3

Air pollution and man

Air pollution affects us in many ways, perhaps more than we realize. It not only affects our health, directly and indirectly, but also our finances. Materials erode and corrode, cultural treasures are lost and production from agriculture and forestry is reduced.

This chapter first describes the effects on our health, followed by the ways in which air pollution affects our opportunities to exploit the forest, soil and water. Finally it looks at the effects on materials and structures. Information on how the economy is affected is given under each heading, and to some extent also in chapter 8.

HEALTH EFFECTS

Many air pollutants are toxic when inhaled and therefore have direct effects on our health. Added to these are a wide variety of indirect effects that are discussed later in this chapter, including the increased mobility of many metals and the effects of climate change.

Toxic air

Although the concentrations of air pollutants are in general on the way down in Europe, the problems remain considerable – especially as regards ground-level ozone and small parti-

TARGET VALUES AND LIMIT VALUES

A number of target values and limit values have been set up with the aim of confining the pollutants to permissible levels.

Target values, such as those from the World Health Organization, are only recommendations, and so are not binding. These are set at levels aimed to protect human health.

Limit values on the other hand are binding, and because they are compulsory their economic consequences have been taken into account when deciding on them.

It has not been possible to determine any minimum dose below which there will be no ill effects from carcinogenic substances. Resort has therefore been made to a **medical low risk level** that will keep the risk of getting cancer under a certain level, for example 1 in 100,000, for individuals who are exposed to the specified concentration throughout their lifetime.

Percentile figures are often used when stating limit values. If for example a one-hour mean value is given as a 98th percentile it means that in one year (8760 hours) the limit value must not be exceeded for more than 175 hours. For a 99th percentile the limit value may be exceeded for 88 hours per year. For a daily mean value, the 98th and 99th percentiles represent seven and four excursions per year respectively. In those cases where no percentile figures are given, a maximum daily or annual mean value applies that should not be exceeded.

Note that the values given apply to one pollutant at a time. The level of knowledge is still generally insufficient to give levels that take into account any combined (additive) effects of different substances.

cles. In some areas, too, the situation continues to become worse.

Air pollution is not easily measured, comprising as it almost invariably does a mixture of many different substances, some of which are more toxic than others. By interacting in some cases, they become even more harmful. For example, sulphur dioxide can affect lung tissue in such a way that carcinogenic substances can penetrate more easily into the cells of the lungs.

The effects of breathing toxic substances may range from a slight feeling of discomfort to premature death. Those most at risk are children, the elderly, asthmatics and people with heart and circulatory problems. Sensitivity varies very widely, however, from one individual to another.

This examination of harmful substances in the air cannot be comprehensive – the exhaust fumes from a petrol engine alone contain thousands of different substances. The description instead focuses on some of the most important substances and groups of substances.

The risks to health come mainly from the following pollutants in outdoor air:

Nitrogen dioxide

When inhaled, nitrogen dioxide (NO_2) can penetrate relatively deep into the airways, where it can cause irritation and damage to tissue. It can also aggravate both asthma and allergic reactions. It also impairs the defence mechanisms of the lungs against bacteria, viruses, and other air pollutants such as

TABLE 3.1. Nitrogen dioxide.

	1-hour mean value	Annual mean value
WHO target value (WHO 2000)	200 $\mu g/m^3$	40 $\mu g/m^3$ (health) 30 $\mu g/m^3$ (vegetation; $NO+NO_2$)
EU limit value, applies from 2010 (A)	200 $\mu g/m^3$ (B)	40 $\mu g/m^3$ (health) (C) 30 $\mu g/m^3$ (vegetation; $NO+NO_2$) (C)

(A) European Union 1999, Directive 1999/30/EC.

(B) Must not be exceeded more than 18 times per calendar year.

(C) Applies from 19 July 2001.

ozone and particulate carcinogens. Repeated exposure to nitrogen dioxide, either alone or in combination with other factors, is suspected of triggering asthma in children. The target and limit values that apply at present are shown in Table 3.1.

Nitrogen oxides moreover have significant indirect effects on health through their contribution to the formation of ground-level ozone and their conversion in the air to very small particles. See below.

