Are we doing enough for human health and our environment?

Effects research in Germany under the UN ECE Air Convention

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Introduction

Air is essential for life. It should therefore be kept as clean as possible, particularly since atmospheric pollution can be transported over long distances and have harmful effects far away from the place where it was generated. The increased concentrations of atmospheric pollutants have primarily been the result of human activities.

Clean air is therefore an important societal goal. For a long time the fo cus was placed mainly on local and regional problems. However, the acidification of surface waters and the associated decline in fish stocks in Scandinavia made plain that atmospheric pollutants acknowledge no borders and can lead to negative impacts over large distances. As a reaction to this, the Convention on Long-range Transboundary Air Pollution (CLRTAP) was agreed in 1979[1], with signatories on both sides of the Iron Curtain.

Two key principles of the international cooperation under this convention are:

- To limit the emissions of pollutants in the individual signatory states, and
- To provide an institutional link between research and policy-making. This involves collecting information on the effects of air pollution on humans, ecosystems and materials and adopting measures which can lead to the greatest possible reduction in the harmful effects.

The work of the CLRTAP is carried out by three subsidiary bodies: (1) A working group on effects, which observes and investigates the effects of atmospheric pollution; (2) The EMEP programme[2], which is responsible for measurements and the transboundary modelling of air pollution concentrations and depositions; (3) A working group on strategies and review, which prepares international proposals and develops strategies for further developments under the Convention. These three groups work closely together and report their results to the Executive Body, which makes policy decisions. An implementation committee supervises the implementation of agreements by the participatory states.

In the 1980s, the European Economic Community began to address the issues relating to air quality. The obligations under the subsequent CLRTAP protocols have been formulated in legal acts, together with augmentations. Scientific results developed under the CLRTAP Convention now frequently provide the basis for legal provisions of the European Union on air quality.

The Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) of CLRTAP from 1999 aims to reduce levels of a number of atmospheric pollutants: initially sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and NMVOCs[3]. It is therefore widely referred to as the multipollutant, multieffects Protocol. Excessive inputs of SO_2, NO_x und NH_3 in ecosystems are responsible for the acidification of soils and bodies of water. Nitrogen compound depositions also contribute to eutrophication[4]. Nitrogen dioxide (NO_2) and NMVOCs are important precursor substances for the formation of ground-level ozone.

In addition to technical guidance and numerous reporting obligations, the Gothenburg Protocol also set agreed emission ceilings (NECs[5]) for these pollutants for each country, which were to be met by 2010. The declared goal was to achieve an appreciable improvement in the state of the environment in comparison with 1990 as a reference year.

1) The Parties to the Convention on Long-range Transboundary Air Pollution within the framework of the UN Economic Commission for Europe (UNECE) are documented on the CLRTAP homepage, http://www.unece.org/env/lrtap/welcome.html. Meanwhile, 50 countries including the USA and Canada and the European Union are parties to the Convention.
2) EMEP: European Monitoring and Evaluation Programme: Cooperative Programme for the Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
3) NMVOCs: non-methane volatile organic compounds
4) Eutrophication: Enrichment of plant nutrients, here in particular nitrogen saturation in soils, jeopardising nutrient balance
5) NEC: National Emission Ceiling

01

After several years of negotiations, agreement was reached in May 2012 on a revised Gothenburg Protocol. Among other things, this included commitments to achieve further reductions in emissions over the period from 2005 to 2020 for the pollutants SO_2, NO_x, NH_3, NMVOCs, and for the first time also for fine particulate matter ($PM_{2.5}$[6]).

The CLRTAP Convention has been extended by eight protocols, including the Protocol on Long-term Financing of the EMEP Programme (1984), as well as protocols on heavy metals (1998, amended in 2012) and persistent organic pollutants (1998, amended in 2009).

I. Overview of International Cooperative Programmes (ICPs) and the Task Force

Overview of International Cooperative Programmes (ICPs) and the Task Force on Health reporting to the Working Group on Effects of the LRTAP convention

Information on all working groups of the WGE see http://www.unece.org/env/lrtap/welcome.html

↗ ICP/Task Force and international chair and programme centre
◉ National programme coordination in Germany

Task Force on Health
The Joint Task Force of WHO and CLRTAP on the Health Aspects of Air Pollution

↗ WHO Regional Office for Europe, ECEH, Bonn (Germany)
◉ Federal Environment Agency

ICP Forests
Air Pollution Effects on Forests

↗ Chair: Germany; Programme Centre: Thünen Institute of Forest Ecosystems, Eberswalde (Germany)
◉ Federal Ministry of Food and Agriculture (BMEL) with support from Thünen Institute of Forest Eco-systems, Eberswalde

ICP Waters
Effects of Air Pollution on Rivers and Lakes

↗ Chair and Programme Centre: NIVA, Norwegian Institute for Water Research, Oslo (Norway)
◉ Federal Environment Agency

6) $PM_{2.5}$: Particulate matter with an aerodynamic diameter below 2.5 micrometres

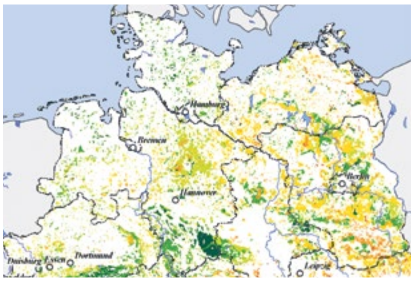
This brochure presents the German national working groups for environmental monitoring and research which contribute to the Working Group on Effects (WGE) of CLRTAP (see Box 1). Their results show the improvements in the state of the environment which have been achieved since 1990, among other things by the implementation of the Gothenburg Protocol, and also shows where further measures are needed with respect to air quality.

Most of these national working groups deliver their results to the programme centres of the International Cooperative Programmes (ICPs), which bring together the national research information and monitoring activities for Europe and North America. The Task Force on Health, a joint working group of CLRTAP and the World Health Organisation (WHO) on the health impacts of air pollution, also ensures the regular updating of knowledge by publishing studies and bringing together experts for discussions.

ICP Integrated Monitoring

Integrated monitoring of air pollution effects on ecosystems

- Chair: Sweden, Programme Centre: Finnish Environment Institute, Helsinki (Finland)
- Federal Environment Agency



ICP Modelling & Mapping

Modelling and mapping of critical levels and loads and air pollution effects

- Chair: France, Programme Centre: CCE, Coordination Centre for Effects, Bilthoven (Netherlands)
- Federal Environment Agency with support from ÖKO-DATA, Strausberg

ICP Vegetation

Effects of atmospheric pollution on natural vegetation and agricultural crops

- Chair and Programme Centre: CEH, Centre for Ecology and Hydrology, Bangor (Great Britain)
- Thünen Institute for Biodiversity, Braunschweig

ICP Materials

Effects of air pollution on materials and historical and cultural monuments

- Joint chairs and programme centres: Swerea KIMAB AB, Institute for Corrosion and Material Research, Kista (Sweden) and ENEA, National Agency for New Technologies, Energy and Sustainable Economic Development, Rome (Italy)
- Federal Environment Agency

7) http://www.unece.org/env/lrtap/WorkingGroups/wge/icps.html

02

8–13

How have emissions of atmospheric pollutants declined and what are the effects for air quality and pollutant depositions in ecosystems?

The Gothenburg Protocol and the NEC Directive[8] of the European Union specified emission ceilings with the goal of reducing the harmful effects of atmospheric pollutants.

The NEC Directive specifies interim environmental targets. For example, by 2010 (in comparison with 1990):

- The areas where critical loads for acidification are exceeded were to be reduced by at least 50 %. It was expected that meeting those objectives would result in a reduction by about 30 % of the area with depositions of nutrient nitrogen in excess of the critical loads for soil eutrophication.
- The ground-level ozone load above the critical level for human health was to be reduced by two-thirds in all grid cells.

The improvement of environmental status is thus a main objective of air quality policies. The next chapters show how the effects of air pollution have changed in Germany over the past 20 years, which air quality goals have been achieved, and where further measures are still necessary. Firstly, changes in emissions are considered together with the effects on pollution concentrations in the air and the pollution depositions in ecosystems. If emissions can be reduced it will represent an important step towards improving the state of the environment.

Core message 1: Marked reductions in emissions of sulphur dioxide, but little progress regarding ammonia.

The emissions into the atmosphere of compounds of sulphur and nitrogen and of precursor substances for ground-level ozone from sources in Germany fell markedly between 1990 and 2010 (Figure 1). Most SO_2 is emitted from power stations and industrial plants. In particular due to the introduction of flue gas desulphurisation and also as a result of economic restructuring after unification in 1989 (modernisation, relocation), these emissions were reduced by more than 90 % in Germany over the following two decades.

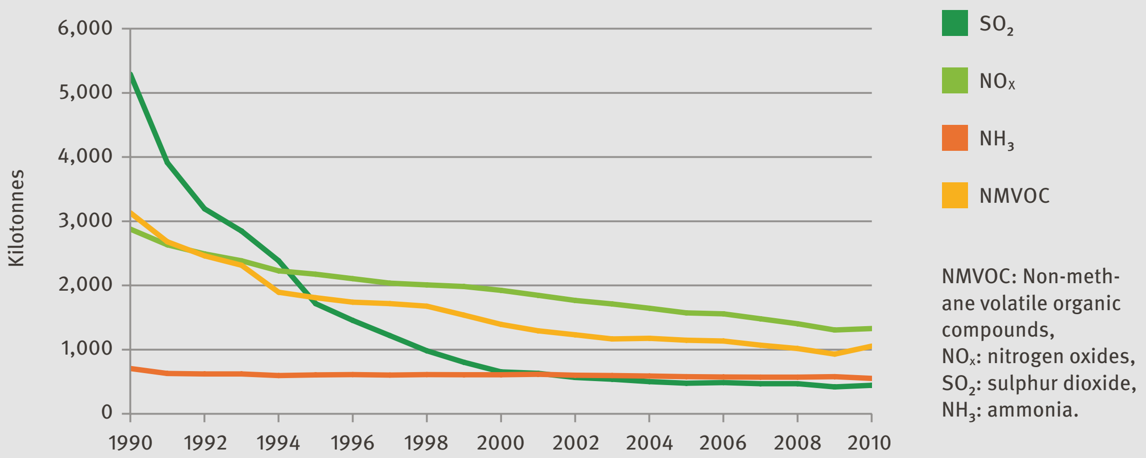
Industrial plants also emit NO_x, but the most important source in this case is the transport sector. Here the EU vehicle emission standards have contributed to a reduction of NO_x emissions, in combination with the tightening of emission limit values for large combustion and industrial plants.

NMVOC emissions result primarily from the use of solvents. By limiting the consumption of solvents in certain processes (e. g. printing, production of adhesives and surface coating materials) and the content of solvents in various products (e. g. paints and varnishes) it has proved possible to effectively reduce NMVOC emissions over the past 20 years.

8) Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants (NEC Directive).

FIGURE 1

Reductions in emissions in Germany of the atmospheric pollutants covered by the Gothenburg Protocol and the NEC Directive 2001/81/EC on national emission ceilings 1990 to 2010.



Source: Central System Emissions (ZSE) of the Federal Environment Agency[9]

NH_3 arises mainly from agricultural sources. These emissions have not shown a corresponding reduction over the past two decades. Meanwhile, NH_3 has become the main pollutant leading to harmful environmental impacts such as acidification and eutrophication. It is also an important precursor pollutant for the formation of atmospheric particulate matter.

Despite some striking reductions, by 2010 Germany had only managed to reduce SO_2 emissions to below the ceiling levels specified by the Gothenburg Protocol and the EU NEC Directive (106 and 76 kilotonnes below ceiling respectively). The emissions of NH_3 were slightly above the ceiling level (+ 2 kilotonnes). NMVOC emissions were 46 kilotonnes above the ceiling in both cases and the NO_x emissions were 144 and 174 kilotonnes above the respective emission ceilings (Table 1).

Various reasons contributed to the failure to achieve emissions which were below the specified ceiling levels. For example, cars and light goods vehicles complying with the new EU vehicle exhaust emission classes Euro 3-5 and heavy goods vehicles complying with classes Euro III-V returned real NO_x emissions which were considerably higher than the test-bed measurements on which the standards were based. In addition, some of the assumptions made when formulating the emission ceilings at the end of the 1990s proved not to be sound, e.g. the proportion of diesel vehicles in the vehicle fleet as of 2010 was underestimated, as were average annual vehicle mileages. In addition, delays in the extension of EU exhaust emission standards to include mobile machines and equipment also contributed to NO_x emissions being higher than were originally projected. A further reason is the high levels of NO_x emissions from the incineration of biomass, a source which had not seemed so relevant when the emission ceilings were being determined. The combination of these factors led to overconfidence in the ability to comply with the ceilings.

Problems with meeting the national emission ceiling for NH_3 were due above all to the reluctant implementation of measures in the agricultural sector.

Despite the progress made in reducing NMVOC emissions, it was also not possible to achieve levels below the ceilings set by the NEC Directive and the Gothenburg Protocol for these substances. In order to make further progress in this case it would be necessary for stricter EU regulations to be introduced limiting the use of solvents, which would then have to be transposed into German law.

9) http://www.umweltbundesamt.de/themen/luft/emissionen-von-luftschadstoffen, as of July 2013.

The national emission reduction commitments specified in the revised Gothenburg Protocol, to be achieved in 2020 and beyond are presented in Chapter 10.

Various factors influence how emissions affect pollutant concentrations and depositions. Physical and chemical processes in the atmosphere determine both the formation of secondary atmospheric pollutants and the regional distribution of pollutants. These processes are highly dependent on meteorological conditions, which differ both seasonally and from one year to the next. For example, pollution concentrations and effects in 2003 deviate from the general trend as the consequence of an unusually hot and dry summer that year.

TABLE 1

National emission ceilings for 2010 in Germany and actual emissions (in kilotonnes per annum)

	SO_2	NO_x	NH_3	NMVOC
Emission ceilings of the NEC Directive	520	1,051	550	995
Emissions 2010	444	1,225[1]	552	1,041[2]
Below ceiling/Above ceiling	-76	+174	+2	+46
	-14.6%	+16.6%	+0.4%	+4.6%
Emission ceilings of the Gothenburg Protocol	550	1,081	550	995
Emissions 2010	444	1,225[1]	552	1,041[2]
Below ceiling/Above ceiling	-106	+144	+2	+46
	-19.3 %	+13.3%	+0.4%	+4.6%

1) Without NOx emissions from agriculture. These emissions were not taken into consideration when calculating the national emission ceilings (NECs) for 2010.
2) Without NMVOC-emissions from the food industry. These emissions were not taken into consideration when calculating the national emission ceilings (NECs) for 2010.

Source: Central System Emissions (ZSE) of the Federal Environment Agency (July 2013).

02

Core message 2:
Air pollution has declined markedly since 1990

Monitoring atmospheric pollution in Germany is mainly the responsibility of the Federal States. As in all other Member States of the European Union, monitoring is based on the provisions of the EU Ambient Air Quality Directives (2008/50/EC and 2004/107/EC). There are some 650 air-quality measuring stations in Germany. These are located in various exposure situations, categorised as rural, urban, urban background, traffic-oriented, or industrial sites, which makes it possible to draw conclusions about important causes of pollution. The Federal Environment Agency operates 7 stations, all of which are located at some distance from sources of emissions, serving among other things to register background pollution levels (long-range transboundary air pollution). These stations are integrated in the European Monitoring and Evaluation Programme (EMEP) and other international measuring programmes (e.g. GAW[10]).

2. Emissions, pollutants, depositions

The following definitions apply for atmospheric pollutants:

- **Emission:** The release of substances (or a substance released) from a source into the atmosphere. Sources may be punctual (e.g. a chimney stack), linear (e.g. roads, railway lines or waterways), or diffuse (for example farmland).
- **Pollutant:** A substance present in ambient air which is likely to have harmful effects on human health and/or the environment as a whole.
- **Deposition:** A substance deposited from the ambient air. Usually quantified in terms of mass of substance per unit area over time (e.g. kg nitrogen per hectare per annum: kg N ha^{-1} a^{-1}).

Today, Germany is in compliance with the limit values under EU law for SO_2, carbon monoxide, benzene, and lead. The maximum ozone concentrations declined considerably as a result of the reduced emissions of precursor substances for ozone (NO_x and NMVOCs), which means that the summer smog which was common in the 1990s is no longer experienced. The trends for the maximum eight-hour mean concentrations over the period 1990 to 2012 (Figure 2) show a marked decline in very high ozone concentrations. Despite this, the target values for a minimum protection of human health (120 µg/m³) are frequently exceeded. Problems are also still encountered regarding compliance with the limit values specified in the Ambient Air Quality Directive (2008/50/EC) for particulate matter (PM_{10}) and nitrogen dioxide (NO_2).

10) GAW: Global Atmosphere Watch: http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html

FIGURE 2

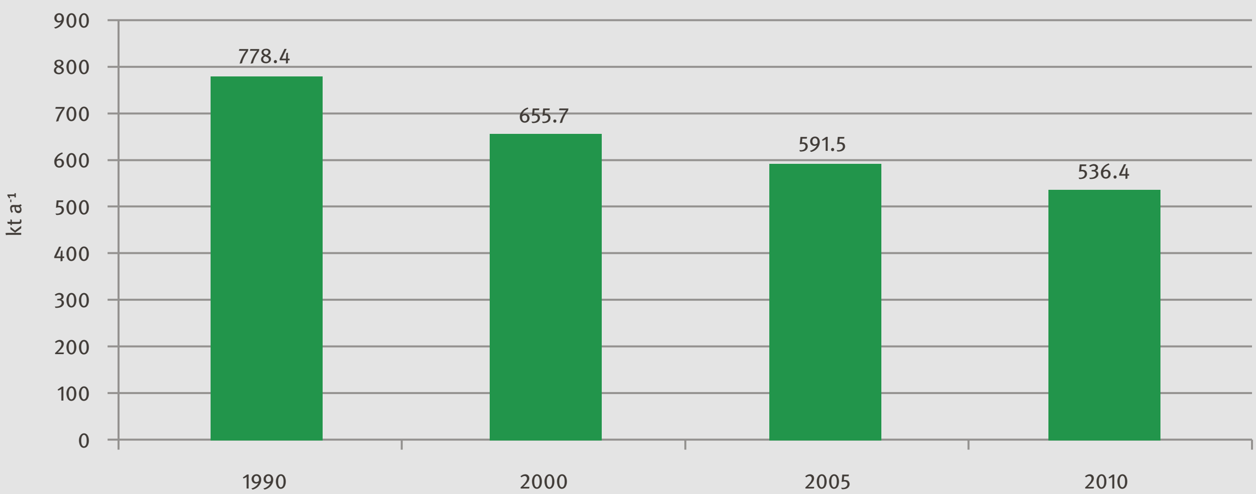
Trend of maximum daily eight-hour mean ozone concentrations according to station sites, with standard deviations (bars).

