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POSTNOTE

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Ambient Air Quality

National and European regulations have improved UK ambient air quality. However, current air pollution levels continue to harm human health and the environment. This POSTnote summarises the evidence for effects of air pollutants and policies to address them.

Overview

- Ambient air refers to the outdoor air.
- Exposure to air pollutants affects human health in a variety of ways, reducing life expectancy and quality of life and increasing healthcare costs.
- The 2008 EU Air Quality Directive set legal limits for air pollutants to be met by 2010. The UK did not meet some of these limits.
- As air pollutants may originate outside UK borders, local and national controls alone may be insufficient to address air pollution.
- To achieve reductions in air pollution cost effectively, approaches are needed that address different objectives across areas such as planning, transport and health.

Background

Poor ambient air quality is projected to be the world's leading environmental cause of mortality by 2050, ahead of dirty water and lack of sanitation.[1] Exposure to air pollutants can affect human health in a variety of ways, causing or exacerbating conditions such as respiratory illness, asthma, allergenic illnesses, diabetes, heart disease, cancer, adverse pregnancy and birth outcomes, and a lowering of male fertility.[2] In 2011, the Environmental Audit Committee noted that the costs to UK society from poor air quality are on a par with those from smoking and obesity,[3] reducing life expectancy on average by six months at a cost of around £16 billion per annum.[4]

The health effects of air pollutants range from acute (short term effects caused by high levels of pollutants) to chronic (from long term exposure). The 2008 Ambient Air Quality Directive (2008/50/EC) uses WHO recommendations to set legally binding limits for concentrations of major pollutants that seek to minimise acute effects. However, these limits do not protect against the chronic effects associated with long term exposure.[5] The wide range of susceptibilities within a population to particulate matter (solid or liquid particles suspended in the atmosphere) and ozone makes it impossible to define widely applicable effects thresholds for these air pollutants (Box 1). While significant public health benefits could be obtained by reducing concentrations of these pollutants, the existing WHO guidelines have yet to be achieved, with over 90% of Europe's urban population exposed to concentrations of fine particulates (Box 2) that exceed the guidelines.[6]

Air pollution also has a significant effect on the environment:

- Deposition of sulphur (as sulphates) and nitrogen (as nitrate, ammonia and nitric acid) from air to the ground can affect vegetation and habitats by acidifying soils and freshwater systems. Nitrogen also causes eutrophication (where excess nitrogen as a nutrient leads to the deterioration of habitats and loss of biodiversity). The 'critical load' of pollution deposits is defined as the rate of annual deposition below which adverse effects are not known to occur for specified elements of the environment.
- Pollutants in the air can also have direct effects on vegetation and ecological processes. The 'critical levels' of gaseous pollutants are defined as the concentration above which adverse effects occur in types of vegetation. In the case of ozone, environmental conditions affect the amount of ozone taken up by plants, the 'Phytotoxic Ozone Dose', which is now the preferred basis for deriving critical levels of this air pollutant.[7]

Health Effects of Key Air Pollutants

Separating out the health effects of different pollutants is difficult, as humans are exposed to a mixture of these substances which can produce combined symptoms. For instance, evidence from epidemiological studies on the health effects of nitrogen dioxide is hard to interpret because of the confounding health effects of particulate matter; the two pollutants are usually encountered together.

Box 1. Susceptibility to Air Pollutants

The surface of the human lung is covered by a thin layer of protective fluid.[8] 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 particulate matter (Box 2), it is not clear whether this is the result of air pollutants directly entering the blood stream via 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 affecting the brain.[9]

Factors that affect individual susceptibility to adverse health effects include age, health status, diet and genetic makeup. 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 (all causes). Children are also particularly vulnerable as they have incomplete metabolic systems, immature immune defences and higher breathing rates than adults.[10]

WHO has argued that more research is needed to identify which of the complex combinations of air pollutants have the largest effect on human health.[2]

Given the difficulty of separating out the individual effects of air pollutants, the International Agency for Research on Cancer has classified ‘outdoor air pollution’ as a carcinogen. Diesel exhaust has also been classified as carcinogenic. Epidemiological and toxicological studies have also linked traffic related emissions to health effects, with elevated health risks associated with living in close proximity to roads.[2] The effects of some individual air pollutants on human health are briefly summarised below.

Particulate Matter

Particulate Matter (Box 2) includes:

- primary particles – those directly emitted from a source, including combustion and mechanical sources, such as traffic emissions
- secondary particles – those formed in the atmosphere as a result of chemical reactions between gases such as ammonia, nitrogen oxides or sulphur dioxide (Box 4).