The main contributor to the concentrations of nitrogen oxides in urban surroundings is usually road traffic. In most European countries the levels of nitrogen oxides in urban air have risen with the growth in road traffic, but are now decreasing thanks to the growing number of vehicles that are fitted with catalytic converters.

According to calculations by the EU Commission for 1995, 65 per cent of Europe's urban population lived in areas where levels exceeded the annual mean value of 40 µg/m^3 laid down in the forthcoming standard. A more recent estimate by the European Environment Agency (2002) indicates that this figure has fallen to just over 40 per cent. Further reductions are expected, but in 2010 it is still expected that the limit value will be exceeded in many areas if no further action is taken.

TABLE 3.2. Sulphur dioxide.

	10-minute mean value	1-hour mean value	max. 24-hour mean value	annual mean value
WHO target value (WHO 2000)	500 µg/m^3	–	125 µg/m^3	50 µg/m^3 (health)
EU limit value, from 2005 (A)	–	350 µg/m^3 (B)	125 µg/m^3 (C)	20 µg/m^3 (D)

(A) European Union 1999, Directive 1999/30/EC.

(B) Must not be exceeded more than 24 times per calendar year.

(C) Must not be exceeded more than 3 times per calendar year.

(D) To protect ecosystem. Applies outside urban areas, with effect from 19 July 2001.

Sulphur dioxide

Sulphur dioxide (SO_2) also causes irritation of the airways. Long-term exposure in combination with airborne particles increases the likelihood of respiratory infections in children. Further effects on health can be traced to the part played by sulphur dioxide in the formation of particles in the air (see below).

The main sources of emissions are the burning of coal and oil. The contribution from road traffic is small. Current target and limit values are given in table 3.2.

In most parts of Europe levels of sulphur dioxide have fallen considerably in recent decades, thanks to improved emission controls for power stations, cleaner fuels, increased use of district heating, etc. According to calculations by the EU Commission, however, in 1995 one quarter of the urban population of Europe was exposed to levels higher than the forthcoming limit values for both one-hour and 24-hour exposure. This percentage is expected to fall to 2–11 per cent by 2010 as a result of decisions already taken.

Particles

Through the use of sophisticated statistical methods and more powerful computers, researchers have been able to identify links between exposure to particles (PM) and a variety of effects on health even at levels that had previously been considered safe.

A large number of studies made both in the US and in Europe have shown that when the concentration of small particles in air rises, even from low levels, there is a rise in mortalities from respiratory, cardiac and circulatory diseases, and more people seek hospital care for bronchitis and asthma.

Even exposure to low levels for long periods is considered harmful. The long-term effects have not yet been very well researched, but living in regions where there are high concentrations of particles is believed to reduce life expectancy.

Calculations have shown that in Austria, Switzerland, and France small particles (PM_{10}) at current levels in air give rise to 40,000 premature deaths a year in these countries, and the average life expectancy of people living in an urban environment is reduced by 18 months. Furthermore, these particles trigger half a million asthma attacks each year and lead to a total of 16 million lost person-days of activity.

A recent study on the health impact of particles in 19 European cities with a total population of 32 million concluded that reducing the levels of PM_{10} by just 5 $\mu g/m^3$ would prevent more than 5500 premature deaths annually in those cities.

It is the very smallest particles that are believed to be the most harmful, because when they are inhaled they can penetrate deep into the lungs. Their shape and chemical composition as well as their size are thought to influence their harmfulness, as do the substances that adhere to their surface.

Particles are now generally measured as PM_{10}, where PM stands for particulate matter and the number 10 indicates the maximum diameter in micrometres (actually particles of such a size that 50 per cent pass through a given sampling filter). For several years an even finer fraction, $PM_{2.5}$, has also been measured in the US. This gives a better measure of the smaller particles, and presumably a better indication of the effect on health. In recent years a start has been made on measuring $PM_{2.5}$ in the EU too, although the present standards only apply to PM_{10}. Some measurements have also been initiated to study the very smallest particles, such as PM_1 and $PM_{0.1}$.

Particles are classed as either primary or secondary:

Primary particles are those that are formed during combustion, but may also consist of dust, small soot flakes, pollen, etc. Major sources are combustion processes (often small-scale burning) and internal combustion engines (primarily diesel engines). At present the extent of these emissions and their distribution among sources are not fully known. Emission inventories are however being developed and improved.