Source: Federal Environment Agency 2013, based on measurement network data from the Federal States and the Federal Environment Agency

Depositions in ecosystems have declined considerably since 1990. In addition to the drastic decline in the deposition of sulphates (SO_4), there are also lower nitrogen depositions – primarily as a result of falling NO_x emissions. The total depositions shown in Figure 3 for Germany correspond to mean annual depositions per hectare of 22 kg N ha^{-1} a^{-1} in 1990 and 15 kg N ha^{-1} a^{-1} in 2010. Depending on the spatial distribution of the atmospheric pollutants and varying filter effects provided by ecosystems, depositions at a specific location may have been higher or lower than this.

FIGURE 3:

Decline in depositions of nitrogen (in kilotonnes p.a.) for Germany



Source: EMEP deposition data[11]

11) Fagerli H, Gauss M, Benedictow A, Jonson J E, Simpson D, Nyríi Á, Schulz M, Steensen B M, Tsyro S, Valdebenito Á, Wind P, Shamsudheen S V, Aas W, Hjellbrekke A-G, Mareckova K, Wankmüller R, Solberg S, Svendby T, Vieno M, Thunis P, Cuvelier K, Koffi B, Bergström R (2012): Transboundary Acidification, Eutrophication and Ground Level Ozone in Europe in 2010. EMEP Report 1/2012. http://www.emep.int/mscw/index_mscw.html


03
14–18

Take a deep breath? – Effects of air quality on health

In order to evaluate the health risks posed by pollutants in ambient air, CLRTAP and the Regional Office for Europe of the World Health Organization (WHO/Euro, Copenhagen) established at the WHO European Centre for Environment and Health in Bonn a joint working group, the Task Force on Health[12]. The assessments were made in accordance with the WHO Air Quality Guidelines for Europe for air quality value below which specified exposure does not constitute a significant health risk[13]. These values do not correspond in all cases to the existing limit values and interim quality targets in Germany and the European Union. It should also be noted that while CLRTAP is concerned above all with long-range transboundary pollution, German and European air quality law pays more attention to local effects (e.g. in the direct vicinity of a road). These two aspects can augment one another, because a local emission will always be added on to a baseline load. In the following, some of the findings of the Task Force on Health are presented.

Core message 1: Extreme ozone episodes no longer pose extreme health risks – but that is no reason to feel complacent

Increased ground-level ozone concentrations in ambient air affect in particular human respiratory and cardiovascular systems. A reduction of exposure helps to reduce adverse health outcomes or even premature mortalities. In addition it can have positive effects such as a reduction of working days lost, hospital admissions, and health costs, as well as improving the quality of life of the people who are exposed. Ozone is not emitted directly, but is formed in the atmosphere from precursor pollutants exposed to sunshine. The Gothenburg Protocol therefore addresses the emissions of these precursor substances.

As a result of the measures introduced to improve air quality, problematic episodes with very high ozone concentrations which have acute effects on human health have hardly been experienced since the mid-1990s. The information and alarm thresholds are only very rarely exceeded (hourly means of 180 and 240 µg m^{-3}, respectively).

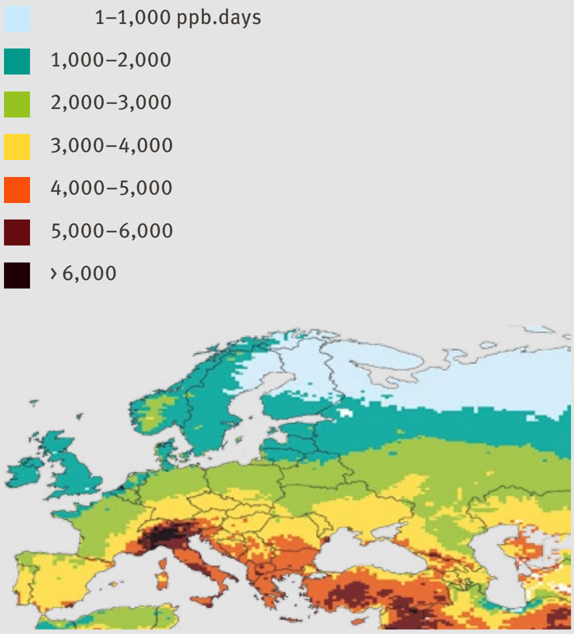
However, a challenge still remains concerning medium-level ozone concentrations, which can lead to chronic health impairment. The legal ozone level introduced in order to prevent acute effects on public health (i.e. the 8-hour ozone mean value of 120 µg m^{-3} on no more than 25 days in a year) is currently exceeded at some 10 % of the air quality monitoring stations in Germany. Furthermore, there are meanwhile clear indications that chronic effects can also result from long-term exposure even below the EU target value of 120 µg m^{-3}.

For the evaluation of chronic exposure, the Task Force on Health developed the SOMO 35 parameter. This is calculated by summing over a calendar year the daily maximum 8-hour means that are above 35 ppb[14]. This is a concentration above which health effects become increasingly common[15]. The frequency of ozone episodes based on the SOMO 35 parameter for 2010 shown in Figure 4 indicates the health risks in Europe. The clear increase in health risks from north to south is attributable to the increased formation of ozone in sunny, hot weather.

12) Joint WHO-CLRTAP Task Force on the Health Aspects of Air Pollution
13) See WHO Regional Office for Europe “Review of Evidence on Health Aspects of Air Pollution, REVIHAAP Project” Technical Report, 302pp., WHO/Euro, 2013.
14) ppb: parts per billion, a dimensionless expression of concentrations. Corresponds here to 70 µg m^{-3}.
15) Amann M, Derwent D, Forsberg B, Hänninen O, Hurley F, Krzyzanowski M, De Leeuw F, Liu S, Mandin C, Schneider J, Schwarze P Simpson D (2008): Health Risks of Ozone from Long-range Transboundary Air Pollution, WHO/Europe

FIGURE 4

Mean values of SOMO 35 in Europe in 2010



Source: IIASA[16]

Core message 2: Continued problems with particulate matter

Particulate matter can find its way directly into ambient air (e.g. black carbon, soil particles) or it may be formed in the atmosphere (e.g. from organic substances, NH_3 or SO_2). PM_{10} refers to all particles with an aerodynamic diameter of less than 10 micrometres (i.e. 10 millionths of a metre). $PM_{2.5}$ is used to refer to those particles with an aerodynamic diameter of less than 2.5 micrometres. In contrast to other atmospheric pollutants such as SO_2 or NO_2, it is not possible to specify concentrations of particulate matter in ambient air below which no harmful effects would be expected for human health. Not only do short-term peak concentrations lead to negative health effects, but lower concentrations over longer periods can also be harmful for public health. Exposure to particulate matter should therefore be kept as low as possible. In Figure 5 it can be seen that the annual mean PM_{10} concentrations in Germany are declining for all types of monitoring site. However there are considerable fluctuations from year to year, caused mainly by varying weather conditions. The reduction in the period 1995 to 2000 is mainly attributable to reductions of SO_2 emissions and direct emissions of PM_{10} particulates. Under current legislation, PM_{10} concentrations should not exceed a daily limit value of 50 µg m^{-3} on more than 35 days in a year, and the annual mean value should not exceed 40 µg m^{-3}. Many towns and cities in Germany are finding it difficult to comply with the limit on the number of days on which the short-term limit value can be exceeded.

Despite the reductions which have been achieved, particulate matter loads remain a problem in Germany, and indeed in all of Europe. According to an EU estimate, over the period 2008 to 2010, some 20 % of the people in the 27 EU Member States were exposed to concentrations of particulate matter above the EU's PM_{10} short-term limit value. Taking the stricter WHO guideline (WHO 2006)[17], more than 80 % of EU citizens have been exposed to particulate matter loads which exceeded the WHO long-term guideline for PM_{10} of 20 µg m^{-3} (as annual mean value).

In order to reduce public exposure to $PM_{2.5}$, the EU has introduced reduction targets to be achieved by 2020 as a percentage of the average load for the period 2008–2010 (moving annual mean value der $PM_{2.5}$ concentrations in µg m^{-3} over three years). For Germany, this resulted in a necessary reduction of 15 %[18] by 2020 compared with the reference year 2010. The target and limit values of the EU relate to urban background measurements. EU limit concentrations of 25 µg m^{-3} were specified for 2015 and of 20 µg m^{-3} to be complied with by 2020.

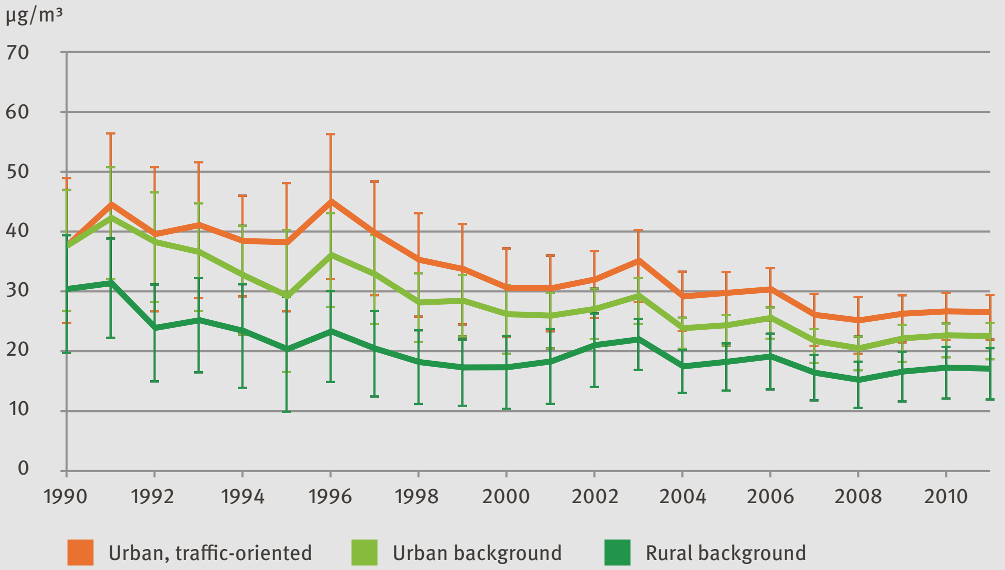
The Task Force on Health assesses the health risks from particulate matter by estimating morbidity and premature mortalities (Figure 6). This is based on modelling of the mean annual $PM_{2.5}$ concentrations across Europe and a statistical exposure-effect function. For Germany, IIASA calculates a mean reduction of life expectancy of 10.2 months in 2000, falling to 7.5 months in 2010 as a result of the implementation of measures to improve air quality throughout Europe in compliance with legal requirements. The impact on public health attributable to exposure to particulate matter reduces the quality of life of individuals and increases health costs for society

16) IIASA: International Institute for Applied System Analysis: http://www.iiasa.ac.at
17) WHO (2006): Air Quality Guidelines – Global Update 2005; WHO Regional Office for Europe, Copenhagen.
18) Article 15 of the Ordinance on air quality standards and emission ceilings (39. BImSchV)

as a whole. The measures so far introduced cannot be expected to provide sufficient protection against the effects of exposure to fine particulate matter, as projections for the year 2020 show.

FIGURE 5

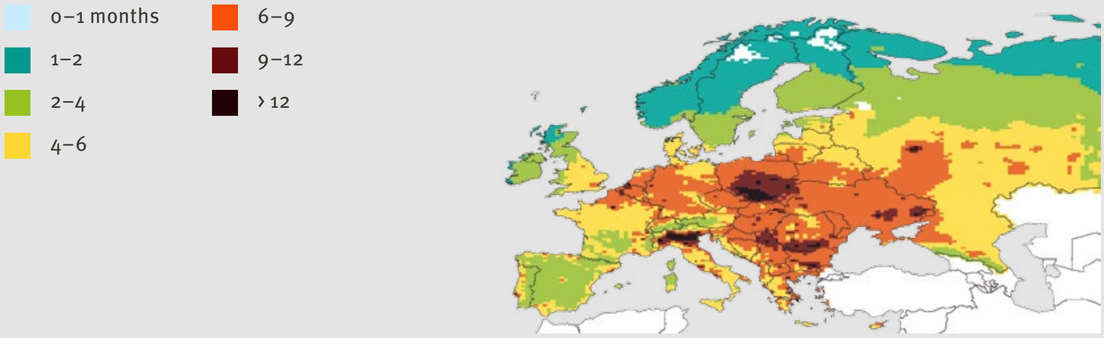
Annual PM_{10} mean concentrations for the period 2000 to 2011 (stations which have measured for at least 9 years).



Source: Federal Environment Agency 2013, own compilation based on measurement network data from the Federal States and the Federal Environment Agency

FIGURE 6

Statistical prediction for 2010 of the reduction in life expectancy in months in Europe attributable to exposure to anthropogenic fine particulate matter ($PM_{2.5}$)



Source: IIASA

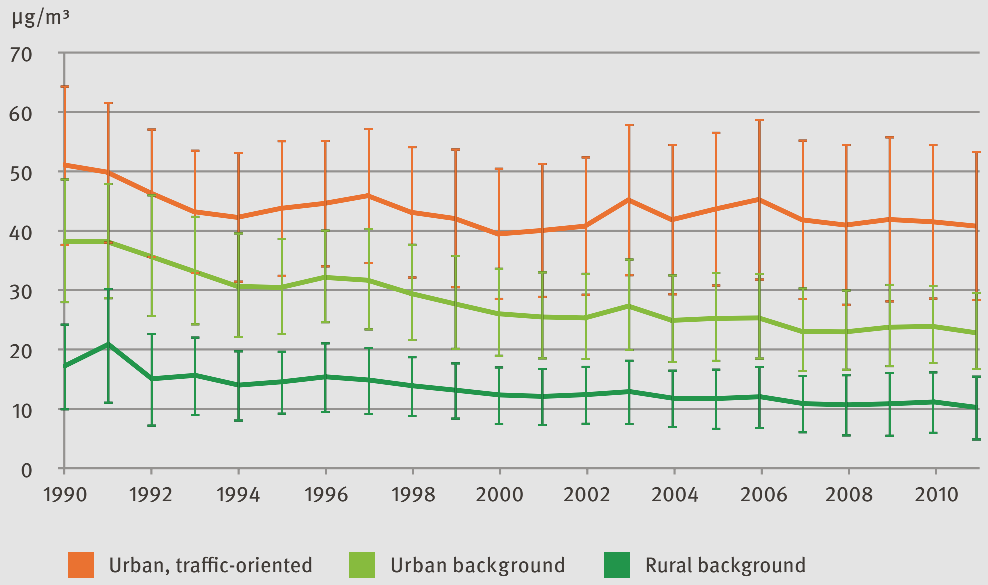
3. Core message: Nitrogen dioxide impacts on health in areas with high levels of traffic

NO_2 is a powerful oxidant which can have deleterious effects on the pulmonary function and on the eyes. If the NO_2 concentration in ambient air increases, individuals with lung complaints are particularly affected. Nitrogen dioxide is also a precursor substance for the formation of particulate matter and ozone. The consequence of high NO_2 concentrations is an increase in respiratory and cardiovascular complaints and increased mortality. Concentrations of NO_2 which can be harmful for human health occur above all in urban areas with heavy traffic (Figure 7).

The EU Ambient Air Quality Directive (2008/50/EC) specifies that the NO_2 concentration over a one-hour averaging period shall not exceed 200 µg m^{-3} more than 18 times in a calendar year. In Germany, the short-term limit value is rarely exceeded this often. For the annual mean value, the limit value since 2010 has been 40 µg m^{-3}. Rural and urban background monitoring stations generally have levels well below this limit, but many traffic-oriented stations in Germany are still not in compliance, despite showing a mild decline in NO_2 annual mean concentration measurements through until the year 2000 and no improvements until 2010.

FIGURE 7

Trends for NO_2 annual means in the period 2000 to 2011 (stations which have measured over at least 9 years).



Source: Federal Environment Agency 2013, own compilation based on measurement network data from the Federal States and the Federal Environment Agency

Forests as pollutant filters? How do emission reductions affect forests?

In the 1980s, a systematic approach was taken to install forest environment monitoring in Germany. Since then, the federal states have investigated the state of the forests on a systematic grid. On a national level, the data for Germany are collated and evaluated by the Thünen Institute of Forest Ecosystems. As shown by the results of the annual Forest Condition Survey published on the website of the Federal Ministry of Food and Agriculture (BMEL), nearly a quarter of forest trees still show visible crown defoliation.

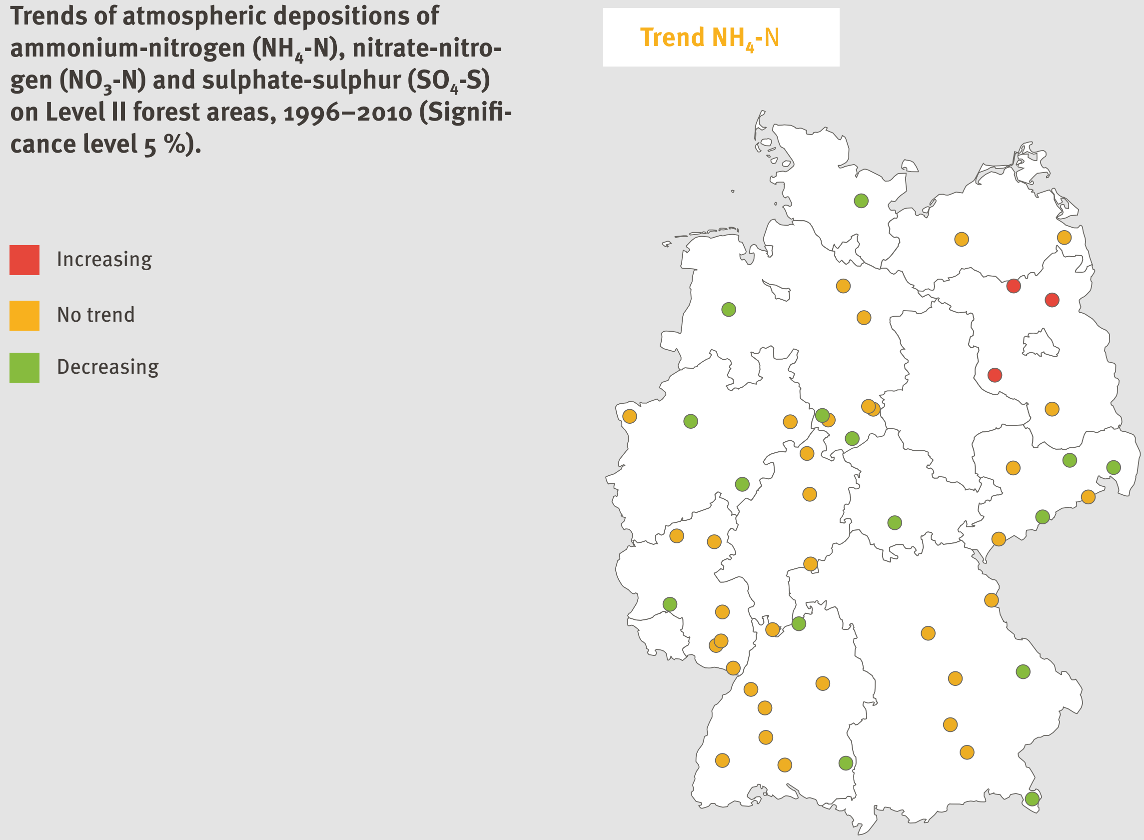
Crown defoliation is not a specific symptom which can be directly linked to a single cause. In order to identify the effects of environmental factors, including pollutants, on the state of the forest, on the vegetation in general, and on soil processes, an intensive investigation programme (Level II) has developed since 1994. In 2010, data on atmospheric depositions and other forest ecosystem parameters were collected for 73 forest locations. Data from the environmental monitoring of forests in Germany are submitted to the European database of ICP Forests.

