Parliamentary Office of Science and Technology

postnote

November 2006 Number 272 **(POSTnote 458 updates this POSTnote)**

AMBIENT AIR QUALITY

Ambient air quality, the condition of the air in the outdoor environment, directly affects the health of humans and ecosystems. National and European regulation has delivered improvements in UK air quality (see POSTnote number 188). Air pollution from major sources such as transport, power generation and industry, are now heavily regulated and declining. However, current air pollution levels continue to cause adverse impacts on human health and the environment, as summarised by this POSTnote.

Background.

European Legislation

EU air quality regulation has recently been reviewed as part of the development of a Thematic Strategy for Air Quality[1]. This aims to achieve air of the quality that minimises risks to both human health and the environment. It sets out a fifteen year programme for reducing key pollutant emissions between 2005 and 2020. A proposed directive entitled 'Ambient air quality and cleaner air for Europe' will replace the existing Air Quality Framework Directive and 3 of its 4 Daughter Directives (Box 1). Member States will be required to draw up plans and programmes to guarantee compliance with legally binding limit values for air pollutants over the period up to 2020.

National Legislation and Policy

The UK 1995 Environment Act required the development of an Air Quality Strategy for the UK and a system of local air quality management, setting legally binding air quality limit values for a number of air pollutants largely in line with European legislation (Box 1). The Department for Environment, Food and Rural Affairs (Defra) published an Air Quality Strategy Consultation in 2006, and will publish a revised strategy in 2007.

Local air quality management measures

In areas where concentrations of these air pollutants are predicted to exceed the given limit values, the Act requires the relevant local authorities to declare an Air Quality Management Area. Most Air Quality Management Areas are declared as a result of nitrogen dioxide or particulate matter levels. So far 192 UK local authorities have declared Air Quality Management Areas (AQMAs) and over half have produced action plans (box 2)[2].

Box 1 European legislation

The EU has a three-pronged approach to controlling air pollution:

- **Ambient air quality limit values**. In 1996, the Environment Council adopted the Framework Directive on ambient air quality assessment and management (96/62/EC). Four daughter directives (Directives 99/30/EC, 2000/69/EC, 2002/3/EC and 2004/107/EC) set either air quality limit values, or in some cases target values (a non-legally binding air quality objective), for specific air pollutants in the atmosphere
- **National annual emission limits for pollutants.** The UNECE Convention on Long- Range Transboundary Air Pollution and the National Emission Ceilings Directive (NECD), set national annual emission ceilings for various air pollutants.
- **Sector specific measures.** Emissions of air pollutants from the industrial sector are regulated mainly through the Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC) and the Large Combustion Plant Directive (2001/80/EC). Vehicle emissions have been controlled through a progressively stricter series of performance standards (Euro 1, 2, 3 and 4) and tighter fuel specifications including the reduction of sulphur content. Sulphur dioxide emissions from shipping are regulated through controls on the sulphur content of fuel, under Directive 2005/33/EC and, in the North Sea and English Channel, by Annex VI of the International Maritime Organisation's Marine Pollution Convention 73/78.

These will continue to be a key aspect of both reducing pollution in local 'hotspots' and implementing national measures. Technological innovations, like catalytic converters, can take a decade to penetrate the vehicle market due to rates of vehicle turnover. The measures listed in Box 2 can be used to ensure rapid market penetration of new technologies in problem areas. The low emission zone being implemented in London in 2008, will exclude all heavy duty diesel vehicles that do not meet Euro 3 standards (Box 1), and gradually impose more stringent standards over time. However, without nationally agreed criteria and standards for such schemes it remains possible that pollution problems can be exported to other areas with less stringent standards.

Box 2. Air Quality Action Plans
More than 110 local authorities have so far produced air quality action plans that are integrated into the Local Transport Plan where road transport is the major source of emissions. Common elements of plans include:

- Inclusion of air quality in relevant decision making processes e.g. land use planning;
- Working with relevant agencies, such as the Highways or Environment Agencies on emission reduction measures;
- Local traffic management measures to reduce emissions in problem areas e.g. low emission zones
- Strategies to inform the public of local air quality issues, to raise awareness and to change travel behaviours;
- Congestion schemes or workplace parking levies (the congestion charge zone in London has reduced the levels of particulate matter emitted from exhausts within the zone by ~12%[3], but was not introduced or designed as part of an action plan);
- Working with public transport partners to reduce bus and taxi emissions through technical fixes; and,
- Green travel schemes for council employees e.g. car sharing.

