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SCIENTIFIC COMMITTEE ON HEALTH AND ENVIRONMENTAL RISKS

SCHER

Opinion on

"New evidence of air pollution effects on human health and the environment"

Adopted by the SCHER
during the 4th plenary of 18 March 2005

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1. BACKGROUND

The European Community has legislation[1] in place that sets limit and target values for air quality with the objective of reducing and avoiding harmful environmental and health effects. The legislation builds on WHO guidelines for air quality in Europe[2] and Commission working groups documents[3]. The previous scientific committee on Toxicity, Ecotoxicity and the Environment (CSTEE) was also consulted and gave its opinions on some key issues related to heavy metals and PAHs[4] as well as on ozone[5] in air.

The Commission's Clean Air for Europe[6] programme will analyse the present and future situation for air pollution and the possible options to reach the environmental and health objectives laid down in the Sixth Environmental Action Programme[7]. These objectives are to achieve "levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment".

The Commission's Environment Directorate-General is presently preparing a Thematic Strategy on Air Pollution, planned to be adopted in May 2005. The Strategy will set out the Commission's future intentions regarding existing and new legislation, and definitive legislative proposals may be amended in the light of the strategy.

The European Commission is considering proposing revised legislation to avoid adverse impact and protect human health and the environment from air pollution, which would include revised air quality standards. In view of the importance of basing policies on scientific and technological knowledge and in order to address the issue appropriately, the SCHER is requested to give an opinion on a number of key questions on air pollution health and environmental effects and risk.

2. TERMS OF REFERENCE

The SCHER is requested to address the following questions:

Airborne particulate matter

Based on the recommendations of the WHO the Working Group on Particulate Matter (WGPM) recommended the use of PM2.5 as a more health relevant metric for the assessment of exposure to particulate matter (PM). Therefore, it recommended introducing PM2.5 as the metric for the standard. The WGPM also proposed to maintain PM10 as an air quality standard.

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[1] Directives 96/62/EC, 1999/30/EC, 2000/69/EC, 2002/3/EC and 2004/XX/EC

[2] Available at http://www.euro.who.int/air/Activities/20020620_1

[3] All available on the Commission website http://europa.eu.int/comm/environment/air/ambient.htm

[4] Opinion expressed by CSTEE plenary meeting, Brussels, 12 June 2001

[5] Opinion adopted at the CSTEE by written procedure on May 21, 1999

[6] http://europa.eu.int/comm/environment/air/cafe/index.htm

[7] http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_242/l_24220020910en00010015.pdf

1a). If an air quality standard for PM2.5 is decided upon, does the Committee agree with the view expressed by the WGPM and the WHO that there is solid scientific evidence to set such standards for the fine fraction of PM (in this context defined as PM2.5) and

1b) is there a need to keep the standard for the coarse fraction (such as for PM10)?

2) The available risk factor of exposure to PM2.5 is based on US studies (Krewski et al. 2000). Given that recent evidence suggests that the characteristics of European cities may differ from American ones and thus lead to an underestimate of the extent of risk, does the Committee have a view of the transferability of the US results to Europe?

3) Does the Committee agree that exposure to PM from specific sources or with specific physico-chemical properties, such as those from combustion and industrial processes, and containing specific substances (like organic substances and metals) are more likely to cause harmful effects on human health than other sources?

Ozone

4) Does the Committee agree with the view that there is scientific evidence to lower the value to protect forests from harmful effects due to ozone?

3. OPINION

Air pollution exists as a complex mixture, i.e., ozone, nitrogenoxides, PM, and their individual effects are influenced by the other components. Historically, particles have been defined based upon size, e.g., TSP, and on the aerodynamical diameter, e.g., coarse particles (< 10 μM), fine (<2.5 μM) and ultrafine (<0.1 μM). In urban environment, usually 40-80% of the coarse particles belong to the group of fine particles and the ultrafine represents a few percentages of the fine particles on the mass basis. In this opinion, coarse particles will be defined as the difference between PM10-PM2.5. Another important measure for particles has been black soot, which usually contributes 5-10% to PM2.5. Different sources of PM2.5 exist and the relative contributions will vary within regions of Europe, between cities, and between urban and rural areas. According to the CAFÉ report, mobile sources and combustion of wood account for more than 55 % of primary PM2.5 emission in the EU-15. The major argument for using PM2.5 rather than PM10 to establish health-based standards is, that PM2.5 is a better measure of anthropogenic activities, especially combustion sources. Lifestyle factors, environmental tobacco smoke and tobacco smoke, do contribute significantly to the in-door level of PM2.5.

