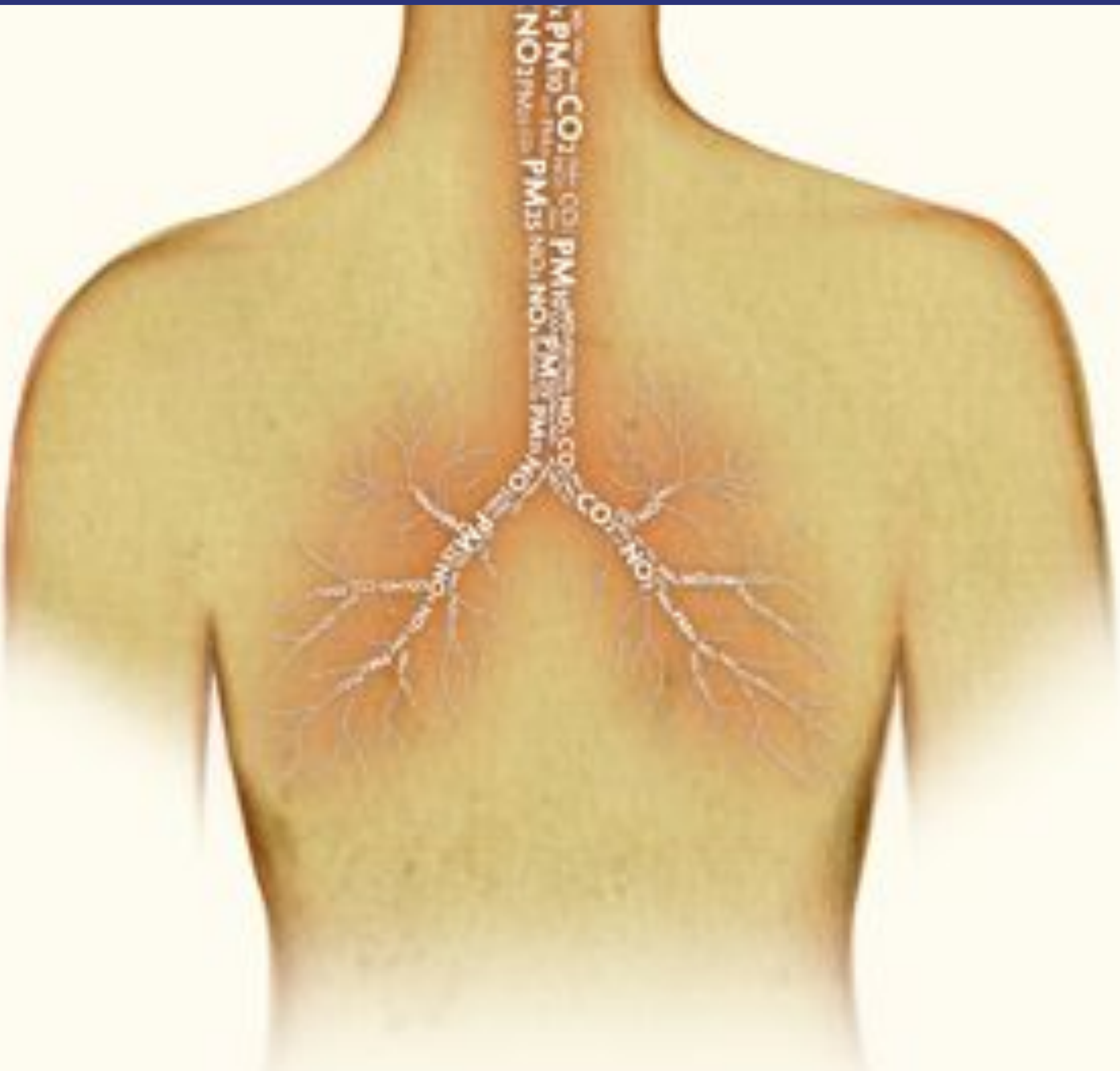
environmental SCIENTIST

April 2013
Journal of the Institution of Environmental Sciences



Air Quality

should we have achieved more?

