

Executive summary

Long range transported air pollution over Europe and the EMEP programme

The discovery of the severe pollution problems associated with sulphur in the atmosphere and in precipitation, combined with its transboundary nature provided the basis for the start of the EMEP network and the implementation of the Convention on Long-Range Transboundary Air Pollution and its agreements on pollution control. Sulphur was the primary pollutant at the start of the programme, but most other air pollution components having a transboundary character have subsequently been included into the programme. New protocols have been negotiated and at present there are agreements to reduce the pollution of sulphur, nitrogen oxides, ammonia, volatile organic compounds, heavy metals and persistent organic pollutants. These compounds are related to effects of acidification, eutrophication, ozone formation, enrichment of toxic compounds in the nutrition chains, and they also contribute to damages on health, vegetation, water and soil ecosystems. The EMEP project has now been in operation during 25 years. Significant emission decreases have been achieved during the period and considerable environmental improvements have been the result of the work related to EMEP.

The EMEP Assessment report

25 years of measurements of concentrations and deposition as well as model calculations of emissions, transport, atmospheric-chemical conversion and deposition of air pollutants over Europe have now been assessed as a joint task between EMEP countries, the EMEP centres and the Swedish ASTA project. The aim of this report has been to address a number of questions concerning the goals of the EMEP programme. With a starting point in the situation in the 1970s - 1980s, it is essential to EMEP to determine how trends in emissions, concentrations and depositions have developed in time. The report aims to establish whether observed trends can be explained by available knowledge. The assessment also intends to answer the question of what has been achieved and what more remains to be done in terms of environmental protection in view of the coming revision of protocols. The assessment includes national reports from the countries of the pollution trend development as well as an overall European evaluation.

Sulphur pollution over Europe

From 1980 to 2000 there has been a considerable decrease in sulphur emissions over most parts of Europe. The overall reduction has been nearly 70%, but there are large differences in achievements between countries and regions. The largest reductions, near 90%, are achieved in regions such as Austria-Germany-Switzerland and the Nordic countries. The least reductions are seen in south-eastern Europe, where the emissions in average have decreased by around 40%. In several Mediterranean countries and in Iceland, there has even been increasing emissions during the period.

The largest decrease in emissions is seen from 1990. This is due to effect of the economical restructuring of eastern European countries after the fall of the Berlin wall. For the period 1990-2000 there are also data available on sector emissions in the EMEP emission database. From such data it can be seen that there is not a single sector responsible for the main reduction, but there is a similar decrease in all anthropogenic sectors. A sector of growing concern is the shipping on international waters where only small emission reductions have been reported.

The emission decrease has resulted in reduced pollution levels in the atmosphere and in the environment as a whole. Long-term monitoring data for sulphur compounds are not available in all parts of Europe to allow an extensive evaluation the development in the environment. However, the data available indicate that sulphur dioxide concentrations have declined mainly by the same order of magnitude as the sulphur emissions.

The monitoring results show also that frequency as well as magnitude of episodically enhanced concentrations – pollution episodes - has decreased. The relatively few episodes of sulphur dioxide concentrations observed during the 1990s are believed to be mainly due to the decrease in emissions. Favourable weather with less frequent winter inversions during the 1990s may, however, have contributed to the development. This is also seen in the seasonal variation of the SO₂ levels. Winter month concentrations have decreased more than summer concentrations of sulphur dioxide, resulting in a less pronounced seasonal variation towards the end of the period.

Sulphate concentrations in air and precipitation have decreased more or less generally over Europe. This decrease has, however, not been as large as for sulphur emission reduction and as the decrease in sulphur dioxide concentrations. This is a consequence of changes in the oxidising capacity of the atmosphere throughout the period. The lower decrease in sulphate is explained by the fact that reduced sulphur dioxide emissions to the atmosphere will allow a greater potential for the oxidants and ammonia in the atmosphere to oxidise a larger part of the emitted sulphur dioxide. The sulphate part of the total sulphur concentration in the air has consequently been shown to increase.

The decrease of sulphate in precipitation is similar to that of sulphate in the air. This decrease has resulted in a general increase of pH in precipitation. Another consequence of the decreased sulphate in precipitation is decreasing wet deposition of sulphur. Together with decreasing air concentrations of sulphur, the total deposition of sulphur has been reduced all over Europe.

Sulphur and nitrogen deposition contributes to acidification of terrestrial ecosystems and surface waters. The deposition of both compounds has been decreased over most parts of Europe and deposition is approaching the critical loads for acidity. In some areas, where acidification was a problem, the deposition has now reached under the critical levels. Generally, the area of exceedances of critical loads as well as the magnitude of exceedance has decreased. However, to protect ecosystems against acidification in all Europe, emissions of acidifying compounds have to be reduced even further.

