European Academies

Science Advisory Council

Impacts of pollution from outside the European Union on Europe's environmental targets

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Transborder pollution: Foreword

Public policies have to take account of the underlying science if they are to make any impact on the issue they are addressing. Equally, they have to accommodate what science tells about the boundaries of a phenomenon: if a problem originates at least in part from outside a country's borders, then a purely national approach to solving it is not going to be very effective. Such a reminder of the limits of national power may not always be welcome, but it can be the essential prelude to effective action.

I therefore strongly recommend this report to those who are tasked with devising and implementing effective policies for the improvement of Europe's environment. In a short statement it demonstrates that Europe's air quality is significantly impaired by sources of pollution that lie outside the EU. The statement grows out of discussions at a workshop hosted by the Academy of Athens, built around a background paper included in this report which details some of the relevant research. Both the statement and the background paper highlight actions that need to be taken to address the issues identified. These actions inevitably have a transnational character going beyond the countries of the EU, and thereby present something of a challenge.

On behalf of EASAC I should like to express my warm appreciation both to the Academy of Athens for the efficiency and generosity with which it hosted the workshop, and to the expert scientists from 12 different countries who contributed to making it a success. I should particularly like to thank David Fowler and John Murlis, respectively Chairman and Secretary of the EASAC Environment Strategy Group, for the skill and energy with which they wrote the background paper, organised the workshop and produced the subsequent statement.

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Impacts of pollution from outside the European Union on Europe's environmental targets

Summary

Environment experts from the European Union's Academies of Science have considered evidence on trends in air quality in Europe and projections for the coming decades. Despite investment by the European Union's Member States, recovery from past damage in some important areas is slower than expected and in some cases the environment is expected to deteriorate further. This stems from the effects of pollution sources that lie outside the scope of European legislation. Action at an international scale is needed, and we urge the European Union to take immediate steps to consider how this might be done.

EU Directives have been agreed between Member States to protect Europe from the effects of major transboundary air pollutants, including acid deposition and ground-level ozone. The Environment Strategy Group of the European Academies' Science Advisory Council met in Athens in October 2003 to consider evidence about the effects of these international agreements on trends in air quality and the extent of recovery of the natural environment from effects of pollutant deposition. The analysis also considered the effects of air quality on human health, current trends and future prospects.

The Member States of the European Union have made considerable reductions in emissions and in doing so have delivered significant benefits to Europe's environment and the health of Europe's citizens. For some areas, the reductions in pollution impacts have been larger than expected. In other areas, however, the evidence showed that reductions in pollution are much smaller than expected. The areas of little or no improvement include some of the very sensitive upland regions in which the effects of acid rain on freshwater ecosystems were most severe.

The causes of this failure to respond to emissions reductions within the EU are interactions between pollutants that were not assessed in the first round of agreements and additional sources of pollutants that were poorly known or not included. The most important of these sources are emissions of sulphur and nitrogen compounds from shipping and major sources of the precursors of ground level ozone in North America and Asia.

It is now clear that emissions of the precursor pollutants geographically outside the framework for control are making important contributions to the environmental problems within Europe. Furthermore, existing controls and additional measures to control sources within Europe will fail to protect human health and the natural ecosystems of Europe from the effects of these pollutants in the absence of control measures taken to reduce emissions of precursor pollutants more widely in the Northern Hemisphere.

In order to tackle this problem, we urge the European Council of Ministers to support or initiate international discussions with non-EU countries in the Northern Hemisphere to control:

- emissions of tropospheric ozone precursor gases throughout the countries of the Northern Hemisphere to prevent surface ozone concentrations exceeding thresholds for effects on human health, agricultural crops and the biodiversity of semi-natural ecosystems throughout Europe; and

- emissions of sulphur dioxide and nitrogen oxides from international shipping to protect the acid- sensitive natural ecosystems of Europe.

Background

The Environment Strategy Group of the European Academies' Science Advisory Council met in Athens in October 2003 to consider evidence on the effects of external pollution sources on Europe's environmental targets.