Good-quality air: working towards a cleaner atmosphere in the 21st century

Published during the European Year of Air, this issue conveys some important thoughts on air quality. Broadly speaking, the articles have three themes: a retrospective showing how we have reached the current situation, a review of some topical issues and an attempt to look to the future.

Martin Williams gives an overview of the development of air-quality management policy over the last 20 years. Given his close involvement in the process, both at UK and European levels, this is an authoritative review, even if some might debate a few of the points raised.

We have two perspectives on the legislation relating to air quality and its application, one from a lawyer, Alan Andrews of ClientEarth, and one from a practitioner (myself). Alan takes a wider view, whereas I look mainly at two domestic aspects and their successes and failings.

We then move onto the topic of how to engage the public, with a contribution from the indefatigable campaigner Simon Birkett, of Clean Air for London. There can be no doubt that Simon has played an important part in raising the profile of air quality and in posing awkward and necessary questions.

Perhaps appropriately, given that they have been long-standing sparring partners at conferences, the piece following Simon's is by Robert (Bob) Maynard. Bob provides an authoritative overview of the health impacts of air quality and how our understanding of the problem has developed.

From here we move on to examine the interactions of air pollution and the aquatic environment. Although one of the major reasons for improving air quality is to address human health problems, it is vital that as environmental scientists we consider all effects of air pollution. Mark Everard examines the interactions between the atmospheric and aquatic environments, and Herman van Dam and Adrienne Mertens present the results of studies that demonstrate that eutrophication remains a problem.

Claire Holman summarises issues related to dust and biological airborne materials. Although they have generally been considered to be nuisance pollutants, these generally larger fractions may also have adverse health effects.

Maria Arnold describes the work of the Healthy Air Campaign which is working to raise awareness of the health impacts of air pollution.

In part to mark 10 years of the Institute of Air Quality Management, the new chair, Roger Barrowcliffe, provides a review of air quality in recent years, concluding with a mixed prognosis: essentially optimistic in the long term but more than slightly tinged with pessimism when considering how the necessary improvements in air quality might be achieved.

Sam Arnold examines the inconsistencies that have hindered improvements in air quality and seeks to identify way that improvements might be achieved.

Finally a number of people who are involved in air quality in different ways speculate on the reasons why there is not a greater public demand for action on air quality. One common strand that also runs through several of the other articles is that what is needed is better communication of the risks associated with air quality.

This, perhaps, suggests part of the way forward for both IES and IAQM. Within these bodies there is a wealth of experience and knowledge in the air quality field which could be used to inform policy decisions. The challenge is to open the doors so that this knowledge and experience can be used properly to strengthen the basis for and lead to better policy decisions.

David Muir has worked in the air quality field for 37 years, with Bristol City Council from 1976 to 2009 and as an independent consultant/researcher since 2009. He gained a PhD from the University of the West of England in 2003. He has been a member of IAQM since its foundation and serves both on its committee and on the IES Council.

CONTENTS

environmental SCIENTIST
The Journal of the Institution of Environmental Sciences

Volume 22 No 2
ISSN: 0966 8411 | Established 1971

The environmental SCIENTIST examines major topics within the field of environmental sciences, providing a forum for experts, professionals and stakeholders to discuss the key issues.

Published by
Institution of Environmental Sciences
34 Grosvenor Gardens
London SW1W 0DH
Tel 020 7730 5516
Email enquiries@ies-uk.org.uk
Web www.ies-uk.org.uk

Views expressed in the journal are those of the authors and do not necessarily reflect IES policy.

Editors Emma Fenton, David Muir

Subeditor Caroline Beattie: beattie.cas@gmail.com

Designer Jenna Edgar: www.jennaedesign.co.uk

Printers Lavenham Press Ltd

Modern life; choices or no choice

David Muir emphasises the importance of good air quality.

There are three basic requirements for human life: we need to eat, we need to drink and we need to breathe. Each of these requires that whatever we consume is not going to be injurious to our health and wellbeing. To this end, in the UK and in many other countries, regulations are in place to try to ensure that the quality of what we eat, drink and breathe is, at the very least, acceptable.