Particulates of different size and composition exert a range of health effects (Box 2). There is a consistent, statistically significant association between long-term exposure to particulate matter and mortality. Exposure significantly increases the risk of cardiovascular and respiratory disease, with toxicological studies showing the inflammatory effects of particles (Box 1). There is also evidence of an association with diabetes, neurological development abnormalities and asthma in children.[2]

Nitrogen Oxides

Nitrogen Oxides (NOx) include nitric oxide (NO) and nitrogen dioxide (NO_2) emissions. Associations between nitrogen dioxide levels with cardiovascular and respiratory mortality have been shown. However, the biological mechanisms and impacts on susceptible groups, such as asthmatics, remain unclear.[2]

Ozone

Ozone is not emitted directly from any sources. It is formed through the reaction of volatile organic compounds with NOx in the presence of sunlight. Peak ozone episodes that raise levels of mortality are often associated with summer heat waves, as occurred during August 2003. The volatile organic compound involved in peak ozone episodes is usually isoprene, emitted by many tree species when temperature stressed. Some studies have associated long-term exposure to ozone is with respiratory illness, but most evidence is for acute respiratory and cardiac mortality in response to short-term exposure to high levels of ozone (Box 3).[2]

Box 2. Particulate Matter

Particles evolve and mix in the atmosphere and may contain a range of substances. Depending on the particle source, these may include carbon, as well as metals, organic compounds or mineral components. There is uncertainty as to how the components of particulate matter influence toxicity.[5] It is not known which particle properties, such as their size or the presence of specific chemical substances, are most responsible for the toxic effects. By convention particulate matter (PM) is defined and measured by size:

- Coarse particles (PM_{10} - $PM_{2.5}$) – particles smaller than 10 µm (10 thousandths of a millimetre or a micron) in diameter but greater than 2.5 µm diameter. Coarser particles arise from re-suspended road dust, brake and tyre wear, sea salt, quarries and soil.
- Fine particles ($PM_{2.5}$ - $PM_{0.1}$) – particles less than 2.5 µm diameter, which include most combustion particles; such as those emitted from diesel engine exhaust, waste burning, bonfires, and domestic biomass burning; and secondary particles of ammonium sulphate or nitrate (Box 3).
- Ultrafine particles ($PM_{<0.1}$) – less than 100nm diameter (100 millionths of millimetre or nanometre), which are emitted in large numbers from diesel engine exhaust.

There is evidence that exposure to fine particles from diesel exhaust both constricts blood vessels and inhibits the dissolving of blood clots, increasing the risk of cardiac events in susceptible individuals.[11] The Air Quality Expert Group (AQEG) reviewed the levels and sources of all airborne particulate matter in the UK for Defra in 2012 and noted a number of shortcomings in inventories of emission sources.[12] Uncertainties in the emission data and lack of measured data, along with uncertainties and lack of understanding of some aspects of the dynamic, physical and chemical processes which need to be described, limits air quality models and predictions of ambient air quality. Until 2000, there was a steady reduction in concentrations of PM_{10} in UK cities, but since then, concentrations have levelled off.

Environmental Effects

Excess nitrogen deposition continues to reduce the number and diversity of plant species over large areas of the UK:[13]

- The area of UK terrestrial habitats exceeding critical loads for acid deposition is only expected to decline from 54% in 2006-08 to 40% in 2020.
- The area of UK terrestrial habitats exceeding critical loads for eutrophication (from nitrogen deposition) is only expected to decline from 58% in 2006-08 to 48% in 2020.

Box 3. Ozone

In the northern hemisphere, mean background ozone levels range from 35 to 40 parts per billion (ppb),[14] compared to pre-industrial levels of about 10-15 ppb, and are increasing by 0.2ppb per year.[13] This ozone either formed outside UK boundaries or from precursor gases originating from outside UK boundaries. By contrast, peak ozone episodes in rural areas of the UK have declined by 30% in the last 20 years.[13] In urban areas, nitric oxide (NO) emissions from traffic react with the ozone to form nitrogen dioxide (NO_2), decreasing ozone concentrations, particularly in winter. Total NOx from urban traffic is decreasing (Box 6), lowering the rate at which ozone is destroyed, and raising urban ozone levels.

Box 4. Secondary Particles

Ammonia reacts with atmospheric nitric and sulphuric acids to form secondary particles depending on a range of factors, such as weather. The resulting products, ammonium sulphate and ammonium nitrate aerosol, comprise a major component of fine particulate matter. Ammonia is partly a local pollutant, that originates mainly from livestock wastes and a significant proportion can be deposited close to where it is emitted, at the farm- or field-scale, but secondary particles and precursor gases can be transported across national boundaries. Regional particle pollution events in the UK are often associated with elevated levels of secondary inorganic aerosols, with the precursor gases partly originating in mainland Europe.[15] Secondary particles account for 60-80% of background concentrations of fine particles in urban areas in southern England.[12]

The effects of ammonia, nitrogen oxides and sulphur dioxide on habitats and vegetation are a transboundary issue (across national or state boundaries). Ammonia emissions play a role in the long range transport of nitrogen through the formation fine particulate matter (Box 4), a major contributor to nitrogen deposition. Sulphur dioxide and NOx emissions in Europe (including the UK) have reduced sharply, but reductions in ammonia emissions, have been smaller.