A background paper for the Athens workshop (Annex I) provided summary details of the existing international Protocols and Directives in place to protect Europe from the effects of major air pollutants that contribute to transboundary air pollution problems in Europe.

These pollutants give rise to effects on human health, primarily through ingestion of aerosols and ozone, and to effects on ecosystems through action of acidified precipitation, ozone absorption and enhanced eutrophication. The secondary pollutants contributing to these problems also play an important role in the radiative forcing of climate, through the effects of aerosols and ozone.

The issue

The Member States of the European Union have made considerable reductions in their emissions and have thereby delivered significant benefits to Europe's environment and the health of Europe's citizens. However, there are areas of Europe in which the changes in pollution concentration or deposition in recent years are not consistent with the expected recovery of air quality. For some of these areas, the reductions in concentration are larger than expected, while in other

areas the reductions in concentration are either much smaller than expected or levels have not changed at all. The areas of little or no improvement include some of the very acid sensitive upland regions in which effects of deposited acidity on freshwater biota were most severe.

The causes of these 'non-linearities' in the source/receptor relationships include interactions between pollutants that were not included in the first generation of long-range transport modelling and additional sources of pollutants that were poorly known or not included. The most important of these sources include emissions of sulphur from shipping and major sources of precursors of ground-level ozone in North America and Asia.

It is now clear that emissions of the precursor pollutants geographically outside the framework for control are making important contributions to the environmental problems within Europe. Furthermore, existing controls and additional measures to control sources within Europe will fail to protect human health and the natural ecosystems of Europe from the effects of these pollutants in the absence of control measures taken to reduce emissions of precursor pollutants more widely in the Northern Hemisphere.

Evidence for measurements and modelling

Current trends in the concentrations and deposition of these pollutants over large areas of Europe show that the effectiveness of existing international control measures, including those undertaken by the European Union (EU) and the United Nations Economic Commission for Europe (UNECE) within the Treaty on Long-Range Transboundary Air Pollution (LRTAP), is being eroded by emissions from countries and continents outside Europe and by emissions from shipping. The recognition that the effects of emissions over very large areas of the planet contribute to the pollution climate of the entire hemisphere has been shown to extend beyond the greenhouse gases into the pollutants with much shorter atmospheric lifetimes. Thus it is necessary to develop regulations operating on the same geographical scale as the emissions contributing to the problem.

The current UNECE protocols and EU directives include specific dates for review, to assess the modelling and measurement data and to show the extent to which the expected compliance and recovery are supported by the available measurements. The review date for the UNECE Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone is rapidly approaching and is likely to reveal non-linearities in several regions, in addition to those already identified. It will be very important to develop a strategy to show how the effects of the non-linearities can be reduced. It will be particularly important to separate the non-linearities arising through uncertainties in the science from those due to sources outside the control of the current protocols. It will then be necessary to develop strategies and agreements to limit the harm from the additional sources. Of course it is important also to emphasise that growing awareness of external influences on European air quality should not in any way lessen national commitments to reductions in emissions already agreed.

The steady increase in concentrations of surface ozone in the mid-latitudes of the Northern Hemisphere has brought annual mean concentrations within 10 ppbV of values shown to reduce the yields of sensitive crops, and within 20 ppbV of values shown to affect the respiratory systems of sensitive children and adults. Given the rate of increase in surface ozone concentrations, it is a matter of a few decades before the mean surface concentrations of ozone in some areas of Europe becomes damaging to human health, the health of natural ecosystems and crop yields.

Current uncertainties in understanding regional problems of eutrophication and global climate change highlight the role of aerosols in these problems. In the case of uncertainties in the effects of anthropogenic activity on global climate, the role of aerosols presents the major uncertainties in the anthropogenic contributions to radiative forcing of climate. The problem stems from weaknesses in understanding the sources, atmospheric processing and deposition of aerosols. These uncertainties include the role of resuspension of aerosols from the surface, for example the Sahara desert, which on occasion may lead to exceedences of air quality standards over large areas of Europe as well as modifying the albedo on a regional scale.