Core message 1: Sulphur and nitrogen depositions are declining – but not for all forest stands

The maps in Figure 8 show deposition trends in forest sites for which continuous data is available for the period 1996 to 2010. The trends differ between the various substances investigated. Whereas the deposition of sulphur showed a statistically significant decline on nearly all sites, the developments for nitrogen compounds were heterogeneous. While there were downward trends at some locations, others showed increasing deposition. There are more sites with a declining trend for nitrate-nitrogen than for ammonium-nitrogen, but in both cases there are more sites showing no significant trend.

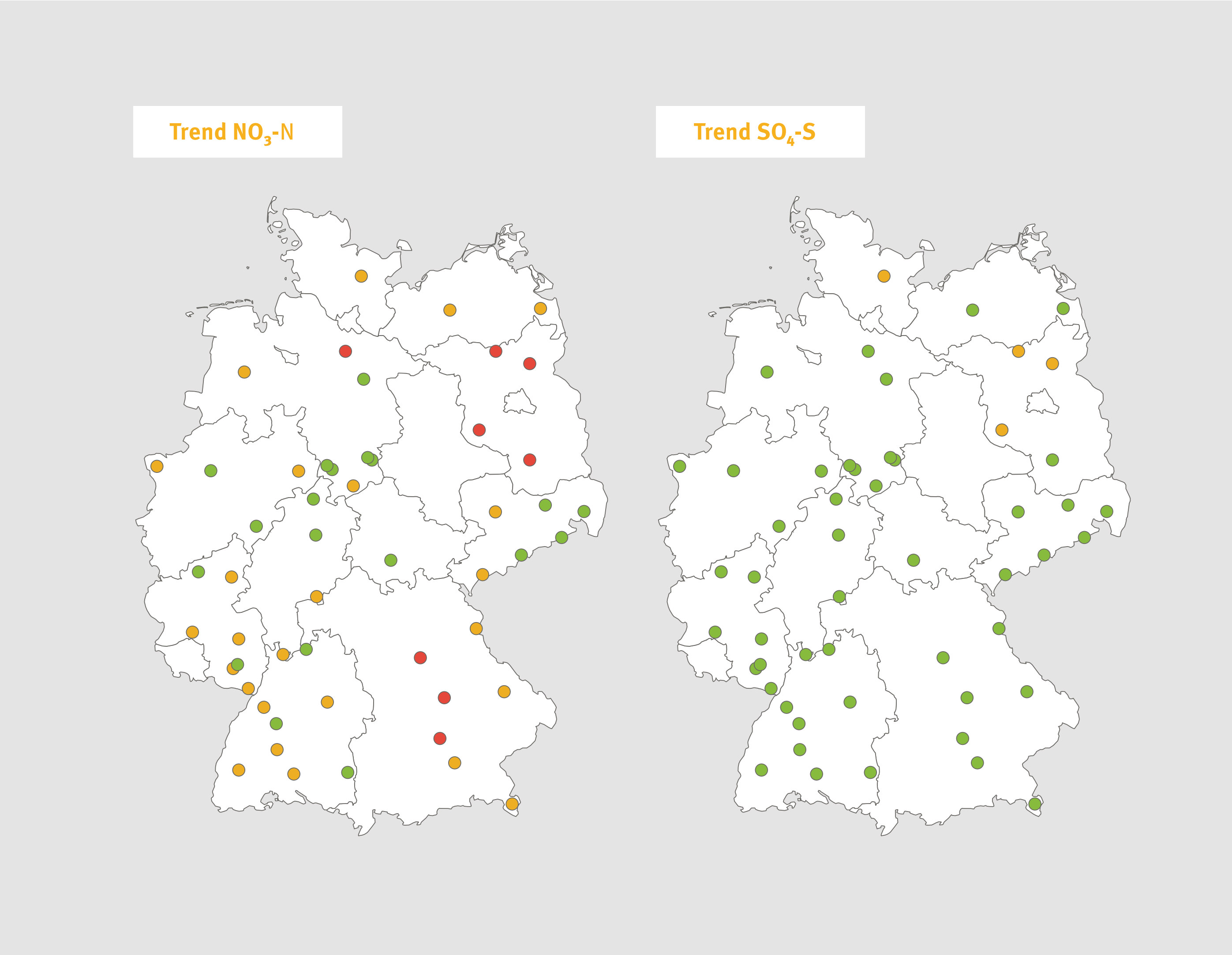
FIGURE 8

Trends of atmospheric depositions of ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and sulphate-sulphur (SO_4-S) on Level II forest areas, 1996–2010 (Significance level 5 %).



Source: Thünen Institute of Forest Ecosystems based on data from forest monitoring of the Federal States

The trends at different locations depend on factors such as the sources of pollutants and the implementation of measures to reduce emissions, but they are also affected by general economic developments. This is clearly shown by the deposition developments at selected locations in Figure 9. The measurements for the spruce stands at Olbernhau (Erzgebirge, Saxony), Solling (a low mountain range, Lower Saxony), St. Märgen (Black Forest, Baden-Württemberg), reflect the general downward trend for the depositions of SO_x and NO_x in the period 1990 to 2010. In western Germany, the main reductions for SO_2 were already registered before the 1990s. In the Erzgebirge in eastern Germany, stands were still exposed in the 1990s to SO_2 emissions from the Czech Republic, but these were dramatically reduced in the following years. Currently only slight further reductions in sulphur



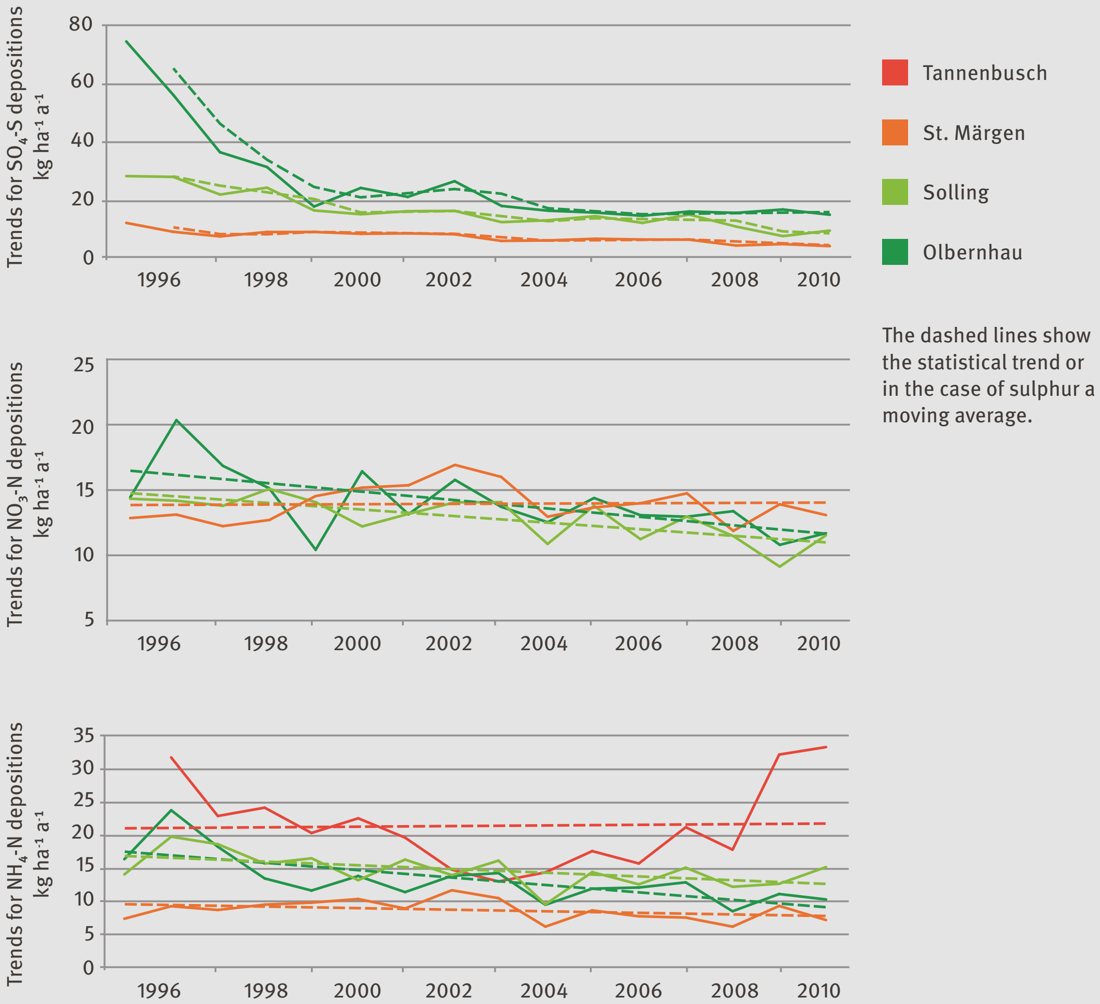
depositions can be observed. For the area in the Black Forest (St. Märgen) there is no downward trend in the case of nitrate-nitrogen, so that the depositions are meanwhile the highest of the three locations. Probably the traffic emissions from the Upper Rhine plain contribute to this effect. The locations also show different developments for ammonium-nitrogen depositions (Fig. 9). Whereas depositions declined in the spruce stands of the previous three locations, they have increased again in recent years in the oak stands of the added location of Tannenbusch on the German-Dutch border, which is close to emission sites. The striking downward trend for Olbernhau is linked to the reduction in the scale of large-scale livestock farming in eastern Germany after unification.

The deposited sulphur and nitrogen compounds have an acidifying effect on forest soils. The net acid depositions are reduced in particular where the depositions of sulphates and nitrates have declined. This is most pronounced in the case of spruce stands, which are known to have a high filtering capacity for atmospheric pollutants.

The nitrogen compounds not only have acidifying effects but also act as a fertilizer. Nutrient imbalances result from both the acidification and the over-supply of biologically active nitrogen relative to potassium, magnesium and other base cations, as well as phosphorus.

FIGURE 9

Trends for depositions of sulphate-sulphur (SO_4-S), nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N) in selected forest stands of the Level II programme.



Source: Thünen Institute of Forest Ecosystems based on data from forest monitoring of the Federal States

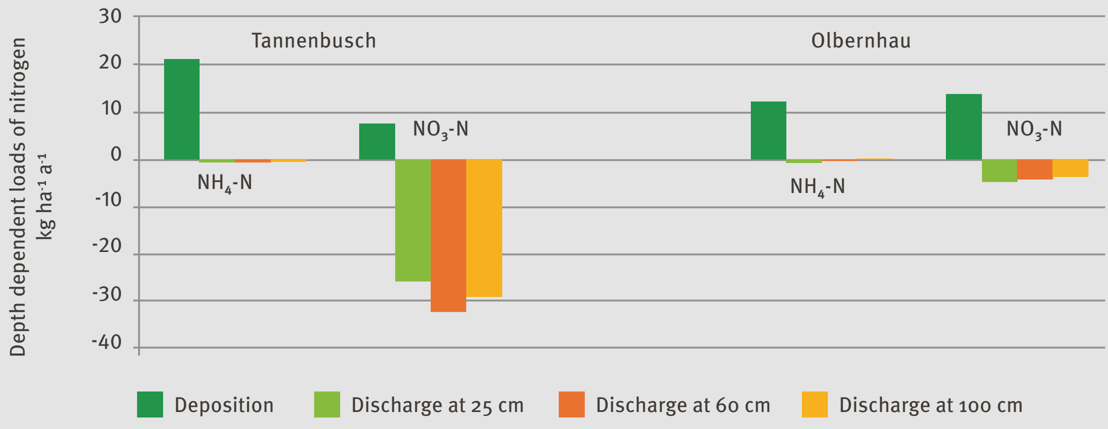
Core message 2:
Depositions impair key forest functions

However, forests do not only provide timber and public leisure and recreation. They also play an important role within the natural ecosystem functioning and provide habitats for numerous species of flora and fauna. These multiple functions can only be fulfilled well in the long term by healthy forests unimpaired by pollution.

Forest ecosystems facilitate multiple interactions between living organisms, biotic communities, and the environment (e.g. climate, soil) in addition to the effects of human activities (e.g. forest management, substance depositions). Forest soils can frequently provide a buffer for pollution depositions over a certain period, so that effects will only become apparent after some delay, if at all. In individual cases it is therefore often impossible

FIGURE 10

Depth dependent loads of nitrogen compounds at two forest stands (1998–2010).



Source: Thünen Institute of Forest Ecosystems based on data from forest monitoring of the Federal States

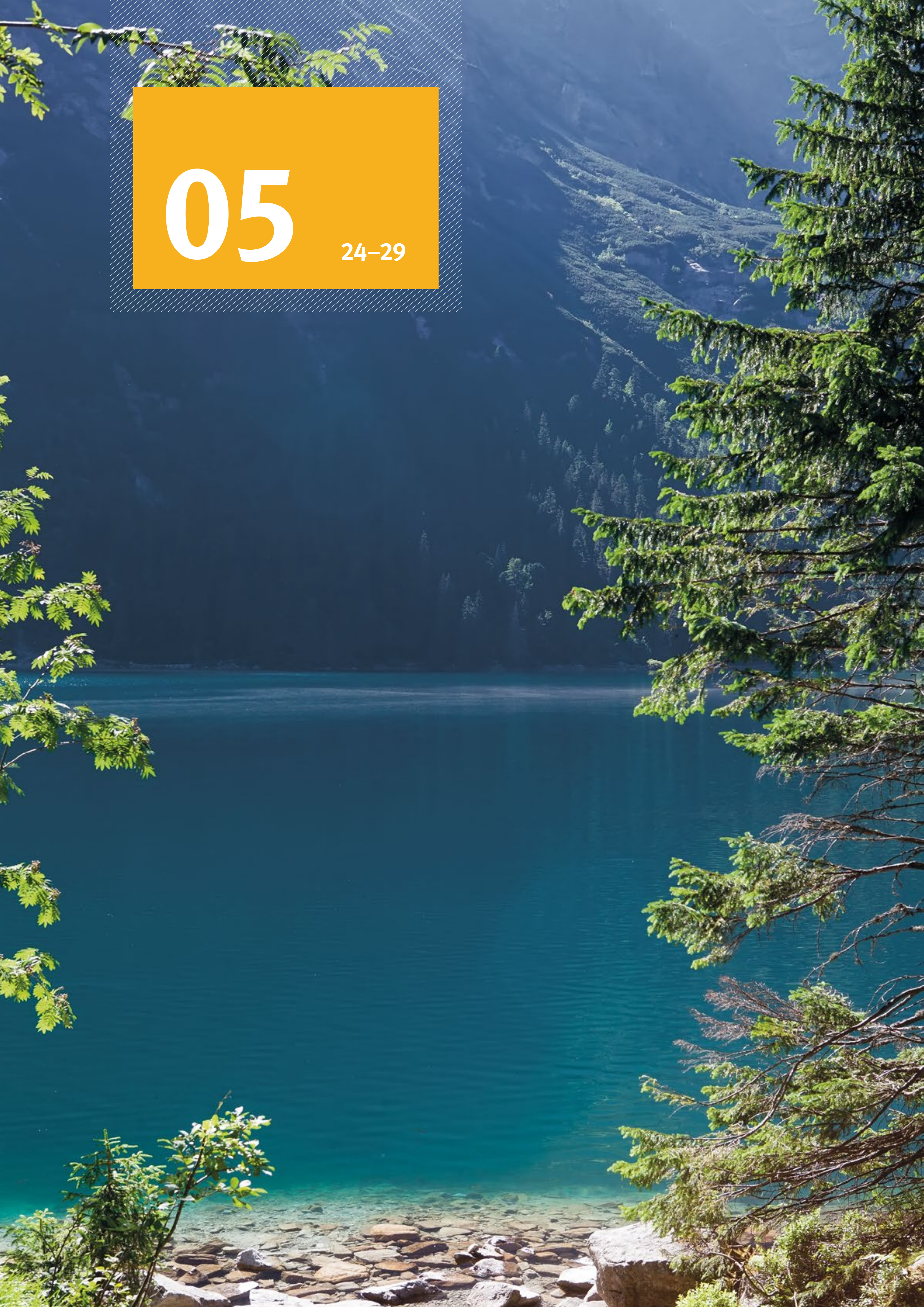
to demonstrate a direct relationship between depositions of atmospheric pollutants and harmful effects, especially because various factors will usually overlap. However, long-term environmental observations of forest ecosystems and the results of ecosystem research have shown that there are regularly reoccurring patterns of reactions to substance depositions. If certain thresholds are exceeded then forests become more vulnerable to stress factors. For example, there is good evidence of links between nutrient imbalances in plants and their increased vulnerability to frost, drought, insect attacks, and plant diseases, e.g. fungal infections. Selected examples show how forest functions can be impaired by pollution depositions.

Buffer function for pollutants: In forests which are not affected by pollution, the limited availability of nitrogen is often a constraint on tree growth. In such cases, the biologically available nitrogen is almost completely taken up by the vegetation. If nutrient nitrogen depositions increase, this initially promotes growth, so that more nitrogen is stored in the biomass. In most forest locations, nitrogen can also be stored in soil humus. In this way, the forest prevents nitrates from finding their way into the groundwater. The oak stand in Tannenbusch (North-Rhine Westphalia) is subjected to ammonium nitrate pollution. It is a good example for how increased nitrogen depositions over long periods can saturate the buffering capacity of forest soils (Fig. 10). The deposited ammonium is transformed to nitrate (nitrification). Almost all the nitrate is then leached out, because the ecosystem is unable to store any more nitrogen. At the Olbernhau location, which is characterised by the deposition of SO_x and NO_x, the ammonium is also completely nitrified, but the nitrate-nitrogen is stored to a large extent in the soil and in vegetation. If this storage capacity becomes saturated, then increased nitrate burdens at this location could also reach the groundwater.

