



Review of Methods for Monitoring of PM_{2.5} and PM₁₀

Report on a WHO Workshop
Berlin, Germany,
11–12 October 2004



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ABSTRACT

The WHO assessment of health aspects of particulate matter (PM) concluded that the fine particles are strongly associated with mortality, hospitalization for cardio-pulmonary disease and other endpoints. This WHO workshop, organized by the WHO European Centre for Environment and Health, Bonn Office, in collaboration with the WHO Collaborating Centre in Berlin, European Commission (EC) Joint Research Centre (JRC) and the European Environment Agency (EEA), reviewed various methods for PM_{2.5} and PM₁₀ monitoring and discussed their comparability and quality. The experiences were presented of field inter-comparisons of various methods of PM_{2.5} monitoring, performed as part of the CEN procedure to establish a reference method. Participants also discussed the experiences of the WHO/EURO Member States in development and operation of the PM monitoring networks oriented towards the population exposure assessment. The workshop gathered 72 experts from 36 Member States, the EC, the EEA and WHO. It was confirmed that in many countries the monitoring of PM₁₀ has dynamically increased in the recent years. However, the relevant information from most of the countries of the Eastern part of the Region is missing. The workshop pointed to the important role of WHO/EURO in promoting PM monitoring, and encouraged international cooperation in capacity building, information exchange and organization of the quality control and assessment networks.

Keywords

AIR POLLUTION – prevention and control
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Background

The WHO assessment of health aspects of particulate matter concluded that the fine particles commonly measured as PM_{2.5} were strongly associated with mortality, hospitalization for cardio-pulmonary disease and other endpoints. Based on this review, the EC Working Group on Particulate Matter recommended to the EC the establishment of additional control measures for PM_{2.5}, including intensive monitoring in urban areas. Monitoring of PM₁₀ should be continued. A WHO workshop on air quality and health in Eastern Europe, Caucasus and Central Asia (St. Petersburg, October 2003) revealed that data on air pollution with particulate matter (such as fine PM) are very scarce in the eastern parts of the WHO European Region. The necessary development of PM monitoring in the NIS should profit from the experiences in other parts of Europe.

There is a wide range of approaches to the monitoring of fine particulate matter, including manual and automatic methods. They do not always provide equivalent results, each having its specific advantages and disadvantages. The methodology of PM_{2.5} monitoring has recently been reviewed and a European Standard describing a reference method to determine PM_{2.5} in ambient air is currently elaborated by the European Committee for Standardization (CEN).

This workshop was convened to review various methods for PM_{2.5} and PM₁₀ monitoring, their comparability and quality. Based on the experiences of the field of intercomparisons, which were performed as part of the CEN procedure to establish a reference method, the features of the proposed reference methods were presented. The workshop also reviewed and discussed the experiences of WHO's European Member States in development and operation of the PM monitoring networks oriented towards population exposure assessment. The technical specification of the equipment, network design and operational procedures (including QA/QC) were presented and discussed. The full programme of the workshop is attached as Annex 1.

The Workshop was organized by the WHO European Centre for Environment and Health, Bonn Office, in collaboration with the WHO Collaborating Centre "Air pollution management and air quality control" at the Federal Environmental Agency in Berlin, the EC Joint Research Centre in Ispra and the European Environmental Agency. The workshop gathered 72 experts from 36 Member States, European Commission, EEA and WHO (see the list of participants in Annex 2). Martin Meadows and Ulrich Pfeffer were elected to co-chair the meeting. Kresimir Segar and Emilia Niciu acted as rapporteurs. Prior to the meeting the participants received the background material (Abstract book) containing summaries of presentations as well as the descriptions of national activities related to PM monitoring submitted from 32 countries.