There is a considerable body of evidence from observations that there are large sources of particles observed throughout Europe that originate outside the geographical scope of the EU. They include Saharan dust, sea salt aerosols, wind blown dust and biomass burning. Whilst EU Air Quality standards refer to the number of episodes above a given level, care has to be taken with standard setting to exclude natural phenomena. The biomass burning associated with the forest and peat fires near Moscow in September 2002 led to the occurrence of particulate matter (PM) episodes in Finland, Denmark and the British Isles, while Saharan dust episodes have been shown to cause exceedences of PM standards in Southern and Mediterranean Europe.

Action required

- Controls on emissions of the precursor gases for tropospheric ozone throughout the countries of the Northern Hemisphere to prevent regional ozone concentrations exceeding thresholds for effects on human health, agricultural crops and the biodiversity of semi- natural ecosystems throughout Europe.

- Controls on the emissions of sulphur dioxide and nitrogen oxides from international shipping to protect the acid-sensitive natural ecosystems of Europe.

These controls can be achieved only through an international framework and will require concerted action by both the European Union and the United Nations Economic Commission for Europe.

As a first step, the impacts of sources outside the EU on Europe's environmental targets should be considered by the European Council of Ministers and by the Executive Body of the UNECE LRTAP within the review of the Gothenburg Protocol.

Annex 1 Background Paper: Will action taken within Europe alone achieve Europe's environment targets? The significance of influences from outside Europe on the European environment

David Fowler, EASAC ESG Chairman
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Introduction

The aims of the October 2003 Athens Workshop are to review current evidence of the influence of sources external to Europe on current control measures, the changes in these sources needed to match measures taken within Europe and the likely changes between 2003 and 2020. The main external influences will include the emissions of other Northern Hemisphere regions, in particular North America and China.

In recent years, the European Union has agreed a wide range of measures to limit emissions of air pollution. These include Directives on acidic emissions from power stations, refineries and road transport vehicles, on emission of the precursors of tropospheric ozone from products, processes and road transport vehicles, and on toxic pollutants from a wide range of industrial and transport sources. It is expected that these measures will carry significant costs to the economies of European Union Member States.

In addition the Union has set itself some ambitious targets on environmental quality. It has been decided that these are of high strategic importance in improving quality of life for the citizens of the Union. The CAFE (Clean Air For Europe) programme of the Commission seeks to ensure that the effects of the measures agreed will add up to the targets.

During the period in which European environmental legislation has developed, a number of international treaties have also been agreed on limiting air pollution, including measures agreed within the framework of the UN Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollutions (LRTAP). The signatories to the Convention include a number of nations outside the European Union, notably the United States of America and Canada. The protocols of the Convention limit emissions, but do not necessarily have a uniform effect in all countries. In some cases, signatories have agreed to a lesser effort than the European Union norm. In addition a number of significant emitters of air pollution outside the UNECE and the EU have yet to take action on a scale commensurate with the UNECE. There remains, then, the possibility that other Northern Hemisphere countries will continue to be significant emitters of air pollution beyond the dates set for European quality targets.

Emissions of sulphur and oxidised nitrogen have fallen across Europe. However, it seems that although deposition has fallen, too, it has fallen to a lesser extent. This points to substantial non-linearities, partly arising from unexpected interactions between pollutants and partly from the influence of sources outside the EU.

Oxidised nitrogen also plays a major role in the production of photochemical pollution. In this case, although peak levels are falling, there is an upward trend in mean levels. This may point to an increase in the tropospheric background levels of ozone, a major constituent of photochemical pollution, to which emissions of precursor pollutants, including oxidised nitrogen, from outside the EU contribute.

The decreases that have been achieved in nitrogen emissions over the last two decades seem to have had little impact on deposition of nitrogen species or on effects such as eutrophication across Europe.

The question this Workshop is addressing, now of crucial importance to policy makers, is whether the measures agreed by the European Union will achieve the targets set in the context of emissions within the Northern Hemisphere as a whole.