Environmental Effects of Ozone

Ozone affects the ability of plants to photosynthesise, reducing crop yields, forest growth and the composition of natural plant communities. In a typical summer, ozone is estimated to reduce wheat yields by 5-15% in southern Britain. Background ozone levels (Box 3) are at a level where they may cause adverse effects on natural vegetation, particularly in upland areas.[13] Sensitivity to ozone varies between plant species, leading to changes in the makeup of plant communities. Along with reductions in the overall productivity, this can affect a range of ecological processes, such as nutrient cycling.[7]

Air Quality Regulations

European Legislation

The EU's air quality objective is to achieve "levels of air quality that do not give rise to significant negative impacts on human health and the environment". A number of EU Directives relevant to air quality (Box 5) were transposed into UK law through the Air Quality Standards Regulations 2010. Equivalent regulations have been made by devolved administrations. In 2013, the requirement for further reductions in emissions by 2030 was set out in the revised EU Thematic Strategy on Air Pollution (A Clean Air Programme for Europe).

Under current plans, 16 out of 43 areas in the UK will not meet Air Quality Directive legal limits for nitrogen dioxide for 2010 until 2020. The worst areas in England for nitrogen dioxide pollution are in London, which is not expected to meet these limits until 2025.[16] Defra submitted air quality plans to the European Commission to demonstrate that the periods exceeding limits would be kept as short as possible. However, in May 2013, the UK Supreme Court found the Government in breach of article 13 of the Air Quality Directive. The proceedings are currently awaiting the outcome of other adjudications concerning the Air Quality Directive that were referred to the Court of Justice of the European Union. However, the Supreme Court could make a mandatory order to compel Defra to comply with article 13.

Box 5. European Legislation

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

- National annual emission limits for pollutants. The UNECE Convention on Long-Range Transboundary Air Pollution adopted new national emission reduction commitments in 2012 to be achieved by 2020 and beyond. It includes reduction targets for sulphur dioxide, nitrogen oxides, ammonia, volatile organic compounds and, for the first time, $PM_{2.5}$. In December 2013, the Commission published a proposed Directive with new national emission limits for these pollutants to be achieved by 2025.
- Ambient air quality limits. For major air pollutants, these are set out in the 2008 ambient air quality directive. Member States are required to draw up plans and programmes to guarantee compliance with legally binding limits over the period up to 2020. Air quality target values for certain heavy metals and polycyclic aromatic hydrocarbons are set out in the fourth air quality daughter directive (2004/107/EC). Revision of this directive will not take place until compliance with existing limits is achieved.
- Sector specific measures. The Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC) and the Large Combustion Plant Directive (2001/80/EC) regulate emissions of air pollutants from the industrial sector. Vehicle emissions have been controlled through a progressively stricter series of performance standards (Box 6) and tighter fuel specifications including the reduction of sulphur content. Sulphur dioxide emissions from shipping are regulated through Directive 2012/33/EU and, in the North Sea and English Channel, by Annex VI of the International Maritime Organisation's Marine Pollution Convention 73/78. These control the sulphur content of fuel: an upper limit of 0.5% sulphur content in all EU seas by 2020, and 0.1% in the Baltic and North seas, and English Channel from 2015 (emissions control areas).

National Legislation

The UK 1995 Environment Act required the development of an Air Quality Strategy by the Government and a system of local air quality management. The first National Air Quality Strategy was published in 1997, with revisions in 2000, 2003 and 2007.

Local Air Quality Management Measures

A Local Air Quality Management (LAQM) system was set up following the 1995 Environment Act, under which all Local Authorities are required to regularly assess air quality for several pollutants. In areas where concentrations of these air pollutants are predicted to exceed the limits, local authorities declare an Air Quality Management Area (AQMA). A Local Air Quality Action Plan describing how the Local Authority will meet the limits is submitted to Defra. The Act stipulates that councils then have 12 months to carry out a 'Further Assessment' of air quality in the designated zone. Defra recently consulted on a range of options for reforming the LAQM system to reduce regulatory burdens, including repealing Local Authorities' existing duties to assess and report poor air quality. By contrast, the Scottish Government is consulting on reforming and retaining the current LAQM system and local monitoring, as it believes that reductions in local monitoring could weaken efforts to improve local air quality and harm public health.