There is an increasing evidence that exposure to PM2.5 is associated with the development of adverse health effects, mortality, i.e. respiratory, CVD, cancer, and morbidity. These effects are especially strong in susceptible populations, like people with predisposing cardiac and pulmonary disease or with increased exposure, e.g. children. An unambiguous threshold dose has not yet been established and it appears to depend on the health effect endpoint, populations and vulnerability.

Exposure-response relationships between PM2.5 and mortality have been demonstrated in US studies. Ultrafine particles may be very important for CVD as they, due to their size, are able to pass from the lung alveolus to the blood circulation, whereas the role of larger particles is not

clear. The toxicity of the particles is linked to the particles physio-chemical properties, and will show large geographic, source and seasonal variations.

A critical level for ozone to protect the vegetation in Europe has been established within the convention on LRTAP. Recent experimental studies suggest that a new AOT40 value should be introduced to protect forests from harmful effects due to ozone.

3.1. Question 1a

If an air quality standard for PM2.5 is decided upon, does the Committee agree with the view expressed by the WGPM and the WHO that there is solid scientific evidence to set such standards for the fine fraction of PM (in this context defined as PM2.5)

Answer

Most of the evidence that ambient PM2.5 exposure is related to adverse health effects comes from short-term studies. Many recent studies have documented that short-term increases in ambient air PM2.5 pollution are associated with increased daily mortality and hospital admissions for respiratory and cardiovascular disease. Only a few European studies have assessed the acute health effects of PM2.5, and the results are inconsistent. PM2.5 exposure was associated with increased ST-segment depression upon exercise by ischemic heart disease patients indicating an increased risk of myocardial infarction (Pekkanen et al., 2002). In contrast, in the three mortality studies the reported associations were not statistically significant i.e., increased mortality with increased PM2.5 levels, and one was significantly negative (Wichmann et al, 2000; Peters et al, 2000; Anderson et al, 2001).

Information on long-term exposure and adverse health effects is from Northern American studies only. Currently there are no European studies, which specifically assess the long-term health effects of ambient PM2.5 exposure. Two European cohort studies suggest that mortality was associated with long-term average traffic-related air pollution, a major contributor to PM2.5 (Hoek et al, 2002; Nafstad et al, 2004).

Information on ambient PM2.5 levels for the European situation is scarce, as regular PM2.5 measurements are not conducted regularly. This is one of the reasons why the present available information about the health effects related to ambient PM2.5 exposure in Europe is limited. Annual mean ambient PM2.5 levels are roughly two-third of PM10 levels, but substantial variations in space and time have been reported, ranging from 40% to 80%. (CAFE Working Group, 2004). Within the European region, differences in PM2.5 sources are to be expected because of regional variations in industrial, economic and domestic activities. While ambient PM2.5 in EU-15 may to a large extent be influenced by traffic related emissions, ambient PM2.5 from the central part of Europe may be highly influenced by industrial emissions, power plants and local heating. Differences in sources may have consequences for the PM2.5 associated toxicity and will therefore influence the exposure – response relationship. While the SCHER is aware of the ongoing EU-projects in the field of PM-toxicity, there is currently no systematic published knowledge available on differences in toxicity of the PM2.5 particle within the European region. Results from the APHEA project show heterogeneity in PM10 results between European cities (Katsouyanni et al, 2001). Effects of PM10 were greater when background NO2 levels were higher, when the proportion of elderly was higher and in warmer climates. No information is available yet on heterogeneity in health effects of ambient PM2.5.

Epidemiological studies have suggested that there is no clear threshold for the relationship between ambient PM2.5 air pollution and mortality/exacerbation of disease. The implication is that specific guidelines values cannot be set that provide absolute safety for the population. Instead, an acceptable concentration needs to be defined based upon the exposure-response function and the accepted level of risk. The lack of European data hampers such a definition and introduces uncertainties.

The SCHER agrees that there is increasing epidemiological evidence that PM2.5 may be related to adverse health effects especially in susceptible populations and vulnerable groups. However, there is currently a lack of knowledge on the exposure-response function for adverse health effects in Europe. However, it is SCHER's opinion that there may be risk for PM2.5 which needs to be limited. If an air quality standard for PM2.5 is decided upon, it is SCHER's opinion, that the scientific basis for the use of a PM2.5 standard would be surrounded with uncertainties and gaps in knowledge for the European situation.