The workshop will consider evidence for non-linearities between emissions reductions and environmental improvements, and will take a view on the likely form of the relationship and in particular the influence of sources external to the European Union.

European environmental targets

(i) Protecting the environment

Targets for the protection of Europe's environment have been developed within the European Union through a series of Directives and within the Protocols of the United Nations Economic Commission for Europe Convention on Long Range Transboundary Air Pollution (UNECE – LRTAP). Increasingly, targets for environmental protection are agreed on the basis of effects. This is partly to ensure that the measures agreed address the problem and partly out of a concern for proportionality between investment in emission reductions and benefits of an improved environment.

The scientific demands of the effects-based approach have been considerable but there now seems to be a solid consensus that this is the way forward for protecting

ecosystems against air pollution. In scientific terms, this has been the driver for a major international research project aimed at understanding the effects of air pollution on the environment. The expression of this work is the development of Critical Loads and Levels for ecosystem protection. Critical Loads and Levels define the maximum amount of deposition of air pollutants or exposure to air pollutants that specific ecosystems can support before damage occurs. Critical Loads and Levels vary geographically and are shown on maps. They also depend greatly on the state of knowledge and are therefore subject to revision as knowledge improves.

There are many complexities to the Critical Loads Approach (CLA), including for example the aggregation of area statistics, definitions of damage and the basics of soil chemistry and plant physiology. The CLA, however, has proved robust in international negotiations and the maps produced remain the best definition of ecological sensitivity of air pollution available to Europe's policy makers.

There has been considerable debate about the relationship between critical loads and levels and environmental targets. However, it now seems that the maps of Critical Loads and Levels do provide a widely accepted aspirational set of targets for European environmental policy, both at EU and ECE levels.

There are now comprehensive and evolving agreements on, for example:

- Critical Loads for protection of terrestrial ecosystems and fresh waters against SO_2 and NO_x
- Critical Levels for protection of vegetation against the effects of ozone

A useful summary, with links to detail, is at http://www.ace.mmu.ac.uk/Resources/Fact_Sheets/Key_Stage_4/Air_Pollution/10.html

(ii) Protecting human health

Targets for the protection of human health are provided in a series of European Union Directives and have increasingly become a part of the rationale for the Protocols agreed under the UNECE LRTAP.

Within the EU, a series of Directives has specified air quality targets in terms of concentrations of air pollutants and the periods over which they are assessed, from hourly to annual. The programme of Air Quality Directives, including the Air Framework Directive and the Daughter Directives agreed under it, are summarised in the DG Environment web site at: http://www.europa.eu.int/comm/environment/air/ambient.htm

In summary, there are now comprehensive standards for a number of major air pollutants, including SO_2, NO_x, ozone and suspended particulate matter. Many of these standards have entered into force in Member States and have become de facto targets for both Member States and the European Union. The European targets are summarised, with a particular example of the Member States' targets, in: http://www.ace.mmu.ac.uk/Resources/Fact_Sheets/Key_Stage_4/Air_Pollution/21.html

Many of these targets depend on local sources, for example traffic pollution. However, as targets become more stringent and as local sources come under control, for example through European Directives on vehicle emission, the influence of sources further away from effected urban centres becomes more prominent. This has increased policy interest in uncontrolled and distant sources of air pollution.

It is widely accepted now that there are both local and regional dimensions to health impacts of air pollution and that there is a strong transboundary component to the pressures on health from air pollution.

(iii) Measures taken

Europe has invested heavily in measures to reduce the air pollution burden through, for example:

- EU Directives on large combustion plant
- EU Directives on vehicle emissions
- EU Directives on fuel quality
- UNECE Protocols under the LRTAP Convention
- EU Air Framework Directive and its daughter Directives

Details of measures taken under the EU can be found from links in the Air Page at http://www.europa.eu.int/scadplus/leg/en/s15004.htm and within the UNECE at http://www.unece.org/env/lrtap/

Although it is difficult to provide a meaningful figure, it is widely accepted that these have added greatly to costs for industry and for consumers across Europe.

