularly basis. During the first years the number of sites of the network may gradually increase, but also some adjustments of site selection may be necessary. Furthermore, the equipment may need to be changed or added at some sites when more detailed data are needed. For example, a continuous automatic monitor may be needed to provide more detailed description of time pattern of PM concentrations, or gravimetric equipment may need to be operated for enabling chemical analyses of PM10.

The analysis of monitoring data from the first few years of network operation will provide information about the spatial distribution of PM in the city. It should be used when considering the need for re-planning the network.

5 Costing

The network planning group must be aware that the monitoring programme has to be cost-effective. However, the financial resources must be identified and available not only for initial infrastructure and purchase of technical equipment during starting phase but also for the network operation, i.e. equipment, material and personnel – during several subsequent years. Also office, workshop and laboratory space have to be provided and adapted. Economic considerations of monitoring programmes need to take full account of installation and maintenance costs, data management, quality assurance and costs for control mechanism.

The tables presented below given approximate current costs of the equipment in euros. However, this should be regarded as a rough benchmark because the real cost will depend on the kind of tender, the number of monitors and equipment ordered, conditions of delivery, manufacturer guarantee, taxes etc. Some estimates will be given only as man-days of work.

Preparatory work

Though the tasks of the preparatory phase are well defined (see Table 6), its cost is difficult to estimate. The workload at this phase depends on the experience of those involved, the size of the area to be covered by the network and the availability and quality of the necessary background information. No special equipment is necessary at this stage.

Purchase of equipment for outdoor activities

The purchase of some items will be needed only at the beginning of the network operation. Some others will need to be supplied either continuously, or only after several years of the network operation. Table 7 gives an overview of approximate costs of various PM monitoring types of equipment currently available, which can be used by the network.

Table 7. Costs of equipment for PM monitoring

Equipment	Data quality considerations	Approximate cost in EURO
Container (including climate control, racks, wind mast)		22,000 – 30,000
Kleinfiltergerät	PM10 reference method	10,000
Digitel	PM10 equivalence method	20,000
Partisol	PM10 equivalence method	15,000
ß-attenuation	Local correction factor needed	16,000 – 30,000
TEOM	Local correction factor needed	12,000 – 30,000
TEOM FDMS *	Local correction factor needed	21,000 – 39,000
Partisol-Plus Dichotomous Configuration	Gravimetry	23,500

* TEOM FDMS (TEOM Filter Dynamics Measurement System) collects a greater part of volatile compounds compared to TEOM

The costs for a PM2.5 version of each device are similar to the one measuring PM10. Additionally, the following equipment is necessary:

- Flow meter (approx. cost: 500 - 2000 Euro)
- Spare parts

Furthermore, an equipment, infrastructure and software for data transfer, processing and storage will be needed. At least one car will be necessary, for transporting the equipment and for maintenance of the monitors during the routine supervision of the stations.

Purchase of equipment and material for laboratory activities

The main cost is related to the equipment needed for weighing the filters, and for chemical analyses.

Table 8. Laboratory equipment necessary for analysis of PM filters.

Instrumentation	Approximate cost in EURO
Air conditioning (temperature and humidity control) for the weighing room	22,000 – 25,000
Balance of higher sensibility	13,000
Balance console	800

For analyzing the chemical composition, the usual analytic laboratory equipment is adequate.

Possible charges for the instalment of a monitoring station

Possible charges may include:

- Purchase of the grounds for containers with the monitoring stations;
- Costs of electricity and telephone connections.

Running costs

The extent of the running costs depends on the number of sites. The running costs cover:

- Electric power;
- Data transfer;
- Rent for the area of the container;
- Fuel for cars for routine supervision of the containers;
- Insurance for container and equipment if required;
- Filter material
    - glass fibre filter, 150 mm diameter, 100 units about 230 EURO,
    - quarz fibre filter, 150 mm diameter, 50 units about 285 EURO.

Costing of man-days

The following table summarizes the procedure of the routine work necessary for running a network, including the necessary frequency of the activities, based on practical experience. The workload estimate is given for a well-trained technician.

Table 10 Workload of routine activities in network operation and maintenance.