Issues

Air Quality and Human Health

The Clean Air for Europe (CAFE) Programme was set up to review the scientific basis of air quality regulation for the EU thematic strategy. CAFE commissioned a World Health Organisation review of the health effects of transport-related air pollution in Europe, which found evidence that exposure to air pollutants can affect human health in a variety of ways. These include respiratory illness and allergenic illnesses, heart disease, cancer, adverse pregnancy and birth outcomes and lowering of male fertility[4]. A recent report by the Committee on the Medical Effects of Air Pollutants (COMEAP), a panel of independent experts that advises the UK government, has concluded that there is a causal link between air pollutants and heart disease[5].

The limitations of air quality limit values
The most serious effects on health occur at the greatest frequency at the highest levels of exposure to air pollutants. Air quality limit values are set at levels which ensure this does not occur. However, the air pollutants particulate matter and ozone have no exposure threshold levels below which adverse human health effects do not occur. Although such thresholds can be established for individuals, the wide range of susceptibilities within a population, makes it impossible to define a more widely applicable threshold value (Box 3). As a result, the derived air quality limit values for 'non-threshold' air pollutants are arbitrary, as significant public health benefits could be obtained by reductions in the pollutants both above and below the set limit.

The key role of particulate matter (Box 4) and ozone (box 5) in producing adverse health effects is clear from epidemiological evidence. However, separating out the health effects of different pollutants is difficult, as humans are exposed to a mixture of these substances producing a set of common symptoms. For example, evidence from epidemiological studies on health impacts from nitrogen dioxide is not clear because these can be obscured by the health effects of particulate matter (the two pollutants are always encountered together). Hence, some air quality experts argue that air pollutants should be regulated on a total air health index basis rather than as individual substances.

Box 3. Susceptibility to Air Pollutants
The surface of the human lung is covered by a thin layer of fluid containing various defences to protect its cells from damage[6]. Once levels of air pollutants overwhelm these defences, the cells become damaged triggering an inflammatory response. Inflammatory effects can spread throughout the body, although in the case of particulates (Box 4), it is not clear whether this is the result of air pollutants directly entering the blood stream in the lung, local production of inflammatory factors or a combination of both. It has also been proposed that particulate pollutants can enter the nervous system through nerve endings in the nose, causing effects in the brain.

Factors that affect individual susceptibility to adverse health effects include age, health status, diet and genetic background. In particular, groups such as asthmatics or those with other pre-existing diseases (such as chronic obstructive pulmonary disease) may be more susceptible to an inflammatory response at lower air pollution levels. The most severe effects occur in the most susceptible individuals, and are reflected in the daily number of deaths occurring. Children are also particularly vulnerable as the process of lung growth and development continues until adolescence, and they have incomplete metabolic systems, immature immune defences and higher breathing rates than adults[7].

In addition, air quality limit values have previously been defined on the basis of acute effects. However, at lower exposure levels over many years, a proportion of the population may have an increased risk of chronic ill health effects later in life. The long term health effects of present levels of air pollution, including estimates of chronic health effects and mortalities brought forward, are the subject of a COMEAP report due to be published in two parts in 2006 and 2007.

Air Quality and the Environment

Criteria have been set at the EU level for the protection of vegetation and ecosystems from air pollutants in the form of 'critical loads' and 'critical levels.' Critical loads specify maximum rates of annual deposition of sulphur and nitrogen permissible while avoiding adverse effects from acidification of soils and/or freshwater systems; or from eutrophication, where excess nutrient nitrogen leads to the deterioration of ecosystems and loss of biodiversity. Critical levels are used to limit excess ozone concentrations, which can damage crop yields and forests.

The UK is currently projected to meet its National Emissions Ceiling Directive targets by 2010, although it is estimated that this will result in critical load exceedences for nearly half of the UK's sensitive ecosystems. Further action is therefore required, and since deposition can take place far from the emission source, this is a transboundary issue (across national or state boundaries). Sulphur dioxide and nitrogen oxides emissions in Europe (including the UK) have reduced sharply, whereas reductions in ammonia emissions, another source of nitrogen mainly from agriculture, have been modest. Hence ammonia is being seen as increasingly important as a pollutant requiring a strategic approach both in the UK and wider Europe; together with emissions of sulphur dioxide and nitrogen oxides from shipping.