In addition to the quality of what we eat, drink and breathe, quantity is also important as deprivation of any of these three can lead to adverse health effects and, ultimately, to death. There is, however, one important difference between eating, drinking and breathing. We have a large measure of choice in what we eat, and although we have to rely on the supplier of domestic water for safe supplies, we do have choices in whatever else we drink. In total contrast we have almost no choice so far as what we breathe.

IMMEDIATE AND DELAYED EFFECTS

It is instructive to look at the timescales involved in the effects of ingesting 'contaminated' food, drink or air. With food, the onset of any effects from eating unfit food is usually a matter of a few hours and in extreme cases this can lead to death, sometimes within a short timescale but possibly after several weeks. Similarly the effects of drinking unfit water will usually be felt within a short period of time. In contrast, breathing polluted air can have both short-term (acute) effects, such as asthma attacks, and long-term (chronic) effects, such as cardiovascular damage. In both cases death is also a possible outcome.

Although much criticism has been levelled at the regulators for the food and drink industry (notably the recent horsemeat episode), it does seem that many instances of food poisoning actually arise from cross-contamination in kitchens (handling raw ingredients after handling meat, where the meat has not been fully cooked, or where food has been prepared by someone carrying an infection). This is not to say that there are not instances where unfit food has been consumed after being purchased in a shop, but such cases do appear to be few and far between, serious as they might be. In summary, although the regulatory system for food and drink may be flawed, there seem to be relatively few instances where its failings have resulted in long-term ill health or death.

FAILING AIR REGULATION

In contrast, the apparent failings of the regulatory system for air pollution, or at least the failures to meet air-quality standards, are estimated to result in some 29,000 'early' deaths per year in the UK. Of these it is estimated that some 4,000 are in London alone.

There are, however, other aspects to the environmental effects of air quality and so as environmental scientists we cannot ignore these. One major issue is the linkage between air pollution and climate change. The linkages here are two way. There are measures that may be taken to improve air quality that may have an adverse effect on climate change. A possible example is the increased CO_2 emissions when catalytic converters were first introduced. The probability is, however, that (at least on a per-vehicle basis) improved fuel efficiency has balanced this out. And there are measures taken to address climate change, such as increased use of diesel engine road vehicles and biomass burning, that are known to have adverse effects on air quality.

