

Trends in air quality in the UK

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Many problems are encountered when assessing trends in air quality, including changes in methods of measuring pollutants over time, different sampling timeframes, and the number and distribution of monitoring sites. Nevertheless, reasonable projections have been established for trends in sulphur dioxide (SO₂), particulate matter, nitrogen dioxide (NO₂), and ozone levels in the UK, which allow some estimate of future levels. The major source of SO₂ is coal-fired power stations. Since the Clean Air Act of 1956, SO₂ levels have decreased substantially. Nevertheless, a small but progressive increase in SO₂ emissions is predicted over the next 15 years, but this is unlikely to exceed current UK air quality standards on a frequent basis. Particulate pollution (as black smoke) has also decreased dramatically since the 1960s, when the main source was fossil fuel burning. In the 1990s, the main source of particle emissions is from heavy goods vehicles. If measures currently under consideration in the UK are implemented, annual emissions may decrease to below 60 kT over the next decade, but a progressive increase is predicted thereafter. No significant changes have occurred with respect to oxides of nitrogen (NO_x) and ozone levels over the last 20 years. It is predicted that NO_x emissions will decline in the future due in part to the introduction of catalytic converters, while trends in ozone levels will depend on substrate supply (NO_x and hydrocarbons) and weather conditions. Despite short-term trends downwards in air pollutant levels, trends may reverse in the next millennium, and continued efforts must be made to develop new ways of reducing ambient air pollutant levels.

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Introduction

The increased interest in air pollution worldwide over the last decade has been regarded as somewhat surprising in some quarters, and not before time in others. However, concern about air pollution and its effects on health, crops, buildings, and overall quality of life, is not new. Many factors will govern whether trends in air quality in the UK are transferable to other cities throughout the world, though it would probably be unwise to attempt this, other than in very broad terms.

Air pollution in the UK up to 1956

The dirty air of London has been a source of concern for centuries. Initially, the burning of sea-coal (high in sulphur) by lime manufacturers was the major cause, but as London increased in size, burning of domestic coal added to the burden (1). By the 17th century, 'great stinking fogs' were associated with increases in mortality, and the diarist, John Evelyn (2), spoke forcefully on the

evils of polluted air. As industrialization spread, factory chimneys also appeared in the Midlands and Northern regions, with their attendant emissions - the Black Country in the Midlands was so-named for good reason! At that time, air pollution was deemed a fair price to pay for more jobs and associated financial benefit. However, this attitude changed completely as a result of a major pollution episode in the Thames basin (London) in December 1952 (3), the London fog incident, which resulted in 4,000 excess deaths. Partly due to public pressure, this led to the first UK Clean Air Act being passed in 1956, which proved to be remarkably effective in reducing black smoke emissions merely by being in force, as there were, in fact, few prosecutions. As a result, from around 1960, the air became visibly clearer, which led to a false sense of security, the Government being advised that the problem of air pollution was over. However, by the mid-1980s, following increasing concern from the US about the effects of air pollution on health, renewed interest began to gather pace in the UK. There is now an increasing body

Table 1. Problems inherent in assessing trends in ambient air pollution levels

- Use of different types of measurement across sites (e.g. PM10 or BS)
- Change in type of measurement over time within a site
- Sampling timeframes
- Spatial distribution of monitoring sites
- Number of monitoring sites
- Qualitative differences in particle content

PM10=particulate matter $\leq 10 \mu$
BS=black smoke

of information on trends and sources of air pollution and its health effects in the UK. Reasonable projections have been established for trends in pollutant emissions, which allow some estimate of future changes in ambient levels. Although ambient air contains a mixture of pollutants, it is easier to assess trends on an individual pollutant basis. Most of the information for the UK is available in three reviews by the Quality of Urban Air Reviews Group (QUARG) (4–6).

