The state of the environment: air quality

July 2018

Chair's foreword

Air quality has hugely improved since the mid-twentieth century. The work of the Environment Agency has played a part in that, but air pollution still poses significant threats, some new and some old, to public health and the environment. More needs to be done to tackle those threats and to reassure the public. Everyone has a role: the Environment Agency, local authorities, government, industry, farmers, and each of us as citizens and individuals.

Clean air is essential to health, the environment, and economic prosperity. The Environment Agency's regulation of industry plays an important role in reducing emissions. We still have a lot more to do, but our partnership approach with businesses has shown it is possible to help commerce thrive while improving air quality for communities living near industrial sites.

England's infamous "pea-soup" smogs ended with the 1956 Clean Air Act and emissions of nitrogen oxides and particulate matter have reduced by nearly three-quarters since 1970. However, in the last decade, increased understanding of modern pollutants' origins and impacts has brought invisible air pollution into sharp focus. Launching the government's consultation on the Clean Air Strategy, the Secretary of State said: "Air pollution is a major public health risk ranking alongside cancer, heart disease and obesity. It causes more harm than passive smoking".

Despite overall reductions in UK emissions, serious threats to health and the environment persist. Unacceptably high levels of nitrogen dioxide, ozone and particulate matter remain in many urban areas. Particulate matter can have impacts on health even below current legal thresholds. High concentrations around homes and schools are a serious public concern.

Driving down pollution requires everyone to act. From individuals, making choices about how to travel and heat homes (such as with wood burning fires), to governments, because transboundary pollution from international emissions contributes to poor air quality in some parts of the country.

While the debates about air quality rightly focus on public health, we also want to highlight the negative impacts on the environment. Ammonia deposition can overload land and water with nitrogen; it acidifies soils, natural habitats and freshwaters. These effects reduce biodiversity in sensitive habitats, creating a knock-on effect for wildflowers and wildlife, like butterflies and bees. Excessive fertiliser use also leads to the release of nitrous oxide, a highly potent greenhouse gas, which contributes to stratospheric ozone depletion.

The Environment Agency is working with farmers to reduce emissions while ensuring food production remains competitive. To help we have recently worked with government and leading farming organisations to publish a new Code of Good Agriculture Practice.

We welcome the government's proposals for a Clean Air Strategy. Clean air is the first of the 10 major goals set in the 25 Year Environment Plan, which contains important commitments: curbing emissions from combustion plants and generators, ending the sale of new conventional petrol and diesel cars and vans by 2040, and improving industrial emissions further by building on existing good practice and the successful regulatory framework. These commitments will help with the Plan's pledge to deliver UN Sustainable Development Goals (in particular Goal 11: to make cities inclusive, safe, resilient and sustainable), by helping to achieve better air quality in England.

The Environment Agency is committed to driving down pollution through our regulation, in our own activities (by improving energy efficiency and reducing travel), and by producing State of the Environment reports to help everyone understand the environment as it is now, so we can all collaborate more effectively to improve it.

Thank you to my colleagues for their work on this report.

Emma Howard Boyd, Chair of the Environment Agency

Key findings

- Emissions and concentrations of most air pollutants have decreased in recent decades.
- Legal limits are currently being met for the majority of pollutants, but concentrations of nitrogen dioxide (NO_2) are a significant exception to this and there are many urban locations where NO_2 limits are being breached.
- Particulate matter ($PM_{2.5}$ and PM_{10}) and ozone are within legal limits but remain at levels of concern for human health in many locations.
- Air pollution related deaths remain at an unacceptably high level, with 5.3% of total mortality attributable to particulate pollution alone in 2016.
- Of England's nitrogen-sensitive habitats, 95% are adversely affected by nitrogen deposition (a 3% reduction since 1996).
- Of England's acid-sensitive habitats, 59% are affected by acidification (a 17% reduction since 1996).
- Emissions of some pollutants such as ammonia and non-methane volatile organic compounds (NMVOCs) are predicted to increase slightly over coming decades if further action is not taken.
- Emission reduction targets for 2030 will not be met for ammonia, nitrogen oxides (NOx), NMVOCs, sulphur dioxide (SO_2) and $PM_{2.5}$ under current projections without further action.

Contents

Air quality and society

Air quality has been a recognised issue in England for hundreds of years, and the causes of air pollution have been a focus of investigation since the 13th century.[1] The industrial revolution brought about emissions to air on a large scale. The greatest changes were caused by dense populations burning wood and coal, and the industrialisation of chemical manufacturing in the 19th century. Hydrochloric acid gas emissions from the production of sodium carbonate used in paper, soaps, glass and detergents were a major issue. The subsequent impact on the environment, including severe damage to plants, led to the Alkali Act of 1863.[2] This provided the foundation of air pollution policy in the UK for the next 100 years.

The Great Smog of 1952 in London and its associated deaths encouraged a Private Members Bill in Parliament that led to the Clean Air Act 1956.[3] In combination with the transition from coal to gas for energy production, legislation has forced improvements in industrial emissions. Road transport has now become a major source of air pollution. This is because of increased use of vehicles powered by fossil fuels over the second half of the 20th century and beyond. Legislation has phased out the use of lead in petrol, and new technologies, more efficient engines and legislation to require their use have reduced vehicle emissions of other pollutants in recent years.