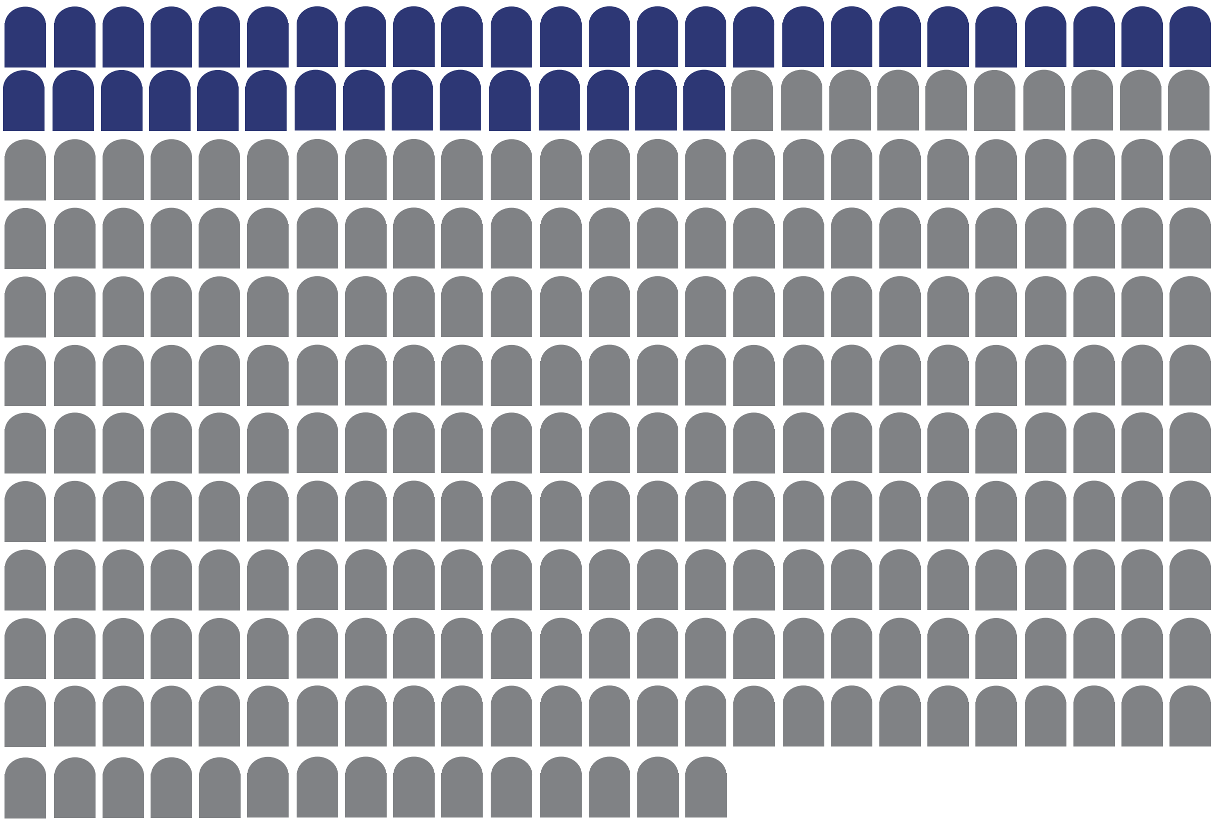
The other main aspects of air pollution are its effects on both the natural environment and the built environment. The effects on the built environment are twofold: there are the permanent effects, mainly the erosion of building materials such as stone, and effects that are usually more or less temporary, such as the soiling of surfaces.

There are many possible interactions between air pollution and the natural environment of which the best known is the case of acid rain. This can have implications for both the flora and fauna of a region.

The aim of this issue of the environmental SCIENTIST is to present to our readers an overview of some of the issues and complexities involved in managing air quality.

ES

David Muir has worked in the air quality field for 37 years, with Bristol City Council from 1976 to 2009 and as an independent consultant/researcher since 2009. He gained a PhD from the University of the West of England in 2003. He has been a member of IAQM since its foundation and serves both on its committee and on the IES Council.



= 100 air-quality related deaths in London

= 100 air-quality related deaths in the rest of the UK

The apparent failings of the regulatory system for air pollution, or at least the failures to meet air-quality standards, are estimated to result in some 29,000 'early' deaths per year in the UK. Of these it is estimated that some 4,000 are in London alone.

The evolution of air quality policies over the past 20 years

Martin Williams reviews developments in UK and European air-quality policy and legislation.

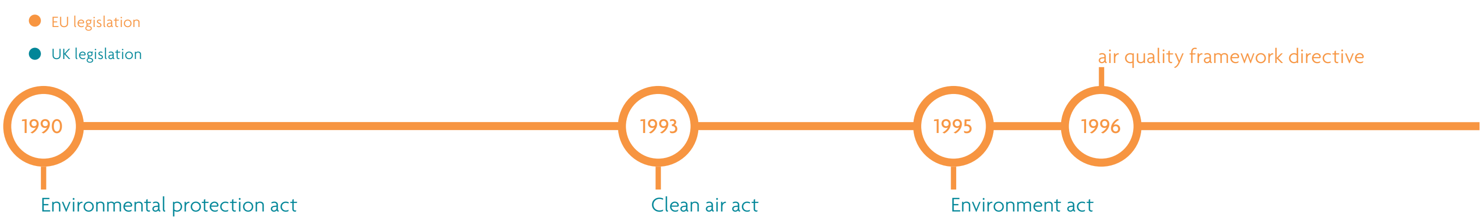
During the 1980s, UK policy on air quality had begun to be driven by EU initiatives. The first air-quality directives were already in place[1,2,3,4] giving the UK an obligation to achieve explicit levels of ambient air quality for the first time. There was a feeling – certainly in the UK – that urban air pollution was a problem solved, and in the 1980s attention had been more focused on ecosystem issues such as acid rain which had a high political profile.