Problems in assessing trends

There are several problems in assessing trends in air quality, especially when considering historical data sets (Table 1). The methods of measuring different pollutants have changed over time, the most obvious example being the measurement of particles. The original method, black smoke (BS), was a reflectance method, measuring the blackness of filter paper through which air was drawn at a specified rate. High volume samplers were later developed which measured the mass of particles in the air, although different metrics were used. Total suspended particulates (TSP) covered quite a wide range of particle sizes, and thus systems which incorporated a size-limiting inlet were developed. Currently, the most frequently used is set at 10μ , giving the measure PM10 (particulate matter of 10μ or less), although there are published data focusing on health effects at maximum particle sizes of 2.5, 7 and 13μ (7). More recently, it has been suggested that particle number rather than mass should be considered as a relevant measure of particulate pollution (8); however, since limited data are available for these less commonly used metrics, only BS and PM10 will be considered here. Another problem in assessing pollution trends is the use of different sampling timeframes. It is wrong, and indeed misleading, to compare an hourly maximum value to a daily mean or a weekly average level. Equally, individual cities may have a single monitoring site or many sites, and these may be positioned near the side of a main road, in a residential street, or even on a suburban hillside.

Finally, there is the problem of qualitative differences in particles. If the prevailing wind in the UK is westerly (Atlantic), the particle content will differ considerably from that provided by an easterly (continental European) wind. Such qualitative differences have received little attention, particularly when assessing the health effects of air pollution. Despite these caveats, several clear trends in UK air quality can be defined.

Sulphur dioxide (SO_2)

After the 1956 Clean Air Act, emissions peaked at around 6,000 kT/year in 1960 and then declined to 4,000 kT/year by the mid-1980s. The main contribution to SO_2 in the UK was, and still is, from coal-fired power stations, with only a small contribution from vehicles (Fig. 1) (9). There has been a concomitant decrease in SO_2 levels, from $150 \mu\text{g}/\text{m}^3$ in 1960 to $30 \mu\text{g}/\text{m}^3$ in 1985, and certain rural areas now have higher levels than urban areas, largely because of rural siting of power stations (Fig. 2) (4). Clearly, SO_2 pollution remains a problem in certain parts of the world, such as Eastern Europe, although there is now evidence of a marked decline in levels in the former East Germany (10). There has been a tendency, certainly in the US, to dismiss SO_2 when considering health effects of air pollutants. However, despite the increasing use of low sulphur fuels, with a projected decrease in current emissions from around 40 to 15 kT/year, the projections for overall emissions over the next 15 years suggest small but progressive increases. Nevertheless, these are not likely to result in the current UK air quality standard of 100 ppb over 15 min being frequently exceeded (11).

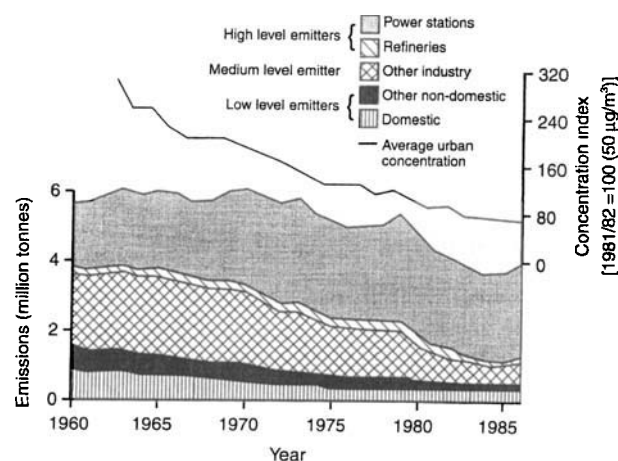


Fig. 1. Trends in UK emissions and levels of sulphur dioxide by source. From Harrison (9), with kind permission.

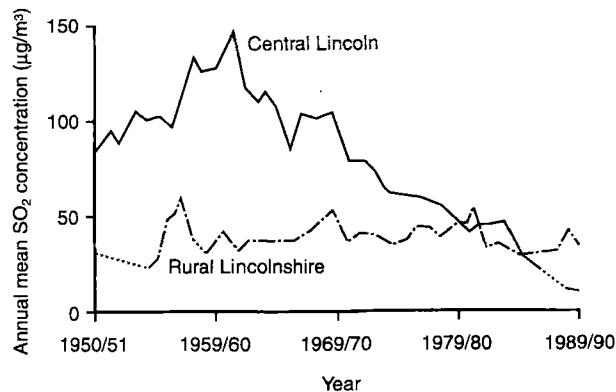


Fig. 2. Trends in sulphur dioxide levels in the city of Lincoln (urban) and a nearby rural area. From Quality of Urban Air Review Group (4), with kind permission.