Results and emerging issues: an assessment

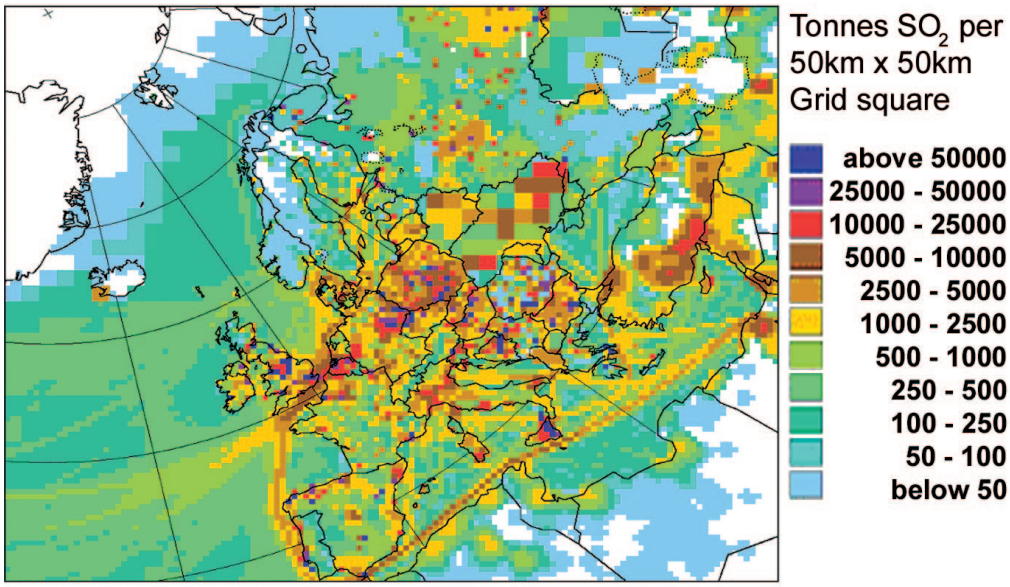
Despite the very considerable effort made to control sources of air pollutants, there is a wide consensus that much remains to be done. In particular, there is a growing feeling amongst the Member States of the European Union and UNECE that further action must be based on a full understanding of the current influences on the European pollution climate, including those sources that lie outside the European jurisdiction.

The following assessment considers four particular cases concerning the pollution climate of Europe in which sources outside the domain of the current control process significantly influence effects within Europe or the effects of European emissions.

(i) Sulphur

The very large reductions in European emissions have led to substantial reductions in concentrations, deposition and exceedences of Critical Loads. However, some important regions of Europe in which effects of acidification were widespread have experienced little or no reduction in deposited acidity, and show no signs of chemical or biological recovery. These areas include the NW fringe of Europe in western Britain, where the emissions of SO_2 from shipping in the eastern Atlantic has made an increasing contribution to the acidifying inputs, offsetting land-based reductions in Europe. These emissions are not currently controlled and are limiting ecosystem recovery from the effects of acid deposition (NEGTAP, 2001).