In the 1990s the two main instruments for controlling air pollution in the UK were essentially source based: the Environmental Protection Act 1990 controlled industrial emissions (through the concept of integrated pollution control, which tries to ensure that any particular solution does not lead to problems elsewhere) and the Clean Air Act 1993 relied on smoke control. Motor-vehicle emissions were also recognised as important sources of urban air pollution and emission standards were in place, but these were essentially capping limits and did nothing of substance to force technological developments or drive emissions down.

At about the same time in the early 1990s, a series of what proved to be ground-breaking papers emerged from the Harvard School of Public Health in the USA through the work of Dockery, Schwartz, Pope and others[5]. They demonstrated associations between adverse health effects, including premature deaths, and relatively low levels of particulate matter (PM) that were previously considered to be harmless. These studies employed sensitive and sophisticated statistical techniques but were initially greeted with scepticism in some quarters. However, further studies by other groups and intensive reanalysis and scrutiny by independent researchers, notably the Health Effects Institute in the USA[6], led to these studies being accepted and their findings used to inform policy development in the USA, the EU and elsewhere. Moreover, the health impacts of long-term exposure to fine particles, $PM_{2.5}$ (defined as particulate matter that passes through a size-selective inlet with a 50-per-cent efficiency cut-off at 2.5 μm), have now been shown to be substantial, and monetisation of these effects is now the dominant factor in cost–benefit analyses of ambient air-pollution policies.

SCIENCE AND STRATEGY

These scientific developments contributed to a resurgence in strategic thinking in the UK with work beginning to develop a coherent strategic approach to air quality that lead to the Air Quality Strategy (AQS) being published in May 1997. During the formulation of the AQS, legislation to incorporate the thinking was also being drawn up and this culminated in the ground-breaking Environment Act 1995, the first piece of primary legislation in the UK to incorporate the concept of ambient air-quality standards in a coherent manner. Space does not permit an adequate appraisal of



the immense amount of scientific and medical research and assessments that have underpinned the UK Air Quality Strategy, its successors and the formulation of legislation and policy.

There has been a series of definitive synthesis reports from expert groups in both the environment and health departments. Over the past 20 years (and even earlier), reports produced by the Photochemical Oxidants Review Group, the Quality of Urban Air Research Group, the Airborne Particles Research Group and more recently the Review of Transboundary Air Pollution and Air Quality Expert Group, together with the series of reports from the Department of Health Committee on the Medical Effects of Air Pollutants (COMEAP) and its forerunner the group on the Medical Aspects of Air Pollution Episodes (MAAPE), as well as the Defra group the Expert Panel on Air Quality Standards (EPAQS), have been tremendously influential in the wider European and international arenas, and have been highly regarded by both scientists and policy-makers.

AIR-QUALITY MANAGEMENT AND EUROPE

At the same time as the UK was developing these policies, the EU also began working along similar lines, formulating a more strategic approach to air-quality policy through the so-called air quality framework directive (96/62/EC)[7], which was agreed in 1996. This paved the way for 'daughter directives' the first of which (99/30/EC)[8] dealt with PM, sulphur dioxide (SO_2), lead and nitrogen dioxide (NO_2) and was agreed during a UK presidency of the EU and then adopted in 1999. Subsequent directives dealt with carbon monoxide and benzene (2000/69/EC)[9] and with ozone (2002/3/EC)[10]. The latter did not contain mandatory limit values like the other directives, reflecting the transboundary nature of ozone and the fact that a member state would not necessarily have complete control over ozone sources measured within its territory. The fourth in the series covered arsenic, nickel, cadmium, mercury and polynuclear aromatic hydrocarbons[11], and like the ozone directive did not set mandatory limit values but incorporated target values for the pollutants concerned.