Box 4. Particulate matter
By convention particulate matter (PM) is defined and measured by size:

- **Coarse particulates** ($PM_{10} – PM_{2.5}$) - particulates smaller than 10 μm (10 thousandths of a millimetre) in diameter but greater than 2.5 μm diameter. Coarser particulates arise from resuspended road dust, brake and tyre wear, construction, sea salt and soil particulates;
- **Fine particulates** ($PM_{2.5} – PM_{0.1}$) - particulates less than 2.5 μm diameter, which include most combustion particulates, such as those emitted from diesel engine exhaust. The Ambient Air Quality Directive will set a new limit value for fine particulate matter to replace an existing one for coarse particulate matter. This will set a mandatory air quality limit value and an exposure reduction target based on existing national levels to be achieved by 2020.
- **Ultrafine particulates** ($PM_{<0.1}$) - less than 100nm diameter (100 millionths of millimetre), which are emitted in large numbers from diesel engine exhaust.

Particulate matter has a wide range of sources and chemical constituents. Primary particulates are those directly emitted from a source, including combustion and mechanical sources. Secondary particulates are formed in the atmosphere as a result of chemical reactions between the constituent gases (ammonia and oxides of nitrogen or sulphur dioxide). Particulates evolve and mix in the atmosphere and may contain a range of substances including carbon, small amounts of ammonium sulphate or nitrate as well as metals, organic compounds or mineral components, depending on source.

It is likely that a range of particulate types, of different size and composition, exert health effects. The exact mechanisms by which this occurs have not been fully elucidated, although metal components in particulates (such as iron, vanadium, copper, zinc and nickel) may play a role. There is also evidence that exposure to ultrafine particulates from diesel exhaust both constricts blood vessels and inhibits the dissolving of blood clots, greatly increasing the risk of cardiac events in susceptible individuals[8]. On the basis of this evidence, air quality experts have criticised the new EU air quality limit value for fine particulates ($PM_{2.5}$) as being too weak.

The Defra Air Quality Strategy consultation proposes a new air quality objective that sets a target value for ozone (Box 5) to protect ecosystems and vegetation. Previously limit values have been set for sulphur dioxide and oxides of nitrogen alone, for this purpose, which now includes specific consideration of sites specially designated for conservation purposes, such as Sites of Special Scientific Interest and Special Areas of Conservation. The strategy consultation does not propose an air quality objective or standard for ammonia, mainly due to the lack of effective control techniques available. In contrast to other three air pollutants, ammonia is local pollutant deposited close to where it is emitted, at the farm or field scale.

Box 5. Ozone
The main air pollutant in rural areas, ozone, is not emitted directly but is formed through the reaction of volatile organic compounds and oxides of nitrogen (NOx) in the presence of sunlight, usually downwind of urban areas. Peak ozone episodes are therefore associated with summer heatwaves. In urban areas, nitric oxide emissions from traffic react with the ozone to form nitrogen dioxide, decreasing ozone concentrations. As emissions of all oxides of nitrogen from urban traffic are decreasing, rural levels of ozone are decreasing, offset to some degree by increasing levels of background ozone of transboundary origin. Conversely, lower levels of oxides of nitrogen in urban areas have decreased the rate at which ozone is destroyed, raising urban ozone levels. Although ozone objectives are being exceeded this pollutant is not part of the Local Air Quality Management system. High ozone levels raise levels of immediate mortality, as occurred during the heat wave in August 2003.

Future reductions in emissions

Current trends in air pollutants

The Air Quality Expert Group (AQEG) is an advisory group that provides independent scientific advice on air quality to Defra and the devolved administrations, in particular on the air pollutants contained in the Air Quality Strategy. AQEG extensively reviewed the levels and sources of airborne particulate matter in the UK for Defra in 2005[3]. Until 2000, there was a steady reduction in concentrations of particulates in UK cities, but since then, concentrations have levelled off despite regulations to decrease particulate emissions from diesel vehicles.

AQEG are producing another report on the rising trend in nitrogen dioxide concentrations at some urban locations in the UK[9]. The likely cause is technical changes to diesel vehicles that have increased the proportion of nitrogen dioxide to nitrogen oxides that they produce. Exhaust emission standards apply to the total oxidised nitrogen and not to this more harmful pollutant fraction. Despite these issues, Defra believe that the measures set out in the Air Quality Strategy consultation will allow all the relevant air pollutant limit values to be met in most places within the appropriate timeframe.