Scientific knowledge and understanding of the impacts of air pollution has increased over the past few years and this has raised the public and media profile of air quality issues. This report aims to clarify and outline the state and trends in atmospheric concentrations of the main air quality pollutants in England. It also covers the societal, environmental and economic impacts, and current and future pressures on the quality of the air we breathe.

Causes of air pollution in England

Air pollution is produced by natural sources and human activities. Many gases such as ozone and nitrogen oxides (NOx) exist naturally, along with particulate matter such as pollen and dust. Natural events such as volcanic eruptions and forest fires contribute to air pollution. Sources associated with human activity include:

- combustion of fuels for heat and power
- agriculture
- industrial processes and manufacturing
- transport

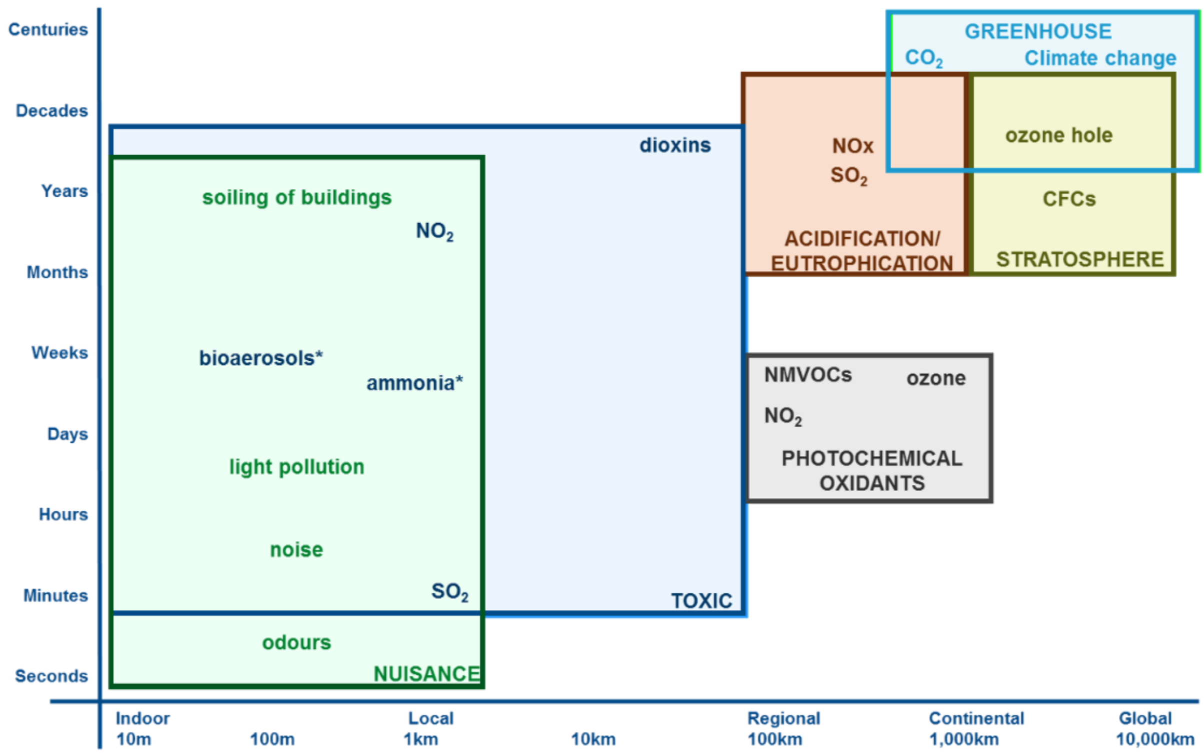
Impacts of air pollution

The impacts of air pollution vary spatially, from very localised (to within a few metres of the source), to regional and even global scales. Odours from air pollution can last for seconds while some air pollutants such as chlorofluorocarbons (CFCs) will damage the environment for decades or even centuries. We can group pollutants into 'impact categories' such as 'nuisance' or 'toxic'. Some pollutants fit into more than one category. For example sulphur dioxide (SO_2) has almost immediate toxic effects on human health, as well as longer term effects on the environment via acidification at much larger spatial scales (figure 1).

This report focuses on air pollutants in the toxic, photochemical oxidants and acidification/eutrophication impact categories. It does not cover indoor air pollutants.

Figure 1

Example air pollutants and their impacts over distance and time



*ammonia and bioaerosols impacts are less well understood

Health impacts

Poor air quality has different effects on health depending on the type and concentration of the pollutant, and exposure time. Health issues linked to air pollution include damage to the cardiovascular and respiratory systems (table 1).