The European Commission consolidated this earlier work in a Thematic Strategy on Air Pollution under the Sixth Environmental Action Programme adopted on 21 September 2005. The objectives of the thematic strategy were achieving "levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment"[12]. The strategy set interim objectives for 2020 as follows:

- 47 per cent reduction in loss of life expectancy as a result of exposure to particulate matter;
- 10 per cent reduction in acute mortalities as a result of exposure to ozone;
- Reduction in excess acid deposition up to 74 per cent in forest areas and 39 per cent in surface freshwater areas; and
- 43 per cent reduction in areas or ecosystems exposed to eutrophication.

It is worth noting here that the thematic strategy is a Commission document, not a directive, and is not binding on member states.

The most recent development in Europe has been the agreement of a revised Air Quality Directive that brought together for revision the first three 'daughter directives'. The new directive (2008/50/EC)[13], which was published in May 2008, incorporated some significant developments in air-quality management, including the concept of exposure reduction for $PM_{2.5}$, foreshadowed in the UK Air Quality Strategy of 2007, and due in no small part to UK input into the European process.

This novel approach was intended to drive air-quality policy to result in improved public health over a much larger part of the population (in principle most of the urban population) as compared to the more difficult, expensive and inefficient (in terms of public health) approach of incrementally approaching single-point limit values in smaller and smaller areas. As the directive turned out however, the final text fell between two stools: the negotiations on the exposure-reduction approach resulted in the driving obligations for $PM_{2.5}$ being non-mandatory, but, contrary to the original concept, with a mandatory limit value that is relatively easily achieved over most of the EU. At the time of writing, the directive seems unlikely to be reviewed as part of the European Commission's review of air-quality legislation, so this state of affairs will continue for some years.

LIMITS AND TARGETS

As noted above, the UK Environment Act of 1995 established the concepts of standards and objectives for ambient air for the first time in legislation. Initially these were based on the work of EPAQS and related advice from other expert groups mentioned above. Accordingly, a series of UK standards was formulated and as the EU process began to develop, a parallel stream of air-quality limit values and target values emerged, mostly, but not completely, for the same pollutants. During the 2000s this led to a relatively cumbersome set of standards (in the broad sense of the word) embodying both UK and EU values. In recent years these have become increasingly harmonised, through the process of transposing the most recent EU directive into UK law, although there are still strong arguments for rationalising even the set of EU limits and targets, not least for PM. This of course should not be seen as a means of avoiding the non-compliance positions in which many member states currently find themselves, particularly for NO_2 and to a lesser extent for PM_{10} (defined as particulate matter that passes through a size-selective inlet with a 50-per-cent efficiency cut-off at 10 µm).

VEHICLE EMISSIONS

So far this discussion has centred on policy on ambient air quality. A large amount of activity has taken place over the past 20 years on source-related emission regulation. Perhaps the most significant in terms of improving air quality has been the series of so-called Euro standards for vehicle emissions. The first directive dated from 1970 (70/220/EEC)[14] and applied to light-duty vehicles. This and subsequent amendments simply set a cap on emission performance rather than forcing technological improvements and large emission reductions, and it was not until the amendment embodied in Directive 88/76/EEC[15] – the so-called Luxembourg Agreement – that significant reductions were achieved. This directive, which has become known as the Euro 1 standard, effectively mandated the use of three-way catalysts (which reduce levels of all three regulated pollutants: carbon monoxide, hydrocarbons or volatile organic compounds (VOCs), and oxides of nitrogen). A fully functioning catalyst can reduce emissions by more than 90 per cent compared to an uncontrolled vehicle.

A subsequent series of directives limiting vehicle emissions, covering light- and heavy-duty vehicles, and extending to particles as well as gaseous emissions, has since been agreed and subsequent improvements are now up to Euro 6 for light-duty vehicles, due to come into force in September 2014. The parallel series of heavy-duty standards are designated with Roman numerals and the most recent level is Euro VI, which came into force in January 2013. The introduction of three-way catalysts in response to the Euro 1 standard for petrol vehicles, the subsequent tightening of the standards and the change to the test cycle sampling to require sampling to include the cold-start emissions, have been responsible for the most significant improvement in urban air quality in the UK and Europe in the last two decades.