3.2. Question 1b

Is there a need to keep the standard for the coarse fraction (such as for PM10)?

Answer

PM10 and PM2.5 represent different sources. Whereas, PM10 represents both natural and anthropogenic sources, PM2.5 is a better and more accurate estimate of anthropogenic sources. The WGPM recommends that PM2.5 should be the principal indicator for standard setting in the EU, rather than PM10. This preference is derived from the WHO Working Group (2004) recommendations combined with WHO response to the CAFE question concerning which of the physical and chemical characteristics of particulate air pollution are responsible for the adverse health effects: "There is strong evidence to conclude that fine particles (< 2.5 μm, PM2.5) are more hazardous than larger ones (coarse particles) in terms of mortality and cardiovascular and respiratory endpoints in panel studies. This does not imply that the coarse fraction of PM10 is innocuous"……. "The present information shows that fine particles (commonly measured as PM2.5) are strongly associated with mortality and other endpoints …… so that it is recommended that air quality guidelines for PM2.5 be further developed. Revision of the PM10 WHO AQGs and continuation of PM10 measurement is indicated for public health protection."

In parallel, WHO concludes that coarse particles have "some effects on health." The question is thus whether the health effects associated with PM10 exposure are sufficiently relevant to warrant separate PM10 guidelines and standard values.

Meta-analyses of European studies comparing the relative importance of fine versus coarse PM have not been conducted due to lack of representative studies. In a recent meta-analysis of time-series and panel studies of PM and ozone by Anderson et al. (2004) it was concluded that there are insufficient studies of the health effects of fine and coarse particles on daily mortality from Europe to calculate summary estimates. Thus no comparison between fine and coarse can be made.

Toxicological studies indicate that PM10-2.5 and PM2.5 have distinct characteristics and that their toxicity differs. However, the relative effects depend on the biological endpoint.

The US-EPA Criteria Document on PM (US-EPA, 2004) presents data on the relative

importance of PM2.5 and PM10-2.5. The results appear inconsistent and of the thirteen cited epidemiological studies larger relative importance for "fine" was found in 4 studies, for "coarse" in 3 studies, and in 6 studies, the outcome was indecisive

There are no apparent differences in the epidemiological studies that might disqualify the outcomes of the studies that indicate a stronger association for coarse PM. The position paper of EPA seems to take a similar position, where it proposes to promulgate a coarse mode standard and concludes that the issue regarding the relative importance of PM2.5 and PM10-2.5 has not yet been fully resolved

The SCHER agrees with the WHO report that revision of the PM10 AQGs and continuation of PM10 measurements is recommended for public health protection. A smaller body of evidence suggests that coarse particles have some effects on health, so a separate guideline for coarse may be warranted. The SCHER acknowledges the health relevance of ambient PM2.5, but that at present there is not sufficient health effects-related evidence available to exclude PM10 as a standard and to favour another (new) PM mass based standard as the sole health-relevant indicator.

3.3. Question 2

The available risk factor of exposure to PM2.5 is based on US studies (Krewski et al 2000). Given that recent evidence suggests that the characteristics of European cities may differ from American ones and thus lead to an under estimate of the extent of risk, does the Committee have a view of the transferability of the US results to Europe?

Answer:

For long-term exposure to ambient particulate pollution, European exposure-response (E-R) functions are not yet available, whereas substantial evidence is available from non-European studies like the recent American Cancer Society study (Pope et al, 2002). In this situation, transferability of these data to the European situation seems appropriate.

European studies on short-term exposure to PM2.5 have partly been consistent with those in the US. However, Anderson et al.(2004) stated that " The summary estimates for North America are larger than for any of the three European studies. This meta-analysis does not in itself answer the question of whether it is better to use a summary estimate based on the more numerous North American Studies or choose a single estimate from European studies. However, the estimate for the largest city studies in Europe (West Midlands Conurbation) is within the range of those from North America, and this indicates that although the estimate is not statistically significant (lower 95% confidence interval 0.992), it is likely that effects of PM2.5 on mortality in Europe do exist. Whether or not these are smaller than in North America cannot be determined from the present analysis, and would require consideration of factors such as the source and composition of PM2.5 in the respective regions and the differences in other potential effect modifiers". However, if deciding to use the US E-R function, additional concern has to be addressed:

Different methodologies for ambient air PM exposure measurements are used in the U.S study (gravimetric) and in many European locations (automatic β-attenuation and TEOM). In order to compensate for losses of volatile material associated with PM occurring within automatic PM measurements, European health impact assessments (HIA) using US E-R functions should apply, when available, a local specific correction factor or the European default correction factor of 1.3

as recommended by WGPM.