Table 1: Health impacts and main sources of key air pollutants

Pollutant	Main source (UK, 2016)[4]	Health effects[5]
Sulphur dioxide (SO_2)	Combustion for energy generation (37%)	Restricts respiratory functions. Aggravates existing illnesses such as asthma and bronchitis, even after very short-term exposure.
Nitrogen oxides (NOx, including NO_2)	Transport (49%)	Short term exposure to high concentrations can cause inflammation of airways. Longer term exposure exacerbates asthma and bronchitis and reduces lung function. Emerging studies have associated NO_2 with increased risks of colorectal cancer[6] and heart attacks.[7]
Particulate matter (PM)	Domestic combustion ($PM_{2.5}$, 40%)[8]	Can irritate the lungs and cause breathing problems. Chronic exposure increases the risk of cardiovascular and respiratory disease, and lung cancer. One recent study suggests that living in areas with higher $PM_{2.5}$ may increase the risk of kidney and bladder cancers.[6]
Ozone (O_3)	Created by photochemical reaction between NOx and non-methane volatile organic compounds (NMVOCs) from vehicles, solvents, household chemicals and industry.	Irritates lungs and causes breathing problems. Irreversible damage can be done to the respiratory system if levels are very high.
Ammonia (NH_3)	Agriculture (88%)	Irritates eyes, nose and throat.[9] Also has impacts related to the formation of secondary pollutants such as $PM_{2.5}$.

Around 40,000 deaths per year in the UK can be attributed to air pollution.[10] There is some uncertainty around this number, because of the difficulty in determining increased risks and the effects of different pollutants.[11] Air pollution is linked to cancer, asthma, stroke and heart disease and associations have been found with diabetes and obesity.[10] In addition it may affect both our susceptibility to infections and the effectiveness of the antibiotics used to treat them.[12] There is also a growing body of evidence to suggest that air pollution affects brain development before and after birth, and exacerbates cognitive decline in elderly people.[13]

Persistent organic pollutants (POPs) are present in the environment at very low concentrations, but are highly toxic and persistent. They accumulate in food chains and can travel long distances. Dioxins, a type of POP, are among the most toxic chemicals known, and can be carcinogenic to humans.[14]

The most vulnerable in society are children, the elderly and people with pre-existing health conditions.[10] Children who live in highly polluted areas are 4 times more likely to have significantly reduced lung function as adults.[10] Health impacts of air pollution can persist for over 30 years after exposure.[15] The poorest members of society are also often affected most by air pollution. For example, London schools that have more pupils from deprived neighbourhoods tend to be in the areas most affected by air pollution.[16]

Reductions in the health impacts of air pollution lag behind emissions reductions.[17] A health outcomes indicator for air pollution (fraction of mortality attributable to particulate air pollution) is calculated for each local authority in England. It is based on modelled concentrations of $PM_{2.5}$. The fraction of mortality attributable to particulate air pollution in England was 5.3% in 2016.[18] The north-east has the lowest values. London has consistently higher values than the average for England.

Environmental impacts

Air pollution can negatively affect natural habitats, ecosystems and processes, and plants and animals. Serious environmental impacts of air pollution occur as a result of nitrogen deposition, acid deposition and direct toxic effects of pollutants in the air. Ozone can be toxic to plants, and contributes to smog in cities which can harm wildlife and domestic animals.[19]

Nitrogen deposition

Nitrogen deposition is one of the main threats to worldwide biodiversity, alongside climate change and habitat destruction.[20] Manure management on livestock farms, manure applied to soils, and nitrogen-based fertiliser application produce high emissions of ammonia. In some urban and industrial areas, NOx emissions from road transport and other combustion sources are high. These air pollutants are transported, react chemically in the atmosphere and are then introduced into habitats through deposition.

Increased levels of nutrients in watercourses encourage plant growth, leading to problems such as algal blooms which reduce light and oxygen levels. This process, known as eutrophication, affects ecosystems, killing fish and altering plant communities.

Increased nitrogen deposition to land can alter the composition and diversity of plant communities, for example by favouring certain plants such as grasses which then outcompete nitrogen sensitive species. [21] In turn this affects the diversity of wildlife. This can be a serious threat to protected habitats and conservation areas. Nitrogen deposition also damages the growth of lichens, which are very sensitive to air pollution. They are recognised worldwide as useful indicators of air quality.[22]

Nitrogen and sulphur compounds can also react with water in the air or soil to have an acidifying effect on the soils. Acidification of soils alters nutrient cycles and damages plant growth. [21]

Of England's nitrogen-sensitive habitats, 95% are adversely affected by nitrogen deposition, a 3% reduction since 1996. Of England's acid-sensitive habitats, 59% are affected by acidification, a 17% reduction since 1996.[23]

Toxic effects on plants and animals

Many atmospheric pollutants, such as ammonia and ozone, can cause damage to plants. Ammonia harms sensitive plant and lichen species through leaf discolouration, bleaching and algal overgrowth. Plants weakened by ammonia or ozone are also more susceptible to attack by pests and diseases.[24] Ozone enters the leaves of plants and causes reduced growth, and, at high levels, visible injuries.[25]

POPs accumulate in the fatty tissues of animals and are concentrated as they pass up the food chain. This means that predatory animals and humans are most susceptible to their toxic effects.[14]

Economic impacts

Health costs associated with particulate matter and NO_2 alone have been estimated to be around £22.6 billion each year.[10] Health problems in children affect their education and can lead to lower earnings in adult life. Poor health associated with, or exacerbated by, air pollution leads to days off work and reduced productivity.

Ozone reduces agricultural productivity by damaging crop plants and reducing yields. This negatively affects both the rural economy and businesses that rely on successful crops. Smog reduces visibility, which can reduce the commercial and recreational use of affected areas.[26] Other pollutants can damage buildings and historic venues, reducing tourism and its associated income.