Routine work	Kind of work	Workload
Preparation for gravimetric measurements	Preparation and conditioning of the filters	10 hours per month and site
Routine supervision	Inspection of an automatic filter changer or a continuous monitor	1,5 hours every 2 weeks (without office-to-container time)
Maintenance		15 hours once a year
Calibration		5 hours twice the year
Documentation		60 hours per year
Reporting / information	First Control / correction of the data	Few hours weekly
Data analysis and reporting	Preparation of reports	1 day / month for monthly report, a few weeks for annual report
Training	Regularly, with growing practice less intensive	2 days per year and equipment type
Revision of the network	At the beginning whenever necessary, later on each 5th year or following changes in regulations and requirements	

Annex A: Methods for monitoring PM

In all devices, ambient air is drawn through a special designed air inlet so that only the PM10 fraction is able to pass through it. By changing the inlet, PM2.5 can be measured instead of PM10. The assessment of mass concentration (µg/m^3) requires control of air-flow (volume per second) at a given ambient temperature and pressure.

Manual sampling and gravimetry

- Ambient air is drawn through a filter at a constant flow rate. The particles are collected on the filter. The mass of the particles is determined by weighing.
- The filters are weighed before and after sampling; the difference is the mass of the particles. In both cases the filters must be equilibrated in an air-conditioned weighing room before each weighing.
- The sampling period is typically 24 hours. The sampling period and the flow rate allow calculating the volume of each sample. The volume is calculated by flow rate times sampling period.
- Each filter has to be handled manually before starting and after ending each sample.

Automatic filter changer

The only but essential difference to manual sampling and gravimetry is that the equipment has a storage magazine up to 16 filters and a mechanism for automatic change of filters every 24 hours, so that the operator does not have to visit the monitoring station every day.

ß-attenuation

After passing the air inlet and a short vertical pipe the air passes through the filter strip collecting the particles. The mass of the particles collected on the filter is determined by measuring the change in ß-radiation absorption "second by second" during sampling period. Another type periodically shifts the filter with the growing mass beneath the air flow for measuring the ß-attenuation. These measuring signals are converted to equivalent PM10 mass data; with increasing sampling time the mass accumulated on the filter will become greater. Since the flow rate is constant during the sampling period, the mass concentration can also be calculated.

Tapered Element Oscillating Microbalance (TEOM)

In principle, after passing the air inlet a fraction of the sample air is drawn to a pipe and the particles are collected on a filter. The growing mass changes the frequency of the filter so that changes in the frequency of oscillation show the extent of the growing mass and can be expressed in mass equivalency. Since the flow rate is constant during sampling period, the mass concentration can also be calculated.

Dichotomous (sequential) air sampler

In a dichotomous sampler using a PM10 inlet, the particulates in the air stream are split into fine (PM2.5) and coarse (particles between 2.5 and 10 µm aerodynamic diameter) fractions using a USEPA-designed virtual impactor for the additional 2.5 µm cut-off point. The system collects particulate matter on two filters simultaneously. The mass of the particles is determined by weighing.

In an automated version the sampler contains two storage magazines, each with a capacity up to 16 filter cassettes, as well a filter exchange mechanism that replaces two filter cassettes at the same time.

Annex B. Estimation of local correction factor for PM10

The following approach describes a practicable way to relate data from continuous automatic monitors to the results of gravimetric equivalent methods. Some basic conditions for carrying out this inter-comparison are given in the EC document "Demonstration of equivalence of ambient air monitoring methods" http://europa.eu.int/comm/environment/air/pdf/equivalence_report2.pdf.

The following text summarizes the guidelines and adapts them to the needs of the framework plan. Remarks based on practical experience are given in italics. The procedure aims at estimation of the linear regression equation:

Y = a + b*X

Where : **Y** is the result of measurement with the reference method
X is the result of measurement with the tested (candidate) method
Coefficients **a** and **b** are the estimated correction factors.