Vehicle emission abatement innovations

The fitting of catalytic converters to all new petrol-fuelled cars and limits on fuel sulphur content were highly effective in abating some transport related air pollutants between 1990 and 2001. Further innovations in diesel vehicles will still deliver cost effective benefits (Box 6). However, emissions from the transport are now heavily regulated; of 15 measures proposed in the Defra consultation 11 are solely applicable to road transport.

There are also issues over the lifespan and maintenance of technical solutions, as well as unintended impacts. Since the widespread adoption of catalytic converters platinum accumulations up to 90-fold higher than natural background levels are being deposited on UK roads per year. Few data are available to indicate whether such levels could have environmental impacts.

Box 6. Diesel emission reduction technologies

Under the Euro 5 standards currently under negotiation (to be implemented in September 2009), particulate matter emissions from light diesel vehicles would be further reduced below 5mg emitted per km travelled. The Commission has also proposed introducing a limit on the total number of solid particulates emitted during Euro 5. This is a far more sensitive measurement that gives a high degree of confidence that emissions of ultrafine particulates will be effectively controlled. To meet these requirements diesel particulate traps that reduce particulate emissions to negligible levels will need to be fitted. Similar emission reduction proposals for heavy duty diesel engines (in buses and lorries) under Euro 6 (September 2010) are awaited.

Many diesel particulate traps oxidise nitric oxide to create nitrogen dioxide to react with particulates, thereby increasing the proportion of nitrogen dioxide emitted. The likely technical solutions for reducing emissions of oxides of nitrogen include oxides of nitrogen absorbers and selective catalytic reduction. There are potential maintenance or lifespan issues with these technologies. Such technologies could achieve a 50-75% reduction in oxides of nitrogen on light duty vehicles, but are costly (£500+) and complex solutions.

Climate change and air quality

Climate change and air quality are linked, through both similar atmospheric processes and emission sources. A recent report by AQEG on climate change and air quality[10] has examined the risks in not addressing the synergies between these areas. Measures to decrease air pollutants can exacerbate climate change and vice versa. For example, proposed emission reduction measures for diesel vehicles (Box 6) will increase carbon dioxide emissions by 3%. Similarly, the widespread planting of willow coppice for biomass energy could increase levels of ozone pollution, as willow emits the volatile chemical isoprene which can increase the formation of ozone in the atmosphere (Box 5). There are, however, also possible complementary measures, with some future energy scenarios generating both lower levels of green house gases and air pollutants. The report suggests a more integrated policy approach is required involving a combination of technical solutions and behaviour change. Influencing behaviour would require an appropriate regulatory framework, that provides incentives to favour complementary options such as reduced car use or increased domestic energy efficiency.

Exposure Reduction

The universal and mandatory application of air quality limit values concentrates resources on reducing pollutant levels in areas of the worst air quality, usually ‘hotspots’ in urban centres, rather than reducing exposure of the population as a whole. The Defra Air Quality Strategy consultation proposes to achieve maximum long term health benefits for non-threshold pollutants by ensuring an overall reduction in mean exposure of the general population. This entails a progressive closure of the gap between natural background levels of air pollution and the current level of exposure, such as the suggested exposure reduction targets for fine particulate matter (Box 4).

However, each tonne of emissions reduction achieved will be progressively more expensive, once all the largest pollution sources have been regulated. A more integrated policy framework will be required to address the diversity of smaller pollution sources. In addition, effective controls will be needed to reduce regional levels of air pollutants to improve ambient local air quality. For example, most ozone in the UK originates outside national boundaries, and emissions of nitrogen oxides and sulphur dioxide from shipping are expected to outstrip land based emissions by 2020.

This may require the imposition of emission reduction requirements and integration of policy responsibilities and decision making throughout the different levels of government. Such a holistic approach could also be cost effective by delivering objectives across policy areas. For example, measures encouraging bicycle use over vehicle use would contribute towards meeting public health targets, as well as air quality and climate change targets.

Overview

- Recent reviews and reports have found evidence for substantial health and environmental impacts from air pollutants at lower levels than had previously been assumed.
- Future ambient air quality policy will aim to deliver health benefits across the population rather than concentrating on areas that breach limits
- Air pollution can no longer be controlled through local and national controls of emissions alone, and further international controls are required.
- Although existing local controls will need to be retained, a more innovative regulatory framework based on holistic integrated policy approaches may be required to deliver further improvements.

Endnotes

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