Sources, state and trends

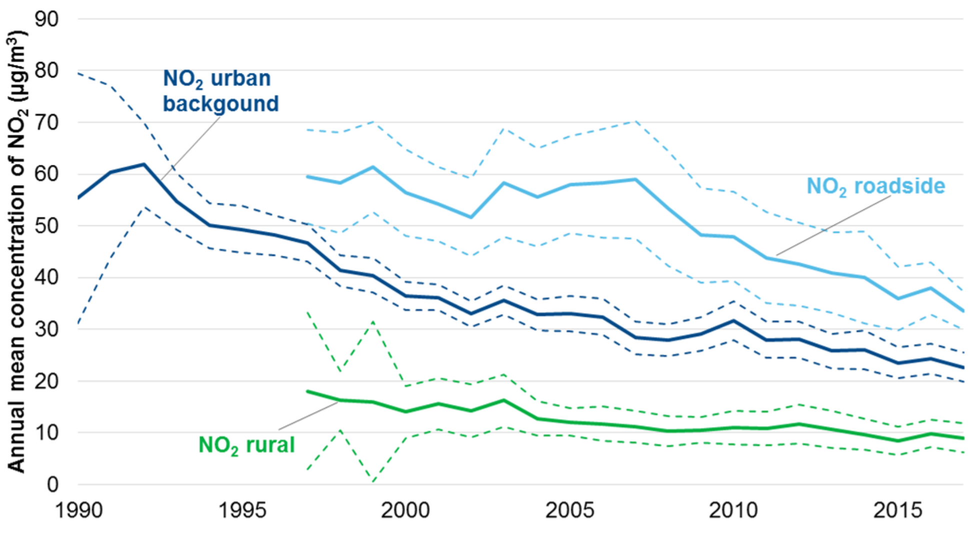
As part of efforts to demonstrate compliance with EU and UK regulatory limits and targets, air quality is monitored with a network of automatic monitoring sites. NO_2 and ozone are of particular current concern because their levels are in breach of regulatory limits or long-term objectives in some locations. In rural areas, high ammonia concentrations are contributing to deposition of nitrogen to land, causing widespread long-term harm to sensitive habitats.

Nitrogen oxides (NOx)

NOx, including NO_2, are emitted by transport and by combustion processes at industrial installations, including power stations. Annual average urban background NO_2 levels decreased between 1990 and 2017 (figure 2),[27] as did levels at roadside locations between 1997 and 2017 (data are not available before 1997).

Figure 2

Annual average NO_2 levels in England, 1990 to 2017 (dashed lines represent 95% confidence intervals)



Data source: DEFRA.

There has also been a declining trend at rural background sites between 1997 and 2017. The declines are linked to reductions in transport emissions.

Many locations in 28 of England's 31 air quality reporting zones breached the EU annual mean NO_2 limit values in 2016.[28] These were mainly in urban areas and at the kerbside of major roads. One air quality reporting zone (Greater London Urban Area) also had locations where EU one-hour limit values set for the protection of human health were exceeded on more than the permitted 18 occasions.

Particulate matter (PM_{10} and $PM_{2.5}$)

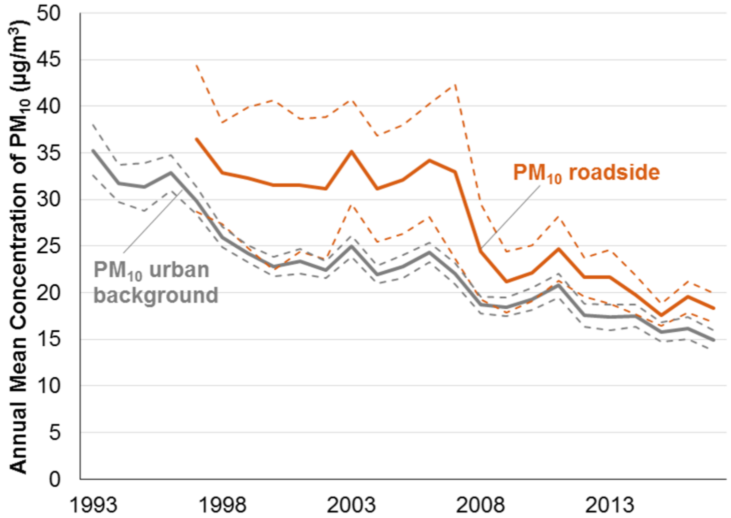
Particulates consist of small airborne particles, such as soot, dust or secondary aerosols formed by chemical reactions in the atmosphere.

PM_{10} refers to particles less than 10 micrometres in diameter, and $PM_{2.5}$ to those smaller than 2.5 micrometres. The primary source is combustion in vehicle engines, homes, industrial processes and commercial premises. Particulate pollution is worse in urban than in rural areas.

Both roadside and urban background levels of PM_{10} have been in decline since the 1990s (figure 3).[27] The long-term decrease can be attributed to improved vehicle emissions standards. The decline slowed after 2002. A similar trend can be seen for $PM_{2.5}$ (figure 4)[27] between 2009 and 2017 (data was not available before 2009).