1. Parallel monitoring should be performed at least at two sites per country, or region in a larger country, which are representative, as far as possible, for the majority of conditions in the country or region. These conditions might, for example, be an urban background site and an industrial or kerbside site. *Practice has showed that variation between even homonymous types of site are quite large; therefore, whenever possible, the number of sites with parallel monitoring should be higher than two*.
2. As a minimum requirement, parallel monitoring should be performed during the cold and the warm seasons. One should also check for variations in the correction factors/equations obtained at different geographical locations. If there are indications that conditions (composition of aerosols, climatic factors etc) vary significantly from site to site within the network, then the country or region should check whether the same correction factor/equation can be applied to all sites. *In practice: This can be done, for example, by running parallel monitoring at more than one site and comparing results. Also, in mountainous areas parallel monitoring is necessary at more sites.*
3. The minimum number of validated data points (pairs of daily averages) per summer and the winter data set should not be less than 30 at any one location. It would be advisable to use significantly more than this minimum number of data points, in order to cover a wider range of climate and particle source conditions than might occur during one month.
4. The correlation between the data of the two methods is regarded as valid if the regression coefficient $b > 0.8$, determination coefficient $r^2 \geq 0.8$ and the intercept ≤5µg/m3. It is stressed that the fulfilment of these and other criteria does not necessarily mean that the slope of the regression between the data of the two methods is 1:1. It simply means that the data can be used to determine the relationship between the two methods. *Practical experience: The numbers for r^2 and the intercept are the results of monitoring data of many sites given by European institutions. These results will not be transferable for all EECCA countries.*
5. Since results of the parallel monitoring depend critically on technical details including: heating of the monitoring device or inlet system; the sampling head; the temperature of the air stream or inlet tube; the calibration; and any temperature/pressure adjustment, it is essential that comprehensive documentation of all measurement parameters is prepared and

retained. The correction factor or equation derived should only be applied to the equipment operated in the same way.

6. If the correction factors/equations of the two seasons are equal, or almost equal, a uniform correction factor/equation for the whole year may be applied. This can be done if the difference between daily means in the range of the limit value (50 µg/m^3), corrected with the two seasonal factors/equations, lies within +/-10% then the daily means corrected with the two seasonal factors/equations can then be regarded as equal and a single factor can be applied throughout all seasons. But any other factor can be chosen if arguments support this decision satisfactorily.

Comment: No idea what this means but I expect your reader will have?

7. If seasonal correction factors/equations are necessary (differences of corrected daily means > +/-10%) it is recommended that interpolation through moving averages of the factors/equations are used to avoid discontinuities in the time series, when changing from season to season. Alternatively, a country or region might use the more stringent factor/equation throughout the year: this would be easier for network operation and management as well as erring on the safe side for reporting.
8. The parallel monitoring should cover the range of concentrations expected to be found. Correction factors or equations should not normally be applied outside the range tested, unless there is good evidence of linearity.
9. Therefore countries or regions should check for linearity of the correction factors/equations. If the relationship is non-linear it is recommended that a correction equation be applied rather than a correction factor.
10. Routine monitoring with continuous automatic monitor will start with the correction factors/equations determined as described above. However, the country or region should check periodically during the routine operation of the network to ensure whether the correction factors/equations once determined are stable over time scales longer than those used in the original study.
11. Where a country is proposing corrections applicable at locations near those in a neighbouring EECCA country, it should liaise with the other EECCA country to ensure, as far as practicable and appropriate, the consistency of the corrections in the two areas.
12. Full and accurate documentation of both equipments used is essential (i.e. full model/serial number, date of manufacture, temperature of inlet, etc) as is a full description of the monitoring locations, time periods, and other relevant information.
13. All raw data collected should be retained for a suitable period consistent with the principles of good data quality management.

The procedure described above should be regarded as a potentially interim strategy until improved instruments are available which sample a fraction of the ambient aerosol similar to that sampled by the gravimetric reference method.

Default correction factor

Following the study conducted in EU countries, it was recognized that there was scatter in the pooled results from the various European countries. Therefore, prescribing one default factor as a mean or median of these data might run the risk of underestimating PM10 concentrations. In this situation, a factor nearer the extreme of the distribution of period mean ratios would be more appropriate. It was important to include this level of safety, bearing in mind that the default factor would be used in a country before it carries out its own inter comparison exercises. It was concluded that a default correction factor of 1.3 could be applied to monitoring data from both continuous automatic monitors given in table 1.

It was agreed that this single factor could be applied to both daily averages and to annual means. At the same time it was stressed that in choosing to use this factor a country accepts and recognizes the uncertainty resulting from the limited data sets and range of locations and seasons from which the data are taken.