Reducing Exposure to Air Pollutants

Current policy approaches concentrate resources on reducing pollutant levels in areas of the worst air quality, usually 'hotspots' in urban centres, often through technology or regulation. However, to achieve further cost effective reductions in overall emission levels will require more integrated approaches.

Technologies for Emission Abatement

The fitting of catalytic converters to petrol-fuelled cars and limits on sulphur content in fuel were highly effective in abating some transport-related air pollutants between 1990 and 2001. Similarly, flue gas desulphurisation technologies have greatly reduced sulphur dioxide emissions from fossil fuel power plants. Flue technologies also exist for reducing particle emissions from industrial sources. Methods for reducing particles and nitrogen dioxide from diesel vehicles may also produce benefits (Box 6), although these would be offset should there be an increase in the total number of diesel vehicles. Pollution suppression methods for urban areas also exist, such as particulate matter suppression sprays and building materials that are claimed to absorb pollutants, but the evidence for their effectiveness is limited.

Low Emission Zones

It has been suggested that a national framework of Low Emission Zones (LEZs), which restrict entry of vehicles into town centres that do not meet certain Euro Standards (Box 5), would be the most cost effective measure to reduce nitrogen dioxide levels. [17] Vehicle standards can take a decade to become widespread without measures such as LEZs. London, Oxford and Norwich are the only UK cities to have LEZs, although Brighton will be implementing a LEZ from 2015 and others cities such as Leicester and Birmingham are considering their feasibility.

The London LEZ covers most of Greater London. All heavy duty diesel vehicles that do not meet Euro IV standards (Box 6) and larger minibuses and vans that do not meet Euro 3 standards, must pay a charge of £100-200, or penalty charges of £250-1000. The EXHALE project is assessing respiratory health, biomarkers of exposure to traffic-related air pollution, genetic susceptibility of 8 and 9 year-old children exposed to air pollution in deprived areas of Tower Hamlets and Hackney over a four year period to assess the impact of the LEZ.[18]

Apart from the Berlin LEZ, which applies strict standards to all vehicle types, there are limited studies of the effectiveness of LEZ regimes. Other possible policy options include scrappage schemes for older vehicles or varying Vehicle Exercise Duty to exempt or reduce charges for vehicles that emit the lowest levels of air pollutants.

Integrated Approaches to Exposure Reduction

To improve air quality cost effectively, an integrated approach will be required that delivers objectives across areas such as planning, transport and health. For example, measures supporting or promoting active travel (walking and cycling) over vehicle use would contribute towards meeting public health, air quality and climate change targets. Tailored solutions may also be needed at the local level. For instance, an expanded Heathrow would not only need to reduce aircraft emissions, but would also have to apply stringent standards to vehicles accessing the airport to meet air quality limits. To improve local air quality, regional levels of air pollutants from both the diversity of smaller pollution sources and transboundary pollutants will also need to be addressed, such as ammonia emissions from agriculture.

Box 6. European Vehicle Emission Standards

'Euro' regulations for vehicle emissions were first introduced in 1992, each subsequent iteration limiting emissions more tightly. These include particulate matter emissions from light (g/km) and heavy duty (g/kWh) diesel vehicles. To meet current requirements (Euro 5, which covers light diesel vehicles and Euro V, which covers heavy duty vehicles), diesel particulate traps are fitted. Traps oxidise nitric oxide (NO) to create nitrogen dioxide (NO_2) to react with particulates, increasing the proportion of nitrogen dioxide emitted. As diesel vehicles already have higher emissions of NO_2 than petrol vehicles, this technology may have exacerbated NO_2 pollution levels. The next generation of Euro regulations, Euro VI and 6 regulations, introduced in 2013 and 2014, will require reductions in NO_2 emissions. Technical solutions for reducing emissions include selective catalytic reduction after the diesel particulate filter to remove NO_2. Such technologies are already used in the US. However, in the UK particulate traps are often removed by owners in order to avoid costs of replacement or to improve perceived vehicle performance.

Climate change and air quality

Climate change and air quality are linked, sharing similar atmospheric processes and emission sources.[19] For instance, both ozone and the black carbon component of particulate matter are short lived climate pollutants. This has led to suggestions that an integrated strategy for the atmosphere is needed, as policy measures, such as active travel, can lead to both lower levels of greenhouse gases and air pollutants. However, other measures to reduce fossil fuel use could affect air quality. For example, domestic biomass boilers have higher levels of particulate emissions per gigajoule of heat delivered, and usually higher levels of NOx emissions, than natural gas boilers. After September 2013, to be eligible for the Renewable Heat Incentive (RHI) biomass boilers must have emissions levels no higher than 30 grams per gigajoule (g/GJ) net heat input for PM and 150g/GJ for NOx. The Impact Assessment of the original RHI emission standards for biomass boilers estimated it would cost £1.8 billion in air quality impacts (health costs).[20]

Endnotes

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