The general linearity of the E-R functions within the ranges studied gives some reassurance in extrapolating data to a region with particulate levels beyond the range of the original study. Assessment is an important tool to visualize the impact of air pollution in human populations, the best available E-R function should be used, but results from HIA should deal with the uncertainties and should at least be presented with relevant uncertainty margins.

The SCHER recommends that whereas there are still uncertainties in applying non-European exposure-response functions to European populations, in the absence of robust European E-R functions, the best available E-R function should be used for the HIA taking into considerations the uncertainties, mentioned in the answer to question 1.

3.4. Question 3

Does the Committee agree that exposure to PM from specific sources or with specific physico-chemical properties, such as those from combustion and industrial processes, and containing specific substances (like organic substances and metals) are more likely to cause harmful effects on human health than other sources?

Answer:

The composition and the characteristics of PM originating from distinct sources are different, and specific PM fractions have caused different toxic effects in experimental studies. The epidemiological evidence also suggests source-dependence for some effects.

The physico-chemical characteristics of PM and the associated biological activities exhibit large regional differences, even from the same type of source, in addition to temporal and seasonal variation. This variation will complicate the analysis of the association between PM exposure and health effects. The most important determinants of the toxicity are the size and chemical composition of the particles.

The **particle size** determines the atmospheric half-life, fate of the particle in the body and contributes to toxicity. The particles in fractions PM10-2.5 and PM2.5 are transported, transformed in air and deposited in the respiratory tract differently. The residence time for PM2.5 in air is long (days to weeks). In principle, the smaller the particle is the deeper it gets into the airways. Coarse particles larger than 5 μm remain mainly in the upper airways and are transported back to the pharynx and swallowed. The particles around 1 μm get deeply into alveoli. The ultrafine particles (0.1 μm and smaller) may get from alveolar space to blood circulation and thus have a systemic effect.

The chemical **composition** of the particles is the other determinant of toxicity. PMs represent a complex mixture of organic and inorganic substances, solid, liquid or solid/ liquid particles. The composition differs according to particles and depends on the source and/or the way of particle formation. Transformation may yet occur over time.

The *coarse fraction* typically consists of particles formed mechanically (break-up of larger particles), of biological material or emitted directly from the source (primary particles). Their atmospheric half-life is short (minutes to hours). Coarse particles contain inorganic ions (for

example calcium, aluminium, silicon, magnesium, and iron) and components with biological activity, e.g., allergens in pollen, toxins in mould spores.

Fine particles are largely combustion particles or formed in atmospheric chemical reactions (secondary particles). The main sources of the primary emissions of PM2.5 are vehicle exhausts, fossil fuel combustion (especially coal and wood heating), industrial processes, other biomass burning and fugitive dust. Large variation in biological activity has been observed in PM from vehicle exhaust, and it depends on driving condition, fuel and engine type, and the maintenance of the vehicle. The main emissions of precursors for secondary PM2.5 -formation are NO_x, SO_2, NH_3, and anthropogenic VOCs from different sources. The long atmospheric half-life (days to weeks) causes a long-term risk for exposure (Schlesinger and Cassee, 2003). Fine particles contain especially elemental carbon and different metals, as well as organic compounds. In the PM2.5 fraction, fine particles (0.1 - 2.5 μm) account for the largest mass, but the largest numbers are ultrafine particles (over 90 %), and the largest surface area per mass is in the accumulation mode fraction (0.1 – 1 μm). Fine particles rather than coarse particles appears to be responsible for reactive oxygen species (ROS) induced toxicity in lung cells (Choi et al, 2004)

Ultrafine particles are primarily formed from gases by nucleation in air (condensation of low-vapour-pressure substances or chemical reactions in air) and their atmospheric half-life is short. The composition of ultrafine particles is elemental and ionic i.e. organic carbon, heavy metals, sulphates and nitrates. In general, there is limited information on the concentrations of ultrafine particles in ambient air because they have not been monitored comprehensively.

The **toxicity of PM** collected from different sources has been studied in *in vitro* and *in vivo* studies, i.e., laboratory animals, voluntary human subjects. The focus has been on local effects in the respiratory tract and mutagenicity, but cardiovascular effects have also been evaluated, especially for fine and ultrafine particles.