Secondary particles consist mainly of sulphate and nitrate salts that are formed in the air from sulphur dioxide and nitrogen oxides. Any source that emits these substances therefore contributes to their formation.

Secondary particles are small and can remain suspended in the air for long periods. There is extensive transboundary migration of these particles – in most places only a small proportion is traceable to local emissions, and a large percentage, particularly of the finest fractions, consists of secondarily formed particles.

TABLE 3.3. Particles (PM_{10}).

	Max. 24-hour mean value	Annual mean value
WHO target value (WHO 2000)	dose-response	dose-response
EU limit value, from 2005 (A)	50 μg/m^3 (B)	40 μg/m^3
Prel. EU limit value 2010 (A)	50 μg/m^3 (C)	20 μg/m^3
Guide value proposed by IMM (D)	30 μg/m^3	15 μg/m^3
Current levels in Europe		10 μg/m^3 remote areas

(A) European Union 1999, Directive 1999/30/EC.
(B) Not to be exceeded more than 35 times per year.
(C) Not to be exceeded more than 7 times per year.
(D) IMM = National Institute of Environmental Medicine, Sweden.

The WHO guidelines do not set any target values for airborne particles, since it is considered unlikely that a level will be found that does not have harmful effects. Instead, they give a dose-response link, see figure 3.1. In Sweden the National Institute of Environmental Medicine (IMM) has proposed limit values well below the levels so far considered acceptable. See table 3.3.

According to calculations by the EU Commission for 1995, almost 90 per cent of Europe's urban population was living in areas where particle levels exceeded the maximum 24-hour mean and annual mean values of the forthcoming EU standard. This proportion is expected to fall to around two-thirds by 2010 as a result of decisions already taken in respect of emission controls for combustion plants and vehicles, as well as of sulphur levels in fuels.

Volatile organic compounds

These comprise a very large group of pollutants. Some are fairly harmless, while others are extremely toxic. They can occur either as gases or bound to particles, and several of the substances in this group contribute to the formation of

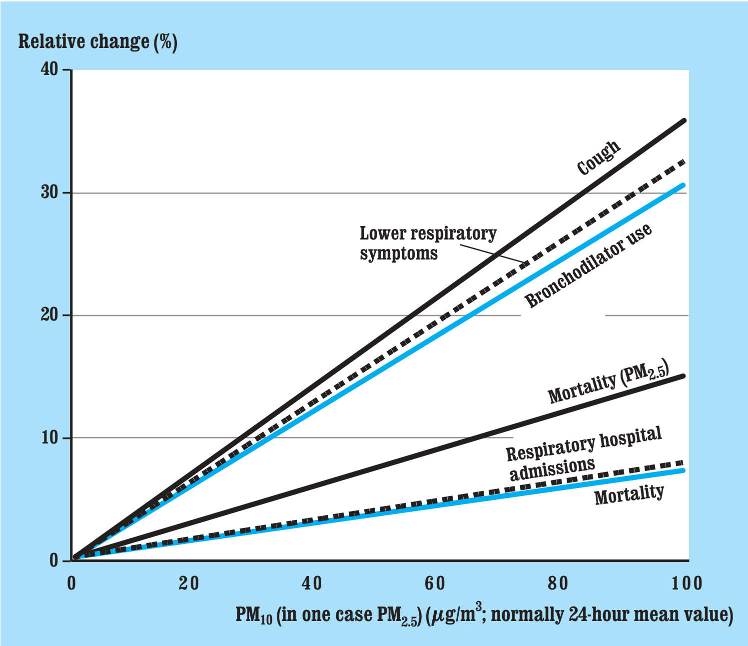

FIGURE 3.1. Link between particles in ambient air and effects on health. Dose response link at exposures below 20 $\mu g/m^3$ is however uncertain. (WHO. Air Quality Guidelines for Europe. 2nd edition, 2000)

ground-level ozone – which probably is the most significant health effect of this group as a whole.

The group includes known carcinogens such as benzo-(a)pyrene, ethene and benzene, as well as various aromatic hydrocarbons. Among the nitrated polyaromatic hydrocarbons (nitro--PAH) are some of the most carcinogenic substances known to man, several of which are present in diesel exhaust fumes.