Figure 3

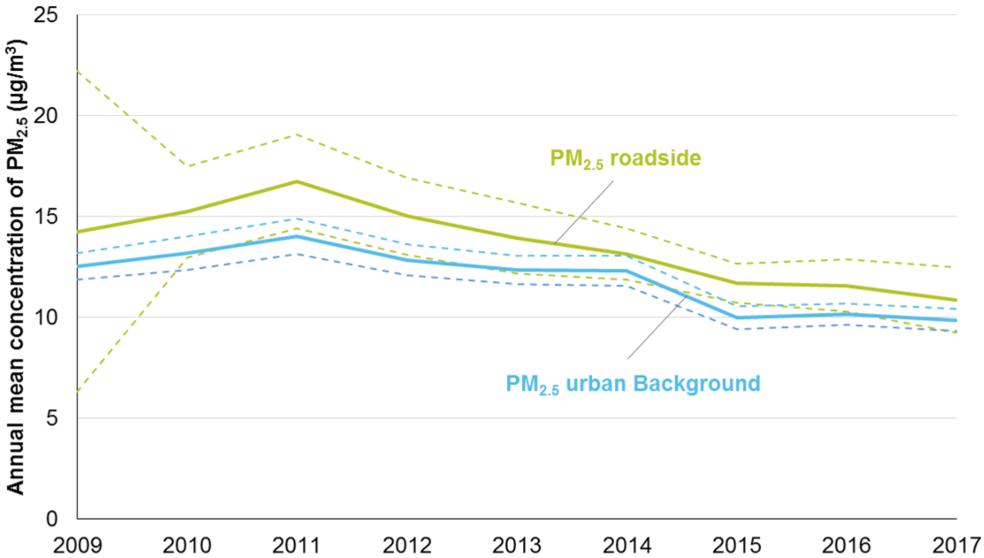
Annual average PM_{10} levels in England, 1993 to 2017 (dashed lines represent 95% confidence intervals)



Data source: DEFRA.

Figure 4

Annual average $PM_{2.5}$ levels in England, 2009 to 2017 (dashed lines represent 95% confidence intervals)



Data source: DEFRA.

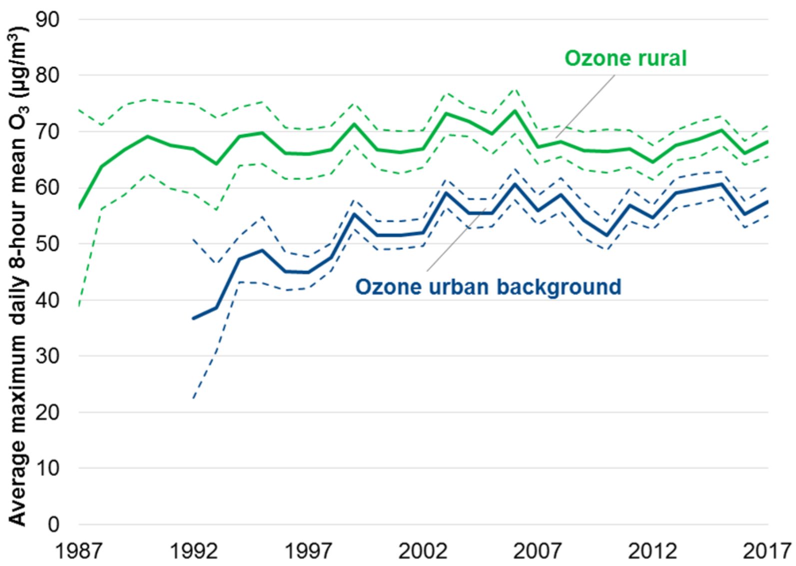
Annual average particulate levels were below EU limit values in all air quality reporting zones in 2016.[28] Adverse health impacts are still detected at concentrations below these limits.[10] Annual average $PM_{2.5}$ levels measured in 31 of 54 English towns and cities listed in the World Health Organization (WHO) air pollution database are above the health-based guidelines that they recommend.[29] $PM_{2.5}$ was the main cause of days of moderate or higher pollution in urban areas in the UK in 2017.[30]

Ozone (O_3)

Ozone is produced by chemical reactions in the atmosphere between other pollutants in the presence of sunlight. It is not emitted from any source in significant quantities. Ozone levels are highest in the summer on hot, sunny, windless days. Ozone can travel long distances, and ozone levels in England are influenced by transboundary pollution from Europe and beyond.[31]

Figure 5

Annual average ozone levels in England, 1987 to 2017 (dashed lines represent 95% confidence intervals)



Data source: DEFRA.

Annual average urban background ozone pollution increased between 1990 and around 2003, after which levels remained relatively stable (figure 5).[27] One of the factors contributing to those increases is that emissions of NOx, which remove ozone from the air under certain circumstances, have declined.