Production function: For both locations, the acidification leads to the release of aluminium ions, which are toxic for plant root systems. The key factor when assessing the resulting risk is the ratio between the aluminium ions and the accompanying base cations (calcium, magnesium, and potassium ions) in the soil water solution. This ratio does not reach a critical value for the tree species growing at the two forest locations.

In addition to the acidification and eutrophication effects, forests are also affected by excessive concentrations of tropospheric ozone. There are clear signs that the production function and carbon storage are impaired as a result (ICP Vegetation, 2012, for more information about the effects of ozone on plants see Chapter 8).

Habitat function: Investigations of ICP Forests (2006 and 2012) show that the composition of soil vegetation and epiphytic lichens are changed by high levels of nitrogen deposition, with an increase in nitrophilic species. Under these conditions they displace less competitive species, which are meanwhile becoming increasingly endangered.



05

24–29

Thriving streams, ponds and lakes – How do lower pollution depositions affect surface waters?

Since 1986, systematic investigations have been carried out in Germany on the effects of air pollution on surface waters, and the results have been fed into the databases of ICP Waters. The acidifying atmospheric pollutants (SO_2, NO_x and NH_3) have particularly grave effects for surface water, leading to acidification events. From the start, the investigation programme concentrated on these acidification effects in areas which are geologically sensitive to acidity, i.e. where weakly buffered waters with low levels of lime are threatened by acidification. Chemical and biological parameters are measured for seven investigation areas at a total of 27 measuring stations, located mainly on the upper reaches of streams and rivers with forested catchments. Measurements include pH-values of the waters, the concentration of acid-forming sulphate, nitrate and ammonium ions, as well as a series of biological parameters to characterise the composition of the biotic communities.

Core message 1: Surface waters are recovering from acidification at different rates

The trend towards acidification could meanwhile be stopped for most of the surface waters under observation, and in some cases reversed (Figure 12). However, the surface waters react very differently to the reduction of acid depositions so that the trends for the various acidification parameters are not always uniform (Table 2). There are a number of reasons for this. For example, the physical-chemical parameters of the water are heavily dependent on the substance transport from the catchment. Soils may store depositions from the atmosphere over long periods, but begin to release the substances to the surface waters when the storage capacity has become saturated. This slows down the chemical and biological recovery of the surface waters. Various species which had not been able to survive in acidified streams, ponds and lakes have meanwhile returned to them. In the following, the trends for selected chemical and biological acidification indicators at the measuring stations are described.

Sulphates

In the period from 1990 to 2010 there was a marked decline in sulphate concentrations in the streams under investigation. At nearly 82 % of the measuring stations there was a statistically significant improvement, but at 18 % no significant trend could be observed. Some two-thirds of the reduction in sulphate concentrations was observed before the year 2000.

Nitrates

In contrast to sulphates, the nitrate concentrations did not show a uniform reduction at measuring stations. A significant reduction in nitrate concentrations could only be determined for some 52 % of the surface waters, for nearly 30 % there was no clear observable trend, and for 19 % the nitrate concentration actually increased over the observation period. This means that while sulphate concentrations have declined, nitrates have become a more important cause of acidification in surface waters.

pH value

At 59 % of the measuring stations, a significant increase in the pH values was observed, which represents an improvement in the acidification situation at these locations. However, this still leaves a rather high percentage of nearly 41 % of measuring stations for which no trend towards improved pH values could be observed.

FIGURE 11

Acid-sensitive macrozoobenthic organisms

Ephemera danica larva

Perla stonefly larva

Rhyacophila caddis larva

Freshwater macrozoobenthos

The species in the biotic communities of surface waters react differently to pollutants. With certain restrictions which are discussed below, it is therefore possible to use the species composition as an indicator of the chemical water quality.

For some time, the invertebrate fauna communities living on the bed of surface waters (macrozoobenthos) have been studied to assess the acidification status of surface waters. At three-quarters of the measuring stations there has been a marked improvement. Acidophilic and acid-tolerant fauna slowly declined in numbers and were replaced in part by acid-sensitive species (examples are shown in Figure 11). Since 2005, however, many streams have shown no further improvement in the evaluation results for the macrozoobenthic communities, and in some cases the situation has worsened slightly. This can be explained in part by the fact that the acidic depositions have levelled out, while at the same time acidifying substances that have accumulated in the soil of the catchments may also be leaching out.

In order to conserve biological diversity it is important to create better survival opportunities for sensitive species. But an improvement in the chemical acidification status of the surface waters will not necessarily lead to an improvement in the biological status. Acid-sensitive species must also have the opportunity to return to the location in question, whether from unaffected surface waters in the vicinity or from another section of a stream or river in which these sensitive species are still present in sufficient numbers. If there are no suitable sources for resettlement in a catchment or if migration is impeded by barriers such as weirs or dams, then even after an improvement in the chemical acidification status there is not likely to be a rapid biological response.

The example of the Grosse Ohe in the Bavarian Forest shows how surface waters react to lower atmospheric pollutant depositions and other changes to their environment (Box 3).

TABLE 2

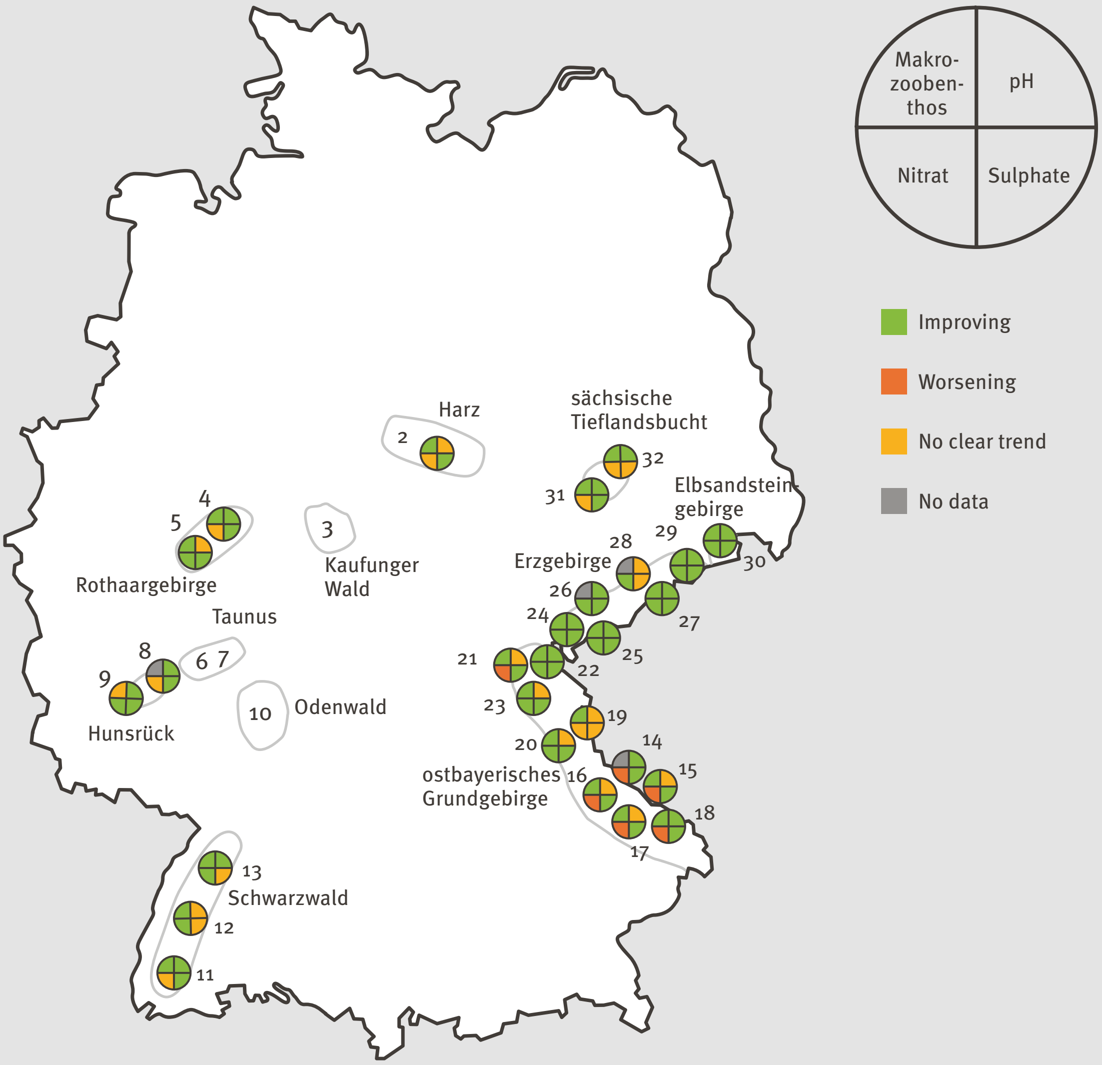
Changes in the acidification situation at 27 measuring stations (1990–2010) (Percentage of measuring stations, n = 27)

Parameter	Better	Worse	No clear change
pH	59.3	0.0	40.7
SO_4	81.5	0.0	18.5
NO_3	51.9	18.5	29.6
Macrozoobenthos	75.0	0.0	25.0

Source: Schaumburg et al., 2008 (changed and supplemented)

FIGURE 12

Trends of selected parameters in regions of Germany threatened with acidification (1990–2010, adapted and augmented after Schaumburg et al. 2008), Stations 3, 6, 7 and 10 have no longer been part of the monitoring programme since 2004



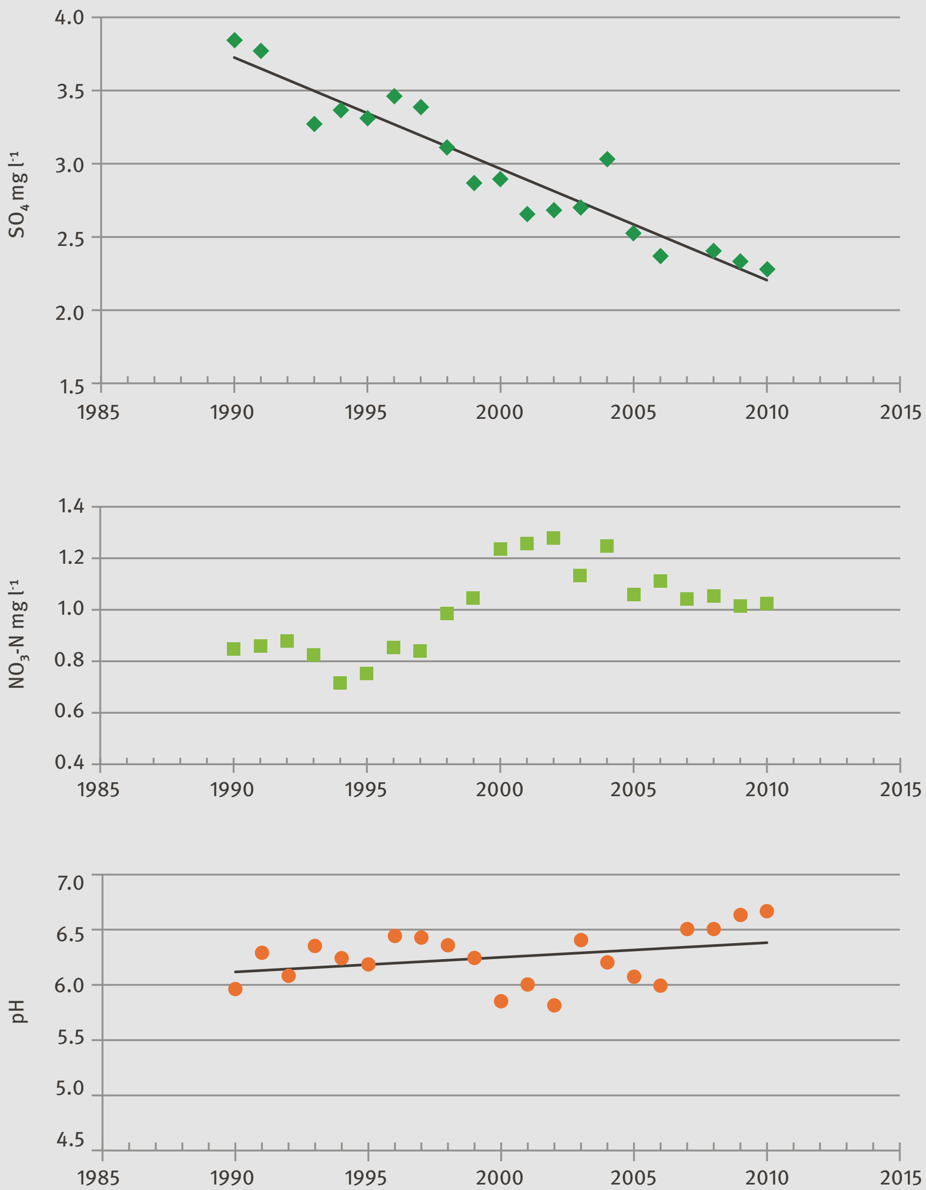
Source: Schaumburg et al., 2008 (changed and supplemented)

3. Hope for the Grosse Ohe?

The success in reducing emissions of acidifying atmospheric pollutants is reflected in the statistically significant reduction in sulphate concentrations in the stream water of the Grosse Ohe, a tributary of the River Ilz in Bavaria. The main reduction was measured between 1990 and 2000. Since 2000, annual mean sulphate concentrations have mostly been well below 3 mg L^{-1} and are thus of secondary importance for the acidification.
In the case of nitrate-nitrogen it is not possible to identify a clear reduction trend. However, a reversal of the initial downward trend in concentrations is attributable mainly to the die-back and decomposition of

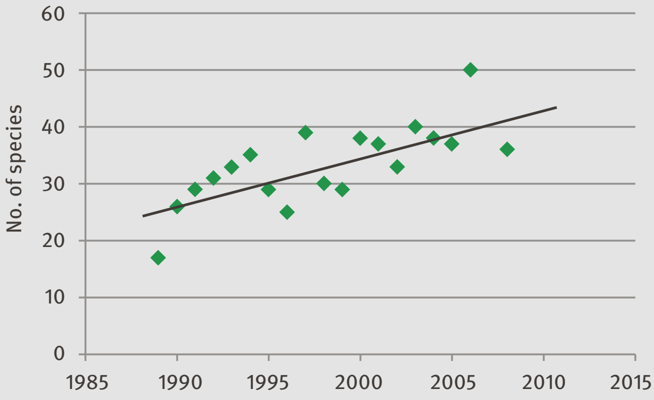
Trends of acidification parameters in the stream water of Grosse Ohe (Bavarian Forest) for the period 1990–2010.

Annual means of concentrations of sulphate (SO_4 in mg l^{-1}), Nitrate-nitrogen ($N\text{-}NO_3$ in mg l^{-1}) and of pH values

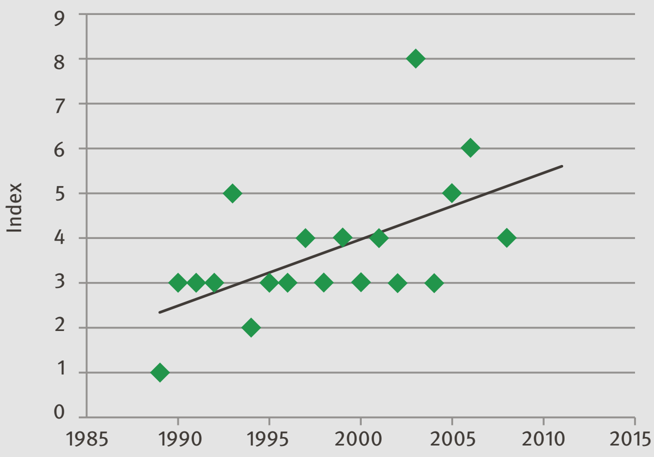


the spruce stands after bark beetle infestation beginning in 1996 (see also the next chapter – the Forellenbach is in the catchment of the Grosse Ohe). Peak values were measured above all between 1999 and 2002, so that nitrates replaced sulphates as the main component of surface water acidification. However, since 2004, the nitrate-nitrogen concentrations have been declining again.
The pH-value increased between 1990 and 2010, representing a statistically significant improvement. This reflects the changes in the two main acidifying pollutants sulphates and nitrates.

Trends of acidification parameters in the stream water of Grosse Ohe (Bavarian Forest) for the period 1990–2010.



Number of macrozoobenthic species (invertebrates living on the bed of the stream)



Acidification index after Henrikson & Medin (1986)

Over the observation period, the number of macrozoobenthic species increased steadily. This means that the new species have compensated for the depletion of the biotic community caused by acidification. The Henrikson & Medin Acidification Index shows the relationship between acid-sensitive species or groups of species and acid-tolerant ones. The lower the index value, the stronger are the acidification effects. Below an index value of 6, acidification of the surface waters is elevated. In the Grosse Ohe, there has only been a partial return of acid-sensitive species. The macrozoobenthos is still dominated by acid-tolerant species.

06

30–35

Ecosystems in focus – What can we learn from the intensive, integrated monitoring of water catchments?

An understanding of the interactions between atmosphere, plants, soil, and surface waters is important if the right conclusions are to be drawn from environmental monitoring data. Therefore ICP Integrated Monitoring adopts a cooperative approach in order to analyse the current state of ecosystems and the impacts of changing environmental conditions and loads. Long-term monitoring of the ecosystems and the measurement of physical-chemical environmental factors at specified locations is essential in order to distinguish the effects due to atmospheric pollutants from natural fluctuations. This is necessary for the investigation of the interrelationships between depositions, climate changes and biological processes in an integrated cause and effect approach. ICP Integrated Monitoring restricts itself to the intensive monitoring of a limited number of sites and works together closely with other cooperative programmes.

The programme monitors catchments in clean air zones which are only influenced by the long-range transport of air pollutants. In Germany, the sites are the forested Forellenbach investigation area in the Bavarian Forest national park (since 1990; 787 to 1290 m above sea level; mainly spruce and beech), and Stechlinsee, with the UBA Neuglobsow measuring station in Brandenburg (since 1998; 69 m above sea level; mainly pine tree and beech). Among other things, the investigations address acidification and eutrophication, ozone impacts on forest trees, material balances for heavy metals, and the impact of climate changes. The findings help to improve our understanding of causal relationships, to identify additional influences (e.g. changing climate), and to improve simulation models (e.g. deposition modelling and ozone flow). In the following some examples are presented.