Petrol-driven cars that have ineffective catalytic converters, or none at all, are a major source of emissions of volatile organic compounds in urban air. Small-scale combustion, such as the household burning of wood or coal, can also make a significant contribution.

TABLE 3.4. Benzene.

	Annual mean value
EU limit value, applies from 2010 [A]	5.0 $\mu g/m^3$
Low risk level [B]	1.3 $\mu g/m^3$
Current levels, urban environment, Europe	1–10 $\mu g/m^3$ background level 20–50 $\mu g/m^3$ roadside

[A] European Union 2000, Directive 2000/69/EC.

[B] Assessment by National Institute of Environmental Medicine, Sweden. Lifetime exposure to this concentration gives rise to 1 case of cancer per 100,000 inhabitants.

At present the limit values in the EU are only for benzene, but standards are also being worked out for polyaromatic hydrocarbons (PAH).

In most European cities the levels of benzene in the air exceed the medical low risk limits by a large margin. For current limit values and levels, see table 3.4.

According to calculations by the EU Commission for 1995, 50 per cent of Europe's urban population lived in areas where benzene levels exceeded the annual mean value of 5 $\mu g/m^3$ set out in the forthcoming EU standard. This percentage is expected to fall to 13 per cent by 2010 as a result of decisions already taken, primarily regarding traffic-related emissions.

Ozone

Ozone is a powerful oxidant and can give rise to eye irritations and irritations of the airways that lead to a reduction in lung capacity, even at relatively low concentrations. Because ozone is a gas with low solubility in water it can penetrate deep into the lungs. During periods of elevated levels a larger number of people are admitted to hospital emergency departments with respiratory problems (see table 3.5). When concentrations rise, even from relatively low levels, the need for increased medication of asthmatic children and increased mortality are among the observed effects. Long-term exposure, even to relatively low concentrations, can lead to permanent lung damage according to new research in the US.

TABLE 3.5. Link between hospital admissions due to respiratory disease and measured ozone levels, according to epidemiological studies. (WHO, 2000)

Increase in ozone levels (μg/m³) for 1 hour	8 hours	Increase in hospital admissions
30	25	5%
60	50	10%
120	100	20%

High levels occur primarily in spring and summer, since ozone formation is a process that is driven by sunlight. Every year concentrations in Europe exceed by a large margin the eight-hour mean target value of 120 μg/m^3 recommended by the WHO to protect human health. Following such episodes high levels can also occur in areas with relatively clean air.

Following national and international agreements that will result in measures to reduce the emissions of nitrogen oxides and volatile organic compounds, episodes of high ozone levels are expected to fall over the next few decades. Levels over Europe are however also affected by emissions from all over the northern hemisphere, which means that increasing emissions in Asia, for example, could counteract the effectiveness of abatement measures in Europe. For target values, see table 3.6.

Carbon monoxide

Carbon monoxide is easily absorbed by the blood, and reduces its ability to transport oxygen. High levels can lead to unconsciousness and death. The main source of emissions is petrol-driven cars that do not have catalytic converters. These are steadily disappearing and current levels of carbon monoxide in outdoor air are probably harmless in most cases. High levels can however occur in multi-storey car parks, garages, tunnels, etc. One reason to further restrict emissions of carbon monoxide is that it contributes to the formation of ground-level ozone. In 2002 the EU decided that the limit value of 10 mg/m^3 for outdoor air should not be exceeded after 2005.

TABLE 3.6. Ozone.

	One-hour mean value (health)	Eight-hour mean value (health)	Three-month mean value (vegetation)
WHO target value (WHO 2000)	–	120 $\mu g/m^3$	-
EU standards (A)	180/240 $\mu g/m^3$ (B)	120 $\mu g/m^3$ (C)	AOT40 (D) = 18000 $\mu g/m^3$ hours (E)
EU long-term objective (A)	–	120 $\mu g/m^3$	AOT40 (D) =6000 $\mu g/m^3$ hours
Proposed target value by IMM (F)	80 $\mu g/m^3$	–	–

(A) European Union 2002, Directive 2002/3/EC.

(B) At 180 $\mu g/m^3$ (information threshold) the population should be informed, and at 240 $\mu g/m^3$ (alert threshold) short-term actions should be taken.