Annual average rural ozone has shown no clear long-term trend, but is consistently higher than levels in urban areas, because of lower vehicle NOx emissions. There were no breaches of EU ozone target values in 2016, but all 31 air quality reporting zones in England exceeded the long-term objective for ozone set for the protection of human health.[28] Three zones also exceeded the long-term objective for ozone set for the protection of vegetation. Ozone was the main cause of days of moderate or higher pollution in rural areas in 2017.[30]

Sulphur dioxide (SO_2)

SO_2 is an acid gas created by burning fuels containing sulphur. The main source is industrial emissions. Annual average SO_2 levels in the UK have decreased significantly since 1992 at all UK long-term monitoring sites and were below the EU limit value in 2016.[28] This reflects large reductions in the amounts of coal and fuel oil being used for energy generation and other purposes.[32] However, there are still occasional breaches of short-term objectives for SO_2 in some locations.[33]

Metallic pollutants

Metallic pollutants are emitted during fuel combustion and in dust from industrial processes. Metallic pollutants monitored in the air include lead, cadmium and nickel. Annual average levels of lead and cadmium have both reduced by more than half since 2004.[28] Where regulations exist, metallic pollutants are generally below EU target and limit values. Nickel levels exceeded EU target values in some industrial areas in 2016, but there was no clear trend between 2004 and 2016.[28]

Ammonia (NH_3)

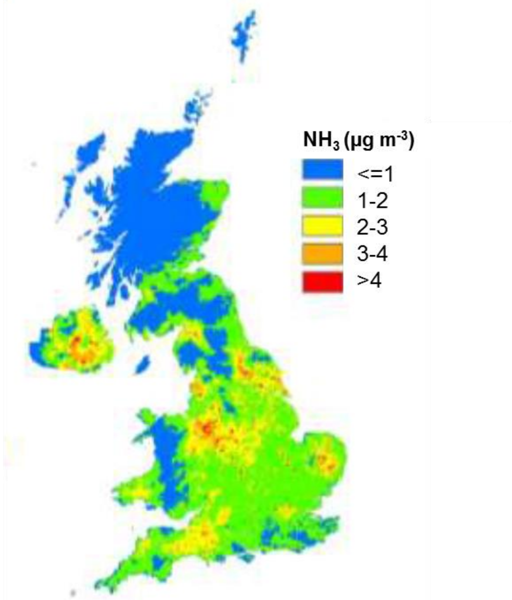
Ammonia is a colourless gas with a pungent smell. Concentrations vary across the UK (figure 6), with higher concentrations and deposition levels associated with areas of intensive livestock production, especially dairy and beef.[24]

Atmospheric ammonia decreased slightly (6%) between 1998 and 2014 in the UK.[34] However this decrease is smaller than might be expected in comparison with ammonia emissions, which decreased by 16%. This is partly because of reductions in SO_2 emissions over the same period, which have altered the make-up of the atmosphere, increasing the time that ammonia remains in the air. Ammonia emissions in the UK have increased by 10% since 2013.[8]

Ammonia concentrations exceeded the critical level for less sensitive plant groups across 4% of England's land area in the period 2013 to 2014. For the more sensitive lichens and bryophytes the figure was 84%.[35] Critical levels are the atmospheric concentrations above which certain organisms are damaged.

Figure 6

Ammonia concentrations in the atmosphere 2011 to 2013



Source: Hall, J. and others. (2017). Defra Contract AQ0843: Trends report 2017: Trends in critical load and critical level exceedances in the UK.

Persistent organic pollutants (POPs)

POPs are synthetic chemicals, many of which are used as pesticides, solvents and pharmaceuticals. They include polychlorinated biphenyls (PCBs), dioxins, dibenzofurans and polycyclic aromatic hydrocarbons (PAHs). PAHs are a large group of toxic and carcinogenic compounds. The main sources of PAH emissions to air are the domestic combustion of coal and wood, outdoor fires and some industrial processes.[28]

Benzo[a]pyrene is one of the more toxic PAHs and is monitored as a 'marker' for the group. Annual average benzo[a]pyrene levels in the UK reduced by more than half between 2008 and 2016.[28] Ambient concentrations of most other POPs have decreased significantly since 1990. These reductions are linked to regulations introduced to industries such as iron, steel, chemicals and waste during and since the 1990s.[36]

Annual mean benzo[a]pyrene levels in all but one monitoring location in England were below EU target values in 2016.[28]

Non-methane volatile organic compounds (NMVOCs)

NMVOCs are a group of chemicals that come from a variety of sources. Vehicle emissions and household chemical products are key sources. A recent study found that around half of all NMVOC emissions in industrialised cities come from the use of substances such as adhesives, printing inks, cleaning agents and personal care products.[37] Some NMVOCs contribute to ozone formation. Others, such as benzene and 1,3-butadiene are carcinogens.

Benzene is produced in vehicle emissions, and from domestic and industrial combustion processes. Background benzene levels fell sharply between 2004 and 2008, since when there has been little change.[28] This decline is linked to the introduction of catalytic converters in cars in the 1990s. EU limit values for benzene were not exceeded in 2016.[28]

1,3-butadiene is also produced in vehicle emissions. Levels of 1,3-butadiene are not covered by any EU directives. Objectives for 1,3-butadiene are set by the UK, and were not exceeded in 2016.[28]

Pressures on current and future air quality

There are pressures on air quality in both rural and urban areas. Some current pressures such as energy production from coal burning are likely to reduce in future and others, such as agriculture, may increase. A growing population will mean more demand for transport, food and energy production, with associated pressure on air quality.