Core message 1: Reduced acidity improves conditions for trees, fish and other organisms – the Forellenbach site as an example

The reduced deposition of sulphur in the form of sulphate (SO_4) in the tree stands of the Forellenbach area followed the dramatic decline in the acidifying SO_2-emissions (Figure 13a). There has also been a change in the composition of the sulphur depositions. Whereas in the early 1990s the depositions were mainly in the form of gases and particulate matter, almost the entire sulphur load is now introduced by precipitation.

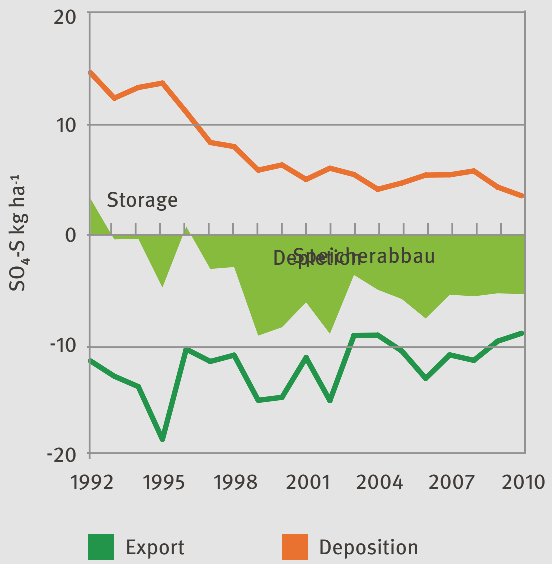
In the Forellenbach area, as in other regions with similar features, the soils reacted very quickly to the reduction in sulphur depositions – showing declining SO_4 concentrations and rising pH values (from pH 4.5 to pH 5) in soil water (Figure 13b). This led directly to the reduction in levels of harmful aluminium ions in soil water and an overall improvement in soil conditions with regard to tree health.

Since the mid-1990s, the Forellenbach has been transporting more sulphate-sulphur (SO_4-S) out of the catchment area than has been introduced into it by atmospheric deposition (Figure 13a). However, the output fluxes have also become lower. They originate to more than 50 % from the stored reserves which were developed in previous decades, above all in the groundwater zone. The root-rich soil has meanwhile become much less important as a sulphur store. Acidification events, which still occur today during high water periods, now result above all from the release of organic acids from the soil.

The improved hydrochemistry of the Forellenbach has led to an increase in the biomass of the macrozoobenthos (see Chapter 5). In particular the acid-sensitive fresh-water amphipod Gammarus fossarum, which had only rarely been encountered in previous decades, has now returned. It forms the main basic food for the brown trout (Salmo trutta fario L.) and bullhead (Cottus gobio L.). Both fish species also benefit directly in terms of reproductive success from the lower acid and aluminium burden during temporary acidification events.

FIGURE 13A

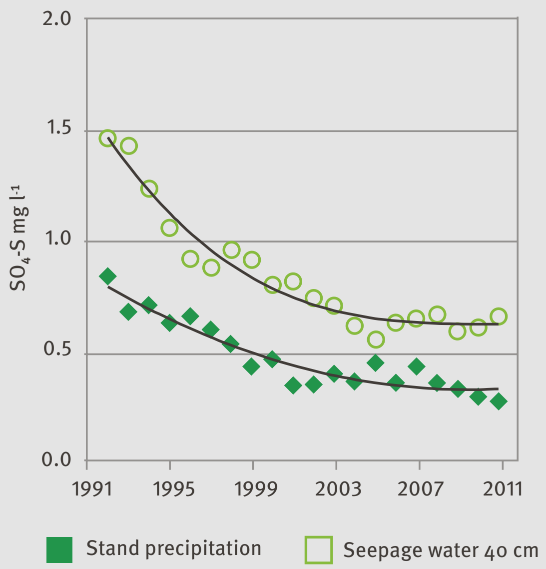
Sulphur balance for the Forellenbach catchment area.



Source: National Programme Centre of ICP Integrated Monitoring

FIGURE 13B

Trends for sulphate-sulphur concentration in stand precipitation and in soil water under beech trees



Source: National Programme Centre of ICP Integrated Monitoring

Core message 2: The storage capacity of the forests for nitrogen is limited – taking Forellenbach as an example

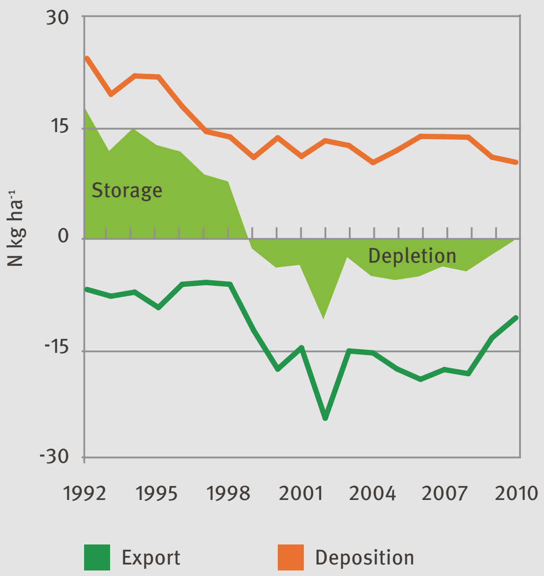
The measures to reduce emissions of NO_x und NH3 have been markedly less successful than for SO_2 (see Chapter 2). In consequence, the annual nitrogen (N) inputs in the form of ammonium and nitrate sank less in the Forellenbach area than the sulphur inputs. They declined between 1992 and 2010 from some 24 kg N ha^{-1} a^{-1} to about 10 kg N ha^{-1} a^{-1} (Figure 14a). The level of the inputs varied with the height above sea level (among other factors due to precipitation and exposure) and also dependent on the nature of the stand. There are also considerable differences within a measurement area as a result of the heterogeneous natural spaces. These observations provide valuable insights for further improvements to national input modelling (cf. Chapter 7).

The nitrogen balance in beech stands shows that on average more than 90 % of the introduced nitrogen is stored by integration in stand and soil biomass (Figure 14b). Biological indicators for this are the measurable increase in the nitrogen content of leaves (Figure 15a) and, favoured by the de-acidification of the soil, the simultaneous increase in the contents of potassium (K) and magnesium (Mg), which are tending to promote tree growth (Figure 15b). This can be expected to contribute to continuing very low nitrate concentrations in seepage water and, as a result, in the groundwater.

It is not clear how long this considerable retention capacity will remain effective. Firstly because the nitrogen reserves in the soil are already very high as a result of the natural site conditions and the historically low use intensity, and secondly because the supply from these reserves is already sufficient to cover the annual requirement for wood production.

FIGURE 14A

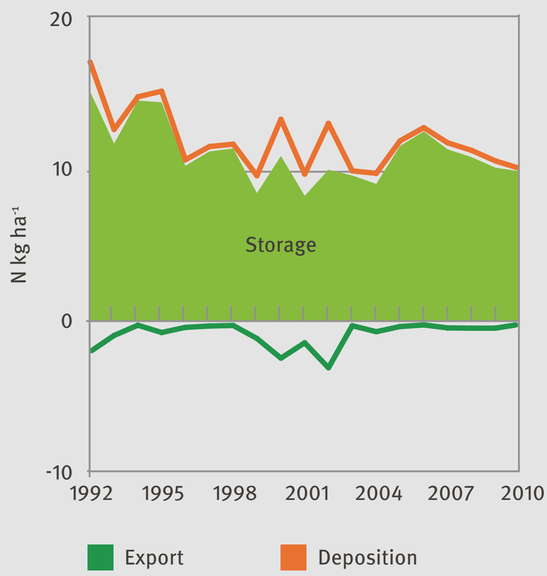
Nitrogen balance for the Forellenbach catchment area overall.



Source: National Programme Centre of ICP Integrated Monitoring

FIGURE 14B

Nitrogen balance for a mature beech stand in the Forellenbach catchment area.



Source: National Programme Centre of ICP Integrated Monitoring

The net storage rates in the ecosystem declined between 1990 and 1998 with the declining overall deposition rates (Figure 14a), whereas the discharge only showed a slight downward trend due to the long retention time of groundwater, which contributes more than 50 % to the annual export. In beech forests, the storage function has remained intact (Figure 14b). In contrast, the die-back of spruce stands over large areas after bark beetle infestation resulted in high levels of nitrogen export for some years from 1996 onwards. Similar ecosystem reactions must also be expected in comparable habitats, whereby the cause of the disturbance (e.g. storms, fire, or timber harvesting) is only of secondary importance. Over a period of years, the release of nutrients from biomass by soil microorganisms will then be greater than the withdrawal of nutrients by the gradually developing shrubby vegetation and young tree stands. It is therefore important to prevent nitrogen from accumulating in ecosystems above the natural level and to keep N-inputs below the critical levels.

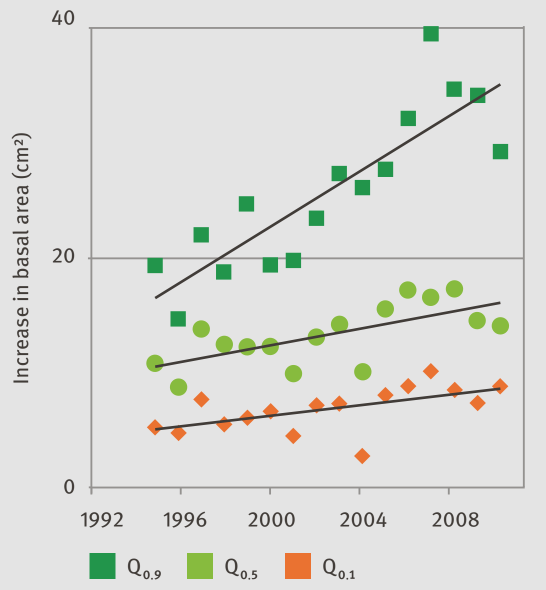
FIGURE 15A

Trends for leaf contents of nitrogen and magnesium ($p < 0.05$ and 0.01 respectively) from beech trees of B1 stand (n = 8 trees) at Forellenbach.

Source: National Programme Centre of ICP Integrated Monitoring

FIGURE 15B

Trends for increased basal area in this stand (25 beeches), in quantiles ($p < 0.01$).



Source: National Programme Centre of ICP Integrated Monitoring

Core message 3: Climate change can present additional risks for forest ecosystems (Stechlinsee lake site as an example)

The Integrated Monitoring programme also investigates water cycles. For example, measurements and simulation data on the hydrologic balance are available for the Stechlinsee area covering a period of more than 50 years. This makes it very well-suited for the examination of changes in the hydrologic balance and possible resultant risks. The measurements for the site show that the annual mean temperature has risen over the past 50 years by approx. 1.6°C (Figure 16), while annual precipitation levels over the same period have fallen by approx. 4 %, and have declined by 7 % for the vegetation period. There has also been a marked decline in seepage levels (Figure 17). These changes have consequences for the lake and the tree stands in its catchment. The temperatures and water content of the soil are also key regulators for the absorption of ozone by the trees and also for the carbon cycle[19]. The findings have been used to develop computer models of substance and water cycles and to improve impact assessment.

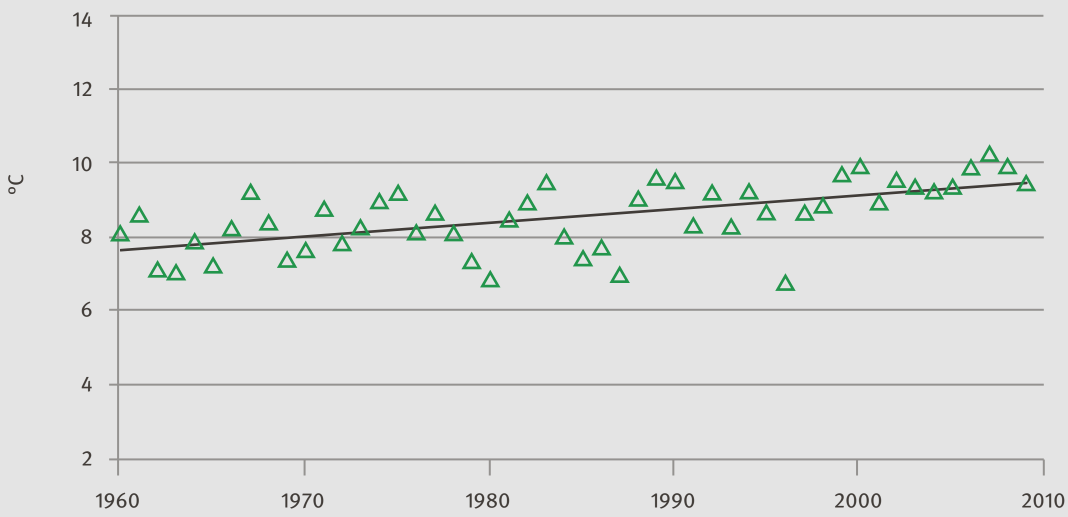
In future, the lower levels of precipitation could reduce the replenishment of groundwater to such an extent that the water inflow to the lake would no longer be sufficient. For the tree stands, the higher temperatures and lower levels of summer rainfall will lead to increasing water stress. This applies in particular for the beech trees which dominate in the catchment area – calling into question their long-term future on this site, which has been designated as a potential beech forest area.

The results of the Integrated Monitoring programme confirm the decline in pollution depositions over the past 20 years and document how this has reduced the load on ecosystems. However, the findings also highlight unresolved problems, due mainly to the depositions of reduced nitrogen compounds and the impact of ozone. Combining a wide range of measurements and observations for one site makes it possible, for example, to investigate how a changed climate could affect ecosystems and their material cycles. This is in accord with the trend towards the strategic consideration of changes in climate and reductions of air pollution under the CLRTAP convention.

19) Schulte-Bisping H, Beese F (2012): Fortsetzung des Integrated Monitoring Programms an der Station Neuglobsow, Final Report (35101040/04), Büsgen Institute, Soil Science of Temperate Ecosystems.

FIGURE 16

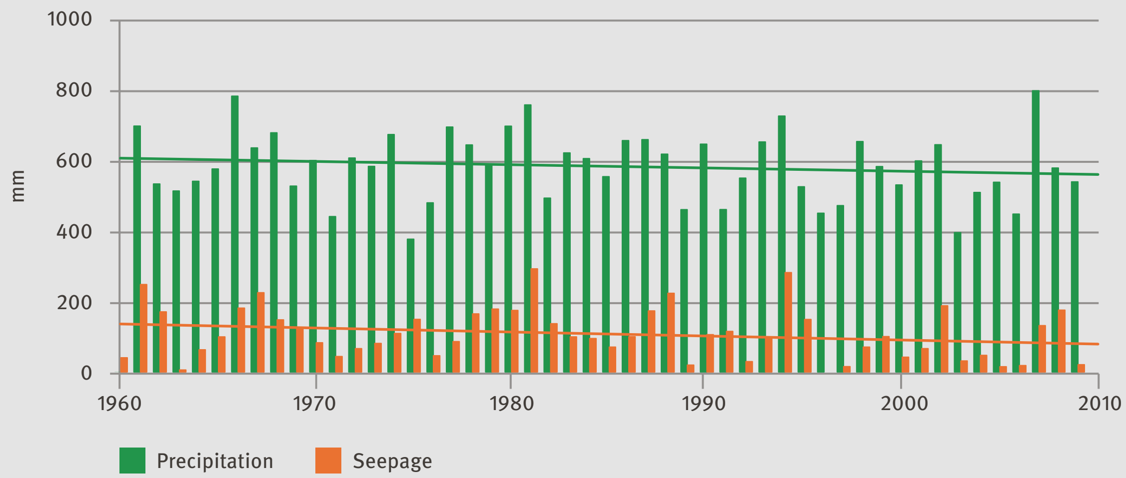
Annual mean temperatures at the Stechlinsee site, 1960–2009.



Source: National Programme Centre of ICP Integrated Monitoring

FIGURE 17

Annual precipitation and seepage at the Stechlinsee site, 1960–2009.



Source: National Programme Centre of ICP Integrated Monitoring

07

36–41

Are ecosystems in Germany safe against acidification and eutrophication over the long term?

In order to assess the environmental situation over Germany as a whole it is necessary to make use of models in order to augment the data gained from monitoring networks, experiments and the intensive observation of specific sites. Based on long-term observations, such models are developed for important processes in ecosystems which make it possible to draw conclusions about the resilience of ecosystems nationwide and to assess the extent to which current pollution depositions exceed critical loads. Such information is vitally important for policy-making deliberations.

Depositions of nitrogen und sulphur have the greatest effects in areas which are unaffected by regular human intervention by fertilisation. Forests, extensively farmed grassland, heaths, moors and other largely unaffected biotopes, which are particularly sensitive to the effects of acidifying and eutrophying atmospheric pollutants, account for some 30 % of the area of Germany. Forests make up much the largest proportion, but there are also numerous open nature conservation habitats. They all offer retreats for many rare and threatened plant species and dependent species communities.

Core message 1: The Critical Loads approach has proved its value as an instrument for risk assessment

Atmospheric depositions of compounds of both sulphur and nitrogen cause acidification, whereas only nitrogen compounds are responsible for eutrophication. The amount of depositions that an ecosystem can withstand depends on the combination of soil properties, the type of vegetation, and climatic factors. A measure for the sensitivity of ecosystems is provided by scientifically-derived critical loads (Box 4). Below this level of exposure to a pollutant, no significant harmful effects occur according to present knowledge. The loads are calculated for all sensitive natural and semi-natural ecosystems in Germany and mapped. The results flow into the European maps of critical loads drawn up by ICP Modelling & Mapping. The datasets provide an important basis for the formulation of European clean air policies. In Germany, critical loads are also used for the local assessment of pollutant depositions, e.g. when considering planning permission for new power stations, agro-industrial plants, or traffic infrastructure measures.