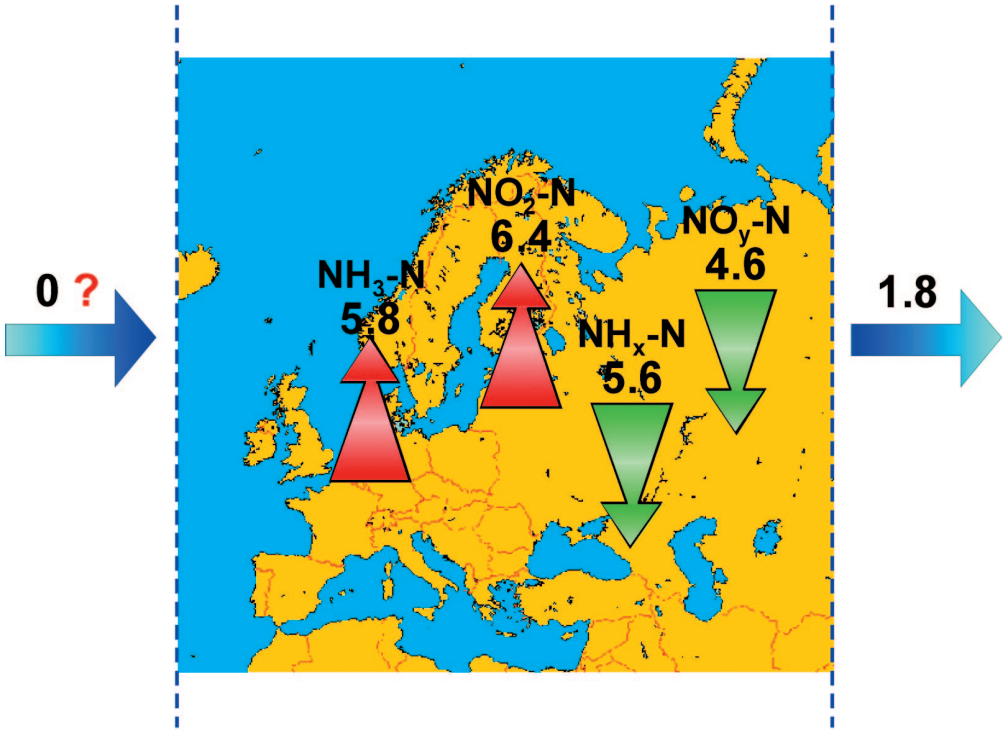
Figure 1 SO_2 emissions in Europe and the Eastern Atlantic, showing the shipping emissions in the Western Approaches to Europe, from Atlantic and in the North and Mediterranean Seas (EMEP/MSC-W, 2001)



(ii) Oxidized nitrogen

The timescale for oxidation and deposition of the nitrogen oxides is rather longer than sulphur dioxide, and as a result, a significant fraction of the emissions within Europe are advected out of the continent, generally to the east, contributing to eutrophication over Asia. There is also a smaller, but significant import of oxidized nitrogen from North America, which contributes to ozone formation over Europe and to eutrophication and acidification in Europe. The net budget for the EMEP domain is shown in figure 2, illustrating the issue. The budget shows that 30% of the oxidized Nitrogen emitted within Europe is deposited to the east, in Asia.

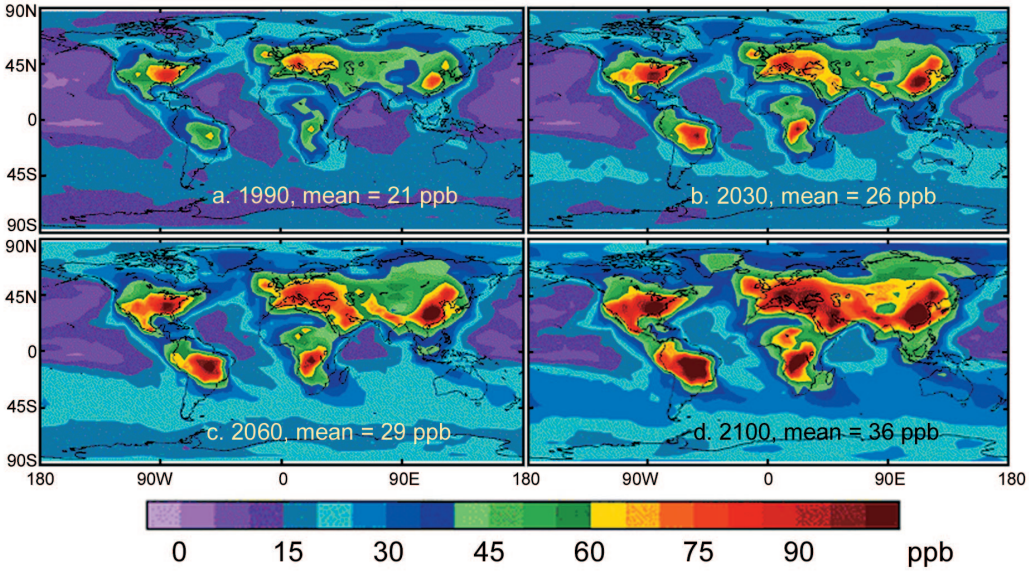
Figure 2 The annual atmospheric mean budget over Europe illustrating the net export of oxidising nitrogen (Mt) (EMEP/MSC-W, 1997)