(C) Target value for 2010, not to be exceeded more than 25 times per year.

(D) AOT40 = Accumulated exposure over the threshold 40 ppb.

(E) Target value for 2010.

(F) IMM = National Institute of Environmental Medicine, Sweden.

Lead

Lead causes brain damage, especially in children. In the EU, levels of lead in the air have fallen dramatically thanks to the fact the lead is no longer added as an octane enhancer to petrol. The addition of lead to petrol was totally prohibited throughout the EU from the year 2000, although some countries have been allowed a few years for the phasing out process.

Asthma and allergies

In many industrialized countries the incidence of asthma and allergies has risen sharply in recent decades. So far no explanation has been found. The incidence of hypersensitive reactions is thought to be due to hereditary dispositions as well as environmental factors. One as yet unexplained phenomenon

THE EU FRAMEWORK DIRECTIVE

In September 1996 the EU Council of Ministers adopted the directive on ambient air quality assessment and management (96/62/EC). This is a framework directive that, among other things, lays down how monitoring systems should be set up so that information on measurements is made accessible to the public. So far the directive has been supplemented by three subsidiary directives. The first was adopted in 1999 and covers sulphur dioxide, nitrogen dioxide, particles (PM_{10}) and lead (1999/30/EC). The second, which covers benzene and carbon monoxide, was adopted in 2000 (2000/69/EC), and the third (2002/3/EC), which deals with ground-level ozone, was adopted early in 2002. In July 2003 the Commission presented a proposals for a fourth daughter directive, covering polyaromatic hydrocarbons (PAH) and a number of heavy metals.

The framework directive says nothing about how the limit values should be achieved; that is up to each member country to decide. However, it does require that corrective measures should be taken if the standards are not met. The specified limit values are minimum standards. This means that member countries can introduce stricter standards if they wish.

is the much greater increase in western Europe than in eastern Europe.

Researchers do not believe that air pollution is a critical factor that could account for this rise, partly because the rise has taken place at a time when the levels of pollutants have fallen. Nevertheless air pollution does play an important role in this context. Nitrogen dioxide, sulphur dioxide, ozone, and particles have all been shown to aggravate and in some cases trigger symptoms of asthma in susceptible individuals. Ozone and nitrogen dioxide have also been proved to increase sensitivity to pollen among sufferers of hay fever. This is because these pollutants damage the mucous membranes of the airways, so that allergenic substances are more likely to trigger a reaction.

Inversions and episodes

When weather conditions are stable, usually during periods of high pressure and light winds, the levels of various air pollutants can occasionally rise by a factor of ten or more, locally or

INVERSIONS AND EPISODES

When weather conditions are stable, usually during periods of high pressure and light winds, the level of pollution in the air can rise to very high levels.

In winter this is generally due to an **inversion**, a weather condition that causes the temperature of the air to increase with height above ground level. This results in very little mixing of the air. Inversions occur most often on clear nights with little wind, usually in combination with high pressure, which allows the heat in the ground to radiate out into space. Heat from the sun generally breaks up the inversion during the day, but occasionally it may hang over an area for several days. Concentrations of various pollutants – primarily sulphur dioxide, nitrogen oxides and particles – underneath this "lid" can then rise very sharply and may appear from a distance as a brownish yellow haze hanging over the area.

Inversions are usually local, but can even affect entire regions. The brown coal areas of the northern Czech Republic are a notorious example. When emissions were at their worst the concentration of sulphur dioxide reached almost 1000 $\mu g/m^3$. During the famous London smog in December 1952 a daily average value of 5000 $\mu g/m^3$ was measured, which is probably a world record.

In summer, the concentrations of various air pollutants can become exceptionally high during periods of fine weather, when a high-pressure front is "parked" over the same area for a long time. The air is not mixed very much and the concentration of ground-level ozone in particular often reaches harmful levels. In sunny summers this phenomenon occurs over large parts of Europe. When these polluted masses of air begin to move and pass over an area they are often referred to as **episodes**, short periods when the concentrations of pollutants in the air are greatly elevated.

regionally. In winter the main pollutants involved are sulphur dioxide, nitrogen oxides and small particles. In summer, the levels of ozone and other oxidants rise the most. See also factfile above.