Oxidised nitrogen pollution over Europe

In parallel to the serious sulphur pollution, expanding traffic emissions during the 1980s was observed as a growing threat. The work on reducing emissions of nitrogen oxides started in the middle of the 1980s, but was not very efficient until in the middle of the 1990s. The decrease so far is consequently not as large as for sulphur. The total decrease in nitrogen oxides emissions is around 25% in the officially reported emission data and around 30% when experts' estimates for one missing source are considered. The differences between regions are, however, far more significant than for sulphur.

Some countries and regions have succeeded to reduce their NO_x emissions with 40-50%. The largest decrease is seen in the former eastern European countries, and is a result of their thorough economical restructuring. Also Germany and Switzerland have achieved a nearly 50% reduction of the NO_x emissions. The decrease in the main part of western Europe is around 30%. In southern Europe as a whole, the emissions have not changed, and in several Mediterranean countries the NO_x emissions have actually increased.

The main decrease during 1990 to 2000 has occurred for stationary combustion in power plants, industry and for residential heating, with almost 40% decrease. The decrease in transport emissions has been of the same order of magnitude as for the total NO_x, around 25%. A growing concern is the emissions on international waters due to shipping. These emissions increase in importance (20% of the total emission in 2000) when other emissions are reduced.

As a result of the different achievements in emission reduction, the trends for nitrogen oxides in air and for nitrate deposition vary considerably. The trend evaluation is further complicated by the fact that there are less long-term monitoring data available than for sulphur. In several countries, the NO₂ trends observed are in line with the national emission reduction. The largest NO₂ decreases are seen at EMEP sites in eastern European countries such as Czech Republic, Slovak Republic and Germany, to a large part due to restructuring of the energy and industrial sectors, and to less intensive traffic. Large reductions are also seen in Switzerland and United Kingdom. Around 30% decrease is seen in many countries including the Nordic, Italy, Netherlands and Switzerland. The introduction of catalysts on cars have been a major cause of decreasing NO_x emissions even if part of the achieved has been counteracted by increasing traffic.

As for sulphur, the most oxidised nitrogen compound - nitrate - show a less pronounced trend. This is due to the fact that reduced sulphur emissions leave a potential for further oxidation in the atmosphere. Long-term monitoring data to make trend studies possible are however, to a large extent lacking. There are observed decreases of 20 - 30% for total nitrate in air at sites in the Nordic countries and United Kingdom. Nitrate in precipitation has decreased in a similar way at most sites, even if inter-annual variations are large.

Deposition of oxidised nitrogen has decreased due to lower concentrations in air and precipitation. Together with decreasing deposition of ammonium, the total nitrogen

deposition has decreased. The nitrogen deposition is now in many areas approaching the critical loads for nutrients. Areas of exceedance as well as the magnitude of exceedance are decreasing. But, as for sulphur, the work on emission reduction must be continued in order to protect terrestrial and marine ecosystems.

Ammonia pollution

Ammonia is mainly emitted from agricultural activities. These emissions introduce - as a total over Europe - amounts of nitrogen into the atmosphere, which are of equivalent importance to what is emitted via nitrogen oxides. When deposited, the nitrogen from ammonia will contribute to the same effects in ecosystems as nitrogen oxides. The emissions have decreased with approximately 20% all over Europe, even if there are large differences between regions. Largest reductions are reported in eastern European countries such as the Baltic States, Czech Republic, Hungary, Poland, Russian Federation and Slovak Republic. In most other parts of Europe the decrease has been of the magnitude 10%. In southern Europe the emissions have been on a more or less constant level for the last 10 years.

The levels of ammonium in Europe vary between regions with a maximum of deposition in north-western Europe. Decreases in ammonium concentrations in air and precipitation show similar development as for nitrate in air and precipitation. Explanations are related to the fact that emission reductions on the large scale are similar for nitrogen oxides and for ammonia. However it is difficult to explain the actual reductions of ammonium in air and precipitation because these are also dependent on the air concentration of sulphate and nitrate.

Base cations in the environment

Base cations are of importance in the acidification of ecosystems. A large contribution is favourable since the acidification process causes losses of base cations in soil. Base cations are emitted as particles via a number of anthropogenic emission sources. A significant part of the base cations in the environment has, however, a natural origin such as windblown dust.

The deposition of base cations has decreased, in western Europe there was a significant decrease in anthropogenic emissions already during the 1970s. In the beginning of 1990s, with the closing of many lignite-fired power stations and many high emitting iron- and steel and other industrial plants, a second reduction of particulate base cation emissions were obtained.

Base cation deposition is essential to map over Europe as a basis for the critical load mapping and for studies of the ecosystem recovery from acidification. Wet deposition data from the EMEP measurements have been crucial in this process. However, data are to a large part lacking to accurately estimate the total deposition of base cations. One task for EMEP during the coming year is to produce a map over European base cation deposition as a basis for the coming revision of the Gothenburg protocol.