"Ambient levels of NO_2 (and NO_x) have not decreased in the last 10 years or so to the extent expected, and in many cases have not decreased at all"

However, for diesel vehicles regulation has been less successful. It is now well known that although the emission limits have reduced consistently over the past two decades, the emissions of oxides of nitrogen (NO_x) from diesel cars in real-world driving have not reduced. This has been largely due to the fact that the regulatory test cycle does not adequately reflect driving conditions in the real world. However, the lack of reduction in ambient NO_2 levels is also due to the increase in the fraction of NO_x emitted as NO_2 at the tailpipe due to the use of oxidation catalysts (to reduce hydrocarbon and particle emissions) followed by particulate traps (which use NO_2 generated from NO (nitric dioxide) in the exhaust to oxidise the particles on the trap).

These facts, coupled with the increase in the number of diesel cars, not only in the UK but elsewhere in the EU in response to targets for CO_2, has meant that ambient levels of NO_2 (and NO_x) have not decreased in the last 10 years or so to the extent expected, and in many cases have not decreased at all. This has contributed significantly to the wide extent of non-compliance across most of the EU with the ambient limit values for NO_2 in the 2008 Air Quality Directive.

VEHICLE EMISSIONS IN THE NEXT TWO DECADES

This article provides a very brief summary of most of the main features of the air-quality policy over the past 20 years or so. What of the next 20 years? In terms of urban air quality and public health, much depends on the success of the Euro 6 and Euro VI standards in delivering real reductions in everyday use, both for NO_2 and for PM. Work is already underway within the European Commission to devise a 'not to exceed' test procedure to be imposed after the improved regulatory test to address real-world driving. Early indications from tests on a very small number of Euro 6 diesel vehicles suggest that improvements over Euro 5 are likely but real emissions will not be at the level of the regulatory standard in grams per kilometre.

The Euro 5 and 6, and V and VI standards have now stimulated the use of selective catalytic reduction (SCR) on vehicles and there is a concern that urban driving may not generate high-enough temperatures for the catalyst to work effectively. Likewise there are already some indications that the diesel particulate filters employed in response to the Euro 5 and 6 standards may not get hot enough to regenerate effectively, leading to increased fuel consumption and reduced performance. Challenges such as these will need to be overcome to realise fully the potential benefits of tighter emission standards.

FUTURE AIR-QUALITY MANAGEMENT

What of the future for approaches to managing ambient air quality more generally? Successive improvements will clearly become more difficult, and much depends on the economic circumstances of the UK and the EU in the future, as ambitious environmental improvements are notoriously difficult to achieve in recessions. There will probably be a review of the ambient air-quality directive in a few years' time. Will the philosophy of air-quality management and policy move further away from a heavy reliance on limit values to a more balanced blend of source-related regulation and ambient controls based on a form of exposure reduction across large areas and populations? There are strong arguments for this approach.

What improvements are likely by aligning policies on climate change and air quality? Ambitious targets for greenhouse-gas emission reductions, such as those in the UK Climate Change Act and the declaration of intent of the G20 (namely reductions of the order of 80 per cent by 2050), could result in large improvements in air quality and public health, but will the actions to achieve the targets materialise on a large-enough scale? Air quality management over the past 20 years has become increasingly regional and international – will this trend continue and result in hemispheric/global action on air quality? To what extent will local actions be important? As a hypothetical example, if the health effect evidence on PM suggests that the primary combustion emissions are the most important in toxicity terms, the balance shifts to a very large degree from the present position where local authorities can do very little on their own about total PM_{10} or $PM_{2.5}$ mass. These are all speculative questions, and there are many others, but what is certain is that the next 20 years will be as challenging and fascinating as the last 20. **ES**

Martin Williams is a professor of air quality at King's College, London, UK. He is Chairman of the Executive Body of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). Prior to this, he was Head of the Air Quality programme in Defra, with responsibility for air-quality policy, industrial pollution control and research. At King's College, his research interests lie in the application of science to policy in air quality and climate change. He holds a Visiting Professorship at the University of Urbino, Italy. He delivered the IES Burntwood Lecture in 2007.