4. Critical Loads

A critical load is a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. Sensitive elements (receptors) can be part or whole of an ecosystem, for example the groundwater or individual plant or animal species. Three different approaches are used to determine critical loads:

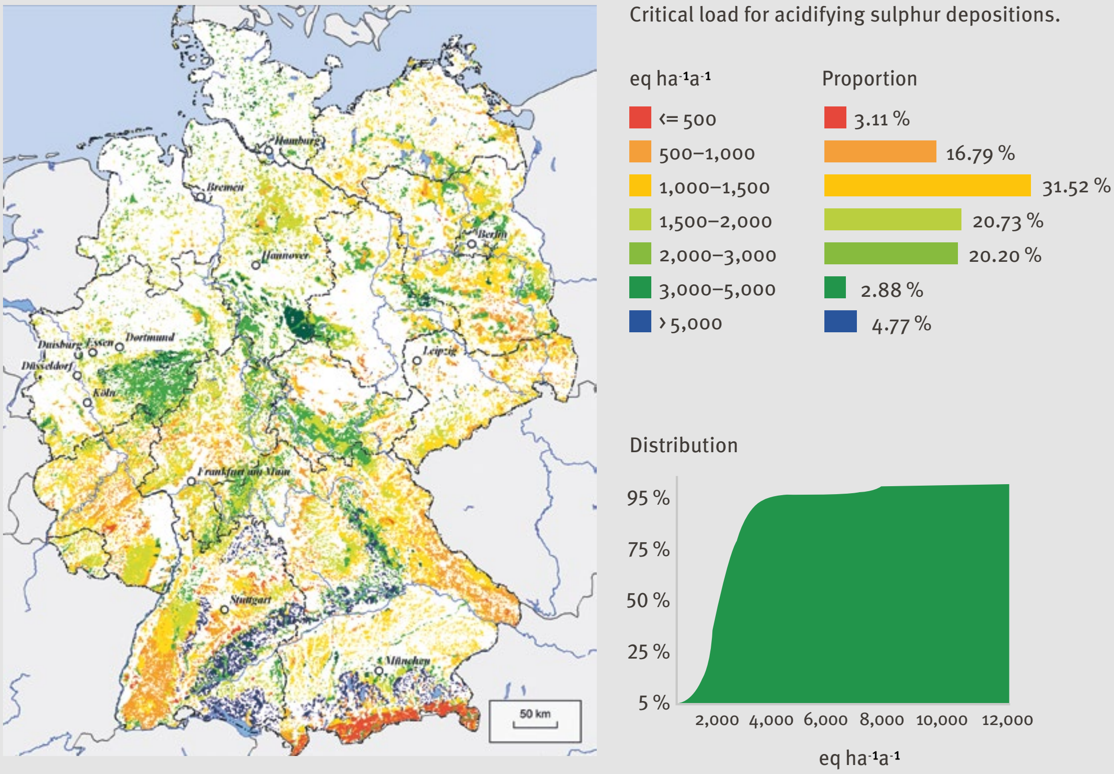
- Empirical approaches (above all for nitrogen),
- The Simple mass balance method,
- Dynamic models.

Critical loads are reviewed and recalculated at regular intervals as methods are refined. Details of the methods for modelling critical loads are provided in a manual (http://www.icpmapping.org/Mapping_Manual).

FIGURE 18

CL_{max}(S): Critical load for acidifying sulphur depositions.

The corresponding critical load for the acidifying effects of nitrogen depositions is slightly higher (not shown). The values are given in equivalence-units (eq ha^{-1} a^{-1}). 1,000 equivalents correspond to about 16 kg sulphur (as sulphate) or 14 kg nitrogen.



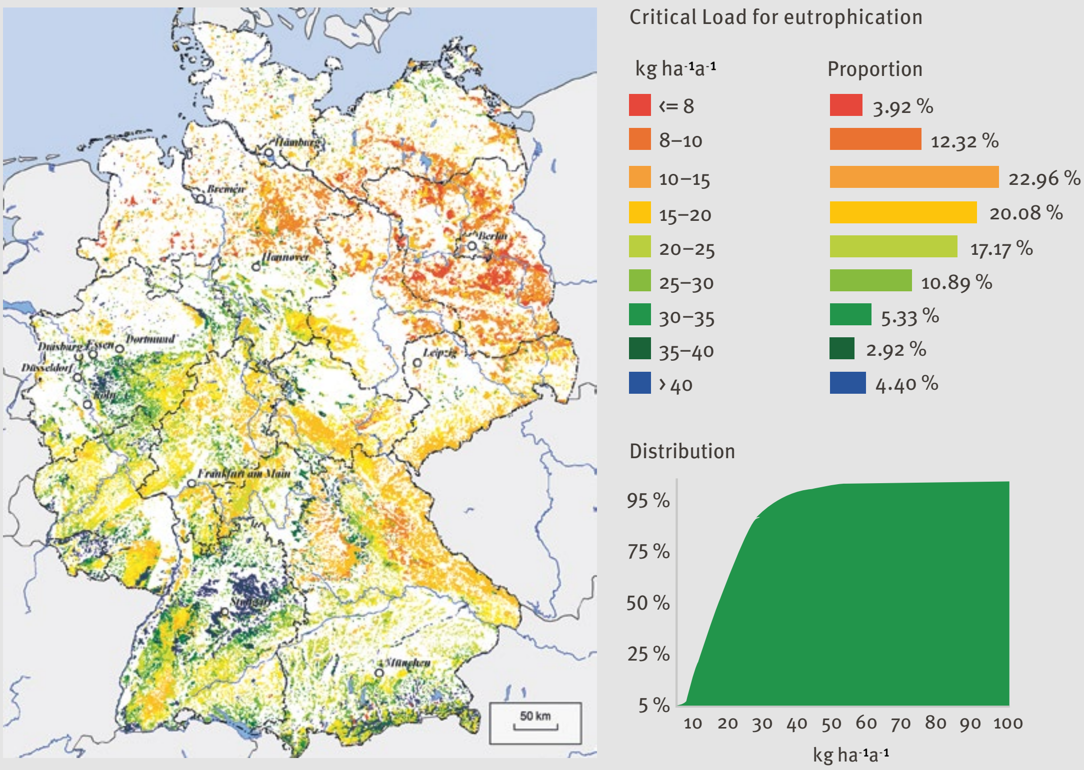
Source: UBA Dessau, DWD Offenbach, BGR Hannover, TNO Utrecht, ÖKO-DATA Strausberg; 02/2013

Critical loads for Germany are calculated using simple mass flows for a 1 × 1 km grid system based on the CORINE Land Cover Map 2006[20] in combination with the use-specific soil map for Germany (BÜK 1000N[21]) and data from the German Meteorological Service (DWD). Critical loads are calculated for eutrophication and acidification, as shown in Figures 18 and 19[22].

Below the critical loads there is no long-term risk for the ecosystem in question. Compliance with the critical loads is therefore a priority for environmental policies. The maps of areas in Germany where critical loads are exceeded are published by the Federal Environment Agency on its Website[23].

FIGURE 19

CL_{nut}(N): Critical load for the eutrophying effect of nitrogen compounds.



Source: UBA Dessau, DWD Offenbach, BGR Hannover, TNO Utrecht, ÖKO-DATA Strausberg; 02/2013

20) CORINE 2006: European land cover mapping, see http://www.corine.dfd.dlr.de/intro_en.html
21) BÜK 1000N, Version 2.3, see http://www.bgr.bund.de/DE/Themen/Boden/Projekte/Informationsgrundlagen-abgeschlossen/BUEK1000N/BUEK1000N.html
22) Scheuschner T, Nagel H-D, Schlutow A (2012): Entwicklung der Critical Loads-Überschreitung für Säure und Stickstoff in Deutschland – Beitrag des ICP Modelling und Mapping zu einer Broschüre über Erfolge der Luftreinhaltepolitik im Zeitraum 1990–2010. UBA Research Report 22511.
23) http://www.umweltbundesamt.de/daten/bodenbelastung-land-oekosysteme

Core message 2: The threat of acidification has been reduced, but not banished

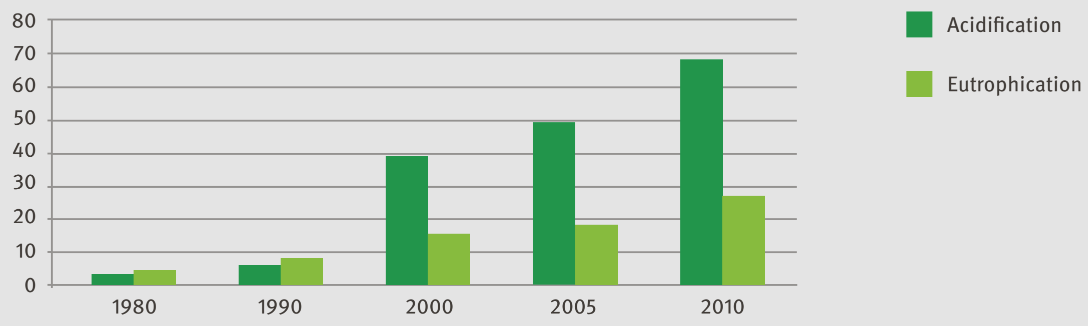
The development of the deposition of acidifying atmospheric pollutants in Germany calculated by EMEP[24] (see also Chapter 2) shows that by 2010 the reduction in sulphur emissions had led to a marked decline in the risk of acidification in sensitive areas (Figure 20). Meanwhile in Germany nearly 70 % of the investigated areas no longer face any acidification risk, which represents a considerable success. However, the National Strategy for Biological Diversity (BMU 2007[25]), with which the international Convention on Biological Diversity (CBD) has been implemented for Germany, sets a goal of protecting all sensitive ecosystems against acidification by 2020. In order to achieve this target, additional measures are needed to reduce atmospheric pollution. In particular the contribution of nitrogen compound depositions to acidification will have to be further reduced.

Core message 3: Atmospheric nitrogen depositions are still harmful for ecosystem functions and biological diversity

Progress in reducing the eutrophication effects caused by nitrogen pollutants has been unsatisfactory. The development of the depositions of reactive nitrogen over recent decades (according to EMEP) led overall to a much less slower increase in the proportion of sites below critical loads for eutrophication than for acidification (see Figure 20). In 2010, the critical loads were exceeded at nearly three-quarters of the ecosystem areas in Germany. The National Strategy for Biological Diversity (BMU 2007) also specified that in the case of eutrophication all ecosystems should be protected against further risks by 2020. As things stand, this goal can only be achieved if considerable additional efforts are make to reduce the emissions of reactive nitrogen.

FIGURE 20

Increase in the percentage of areas where critical loads for acidification and eutrophication in Germany were not exceeded over the period 1980 to 2010.



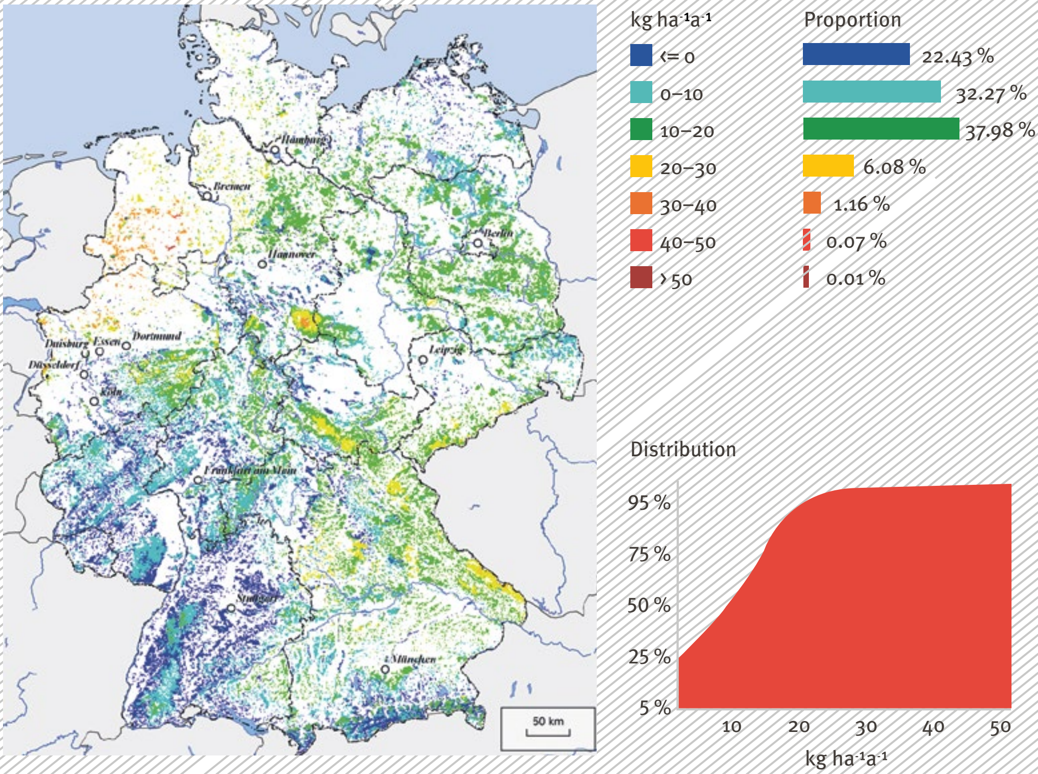
Source: CCE[26]

24) European Monitoring and Evaluation Programme (EMEP), see http://www.emep.int
25) BMU (2007). Nationale Strategie zur Biologischen Vielfalt: http://www.bmub.bund.de/P3529/
26) Source: CCE. Basic data for CCE Status Report 2012: Posch M, Slootweg J, Hettelingh JP (eds.) (2012): Modelling and Mapping of Atmospherically-induced Ecosystem Impacts in Europe, Coordination Centre for Effects, Bilthoven, The Netherlands

5. Deposition models

Pollution depositions can be modelled at various scales. The EMEP Programme calculates a low resolution dataset for all Europe. For the calculation of national indicators in Germany (e.g. deposition in excess of critical loads as indicator for the implementation of the national biodiversity strategy), the Federal Environment Agency commissions calculations of the depositions at a higher resolution. In the period under consideration, changes were made to the methodology used to calculate depositions from the air in order to take new insights and data into account. In the EMEP Programme, new insights are frequently applied retrospectively to previous periods. For the national modelling of atmospheric pollution, these advances could not yet be applied to the earlier data over the entire time series, so that no methodologically consistent dataset is available for 1990–2010. Figure 3 (in Chapter 2) and Figure 20 (here) are based on the deposition developments 1990–2010 from the EMEP programme calculated using a uniform methodology. In contrast, the map of depositions in excess of critical loads in this box is based on the high-resolution national calculations of deposition. The areas not exceeding critical loads in Figure 20 are therefore not directly comparable with the areas shown in this box as not exceeding the critical loads.

Depositions in excess of the critical loads for eutrophication in sensitive ecosystems in 2007[27]



Source: UBA Dessau, DWD Offenbach, BGR Hannover, TNO Utrecht, ÖKO-DATA Strausberg, 07/2013

27) Builtjes P, Hendriks E, Koenen M, Schaap M, Banzhaf S, Kerschbaumer A, Gauger T, Nagel HD, Scheuschner T, Schlutow A (2011): Erfassung, Bewertung und Prognose von Stoffeinträgen und ihren Wirkungen in Deutschland. FKZ 3707 64 200. UBA-Texte 38/11. http://www.uba.de/uba-info-medien/4137.html

08

42–47

Are crops and wild plants suffering fewer ozone injuries?

Since the late 1980s, the International Co-operative Programme Vegetation has been investigating and assessing the effects of atmospheric pollution on vegetation. The activities have concentrated on investigating agricultural crops and horticultural plant species, as well as plants from natural and semi-natural vegetation, mostly herbaceous species. Right from the start, the focus of interest was on the assessment of the effects of ground-level ozone as the component with the highest direct phytotoxic potential. ICP Vegetation does not have a structured, systematic network of environmental monitoring stations, but rather develops its findings by means of research activities (e.g. experiments and observations) carried out by individual working groups in the participating countries on questions relating to the effects of atmospheric pollutants. As a rule it is therefore not possible to present exposure-effect relationships for ozone for specific areas in individual countries. Rather, the national findings are interpolated to produce ozone-impact maps on a large scale (in particular for Europe). For the same reason it is also difficult to present trends for ozone concentrations.

Core message 1: Peak ozone concentrations occur less often, but background concentrations are rising

Increased ozone concentrations in the ground-level atmosphere are produced mainly from anthropogenic NOx and hydrocarbons under the influence of sunlight. For large parts of western Europe over the past two decades there has been a noticeable absence of the short-term high ozone concentrations (summer smog episodes) that had previously been experienced (see Figure 2 for German monitoring stations). This is attributable to legislative measures to reduce levels of ozone precursor substances (NO_x, hydrocarbons). However, investigations for western Europe still show a slight upward trend for background concentrations[28], which is probably due to the long-range transport of precursor substances from other regions of the northern hemisphere. In Germany there was also a slight increase in the annual mean ozone concentration between 1990 and 2011. It was not possible to identify any such statistically significant trend for Germany over the past decade. Fluctuations are probably the result of differing weather conditions (UBA 2012)[29].

28) Sitch S, Cox PM, Collins WJ, Huntingford C (2007): Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. Nature 448, 791–794.| Hollaway MJ, Arnold SR, Challinor AJ, Emberson LD (2011): Intercontinental trans-boundary contributions to ozone-induced crop yield losses in the Northern Hemisphere. Biogeosciences Discuss. 8, 8645–8691. | Parrish DD, Law KS, Staehelin J, Derwent R, Cooper OR, Tanimoto H, Volz-Thomas A, Gilge S, Scheel HE, Steinbacher M, Chan E (2012): Long-term changes in lower tropospheric baseline ozone concentrations at northern mid-latitudes. Atmos. Chem. Phys. 12, 11485–11504.

29) http://www.umweltbundesamt.de/publikationen/air-quality-2012

Core message 2: Ozone is an important phytotoxic atmospheric pollutant

Ground-level ozone is taken up by plants mainly through the stomata. It impairs important metabolic processes as a result of its high oxidation capacity and its cytotoxicity. The results can affect the quality and yield of crops. Visible injury such as discolouration and die-back can also affect the marketability and quality. In the case of wild plants, i.e. natural and semi-natural vegetation, some sensitive species react with impaired growth and lower reproduction (Figures 21 and 22). The key parameter for the ozone effects on plants and the degree of leaf injury is the ozone flux through the stomata into the plant, i.e. the amount of gas which is actually taken up. As a result of various genetic and environmental factors, the ozone sensitivity of plant species and varieties can differ considerably (Figure 23). A reduction in the ozone exposure is of benefit for agriculture and horticulture (and also for forestry) because it increases the competitive ability of ozone-sensitive wild plants and in this way helps to maintain biological diversity.