Acidification and health

The mobility of many metals increases in acid environments. The human body needs small amounts of certain metals, such as copper, manganese and iron. But if the concentrations are too high they quickly become harmful. Other metals, such as mercury, cadmium and aluminium, serve no purpose in the human body. Some of them are toxic at very low concentrations.

Aluminium is one of the most widely occurring metals in the Earth's crust, but it is tightly bound in various minerals. The concentrations of various aluminium ions increase significantly when water becomes acidic. These are highly toxic to some aquatic organisms. It is not clear whether they affect humans.

The average levels of **cadmium** in groundwater have been shown to be three times higher in water with a pH value under 5, compared with water that has a pH above 6. However, we get most cadmium from food. The cadmium uptake of crops rises when the pH of the soil drops. For non-smokers, cereal products and vegetables contribute 75 per cent of the total intake of cadmium on average.

The concentrations of cadmium that parts of the population are exposed to are already close to the levels at which kidney damage can occur. Cadmium is also suspected of giving rise to bone embrittlement at relatively low exposures. Our uptake of cadmium increases significantly if we are deficient in iron.

Copper is used in water pipes. When water is acidic it can dissolve the metal that pipes are made of. High levels of copper discolour porcelain and can cause diarrhoea in children.

Fish that have high levels of **mercury** are found mainly in acidified lakes, although the reason for this is not fully known. There is nothing to indicate that acidification should increase the leaching of mercury from soil into water. In contrast to many other heavy metals, mercury remains tightly bound to humic substances in the soil, even when the pH drops. A more likely reason is that acidification reduces the amount of biomass in acidified lakes, so the mercury that is present becomes more concentrated. Another theory is that the fallout of sulphur may favour the bacteria that are able to convert (methylate) mercury to produce a phase that is taken up by organisms more easily.

As far as is known, the vitality of aquatic organisms is not directly affected by high levels of mercury. However, man is often at the very top of the food chain. For us, the regular consumption of fish containing high levels of mercury can be harmful. In Sweden, women who are pregnant, breastfeeding or plan to have children are advised to avoid fish from lakes entirely, since even small amounts of mercury can cause brain damage in embryos.

The climate and health

If the climate changes it also affects our health. Even if the mean temperature during the year rises just a few degrees it could mean that there are several times as many hot days. Severe heat waves usually lead to many elderly people dying prematurely. The number of very cold days is generally decreasing worldwide.

Many researchers fear that a warmer climate will lead to more extreme weather conditions. This would also mean more injuries and deaths due to flooding, hurricanes, etc., as well as extensive material damage. Because of this the big insurance companies are taking the enhanced greenhouse effect very seriously.

Another expected effect of a warmer climate is the wider occurrence of diseases that are spread by insects and various parasites, e.g. malaria and bilharzia (schistosomiasis), since the parasites and their hosts can extend their habitats. In the case of malaria the expected climate change over the next century could mean that 60 per cent of the Earth's population live within the risk zone, compared with 45 per cent today. Areas that are currently malaria-free, such as mountain regions in the tropics, could be affected.

A warmer climate can also give rise to more cases of food poisoning and water poisoning, since living conditions would be more favourable for bacteria and parasites.

The availability of drinking water, food, housing and opportunities to earn a living are naturally of central importance to people's health, and these necessities may be more difficult to obtain if the climate changes. In general it is those who are already poor who are expected to be worst hit by climate change, since they have the least resources to take preventive action and counter measures.

OTHER EFFECTS

Air pollution and forestry

In northern Europe, forest growth is largely dependent on the length of the growing season, which will increase if it gets warmer. The extent of the increase in production will however depend on how the availability of water and nutrients changes. These are the factors that govern growth over large parts of Europe.

The availability of nutrients may increase, since decomposition will speed up if the climate gets warmer. Nutrients will circulate faster, and this could support increased production.

Most scenarios point to warmer, more humid weather in the north, with a consequential increase in growth. In central and southern Europe, however, the temperature rise is likely to be combined with a sharp reduction in rainfall, which would be a major problem for the existing forestry industry.

The higher level of carbon dioxide in the air is itself favourable for forest growth – since plants use carbon dioxide for photosynthesis, and if there is more carbon dioxide in the air the trees can also conserve water better. But in practice the ability of plants to exploit this fertilization with carbon dioxide will often be limited by some other factor.