(iii) Ozone

The photochemical production of ozone throughout northern mid-latitudes has created a zone of enhanced ozone concentration from the precursor emissions. The background concentrations between 30° N and 60° N are believed to be between a factor of 2 and 3 larger than in pre-industrial times (Prather et al, 2003). The consequence of the background surface ozone concentrations for European control strategies is that the controls on the NO_x and VOC emissions to date have reduced the peak concentrations substantially, but the growing background from emissions elsewhere in the Northern Hemisphere remains outside the control process. Furthermore, the background concentrations are now close to the thresholds for effects on vegetation and human health, and in the absence of controls in the other major emission areas, the background concentrations will in a few short decades be causing widespread damage to crops, natural ecosystems and human health.

Figure 3 Global surface ozone concentrations during the period 1990 to 2100 (Stevenson et al, 1998)



(iv) Aerosols

The primary concern over effects of atmospheric contaminants on human health in Europe is the link between aerosol concentrations and human mortality. The precise agent within aerosols responsible for the increased mortality in areas of high aerosol concentration remains unknown, but the physical properties and size are an important focus of current interest. Among the pollutants, the sources, atmospheric processing and fate of aerosols remains a challenge to the atmospheric science community, and the uncertainties in these factors introduce considerable uncertainty in the development of control strategies.

The contribution of Saharan dust to the chemical climate of the atmosphere over the Mediterranean basin leads to base cation deposition throughout the region. A base cation is essentially a positively charged ion from group 1 or 2 of the periodic table (ie the alkali metals or alkaline earth metals). The most environmentally abundant of these are sodium, potassium, calcium and magnesium. Base cations are important in the environment because their deposition has an impact on the surface pH. The deposition of base cations increases the alkalinity of the surface; the effect is to buffer or neutralise the effects of the acidity generated by deposition of sulphur or nitrogen (which in their mobile anionic form as SO_4^{2-} and NO_3^- leach calcium and magnesium from the soil) and to offer some protection from the effects of deposited acidity. However, the contribution to human health effects and climate effects of this particulate matter must also be considered.

The majority of the long-range transport of the pollutants with relatively short lifetimes in the atmosphere (days) occurs primarily in the aerosol phase. Thus the improvements in understanding needed for many of the key issues concerning atmospheric pollutants require correspondingly improved understanding of many aspects of the underlying processing of aerosols, their sources, transformations and removal from the atmosphere. In the absence of this improved understanding, control strategies developed to solve the currently known problems will produce less benefit than expected and further measures will be required.

Future action

The main questions for policy makers are now:

- What more needs to be done: can we measure the gap between what has been achieved in reducing levels of air pollutants and the targets set for protection of health and the environment?

- Where could further reductions in the key emissions (sulphur and oxidised nitrogen) come from?

- Future source apportionment: which sources of sulphur and oxidised nitrogen will have most influence in future?

Conclusions

The workshop will need to consider the evidence available and to highlight areas where further understanding is crucial to progress in the policy processes, especially:

- Evidence of need for further action
- Evidence for impacts of sources outside the EU
- Scale of reductions needed in Europe and externally

There are three levels of understanding:

- Those matters upon which there is broad scientific consensus
- Those areas in which there is a spread of opinion
- Those areas in which the current state of knowledge is inadequate to reach any sensible conclusion

From discussion of this background paper and other contributions to the workshop, EASAC will develop a timely statement intended to focus the attention of EU policy-makers on practical ways of addressing these important issues.

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