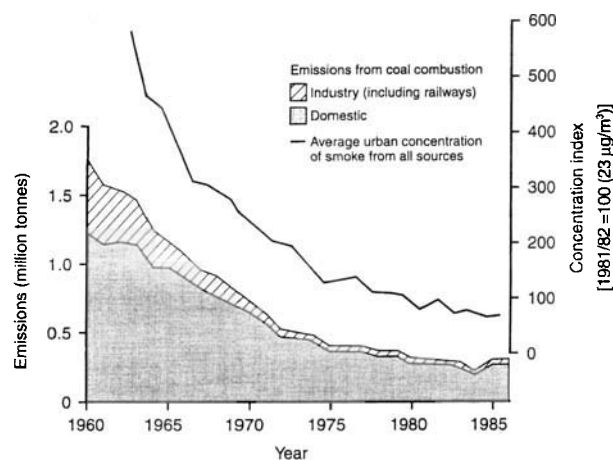


Fig. 3. Trends in UK emissions and levels of black smoke. From Harrison (9), with kind permission.

Particulates

The UK has had an extensive BS monitoring network for many years, although it is concentrated largely on urban areas. Emissions have declined dramatically since 1960 (Fig. 3), and have been matched by an equally impressive reduction in BS from $180 \mu\text{g}/\text{m}^3$ (annual average) in 1960 to $12 \mu\text{g}/\text{m}^3$ in the 1990s (9). There is a relatively limited PM₁₀ data set in the UK, but available data show seasonal increases (winter peaks) (as existed for BS in the 1950s and 1960s), with no obvious increase in urban background PM₁₀ over the last 5 years. There are, however, marked differences in roadside compared with general urban background levels. In Birmingham, 24 h mean roadside levels of PM₁₀ are around $50 \mu\text{g}/\text{m}^3$ [the new UK air quality standard (12)] compared with a $25 \mu\text{g}/\text{m}^3$ urban background level. The distribution of particle number and size also varies markedly between the two sites (Fig. 4), with higher numbers of ultrafine

(<0.10 μ) particles in roadside air (6). Particle numbers vary considerably compared with PM₁₀ levels, both within a 24 h period (Fig. 5) and on a daily basis (Fig. 6). On any two days of equivalent PM₁₀, there may be as much as a three-fold difference in particle numbers. The greater the number of particles inhaled, the greater is the area of exposed lung, and numbers may be more important than mass in this regard.

Clearly, particulate levels will increase markedly on some days, usually when high barometric pressure prevails, with a greater likelihood of temperature inversions. Air pollution episodes, such as those that occurred in London in December 1991 (13) and in Birmingham in December 1993 (14), are associated with increases in particles and nitrogen dioxide (NO₂) to levels well in excess of current guidelines or standards. In the London episode, NO₂ levels reached 423 ppb and BS $225 \mu\text{g}/\text{m}^3$. Although peak levels of NO₂ and PM₁₀ were lower in the Birmingham episode, there was also an associated increase in SO₂ to over 200 ppb due to emissions from power stations to the east of the city. While such severe exceedances of air quality levels are rare, lesser events are not infrequent, and almost always occur in the winter months.

Total emissions of particulate matter peaked at around 70 kT in the early 1990s (Fig. 7) and are projected to fall to around 60 kT/year over the next decade (4), the major contributor being heavy