Another way that air pollution can promote growth is through the fallout of nitrogen. The deposition of nitrogen serves to fertilize the forest. Fallout over large parts of Europe amounts to several tens of kilogrammes of nitrogen per hectare each year.

Not just benefits

Air pollution also has a number of major drawbacks for the forestry industry:

- Some species of trees do not like warmer weather. Norwegian spruce (*Picea abies*) needs a gradual fall in temperature in order to acclimatize for winter, otherwise it becomes very sensitive to frost in early spring. Scots pine (*Pinus sylverstris*) is better at coping with warmer and drier climate, but may be driven out by broad-leaf trees that are favoured more than coniferous trees.

- Many forest pests – especially insects and fungi – are favoured by a warmer and more humid climate.
- Acid fallout acidifies the soil and, among other things, reduces the availability of important nutrients for trees. It also slows down decomposition.
- Ground-level ozone damages plants. Several studies in Europe indicate that ozone is an important contributory factor to damage in Norwegian spruce and beech (*Fagus sylvatica*). In southern Sweden it is estimated that current ozone levels result in a loss of yield from spruce of up to around 10 per cent over a forest generation.

Air pollution and agriculture

A crucial issue for agriculture worldwide is the availability of water. For instance, availability in summer is expected to fall in central areas of continental Europe and around the Mediterranean as a result of the enhanced greenhouse effect. The climate in already dry areas of southern Spain may become almost desert-like. Conditions for farming may change drastically in many parts of the world, resulting in food shortages and social problems. The seriousness of these problems will depend largely on the extent of the climate changes. It is a fairly obvious conclusion that the people who have the least opportunity to adapt – the poor – will be affected worst of all.

In northern Europe it is likely that agricultural yields will rise – the growing season may be extended by a few months and precipitation can be expected to increase. On the negative side, however, the higher temperatures could also lead to increased attacks by insects and fungi.

Ozone is probably the pollutant that causes the largest harvest losses in agriculture today. A warmer climate could lead to increased formation of ground-level ozone. In Europe it is estimated that today's levels could give rise to annual harvest losses worth over 6 billion euro. Of these losses, one third is attributed to wheat, one fifth to potatoes, and one tenth to sugar beet. Other crops for which individual losses account

Generally speaking more people will be harmed than benefited, even by a small increase in temperature. And the higher the rise, the more serious will be the effects. The poorest countries will be the hardest hit.

for more than 3 per cent of the total economic loss are pulses, grapes, maize, sunflower, cotton, rapeseed, and tomatoes.

Air pollution and fishing

Fishing in northern Europe will probably be affected by a warmer climate, although it is difficult to say how. Cod spawning is, for example, relatively temperature-dependent. More severe effects are feared in tropical waters. Coral reefs are extremely sensitive to rises in temperature and a large proportion of the fish that are caught in coastal areas in tropical seas depend on the coral reefs for their survival. These fish are also the main source of protein for millions of people.

The eutrophication of seas that airborne nitrogen fallout contributes to has both positive and negative effects on fish. One positive effect is that the increased availability of nutrients leads to increased production throughout the ecosystem. On the negative side, some species may be driven out and the shortage of oxygen may lead to the disappearance of fish from large areas (if eutrophication is severe).

In Scandinavia, acidification due to air pollution is probably the largest single cause of damage to fish stocks, mainly to the annoyance of anglers. Most of the lakes affected are small and commercial fishing has hardly been affected.

Buildings, infrastructure and cultural heritage

A long list of civil structures in our society are being destroyed or are in danger as a result of air pollution.

Climate effects

The largest future threats in this area worldwide are likely to be the rising sea level, increased precipitation and a possible increase in extreme weather conditions due to the changing climate. The heavier winter rain that is predicted will increase the risk of flooding along rivers and waterways in large parts of Europe.

In the wealthy parts of the world we are to some extent prepared to cope with more extreme weather conditions, although the effects could still be serious. The situation could be much worse in places that have poor economic resources and where a large proportion of the population live and work in low-lying areas, such as coastal cities, flood deltas and coral islands. One billion people currently live within 30 kilometres from the coast, and on average the population in these areas is growing twice as fast as in the world as a whole.