Summary of the meeting discussion

Introductory presentations

A fine fraction of particulate matter (PM_{2.5}) is strongly associated with a range of health outcomes. This was the conclusion of the WHO project "Systematic Review of Health Aspects of Air Quality" conducted by a large group of scientist from Europe and North America recently published in a series of WHO documents accessible through the WHO web page (http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20020530_1). These effects are observed at all exposure levels, even those which are very low. The American Cancer

Society (ACS) study (Pope et al. 2002) shows a 6% increase in mortality per 10 µg/m³ PM_{2.5} for long term exposure, with a special impact on cardio-vascular and lung cancer mortality. The conclusions of a large number of time-series studies, assessed by a recent WHO meta-analysis (Anderson et al., 2004) point out that even short term changes produce signals on mortality outcomes. This WHO assessment concludes that there are significant health impacts of the pollution at levels common in Europe and that further action is needed to reduce the pollution and its health effects. There is also a need for better understanding of the underlying mechanisms of the impacts and strengthening the scientific evidence, especially that concerning the effects of long term exposure. This research is hampered by a lack of PM_{2.5} monitoring data able to support epidemiological studies in Europe.

The WHO evaluation has been already used in preparation of the 2nd Position Paper on Particulate Matter for the EC Clean Air for Europe (CAFE) programme. Decisions concerning the possible future requirements for PM_{2.5} monitoring will be formulated by the Clean Air strategy, which will be published by the European Commission in the late Spring 2005. Regarding PM monitoring, special consideration should be given to uncertainties in PM mass measurements due to possible losses of semivolatile compounds and requiring adjustments for the difference between reference and non-reference methods.

Standardization of PM_{2.5} measurements: CEN exercise

For air quality across the European Union to be assessed on a consistent basis, EU Member States need to employ standard measurement techniques and procedures, following Community Directive 96/62/EC on ambient air quality assessment and management, and Directive 1999/30/EC. Prompted by these EU requirements, CEN/TC 264 *Air Quality* established working group CEN/TC264/WG15 to present a manual standard gravimetric measurement method for the determination methods for low (LVS) and high volume (HVS) sampling regimes respectively.

Also for the automatic instruments, a good correlation with the standard method ($R^2 = 0,94$ or higher) is observed at individual specific sites. This finding indicates that with suitable correction of the PM_{2.5} mass concentration of suspended particulate matter in ambient air. There are no traceable reference standards for PM_{2.5} measurements. Therefore, the standard measurement method set out in the designated draft standard effectively defines the measured quantity by convention, specifically by the sampling inlet design and associated operational parameters covering the whole measurement process.

To support the designated draft standard (prEN 14907), working group CEN/TC 264/WG 15 on PM_{2.5} carried out a field evaluation programme at various test locations throughout the EU. It proposed two standard algorithms, in these specific site conditions, good agreement between various automatic instruments and the standard method can be obtained. However, when comparing the automatic instruments with the standard one for all sites combined, the scatter of the data is significantly worse than per site separately. This indicates that the agreement between the automatic instruments and the standard methods varies at different sites and in different conditions. This is to be expected in view of the way semi-volatile material is treated in the various automatic instruments, and provides support for the requirement within the equivalence procedure for candidate instruments to pass several independent comparability tests.

Moreover, this also shows that equivalence does not necessarily cover in a uniform way the wide range of prevailing conditions within the European Union. Equivalence could also be limited to specific ambient situations at national or regional level within EU member states.

Dr Borowiak from JRC presented the QA procedures for the validation of the method of PM_{2.5}. There had been a substantial effort to ensure harmonized procedures, taking into account the variety of candidate samples. Important sources of uncertainty considered by the procedure were flow verification and calibration, filter weighting procedures, weighting room/balance resolution and influence of relative humidity.

The discussion addressed the need for a better assessment of the components of the PM in the collected samples. Another aspect considered in the discussions was the placement of monitoring sites to reflect better the exposure of population to PM and its health impact. While appreciating the relevance of PM_{2.5} measurements for assessment of health risks of the pollution, representatives of countries expressed their concern about the additional burden which might be required if the PM_{2.5} monitoring is required in addition to the PM₁₀ monitoring.

National and international experiences in development of PM (10&2.5) monitoring

Experts from 17 Member States summarized the status of PM monitoring in their countries¹. Full sets of abstracts from the presentations as well as summaries of the national experiences (not presented) were available at the workshop as background material. These presentations indicated rapid progress in PM₁₀ monitoring in Europe, and in the EU countries in particular, in the last few years. The available data indicated that a decrease in PM concentrations observed in the 1990s had stopped and no improvement in air quality could be seen in the more recent years. Among the main problems indicated by the presentations were:

- Appropriate use of correction factors if automatic methods for PM₁₀ monitoring were used;
- Standardization of siting criteria for the sampling locations;
- Comparability and exchange of information/data between the diverse AQ monitoring networks operating in the country,
- Use of the monitoring data for public information, national and international reporting.