Coarse, fine and ultrafine particles of ambient PM all cause *inflammation* in lungs and inflammatory responses in cells of the respiratory tract. Considerable heterogeneity in the results has been shown. Using induction of IL-6 as a marker, coarse particles induced a 10-fold higher level than fine particles that induced a 3-fold higher level than ultrafines (Becker et al, 2003). The explanation could be different composition of the PM, e.g., coarse particles contain variably amounts of endotoxin, and it has explained a major part of the inflammatory potential of PM10. Inflammation and cytotoxicity in lungs are the typical and the most consistent effects of PM10.

Ultrafine particles pass into blood circulation, and may enter target cells and cause toxicity, e.g. cardio-toxicity. In general, small particles are considered more toxic than larger particles. Ultrafine particles stimulate production of toxic ROS, and cellular damage by ROS may be one mechanism of toxicity. Generally, pro-inflammatory cytokine release is involved in toxicity and it has been suggested that material absorbed on the particles are responsible for the release of inflammatory mediators. The mechanisms of cardiovascular toxicity of fine and ultrafine particles are not known, but may include neurogenic components mediated by the autonomic nervous system.

Fine particles are *mutagenic* and exposure has been associated with lung cancer. They contain PAHs, nitro-PAHs and other known carcinogens. They cause DNA-damage *in vitro* and ROS is one plausible mechanism of the observed genotoxicity. A human study has shown an association between PM2.5 exposure and oxidative damage to DNA, but not with PAH related adducts (Sørensen et al, 2003). It is plausible that known carcinogens associated with the PM are

responsible for the lung cancer risk attributable to PM2.5 exposure, however it could not be ruled out that particulate matters are able to cause cancer independent of the presence of known carcinogens (Harrison et al, 2004).

There are only a few studies on controlled human exposure to ambient PM, and generally PM exposure of healthy individuals induces inflammation in lungs (both coarse and fine fractions). Diesel exhaust has increased airway hyper responsiveness in asthmatics. The experimental studies in humans have not so far revealed consistent mechanism(s) to explain cardiovascular toxicity of PM.

At environmentally relevant concentrations the surface properties and/or chemical agents dissolved from particles are very likely responsible for the adverse effects. Presently it is not possible to pinpoint any single compound responsible for the adverse effects in any PM fraction. There are likely also differences in components bioavailability and interactions between PM components. Endotoxin, transition metals (such as iron, zinc, vanadium, nickel, copper) and PAHs have regularly been associated with the toxicity.

There is some epidemiological evidence that cessation of a specific PM exposure reduces adverse effects. For example, reduction in mortality was observed in Dublin in the 1990s when coal sales were banned and residential heating with coal was stopped thus reducing the emission of PM (Clancy et al. 2002).

The SCHER agrees that there are strong reasons to assume that PMs from various sources have different toxicological profiles, and thus quantitatively and qualitatively different effects on human health. The regional and seasonal variation in the toxicity complicates integration of the toxicological information into epidemiological studies. PM10-2.5 and PM2.5 have distinct characteristics and sources and their toxicity may differ, and thus different air quality standards for PM2.5 and PM10 would be justified.

3.5. Question 4

Does the Committee agree with the view that there is scientific evidence to lower the value to protect forests from harmful effects due to ozone?

Answer

The current value to protect the forest in Europe was developed within the Convention on LRTAP. In 1996 it was decided to use the concept of AOT40 as the basis for ozone critical levels for the protection of vegetation (Kärenlampi and Skärby, 1996; Fuhrer et al, 1997). A value of 10000 ppb h, accumulated annually during daylight hours 1 April – 30 September and evaluated as a mean value over five years, was decided for the protection of forest.

Since 1996, new experimental data on the impact of ozone on trees have been published. These new data have contributed to reduce the size of the confidence limits of the regression analysis used to derive ozone exposure – response relationships. The experimental data for the sensitive deciduous trees species (Silver birch, Betula pendula, European beech, Fagus sylvatica) were used to generate a new value to protect forests from harmful effects due to ozone (Karlsson et al, 2004; LRTAP, 2004). The new, AOT40-based, value of 5000 ppb h accumulated annually during daylight hours 1 April – 30 September should be used as a mean value over a five-year period.