FIGURE 21

Visible ozone damage to crops and wild plants

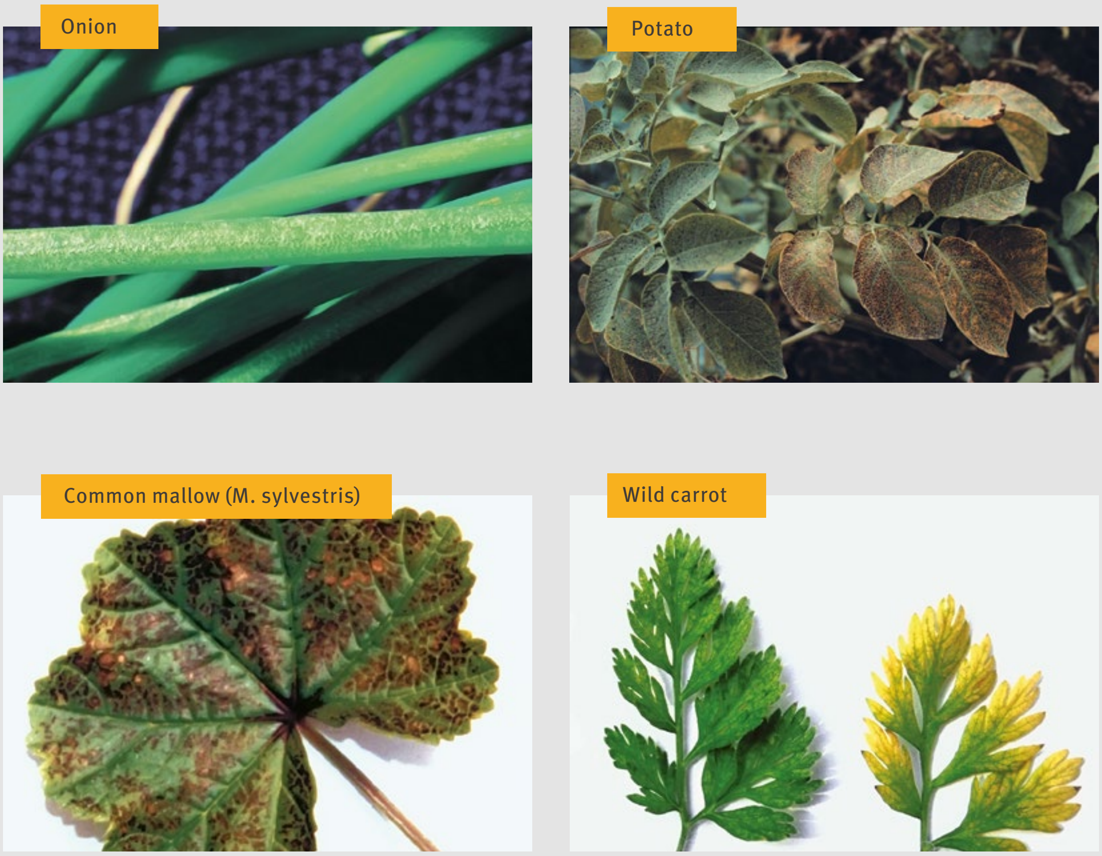


FIGURE 22

Impaired growth and accelerated senescence of wheat at increasing ozone concentrations

check

60 µg/m³ Ozon

120 µg/m³ Ozon

180 µg/m³ Ozon

220 µg/m³ Ozon

Core message 3: Critical levels for ozone are constantly being revised on the basis of scientific findings

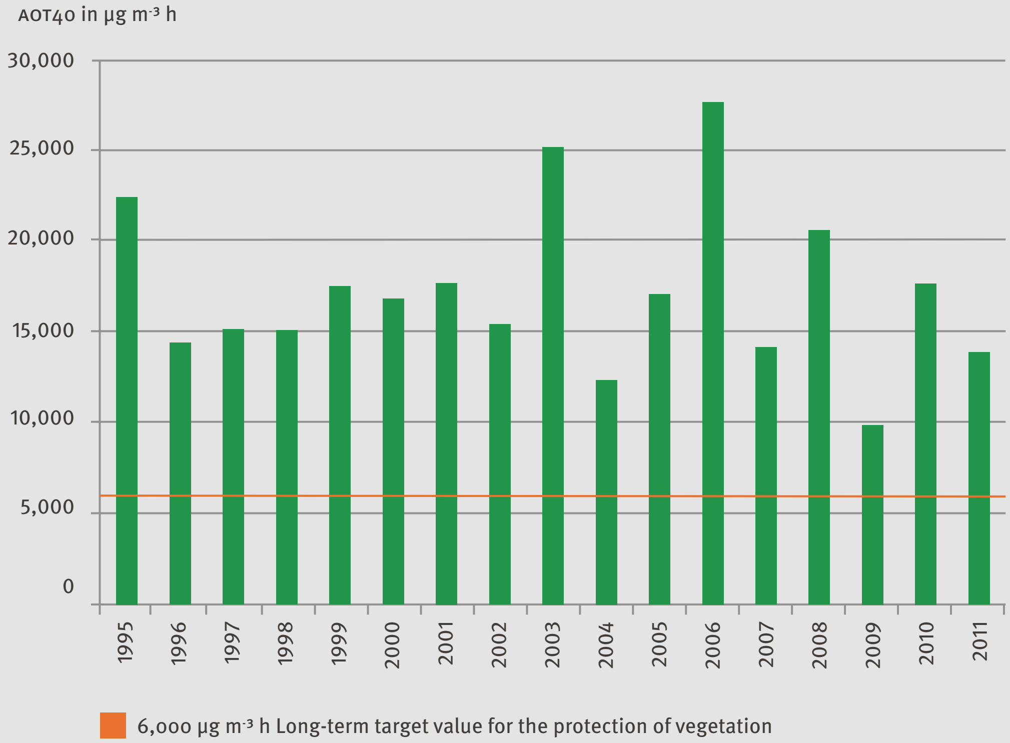
ICP Vegetation uses critical levels to assess the effects of ozone on selected plant species. Long-term research has been carried out on the transport processes involved in the uptake of ozone by plants and their physiological reactions, including experiments in which plants are subjected to varying levels of ozone. A distinction is made between "concentration based critical levels", which are based on the ozone concentration in the ambient air, and "flux-based critical levels", which calculate or model the actual uptake of ozone. When deriving these critical levels it is important in both cases to take weather conditions into account.

Since the 1980s, concentration-based critical levels have mainly been used when assessing the impact of ozone on vegetation. Whereas mean ozone concentrations over various periods were used in the past (e.g. 7-h or 24-h daily mean), accumulated ozone concentrations are now calculated. The so-called AOT40-value (accumulated ozone exposure over a threshold of 40 ppb) is the sum of all hourly means above 40 ppb (which is equivalent to 80 µg m^{-3}). In the case of agricultural crops, for example, this sum should not exceed the critical level of 3,000 ppb h (or for forests of 5,000 ppb h).

In Germany, AOT40-values are determined at the stations of the air measurement network of the Federal Environment Agency and of the Federal States. Figure 23 shows a comparison with the long-term target values for the protection of vegetation in accordance with the Ambient Air Quality Directive 2008/50/EC, developed on the basis of the AOT40-value as critical level for agricultural crops (3,000 ppb h = 6,000 µg m^{-3} h). The fact that even the mean of AOT40-values measured at rural background stations was well above the target value every year shows clearly that the goal under the national biodiversity

FIGURE 23

Annual mean values of AOT40 measured at rural background stations



Source: based on measurement network data from the Federal States and the Federal Environment Agency

strategy of complying with the critical levels by 2020 is still a long way off. The fluctuations from year to year are due above all to meteorological effects – there is no sign of an improving trend.

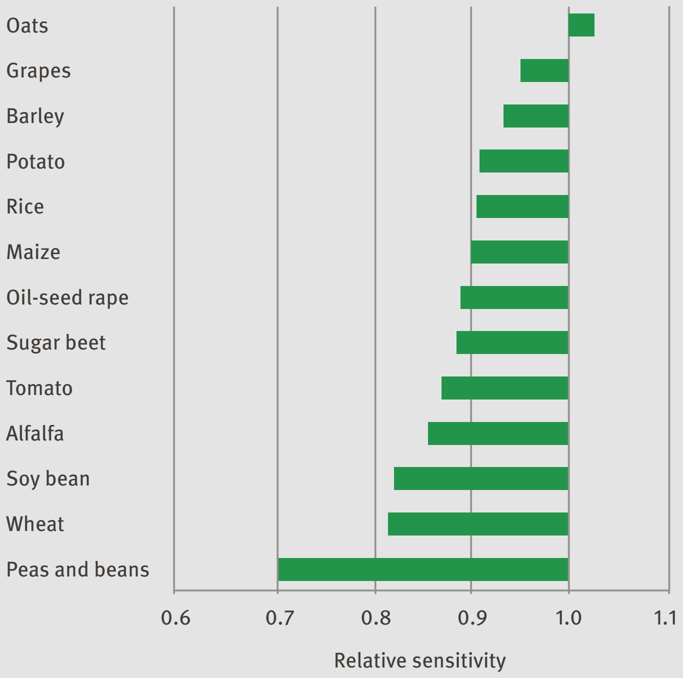
Flux-based critical levels offer a much better reflection of the physiological effects of ozone. However, this more sophisticated method is also more demanding. The sum is taken of the modelled ozone fluxes through the plant stomata which exceed a threshold value Y (the phytotoxic ozone dose, POD_Y).

Core message 4:
Ozone pollution can lead to economic losses

In view of the fact that many important farm crops are very sensitive to ozone pollution (Figure 24), that ozone concentrations in rural areas in agriculturally relevant regions of the earth can be expected to remain high or to increase, and that in order to ensure global food security it is important to avoid or reduce stress situations for crop plants, various global and regional model estimates have been made of ozone-related yield losses and the associated economic losses. These estimates indicate considerable potential economic losses for the European region (Figure 25). They show that in addition to climate change, the impact of direct exposure to atmospheric ozone will continue to represent a relevant threat for agricultural production.

FIGURE 24

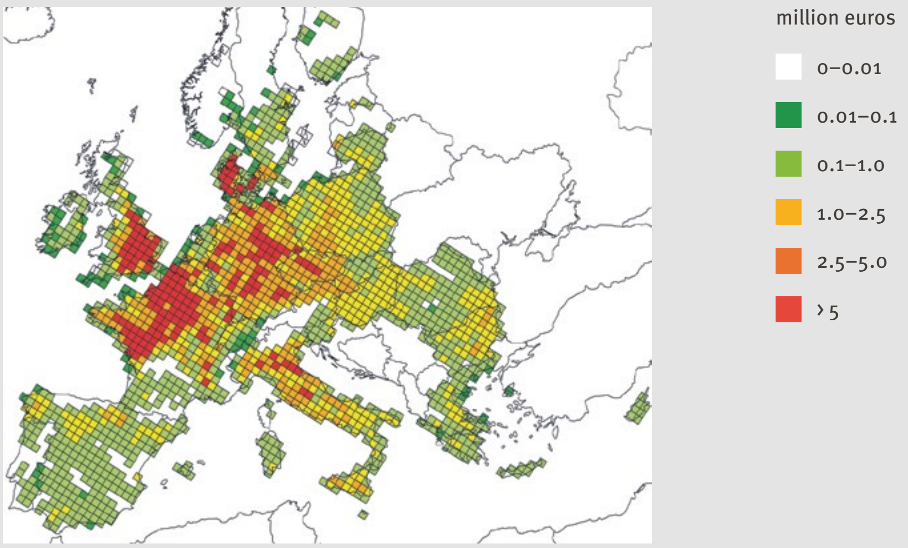
Relative ozone sensitivity of crops expressed by the yield at 60 ppb ozone relative to the yield at 30 ppb (based on published data).



The sensitivity decreases from bottom to top, 1.0 means "no effect".

FIGURE 25

Predicted economic losses in 2000 due to ozone effects on wheat in million euros



Source: ICP Vegetation[30]

30) Ozone Pollution: A hidden threat to food security, Eds. Mills G, Harmens H (2011), ICP Vegetation, http://icpvegetation.ceh.ac.uk/publications/thematic.html, with friendly permission by DEFRA: Department for Environment, Food & Rural Affairs, United Kingdom, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/1/open-government-licence.htm

09

48–52

Improved air quality for building materials and our cultural heritage

Air pollutants can attack material surfaces. Acidifying substances accelerate the weathering of building materials such as metals and natural stone. This reduces the operating life of industrial plants and threatens our constructed cultural heritage. Soiling impairs the transparency of glass, which not only affects window panes, but can almost reduce the performance of solar collectors. Soot can also lead to unaesthetic soiling of building facades or sculptures and result in the accumulation of other pollutants. Every year, atmospheric pollutants lead to high additional costs for protective measures, cleaning, and restoration work on buildings and historical monuments.

The effects of atmospheric pollutants on various materials are investigated by the ICP Materials task force throughout Europe. Material samples (currently various types of steel and other building metals, stone, and glass) are exposed at a number of sites in the participating countries. With different levels of atmospheric pollution and varying climatic conditions, these sites form a comprehensive network which provides good coverage of the complex influencing factors. Germany participates in the programme with two sites that have relatively high levels of pollution: Bottrop (industrially oriented) and Berlin (traffic oriented). Because these sites do not reflect the average situation in Germany, overall results of ICP Materials are presented here and conclusions are drawn from these for Germany.

In addition to the deterioration of the material (weathering rates for stone, mass loss through the corrosion of metals, and soiling of glass) measurements are also recorded for all relevant environmental parameters (atmospheric pollutant levels and meteorological data). The correlation of the data provides statistically reliable dose-response functions. These can be used to calculate the extent of material deterioration or soiling by atmospheric pollutants in regions with higher pollution levels compared with areas with only “background” pollution. Based on the values measured for the mean material deterioration or corrosion in areas with ‘clean’ air (largely unaffected by human activities leading to higher concentrations of atmospheric pollutants), threshold values are determined below which impacts are tolerable, and the rates of material deterioration or corrosion are compared with these[31]. On the basis of such model calculations, risk maps are then drawn up for regions or individual towns and cities.

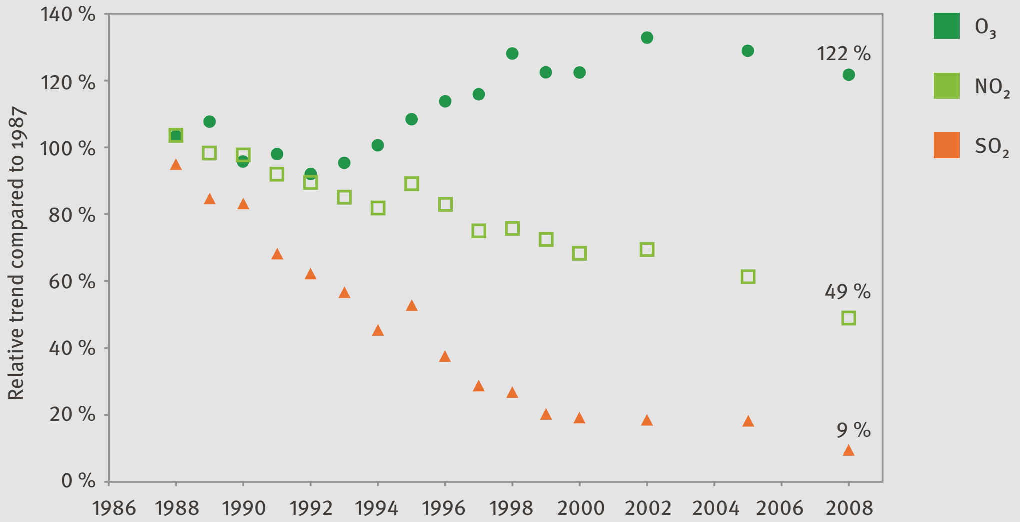
Core message 1: Despite decreasing concentrations of acidifying pollutants, material damage is still at inacceptable levels

Figure 26 shows the mean change in the concentrations of NO_2, SO_2 and ozone at the sites of ICP Materials over the period 1987 to 2009. Whereas NO_2 and SO_2 showed a striking decline over the entire period, in the case of ozone (a strong oxidant which attacks plastics in particular) an increase was observed through until the year 2000.

31) Manual on Methodologies and Criteria for Modelling and Mapping, UBA (2004), current version under www.icpmapping.org – Manual, Chapter 4

FIGURE 26

Mean trends for SO_2, NO_2 and O_3 at sites of ICP Materials in European countries (1987 = 100 %)



Source: ICP Materials

As a consequence of the declines in emissions of SO_2 and NO_2, corrosion rates of construction steel also declined considerably over the same period (Figure 27), particularly at industrial sites, followed by urban sites close to heavy traffic. This demonstrates the effects of measures to treat flue-gases from industrial plants and the introduction of vehicle catalytic converters. In addition, in rural areas of Europe weathering rates were on average more than halved.

FIGURE 27

Mass loss (in g m^{-2}) of construction steel for industrial, urban, and rural exposure sites of ICP Materials for the period 1985 to 2009

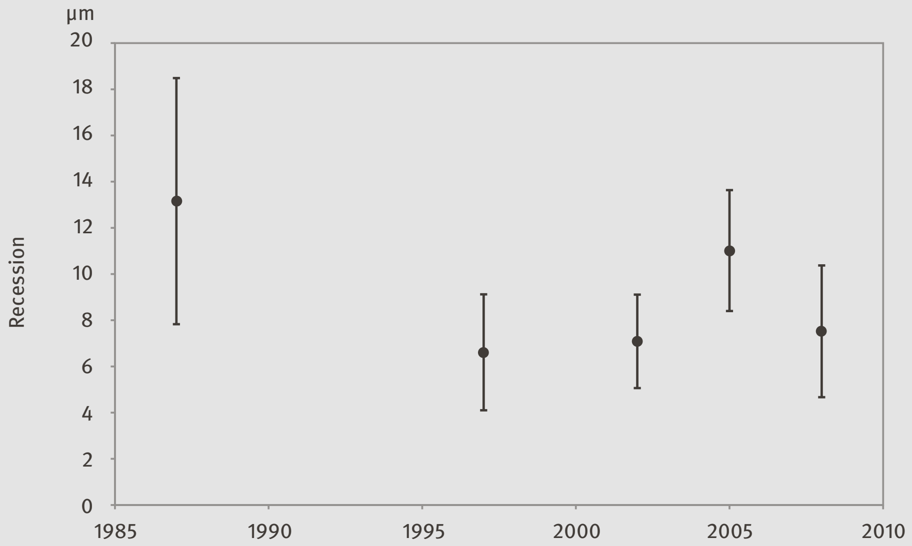
Source: ICP Materials

Similarly, declining trends could initially be identified for the weathering of limestone (Figure 28) and the corrosion of zinc (Figure 29), although there are considerable fluctuations between the one-year investigations, probably due to weather dynamics. Since the mid-1990s there was no longer a recognisable downward trend.

Both materials are more vulnerable to natural climatic influences than construction steel, so that as air pollution levels decline, the fluctuations of climate parameters make a greater contribution to the rates of weathering or corrosion. Overall, the current rates of corrosion and weathering of materials are still unacceptably high.