Relevant information from most of the countries of the Eastern part of the Region was missing, due to continuing low awareness of health impacts of PM, the lack of legal and organizational basis as well as insufficient financial and human resources for PM monitoring. National QA/QC systems were important instruments to verify data quality and allow comparability of information generated by various networks. Both national (German) and international (AQUILA, run by JRC) systems were presented. The Network of Air Quality Reference Laboratories AQUILA offered a forum for the exchange of information, providing expert judgement, promoting the harmonization of air quality measurements, organising training courses/workshops/conferences and co-ordinating QA/QC activities as well as developing common research projects and pilot studies.

The most comprehensive collection of data from air quality monitoring provided the European Air Quality database system, AIRBASE, managed by the European Topic Centre on Air Quality and Climate Change (ETC/ACC), under contract to EEA. The information stored in AIRBASE

¹ Copies of the PowerPoint presentations and the abstract book are available through http://www.euro.who.int/eprise/main/WHO/Progs/AIQ/Activities/20040513_1

was available to the public via the Internet. Currently data from 1306 stations monitoring PM10 and 42 stations monitoring PM2.5 in 2002 had been stored in AIRBASE. However a number of points had been identified for necessary improvements of PM data collected and reported in AIRBASE. Particularly, comparability of PM10 (and PM2.5) data measured throughout Europe by automated method had to be assured and procedures for demonstration of equivalence with reference method had to be implemented and reported. Since the data allowing assessment of PM10 trends were sufficient only from 1999, possible additional national historical PM data series, hitherto not made available to AIRBASE, need to be considered by the MS.

Independent assessments of the existing air quality reporting data and information submitted to the AIRBASE indicated that a lot of information useful for population exposure assessment was still not available in AIRBASE. The workshop emphasized that countries should make an effort to make their data accessible for international comparisons.

Presentations of the EMEP work illustrated the efforts to allow better understanding of the long range transport of PM and its precursors. An intensive air quality monitoring programme, recommended by EMEP, was presented. This monitoring, modelling and assessment were important elements supporting air quality management since, in some urban areas, a substantial proportion (up to 40-50%) of fine particulate matter originated from remote emissions.

Conclusions/recommendations

Organizational

1. All countries should develop and increase monitoring of PM2.5, according to their capabilities, and should also develop and maintain an appropriate level of PM10 monitoring. EU MS should place an increasing emphasis on PM2.5 monitoring with the additional priority of meeting likely future compliance requirements of Air Quality Directives. This monitoring should be designed to provide information on population exposure to ambient PM2.5 to help inform the public about the health impacts of the pollution.
2. All MS are encouraged to report and exchange monitoring information to help assessment of health impacts of PM10 and PM2.5 and to increase understanding of the characteristics of PM in the region. AIRBASE is an important resource for data exchange but its data coverage is still limited and should be improved.
3. Development of PM monitoring in some WHO/Euro MS has been slow due to:
 - a. Lack of financial and human resources
 - b. Lack of a legal and organizational basis
 - c. Low awareness of health impact of PM and lack of dissemination of information to the public and decision makers.
4. In many countries, several networks operate in parallel. Inter-network harmonization, QA/QC and data exchange should be implemented at national level to assure reliability and comparability of data produced by various networks. Countries in the WHO European Region were encouraged to participate in appropriate national and international QA/QC and information exchange networks.
5. This workshop encouraged developing links between the EU Network of Air Quality Reference Laboratories AQUILA and the non-EU countries in the WHO European Region,

e.g. through organization of future workshops or training sessions. Bilateral country collaboration (such as twinning projects) and other various bi- and multilateral collaborations were encouraged.