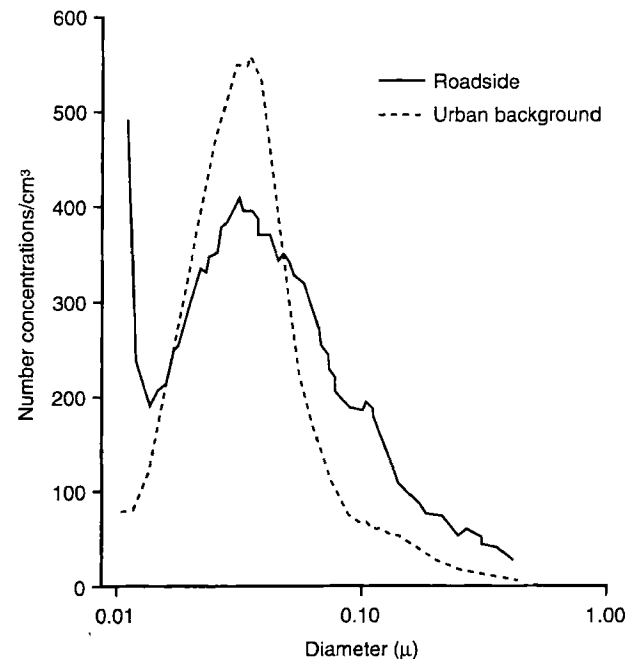


Fig. 4. Differences in the distribution of particle numbers by size in the submicron fraction of roadside and urban background air (Birmingham, UK, 1994). From Quality of Urban Air Review Group (6), with kind permission.

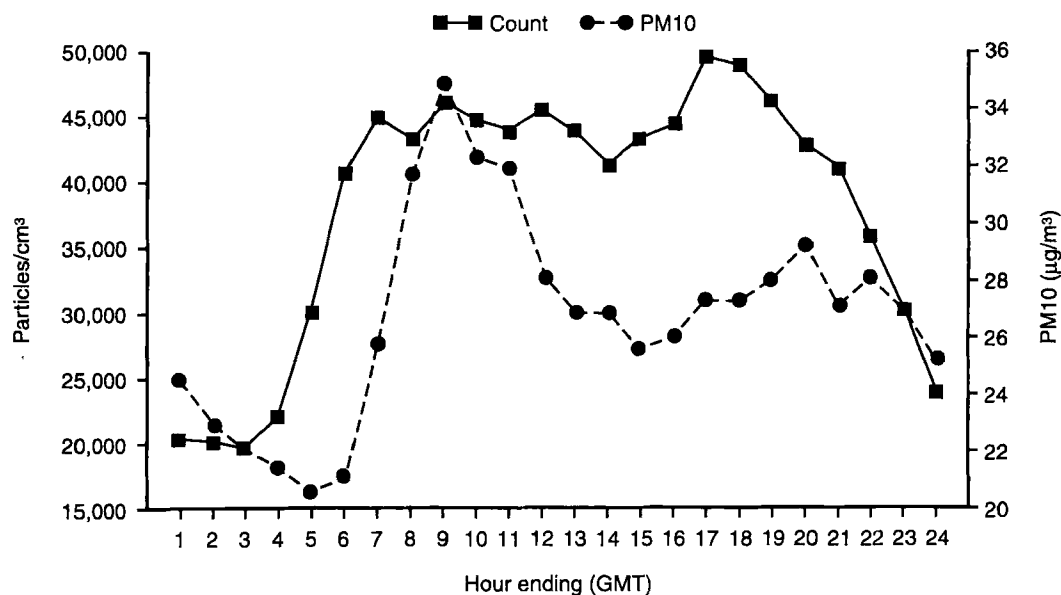


Fig. 5. Differences between particle numbers and PM10 over a 24 h period (Birmingham, UK, 1994). From Quality of Urban Air Review Group (6), with kind permission.