Particles in air

Particles in air is a parameter of growing concern over Europe. It was long considered as a local pollution problem, but awareness on their transboundary nature led to their inclusion in the EMEP programme in 1999. Since then PM₁₀ measurements have been reported to EMEP from an increasing number of sites. The available monitoring data indicate that the present levels in rural areas are of a magnitude - around 20 µg/m³ or even higher - which are likely to be of risk for health effects.

Particles in air (PM) are also of a complex nature, including particulate matter of many different sizes, having a wide variety of physical and chemical characteristics, and emanating from a number of anthropogenic and natural sources. Particles are not only emitted, but also formed in the air via oxidation and reactions between gases. Primary PM emission data are so far not reported to the same extent as those for sulphur and nitrogen. Data are available only for the recent years.

Available information national studies shows that there have been substantial reductions made in particle emissions. Although PM monitoring has been using a selection of methods, which are not always comparable, the data on total suspended particles and soot/black smoke measured at EMEP sites in parallel with the EMEP parameters indicate considerable decreases in different parts of Europe. The sulphate and nitrate and ammonium part of the particle mass has so far not decreased in proportion to emissions reductions made. When making prognoses for the future particle levels, all the different contributions to particle levels must be considered. Particle concentrations will be a key parameter for the work on including health effects into the new protocol.

Surface ozone

Threshold values for the protection of vegetation and human health are presently exceeded over large parts of the continent. The ozone levels and exceedances are generally highest in middle and southern Europe. Based on the AOT40 concept the threshold for crops and semi-natural vegetation is exceeded over most of Europe except furthest north and northwest, while the exceedance of the threshold for forests is confined to the European mainland. The highest values represent a six-fold exceedance of the threshold for crops and semi-natural vegetation and a three-fold exceedance of the threshold for forests. It may, however, be misleading to compare these two types of exceedances, and new flux-based thresholds may modify the picture.

Long-term trends in ozone are difficult to assess for many reasons. Firstly, ozone in air is a pollutant formed by photochemical reactions between nitrogen oxides and volatile organic compounds and thus closely linked to the regional weather conditions from year to year. Secondly, the hemispheric background concentration of ozone, determined by emissions and physical processes outside Europe is an important contributor to the European ozone problem. Finally, only in certain areas of Europe are the monitoring time series long enough to detect long-term trends with sufficient significance.

Nevertheless, a reduction in peak ozone values during the 1990's are reported from several regions in Europe, while there is no clear trend in the exceedances of the threshold values for AOT40 (accumulated ozone exposure over the threshold of 40 ppbv). Stations in the north and west report increasing hemispheric background concentrations of 0.3-0.5 ppbv yr⁻¹. The declining trend of the peak values is to some extent counterbalanced by the gradual rise in the background ozone and may also be counteracted by climatic change giving higher risks of hot and ozone-rich summers.

The reduction in peak ozone values is in line with model predictions based on the reduced European precursor emissions and is a very likely result of this emission abatement. The fact that long-term exposure indexes as AOT40 on the other hand is not significantly changed reflects that intermediate ozone concentrations are much more difficult to reduce. The counteracting influence from an increasing background may also mask the effect of European emission reductions.

Continued ozone monitoring as well as further precursor emission abatement policies including the cross-continental, hemispherical perspective will be necessary to meet air-quality measures in the future.

Heavy metals

Human activities has drastically changed the biochemically cycles and balance of most heavy metals. The main anthropogenic sources of heavy metals are various industrial processes, mining, foundries, smelters, combustion and gasoline. The major heavy metals of concern to EMEP are mercury (Hg), cadmium (Cd) and lead (Pb). The emissions as well as concentrations of lead in air and deposition have decreased by 60-70 % between 1990 and 2000. The decrease is due to the phase out of lead in petrol all over Europe. The emissions and concentrations of cadmium in air and deposition have decreased by 30-40 % between 1990 and 2000. This decrease of Cd emissions is mostly related to the employment of highly efficient emission control abatement in Europe to reduce the emissions of particles. For the period from 1990 to 2000 mercury anthropogenic emissions in Europe were reduced by half and depositions decreased 1.5 times. Introduction of flue gas desulphurisation in European power plants to remove sulphur dioxide, but also gaseous Hg has contributed mainly to the documented European emission decline of this element. It is quite evident that the spatial distribution of monitoring sites in Europe is unsatisfactory to provide a valid study of concentration trends.

Persistent Organic Pollutants

The chemical industry launched a new effective tool for dealing with insect pests in 1945: DDT. Although significant improvements in our understanding of persistent organic components have been made over the last decade, it probably remains the least understood part of the overall distribution and fate of these chemicals in the environment. There are decreasing trends in emissions as well as depositions and concentrations for various HCBs, PCBs and PAHs from 1990 to 2000. This is due to regulatory measures and restrictions. As for heavy metal measurements, the distribution and number of sites measuring POPs are insufficient.