In addition to flooding, problems can also occur through salt permeation into groundwater, leading to lack of fresh water. With a combination of rising sea level and more storms, hundreds of millions of people are at risk of losing their homes and/or their means of earning a living.

Corrosion

The effects of wind and weather naturally mean that all materials will decay sooner or later, but air pollution speeds up this process. Buildings, vehicles, metal structures, statues, rock carvings, museum artefacts, water pipes, electrical cables etc., are all attacked and damaged. Objects made of limestone and some types of sandstone are especially vulnerable to acid substances, but not even the hardest granite can resist entirely (see figure 3.2).

The greatest damage is caused by sulphur dioxide, which is corrosive in both gaseous form and when converted into sulphuric acid. Nitrogen oxides also contribute to the damage, partly through the formation of corrosive nitric acid, and partly by reinforcing the damaging effects of sulphur dioxide. Ozone and other oxidants react readily with organic substances. They contribute mainly to the breakdown of textiles, leather and rubber. As a result of its oxidizing ability ozone

FIGURE 3.2. A survey of the 3000-year-old rock carvings in Bohuslän on the west coast of Sweden in the 1990s showed that 80 per cent of the carvings had suffered erosion damage, and studies have shown that the erosion rate then was four times higher than in the 1930s.

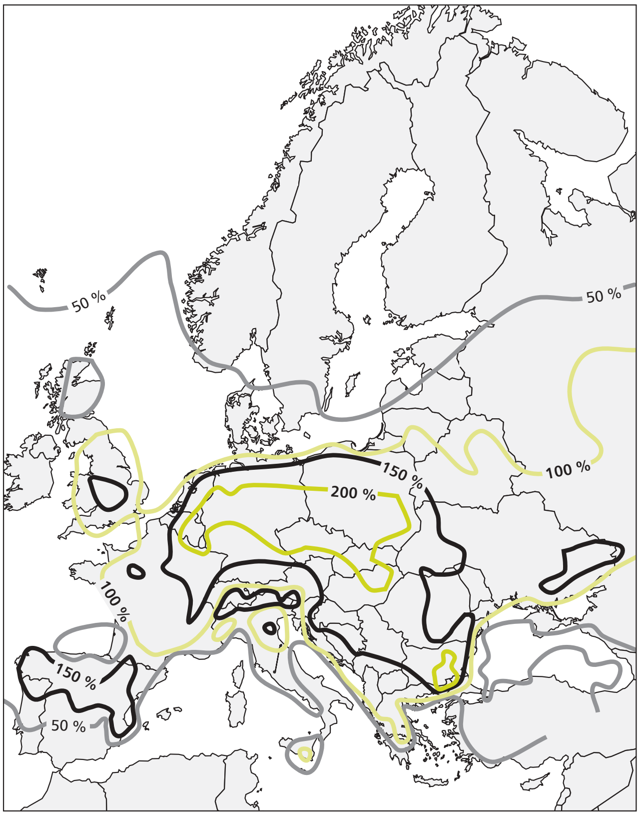

FIGURE 3.3. Copper corrosion rates above the background rate (in %). (EEA, Air Quality in Europe, 2002)

can also increase the corrosiveness of compounds of sulphur and nitrogen oxides.

Dry fallout is considered to do more damage than wet, since it can dissolve in the film of condensation on various surfaces and remain there for a long time. This can lead to high concentrations that are highly corrosive, since the pollutant is dissolved in such a small quantity of water. It also means that the pollutant can be "reused" as long as it remains there. It may dry out in the meantime, but can go back into solution whenever the surface becomes moist, with dew for example.

Rain on the other hand, even if it is acidic, washes the pollutants away.

Major economic losses are caused by the acceleration of corrosion due to air pollution. The annual damage to modern buildings and materials in Europe was estimated at 11 billion euro in 1995. Added to this is the extensive and serious damage caused to our cultural heritage, which in many cases is impossible to repair or measure in economic terms.

In northern Europe this corrosion has decreased markedly during the 1990s, thanks to reduced emissions of acidifying substances. However it is still estimated that corrosion over large parts of Europe is at least twice as rapid as the natural background rate, see figure 3.3.