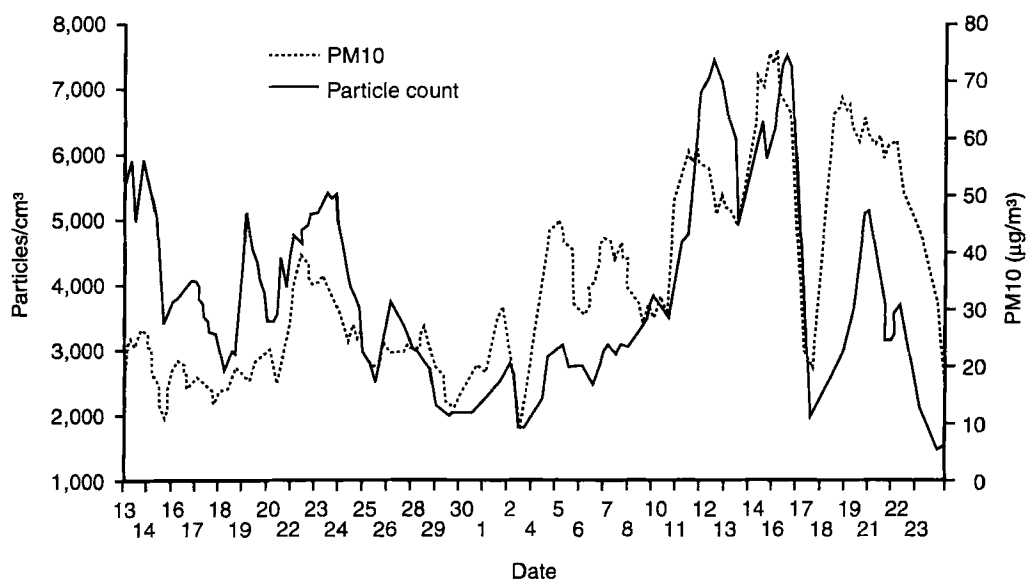


Fig. 6. Differences between particle numbers and PM10 by day over a 40-day period (Birmingham, UK). From Quality of Urban Air Review Group (6), with kind permission.

goods vehicles (HGVs). If particle emissions from HGVs can be reduced by measures currently under consideration (e.g. green diesel, particle traps, more strict vehicle checks), annual emissions may decline even further, but it is predicted that after that time, there will be a further upward trend.

Nitrogen dioxide (NO₂)

Trends in emissions of oxides of nitrogen (NO_x), of which NO₂ is generally regarded as the most important, have been remarkably flat over the last

20 years in London (Fig. 8) (4) and NO₂ levels, with the exception of pollution episodes, have been maintained at around 30–40 ppb (urban background). It is important to realise, however, that the relationship between NO_x and NO₂ levels is not linear, at least in urban areas. While there is an initial linear relationship between the two (Fig. 9), NO₂ levels plateau thereafter over quite a large range of NO_x, which is related to the chemical interaction between ozone and the various nitrogen oxides. However, when NO_x levels reach around 400 ppb, NO₂ begins to form in excess, and levels

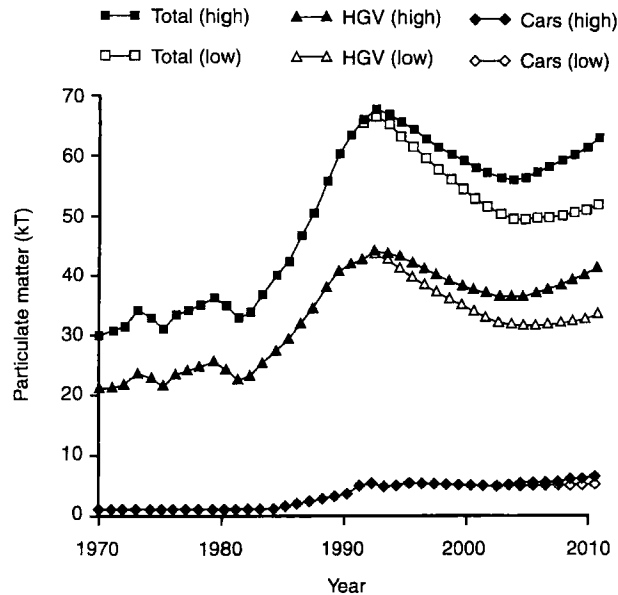


Fig. 7. Projected emissions (in kT/year) for particles in the UK by source. From Quality of Urban Air Review Group (4), with kind permission.

increase. Rural levels of NO_2 are generally around half those of urban background in the UK, and may be as low as 10 ppb in remote areas. The spatial distribution of NO_2 over a city can also vary, but generally is higher over the city centre and declines peripherally. NO_2 isopleths can be constructed using NO_2 diffusion tube surveys, which demonstrate this clearly on a day-to-day basis. However, during air pollution episodes, with a temperature inversion, NO_2 levels tend to be uniform over the affected area. The current air quality standard for NO_2 for the UK has been set at 150 ppb as a 1 h average.