Legislative and regulatory tools, market forces and changes in society's behaviour will all be needed to improve air quality in England. Great reductions have been made in emissions through tighter regulation of industry, and with the introduction of cleaner, more efficient car engines and fuels. Between 1970 and 2016, emissions in the UK of:[4]

- NOx reduced by 72%
- PM_{10} reduced by 73%
- SO_2 reduced by 97%
- NMVOCs reduced by 66%

Although the majority of air pollutant emissions are projected to continue to decrease in future decades, ammonia and NMVOC emissions are likely to increase slightly between now and 2030, if actions are not taken to reduce them.[38] Without new policies and commitments to reduce air pollution, it is expected that emissions ceilings for NOx, SO_2, NMVOCs, $PM_{2.5}$ and ammonia will be breached by 2030.[39] As a result, the health and environmental impacts associated with these pollutants will continue to be felt.

Emerging pollutants such as nanoparticles and microplastics are being detected in the air in some European cities. Research is needed to understand the possible health and environmental impacts of this, and whether regulatory intervention is required in the UK.

Industrial emissions

Industrial emissions from the industries the Environment Agency regulates account for 28% of NOx, 60% of sulphur oxides (SOx) and 16% of PM_{10} emitted in England.[40] The main industry affecting air quality is energy production. Reductions in the use of coal, improved gas scrubbers and the use of new technologies such as renewables have contributed in large part to the reductions in emissions of NOx, SOx and particulate matter in recent decades.

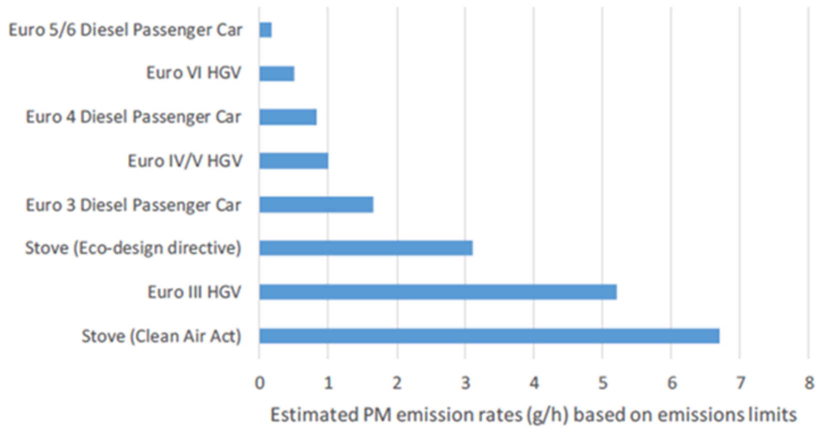
New energy industries may bring additional air quality challenges. A study has shown that the development of onshore oil and gas sites may lead to localised increases of some pollutants, for example methane (CH_4), NOx and NMVOCs.[41] Regulation will help to minimise emissions.

Household wood burning

Wood burning has become one of the biggest sources of air pollution in cities. Wood burning accounts for between 23% and 31% of $PM_{2.5}$ emissions in Birmingham and London.[42] Emissions from the combustion of wood include particulates and gases such as carbon monoxide, carbon dioxide, NOx, NMVOCs and SOx. POPs such as PAHs and dioxins are also present depending on the quality of the wood. Emissions from wood burners are highly variable depending on the fuel and burning conditions.[43] Many 'low emissions' wood burners produce more pollution than their laboratory tests indicate.[44] Many stoves can emit more particulates per hour than a diesel car (figure 7).[45] In London in 2014, 68% of wood-burning appliances were open fires.[46] It is illegal to burn wood on open fires in the many parts of the UK designated as smoke control areas.[47]

Figure 7

Estimated PM emission rates from a 5 kW stove compared to typical rates from vehicle exhausts (based on emissions limits)



Source: Air Quality Expert Group. (2017). The potential air quality impacts from biomass combustion. © Crown copyright.

Transport

Vehicles emit a range of air pollutants. Improved engines and emission standards have helped bring about the reductions in NOx emissions seen in recent decades. The use of catalytic convertors aided the decline in emissions of NMVOCs. Reduction of sulphur in fuels has contributed to a decline in SO_2 emissions from the transport sector. The reduction and eventual removal of lead from petrol contributed to a 98% decrease in lead emissions in the UK between 1990 and 2016.[48]

Despite tighter emissions standards, a rise in diesel vehicle numbers has held back further improvements. In addition, some vehicle manufacturers were recently found to have fitted new vehicles with defeat devices to ensure they passed laboratory emissions testing. The actual emissions of these vehicles exceeded legal requirements. Some diesel vehicles in England have also had their particulate filters removed. Diesel particulate filters remove around 30% to 95% of particulates from exhaust emissions.[49] It is illegal to drive a diesel car that has had the particulate filter removed.

Emissions from road traffic, including the non-exhaust component (for example brake and tyre dust), make a significant contribution to the urban background level of particulates. In 2017 road transport contributed an average of 80% of NOx emissions in areas where limits were being breached.[50]

Electric and hybrid vehicles produce atmospheric pollutants in much lower amounts than petrol and diesel cars. However, more than 90% of particulate emissions from conventional petrol and diesel vehicles can come from non-exhaust sources such as tyre wear, brake pads, and road particles. This is higher for electric and hybrid vehicles because they are heavier. This means that their total particulates emissions are comparable with those of conventional vehicles, even when brake wear is not included.[51] Indirect emissions also occur from the generation of the electricity for charging.