This new value to protect forests from harmful effects due to ozone has been accepted by the LRTAP convention (LRTAP, 2004). It should be noted that the methodologies to describe ozone impacts on vegetation are under continuous development. It is now generally recognised that the effective dose based on stomatal uptake (flux) of ozone into the leaves represents the most appropriate approach to setting future ozone values for the protection of forest trees (Karlsson et al, 2003; LRTAP, 2004). However, uncertainties in the development and application of flux-based approaches for forest trees are at present too large to justify their application as a standard risk assessment method at a European scale.

While emissions of NO_2 most likely will decrease in parallel with reduced emissions of PM, this will not be the case with the other important precursors for ozone formation, the VOCs. Thus, target settings for ground-level ozone will have an important role for the reduction of VOC emissions.

The SCHER agrees with the view that there is scientific evidence to lower the AOT40 to protect forests from harmful effects due to ozone. This recommendation is based upon effects on young trees, since studies of ozone impacts on old trees are as yet insufficient. The SCHER also recommends to explore the use of Flux-based approaches for describing the effects on vegetations as soon as sufficient evidence becomes available, and to consider the significant differences among European regions.

4. CONCLUSION

The SCHER agrees, that there is increasing epidemiological evidence that acute PM2.5 exposure is related to adverse health effects, especially in susceptible and vulnerable groups. However, there is currently a lack of knowledge on the exposure-response function for health effects in Europe following chronic exposure. Thus the establishment of an air quality standard based upon PM2.5 will be surrounded with uncertainties. The major sources of PM2.5 and thus the toxicity are different between the USA and Europe, and even within Europe due to different type and level of economic activities. These differences may influence the exposure-response function used for HIA.

The SCHER acknowledges the evidence for PM2.5 as health-relevant. The importance of separate guidelines for coarse and fine particles are evident and presently there is not sufficient health effects-related evidence available to exclude PM10 as a standard and to favour PM2.5 mass based standard as the sole health-relevant indicator. Similar to the US EPA recommendation, SCHER proposes to continue monitoring both PM2.5, and the PM10-PM2.5 fraction, as the relative importance of these two fractions has not been fully resolved. The sources and chemical composition of coarse and fine particles differ and thus the toxicity of the particles. Furthermore, the ratio between the two types of particles differs greatly with the season and geographic regions.

The SCHER recommends that, in the absence of a robust European E-R function, the E-R function based upon the US data could in general be used for HIA. However, there are uncertainties in applying non-European exposure-response functions to European populations, e.g., differences in monitoring protocols and PM sources. Differences in the sources of PM may have consequences for the toxicity and therefore for the exposure – response function.

The SCHER acknowledges the large difference in toxicity of particles depending on their size and chemical composition. This toxicity will furthermore depend on the source of the particles, and will furthermore show both seasonal and geographical variations. A systematic approach to study the toxicity as a function of these variables is warranted. Integration of toxicological information into epidemiological studies will facilitate the establishment of more accurate exposure-response function.

The SCHER is aware of the emerging evidence of variation in susceptibility, acquired or genetic, to ambient PM2.5. This variation should be considered when establishing the air quality guidance values in order to protect the most susceptible and vulnerable groups.

A critical level for ozone to protect the vegetation in Europe has been established within the convention on LRTAP. New experimental studies suggest that a new AOT40 value should be introduced to protect forests from harmful effects due to ozone.

5. GAP OF KNOWLEDGE

1. The SCHER agrees that measurements of PM2.5 need to be intensified to give representative data from Europe, covering all relevant area types, and that epidemiological studies should be linked to these monitoring networks.

2. The SCHER realizes that more European-based information on the exposure – response functions of PM2.5 is needed.

3. The SCHER recommends that the physical/chemical properties of particles as a function of location and source and the formation of secondary particles should be elucidated, and their relative toxicity estimated.

4. The SCHER recommends increasing focus on the susceptibility and vulnerability of the population and different population groups, e.g. low socioeconomic groups, children, and people with predisposing disease.

5. The SCHER promotes the development and application of exposure indices for forest trees based on the amount of ozone taken up by leaves.

6. ABBREVIATIONS:

AQG	Air Quality Guidelines
AOT	Accumulated exposure Over Threshold
CAFÉ	Clean Air for Europe
CVD	Cardiovascular Disease
E-R	Exposure-response
HIA	Health Impact Assessment
LRTAP	Long-Range Transported Air Pollution
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate matters
ROS	Reactive Oxygen species
TSP	Total Suspended Particles
VOC	Volatile organic compounds
WGPM	Working Group on Particulate Matter

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