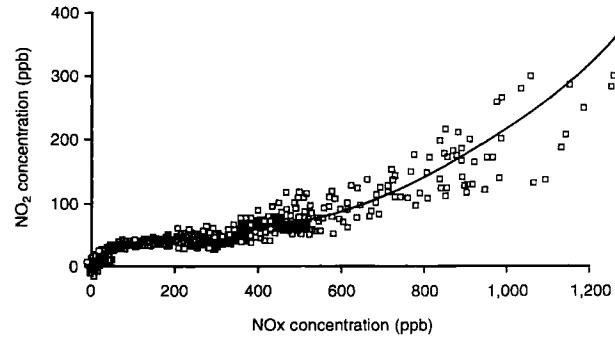


Fig. 9. Relationship between NO_x emissions and NO_2 levels in an urban area. From Quality of Urban Air Review Group (5), with kind permission.

Ozone

Ozone is a secondary pollutant formed by the action of sunlight on oxides of nitrogen and hydrocarbon fragments. Significant levels of ozone are therefore only seen in the summer months in the UK, with days of high ozone being more frequent in the south. This contrasts with cities in hotter climates, where significant ozone levels may be detected throughout the year. Ozone is formed within the atmosphere at a relatively slow rate, such that levels upwind of a city are higher than those over the city itself. This effect is compounded by the neutralization of ozone by nitric oxide over cities. Consequently, rural levels are always higher than urban levels (Fig. 10) (4). When considering the mean and 95th centile values (which gives an indication of exceedance), levels of ozone have not changed significantly over the last two decades (Fig. 11) (4). Future trends will depend not only on substrate supply, but also on weather conditions. If

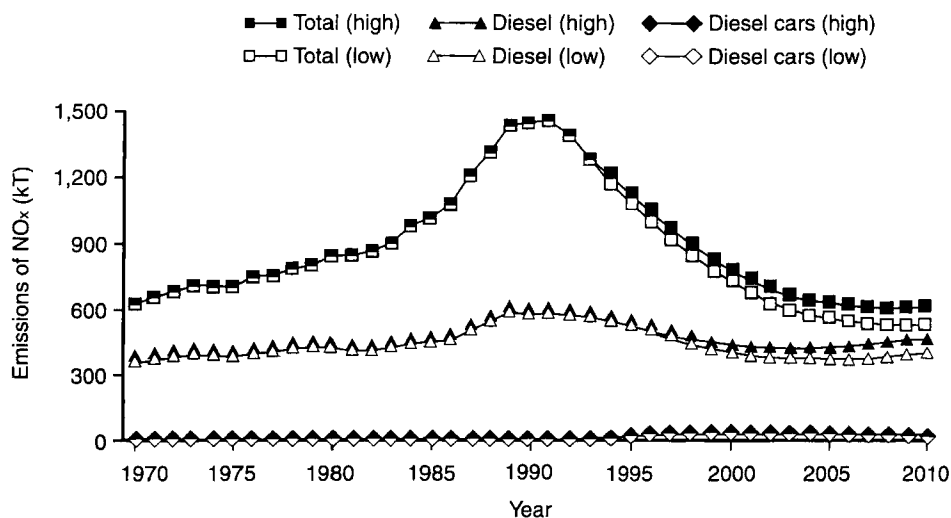


Fig. 8. Past trends and future projections in emissions of oxides of nitrogen in the UK since 1971. From Quality of Urban Air Review Group (4), with kind permission.

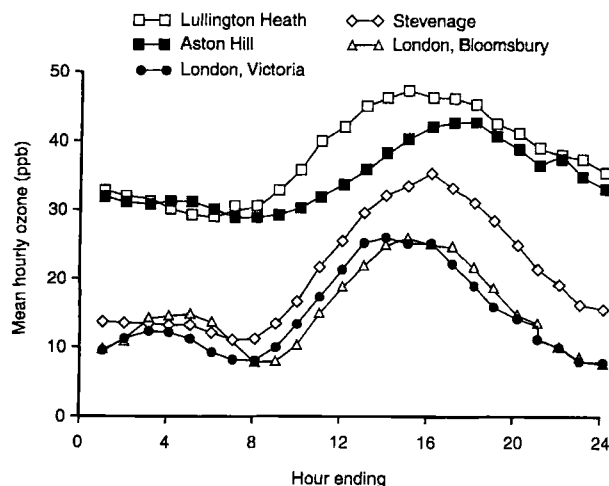


Fig. 10. Urban-rural differences and diurnal variations in ozone levels (UK, May–July 1992). From Quality of Urban Air Review Group (4), with kind permission.

the predicted decrease in NO_2 is realized, then it may be assumed that ozone levels will not rise significantly over the next decade. Theoretically, however, the greater use of catalytic converters could increase overall ozone levels towards those currently seen in urban upwind sites; confident prediction of future ozone trends is therefore difficult.