Shipping and air travel also contribute to air pollution. The UK is close to major shipping lanes and has many busy ports. The shipping sector makes a large contribution to NOx, SO_2 and particulate concentrations.[52] Commonly used shipping fuels can produce emissions of a wider range of pollutants at higher concentrations than diesel fuels.[53] Areas most affected are the Channel, along the south and east coasts, and the Thames estuary. A recent study in Sweden[54] found that almost half of all $PM_{2.5}$ in coastal air samples was from shipping activity.

Aircraft emit NOx, particulates and NMVOCs. Major airports can contribute to NO_2 hot-spots that breach annual EU limits.[55] This is caused mainly by increased road traffic, with a contribution from aircraft emissions.[56] In Europe a total of 3,700 deaths per year are attributed to aircraft-related exposure to $PM_{2.5}$ and ozone.[57] With numbers of air passengers in the UK predicted to more than double by 2050, careful regulation of related emissions will be required.

Transboundary pollution

UK air quality is affected by pollutants from overseas (and vice versa). Emissions of pollutants such as ammonia, NOx and SO_2 from the UK and mainland Europe often undergo chemical reactions in the atmosphere to produce secondary particulates over a large area. Under certain weather conditions, up to 50% of $PM_{2.5}$ concentrations in some parts of the country can come from sources outside the UK[39] and such events can push annual averages close to legal limits.[58] UK emissions of ozone-forming substances have decreased, but ozone and its precursors arrive in England from Europe, North America and other parts of the world. This contributes to ozone problems in both rural and urban areas in the UK.[30]

Agriculture

The agricultural sector is the largest source of ammonia emissions. In 2016, 88% of all ammonia emissions in the UK were from agriculture.[4] Manure management on livestock farms (41%, of which almost three-quarters comes from cattle), manure applied to soils (24%) and nitrogen-based fertiliser application (22%) are the main contributors to the agricultural total.[8]

Excessive fertiliser use also leads to the release of nitrous oxide (N_2O), a highly potent greenhouse gas, which also contributes to stratospheric ozone depletion.[59]

Emissions of bioaerosols, mainly from intensive livestock housing and using manure and slurry, are an emerging concern for localised air quality and human health impacts.[60] Bioaerosols are airborne particulates of biological origin, such as bacteria and fungal spores. There are currently no regulations covering emissions of bioaerosols in England. There are only guideline levels aimed at protecting human health.

Non-road diesel use

Non-road machinery uses 15% of diesel used in the UK. It is used across a range of sectors, including rail, shipping, agriculture, stationary combustion sources such as generators and boilers, and a range of non-road mobile machinery (including construction, mining, and airport support vehicles). In 2016 non-road diesel use accounted for 21% of emissions of NOx and 7% of fine particulate matter.[39] Use of diesel generators is increasing and is already a significant source of air pollution.[61]

Climate change

A changing climate will have an impact on the emissions entering the atmosphere and the behaviour and transport of pollutants.[62] Increasing temperatures could lead to more air pollution events such as increased occurrences of smog. A warmer climate may increase emissions of ammonia from agriculture and natural sources, and levels of nitrogen deposition.[63] This is partly because ammonia is released into the air more readily at higher temperatures.

Policies for dealing with air quality and climate change have generally been developed separately, leading to unintended effects on air quality. For example, incentives for using carbon-neutral fuels such as wood to reduce climate change lead to increased emissions of NO_2 and particulates.[45] Diesel cars, which emit less carbon than petrol cars, have also had the side effect of increasing emissions of NO_x and particulates. Some carbon capture and storage technologies can produce emissions of ammonia and potentially toxic substances such as nitramines.[64]

Emerging pollutants

Technological developments have made ultrafine particles (airborne nano-scale particulate matter with a diameter of 1 to 100 nanometres) easier to detect, leading to greater awareness of their effects on air quality. For example, carbon nanotubes are now known to be a component of the particulate matter emitted by both petrol and diesel engines.[65] They were found in the lungs of every child in a sample of 69 school children in Paris. There is some evidence to suggest that carbon nanotubes may cause similar immune reactions to asbestos.[66]

Microplastics are widespread in the water environment and have now also been found in the air we breathe. The smaller particles (less than 600 micrometres) are more likely to be airborne.[67] This means they can enter the lungs, potentially damaging health.[68] A study found atmospheric deposition of microplastics of 29 to 280 particles per m^2 per day in Paris.[67] The variation in concentrations was linked to rainfall events. Sources of airborne microplastics include synthetic textiles, erosion of synthetic rubber tires, and city dust.[68] A possible additional source of aerial microplastics is dust arising from the spreading of sewage sludge.

Looking ahead

We are all affected by air pollution, be it through the health, economic or environmental costs it brings about, and whether we live in cities or in the countryside. There have been significant reductions in levels of some pollutants in recent decades. However there is still much to be done, and a worsening picture for some substances, such as ammonia. These, and roadside pollutant levels from traffic must be urgently addressed. Our increasing scientific knowledge of what is in the air we all breathe means that we are uncovering new and emerging pollutants. Some of these come from familiar sources such as road transport, while the sources of others, such as microplastics, are less clear. With the right regulation in place it is not too optimistic to say that improvements made over past decades could continue, allowing people and the environment to look forward to a healthier future.

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