Technical

1. There is extensive expertise and experience in WHO/Euro MS in the operation of PM measurement instruments and networks. WHO/Euro MS should exchange experience to help develop PM monitoring capacity throughout the Region by, for example, developing a “Good Practice Guide for PM monitoring”.
2. Comparability of PM₁₀ concentration data from standard gravimetric method and non-standard methods remains an issue. Many networks have developed location and time dependent correction factors (CF), but some networks still do not apply correction factors. More investigations to define CF were encouraged. When no local CF existed, a default CF=1.3 was recommended for Beta Gauge and TEOM instruments for PM₁₀ data reporting. It was important to publish with PM data the value of any correction factor used.
3. National and international network QA/QC programmes, such as that initiated by AQUILA, were encouraged.
4. Consistency of categorization, representativeness, distribution and location of air quality monitoring sites was still a difficult issue. It was recommended that a comprehensive guidance document be prepared, developing further and refining existing guidance on these characteristics of air quality monitoring network.

Annex 1

WORKSHOP PROGRAMME

Monday, 11 October 2004

- 8:30 Registration
- 9:00 Opening, welcome, appointment of chairman and rapporteur
- 9:15 Introduction:
- results of WHO assessment of PM health effects (WHO – M. Krzyzanowski)
 - CAFE PM group results and EC plans re PM2.5 monitoring (EC- Stefan Jacobi)
- 10:00 Standardization of PM2.5 measurements: CEN exercise:
- Draft CEN standard for PM2.5 concentration measurement (T. van der Meulen, NL)
 - The quality assurance procedure for the validation of the standard method PM2.5 (A. Borowiak, JRC)
 - Results of the intercomparison exercise and recommended methods (L. Laskus, UBA Germany)
- 11:00 Coffee break
- 11:20 Discussion of plans for the PM2.5 monitoring in Europe
- 12:15 PM10 inter-comparison of the German states (U.Pfeffer)
- 12:30 Lunch break
- 13:30 Experiences from the MS in development of PM (10 & 2.5) monitoring
- Albania (A. Deliu, Q. Kodra)
 - Austria (M. Froehlich)
 - Belgium (E. Roekens)
 - Bulgaria (D. Lolova)
 - France (R. Stroebel)
 - Greece – National network (S. Koloutsou-Vakakis)
 - Greece – PM2.5 measurements in Athens (Ch. Vassilakos)
 - Latvia (A. Leitass)
 - Malta (N. Axisa)
 - Poland (J. Swiatczak)
 - Russia (L. Privalova)

- 15:30 Coffee/tea break
- 15:50 Experiences from the MS in development of PM (10 & 2.5) monitoring, cont.
- Serbia & Montenegro (S. Matic-Besarabic)
 - Slovak Republic (E. Michalikova)
 - Slovenia (T. Bolte)
 - Spain (X. Querol)
 - Switzerland (R. Gehrig)
 - Turkey (G. Gullu)
 - United Kingdom (M. Meadows)
- 17:00 Experiences from the MS in development of PM (10 & 2.5) monitoring - discussion
- 17:30 Closure of Day 1

Tuesday, 12 October 2004

- 9:00 Assessment of PM compliance data reported to EC (S. Jacobi, EC)
- 9:20 A joint JRC-AQUILA quality assurance programme for PM (A. Borowiak, JRC)
- 9:40 Assessment of information on PM collected by AIRBASE (J. Fiala, EEA)
- 10:10 Monitoring of background PM by EMEP network (J. Schaug, NILU)
- 10:25 Discussion: international PM monitoring activities in Europe
- 10:40 Coffee break
- 11:00 Use of modeling of PM concentrations for population exposure assessment – need for AQ monitoring data for models validation (J. Schaug, NILU)
- City-Delta project
 - EMEP model
- 11:20 Health impact assessment of air pollution:
- use of PM monitoring data by APHEIS project (H-G.Muecke, UBA WHO-CC)
 - Use of EMEP estimates in integrated modeling conducted by IIASA; AirQ2.2 WHO software tool for calculation of impacts of PM on life expectancy (M. Krzyzanowski, WHO)
- 12:10 Core environmental health indicators related to ambient air quality (M. Krzyzanowski, WHO)
- 12:20 Discussion on use of PM monitoring data
- 12:30 Lunch break

13:30 General discussion on workshop conclusions and recommendations

15:00 Acceptance of conclusions and recommendations

15:30 Closure of the workshop

15:45 Informal session to discuss plans for the WHO workshop “Health basis of air quality management in the countries of Eastern Europe, Caucasus and Central Asia (EECCA)” to be organized in the Spring 2005

16:45 End of the session

Annex 2

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