Impact of catalytic converters and diesel vehicles

Having peaked at around 1,500 kT/year, it is projected that NO_x emissions will decline due to the

impact of three-way catalytic converters, perhaps decreasing to around 600 kT by the year 2010. It is difficult to ascertain how this would translate in terms of NO_2 levels because of the chemistry of nitrogen oxides; however, the trend must surely be towards a significant decline. While catalytic converters have a beneficial effect on NO_x emissions, they have no impact on particles, and cannot be fitted to diesel vehicles. Consequently, a major factor governing future trends in emissions of these vehicle-generated pollutants is the number of diesel vehicles on the roads. If the percentage of diesel vehicles in the fleet remains unchanged at 16%, then it is estimated that particle emissions will fall by half, NO_x emissions by around 40%, and volatile organic compound (VOC) emissions by around 75% by the year 2005. However, if the proportion of diesel vehicles increases to 49%, particle emissions will remain unchanged, with NO_x and VOC emissions falling by 50% and 80%, respectively.

Summary

Current measures of air pollution levels perceived to be important with respect to allergic disease suggest that no significant increases will be seen over the next 10–15 years in the UK. However, there is a need to address the increasing concern that different measures (such as particle number as opposed to particle mass) may be of greater relevance to exacerbation of disease, and perhaps to initiation of the expression of allergic conditions. The trends and projections described here should

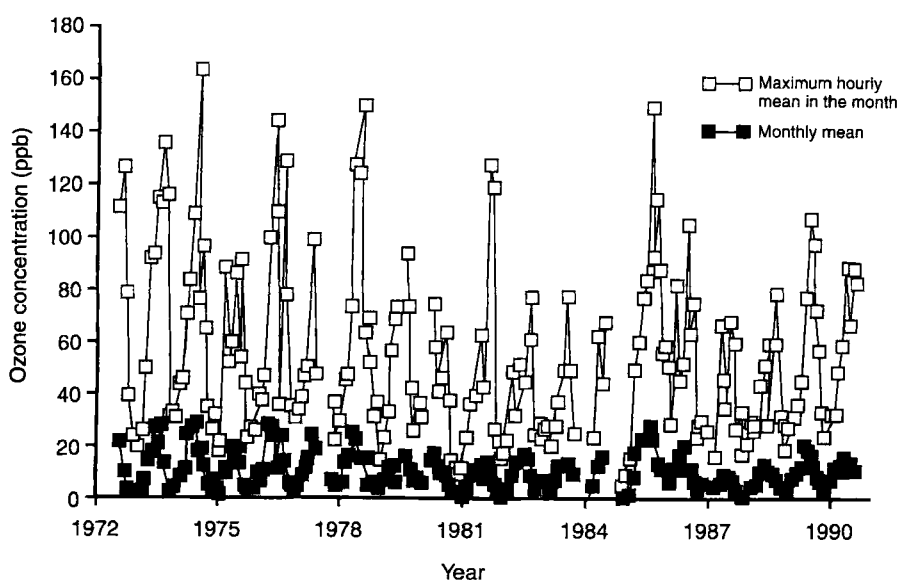


Fig. 11. Mean and maximum monthly ozone concentrations (ppb) recorded in London, 1972–1992. From Quality of Urban Air Review Group (4), with kind permission.

not be transferred to other countries with any certainty, although those with similar climates, size, and type of vehicle fleets may show similar trends. The fact remains that we cannot be complacent about air pollutant emissions. Control of pollutant sources will lead to improved air quality, whether these are the standard pollutants described above or other pollutants which may prove to be of relevance to allergic disease in the future.

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