FIGURE 28

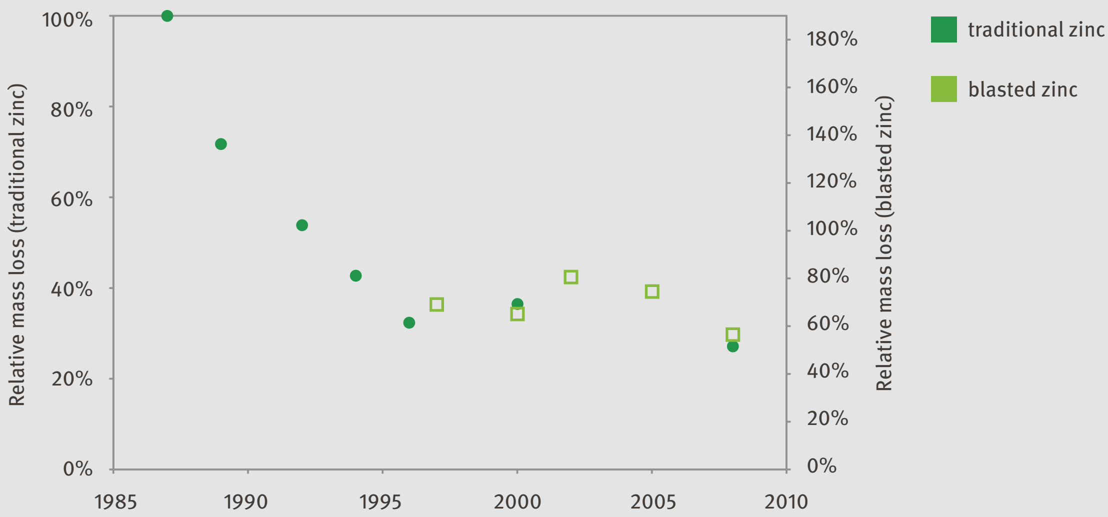
Mean values and standard deviations for weathering of limestone in µm at ICP Materials exposure sites (one year exposures).



Source: ICP Materials

FIGURE 29

Mean relative zinc mass loss (in g m^{-2}) at ICP Materials exposure sites.



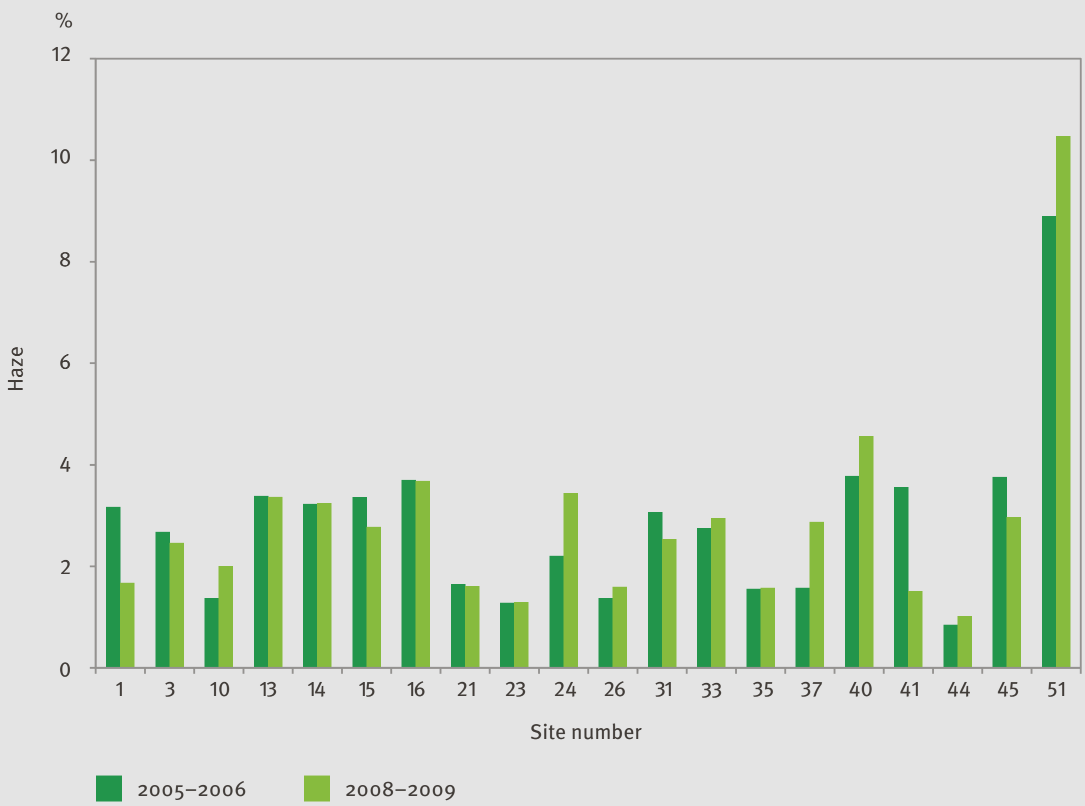
Values for both traditional zinc and blasted zinc were expressed relative to the results from the exposure period 1987–1988.

Source: ICP Materials

Core message 2: Soiling levels remain too high.
The effects of soiling have been investigated systematically in ICP Materials since 2005. Glass samples were exposed for one or more years (2005 to 2006 and 2008 to 2009) at sites with varying levels of exposure to dry atmospheric depositions. In both exposure periods, the samples of a site showed similarly high rates of soiling. It is not yet possible to identify any trend towards increases or decreases (Figure 30). However, the data do show very different levels of soiling at the different sites across Europe. The effects at the German locations (No. 10 = Bottrop, No. 41 = Berlin) are fairly average, compared for example with the situation in Athens (No. 51). However, there is not yet sufficient data for more precise judgements to be made. It is necessary to wait for an evaluation of the results for the on-going four-year period. Current research is also working to establish dose-response functions and limit values for levels of black carbon as a special component of particulate matter[32].

FIGURE 30

Soiling of modern glass at ICP Materials test sites in Europe, measured as loss of transparency (haze)



Source: ICP Materials

32) Gordon A, Tidblad J, Lombardo T (2012): The effect of black carbon on soiling of materials, Convention on Long-range Transboundary Air Pollution, International Co-operative Programme on Effects on Materials, including Historic and Cultural Monuments, Report No 71, SWEREA KIMAB AB, Stockholm, Sweden

The revised Gothenburg Protocol: What is being achieved? What remains to be done?

As the previous chapters have shown, the environmental situation has improved considerably over the past 20 years. This is due in some part to the national emission ceilings agreed on in 1999 in the Gothenburg Protocol of the Convention on Long-range Transboundary Air Pollution (CLRTAP), which have been binding since 2010. However, it was already clear at the time that the implementation of the Protocol would only reduce the negative impacts on humans, ecosystems and materials, but would not eliminate these completely.

Further measures will be necessary in order to achieve the long-term goal of an air quality that is without appreciable harmful effects. A first step in this direction was made in May 2012 with the agreed amendments to the Gothenburg Protocol. An important scientific basis for the policy negotiations was provided by the investigation of the expected effects of reduced emissions with regard to improvements to the state of the environment. Important contributions were made by the programmes presented here. According to these, the commitments made for the reductions of pollutant emissions by 2020 (see Table 3 for Germany) will lead to a further reduction of impacts on humans and the environment. For example, in Germany it is expected that the loss of life expectancy as a result of exposure to particulate matter will have been halved by 2020 and the ecosystem area not exposed to acidification will have been more than doubled (in each case compared with the situation in 2000)[33]. A large part of these improvements, however, was already achieved by reduction measures implemented before 2010.

33) Guidance document VII on health and environmental improvements, Executive Body, 30th Meeting, 30 April–4 May 2012, Informal document prepared by the Working Group on Effects

TABLE 3

Pollutant	German emissions 2005 [kilotonnes]	Reduction commitment under the Gothenburg Protocol 2005 2020
SO_2	477	21 %
NO_X (without agriculture)	1,461	39 %
NMVOC	1,146	13 %
NH_3	579	5 %
$PM_{2.5}$	125	26 %

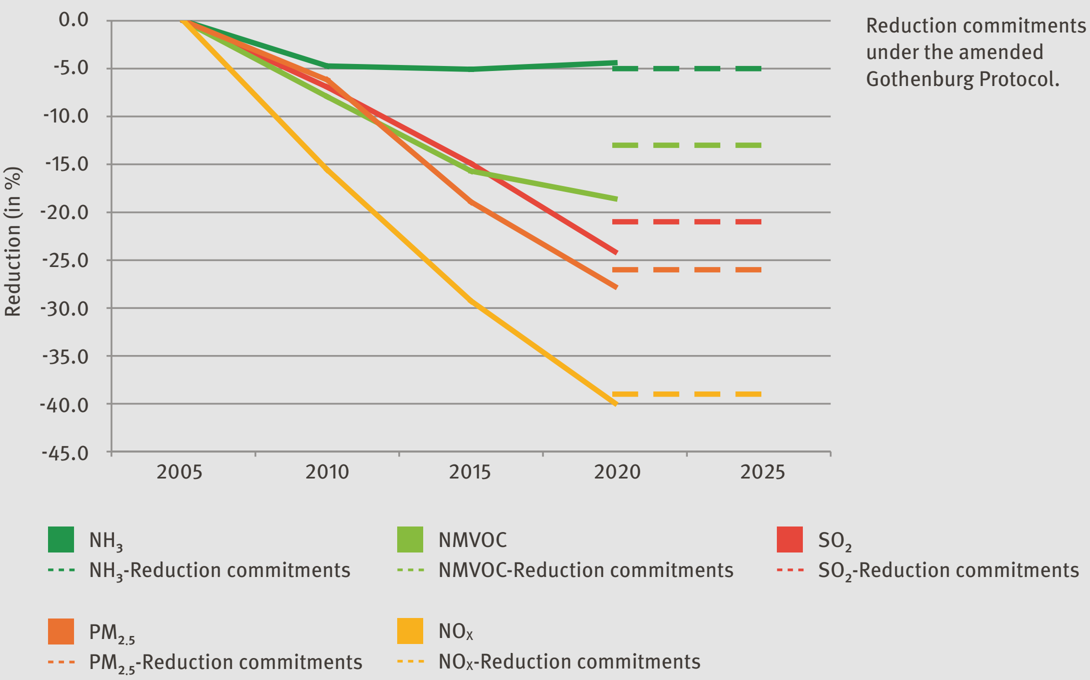
Emission reduction commitments for Germany in the amended Gothenburg Protocol of 2012, to be achieved by 2020. In contrast to the absolute values in the Gothenburg Protocol of 1999, these are expressed as reductions relative to the emissions in 2005[34]. The data provided here are identical with the official emission reporting of Germany in 2013.

Source: CLRTAP, 2012[34] ZSE, UBA

In accordance with the provisional emission projections of UBA[35], the implementation of measures which have already been agreed, (e.g. the introduction of the exhaust emission classes Euro 6/VI for cars, light and heavy goods vehicles and stricter emission limit values for large-scale combustion and industrial plants) will make it possible for Germany to comply with the emission reduction commitments for all pollutants with the exception of NH_3 (see Figure 31). For this pollutant, further measures are required. These are available but have so far only been implemented reticently.

FIGURE 31

Predicted development of atmospheric pollutant emissions from 2005 to 2020 in Germany.



34) Amendment of the text of and annexes II to IX to the 1999 Protocol to Abate Acidification, Eutrophication and Ground level Ozone and the addition of new annexes X and XI; http://www.unece.org/env/lrtap/executivebody/eb_decision.html

35) From the UFOPLAN project "Luftqualität 2020/2030: Weiterentwicklung von Prognosen für Luftschadstoffe unter Berücksichtigung von Klimastrategien" (Jörss W et al., June 2013).

The priority of achieving an air quality that is without negative impacts will not be achieved by 2020 under the provisions of existing legislation. The average life expectancy in Germany will still be shortened by about half a year solely as a result of exposure to particulate matter in ambient air, about half the ecosystem area will still be at risk of eutrophication, and about a fifth at risk of acidification. Over large areas, plants will still be injured by ground-level ozone and materials will experience deterioration due to exposure to a mixture of various atmospheric pollutants – to name only some of the remaining problems[36]. Further emission reductions are therefore required.

Cost-efficient technical measures are available to reduce NMVOC emissions, e.g. regarding the use of solvents. The farming industry can reduce NH_3-emissions relatively quickly and cost-effectively by some 12 kilotonnes per annum if farmers also work poultry litter into the soil immediately after spreading on untilled arable land[37]. Further reductions are possible, but these would only become effective in the medium term due to the requisite transitional periods. Increased use should be made of these possibilities, e.g. reductions of up to 45 kilotonnes NH_3 per annum by using low-emission methods for spreading liquid fertiliser on fields of crops. In addition, changes in behaviour (mobility, consumption) can also make an important contribution towards reducing emissions. How soon the long-term goal can be achieved is ultimately a question of political and societal commitment.

The amended Protocol also addresses newly recognised challenges. For example, for the first time emission reduction commitments have been introduced for fine particulate matter ($PM_{2.5}$), which also includes black carbon. This not only has harmful effects on health, but also influences the climatic system. Ground-level ozone is also both a significant atmospheric pollutant (see Chapters 4 and 8) as well as an important greenhouse gas. Both black carbon and ozone are short-lived climate forcers. If their concentration in the atmosphere can be reduced, this would improve the air quality and at the same time represent a step against global warming. Due to these synergy effects and in view of the combined effects of atmospheric pollutants and climate change on receptors, it makes sense to always consider climate policies in combination with air quality policies (see Chapter 6).

The example of ozone also shows that the global transport of atmospheric pollutants is playing an increasingly important role (the same also applies for mercury or persistent organic pollutants). In the winter months, the contribution of the intercontinental transport of pollutants to the formation of ozone baseline levels is as large as or greater than the effect of pollutant emissions in Germany and Europe[38]. Therefore, the cooperation between CLRTAP and other initiatives, programmes and organisations from the northern hemisphere and worldwide is becoming increasingly important.

For an improvement of air quality everywhere, internationally agreed reductions in emissions are not sufficient. Despite overall reductions in emissions there can still be excessive concentrations of pollutants and levels of deposition at specific locations (e.g. close to sources of emissions) and these will impact on local populations and ecosystems. In consequence, the EU air quality directive augments the national emission reduction commitments with binding air quality standards, i.e. limits on pollutant concentrations which have to be complied with at all sites. Above all in conurbations, and in particular in the vicinity of roads, meeting the air quality standards represents a challenge which can only be met by coordinated measures at local, regional, national and international levels.

The extent of the influence of air quality on surface waters was shown in Chapters 5 and 6. Acidification in the upper reaches of streams is declining in many cases due to the reductions in emissions, even if this has not yet resulted in a complete recovery of the biotic communities. Additional measures must be adopted, for example, with regard to atmospheric nitrogen depositions into the seas and oceans, and the reduction in mercury pollution, to which atmospheric depositions also contribute.

36) Guidance document VII on health and environmental improvements, Executive Body, 30th meeting, 30 April–4 May 2012, Informal document prepared by the Working Group on Effects.
37) It is intended to extend the existing Fertiliser Ordinance (DüV) to include poultry manure.
38) TFHTAP (2010): Hemispheric transport of air pollution 2010, Part D: Answers to policy relevant science questions, Air Pollution Studies No. 20, Task Force on Hemispheric Transport of Air Pollution, Convention on Long-range Transboundary, United Nations, New York and Geneva

11

56–57

Conclusions

The shared goal of the Convention on Long-range Transboundary Air Pollution (CLRTAP) and the air quality strategy of the European Commission is to completely avoid harmful effects for human health and the environment in the long term. Emission reduction strategies are particularly promising when an acceptable effort leads to the greatest possible improvements in the state of environment. An effective environmental policy can only be developed on the basis of extensive observations of the state of sensitive receptor elements and a broad understanding of causal relationships and the spatial and temporal distribution of pollutants. In addition to close cooperation with research facilities, this also requires the implementation of monitoring programmes, the development of models to predict concentrations and deposition levels, and the assessment of effects and measures. Long-term environmental observation programmes provide a basis of data for assessing the state of the environment, so that model assumptions can be verified by empirical results, and the effectiveness of air quality measures can be checked on the basis of agreed indicators.

Since its foundation, the Working Group on Effects with its seven programmes for environmental monitoring, modelling and effects research has made a vital contribution to the work of the CLRTAP. The German working groups have actively supported this process. Their contributions continue to be essential for the investigation of the effects still caused by atmospheric pollutants, taking into account the alterations attributable to climate change. The effects of nitrogen compounds and other atmospheric pollutants on the diversity of flora and fauna and certain ecosystem functions are complex and far from being fully understood. This also applies for interactions of nitrogen und carbon in ecosystems, the frequently delayed reactions of ecosystems to the effects of pollutants, but also to pollution reductions. It is therefore necessary to continue to gather data and to further clarify causal relationships. This requires the long-term continuation of the programmes.

Abbreviations and units

A

AOT40: Accumulated ozone exposure over a threshold of 40 ppb

B

BImSchV: Federal Pollution Control Ordinance
BMEL: Bundesministerium für Ernährung und Landwirtschaft (Federal Ministry of Food and Agriculture)

C

CBD: UN Convention on Biological Diversity
CL: Critical load (for environmental pollution)
CLRTAP: Convention on Long-range Transboundary Air Pollution

E

EMEP: The European Monitoring and Evaluation Programme: Cooperative Programme for the Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
EU: European Union/European Community

G

GAW: Global Atmosphere Watch

I

ICP: International Cooperative Programme
IIASA: International Institute for Applied Systems Analysis, Laxenburg, Austria

N

n: Number (of investigations)
NEC: National emission ceilings
NH_3: Ammonia
NH_4-N: Ammonium-nitrogen
NMVOC: Non-methane volatile organic compounds
NO_3-N: Nitrate-nitrogen
NO_2: Nitrogen dioxide
NO_x: Nitrogen oxides

O

O_3: Ozon

P

pH value: A logarithmic index for hydrogen ion concentration in aqueous solutions as a measure of acidity.
PM: Particulate matter

S

SO_2: Sulphur dioxide
SO_4: Sulphate
SO_4-S: Sulphate-sulphur
SOMO 35: The sum of means over 35 ppb or 70 µg m^{-3} (daily maximum 8-hour) for a calendar year (for ozone)

U

UBA: Umweltbundesamt (Federal Environment Agency)
UNECE: United Nations Economic Commission for Europe

W

WGE: Working Group Effects of CLRTAP
WHO: World Health Organisation

Z

ZSE: Central System Emissions

Selected units

mg L^{-1}: Milligrams per litre

g m^{-2}: Grams per square metre

µg m^{-3}: Micrograms per cubic metre

kg N ha^{-1} a^{-1}: Kilograms nitrogen per hectare per annum

eq ha^{-1} a^{-1}: Acid equivalent per hectare per annum

ppb: Parts per billion

ppb h: ppb × hours


Are we doing enough
for human health and
our environment?