SOURCES

1. Council Directive of 15 July 1980 on air quality limit values and guide values for sulphur dioxide and suspended particles (80/779/EEC).
2. Council Directive 82/884/EEC of 3 December 1982 on a limit value for lead in the air.
3. Council Directive 85/203/EEC of 7 March 1985 on air quality standards for nitrogen dioxide.
4. Council Directive 92/72/EEC of 21 September 1992 on air pollution by ozone.
5. Dockery, D.W., Pope III, C.A., Xu, X., Spengler, J.D., Ware, J.H., Martha, E.F., Ferris Jr. B.G., Speizer, F.E., 1993, An association between air pollution and mortality in six U.S. cities, *New England Journal of Medicine*, 329, pp. 1753-1759.
6. Health Effects Institute, *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality*, Special Report, Health Effects Institute, July 2000.
7. Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management.
8. Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air.
9. Directive 2000/69/EC of the European Parliament and of the Council of 16 November 2000 relating to limit values for benzene and carbon monoxide in ambient air.
10. Directive 2002/3/EC of the European Parliament and of the Council of 12 February 2002 relating to ozone in ambient air.
11. Directive 2004/107/EC of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.
12. Communication from the Commission to the Council and the European Parliament, Thematic Strategy on air pollution, COM(2005) 446 final.
13. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.
14. Council Directive 70/220/EEC of 20 March 1970 on the approximation of the laws of the Member States relating to measures to be taken against air pollution by gases from positive-ignition engines of motor vehicles.
15. Council Directive 88/76/EEC of 3 December 1987 amending Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by gases from the engines of motor vehicles.

Air quality law: the EU context

Alan Andrews reflects on the fact that the domestic air quality regime laid down in the Clean Air Act and Environment Act interacts in a complex and often confusing way with EU law.

Air quality was one of the first environmental issues addressed by the EU. Early directives such as the 1982 Directive on lead in the air[1] established legally binding limits, called 'limit values', on concentrations of harmful pollutants in ambient air. The European Court of Justice (ECJ) ruled that these limit values conferred rights on individuals that could be relied on in court:

"The obligation implies, therefore, that whenever the exceeding of the limit values could endanger human health the persons concerned must be in a position to rely on mandatory rules in order to be able to assert their rights"[2].

To complement the ambient air quality legislation, EU legislation also regulates emissions of air pollution from mobile sources (such as vehicle engines and ships) and non-mobile sources (such as industrial facilities and power stations).

The current ambient air quality system has its origins in the 1996 Air Framework Directive (AFD), which tried to bring previous laws together into a coherent, overarching legal framework. The AFD laid down a framework system of limit values, which member states were required to comply with. Limit values were informed by World Health Organisation (WHO) guidelines.

Flesh was added to the bones of the AFD through various 'daughter directives'. The 1999 Daughter Directive laid down limit values for particulate matter with a diameter of 10 µm or less (PM_{10}), nitrogen dioxide, sulphur dioxide and benzene. This specified deadlines for achieving compliance, including 2005 for PM_{10} and 2010 for nitrogen dioxide. It also included a requirement that member states draw up action plans where there was a risk of limit values being breached.

However, many member states struggled to ensure compliance with the PM_{10} limit value by 2005. A resident of a busy road in Munich, where breaches of the limits were frequent, went to court to demand that the authorities take action. The case was eventually referred to the ECJ for a preliminary ruling, which went some way towards reinforcing the idea, first suggested in the *Commission v Germany* case, that citizens enjoyed a right to clean air:

"Natural or legal persons directly concerned by a risk that the limit values or alert thresholds may be exceeded must be in a position to require the competent authorities to draw up an action plan where such a risk exists, if necessary by bringing an action before the competent courts"[3].

However, the court made clear that there was no requirement that limit values must never be breached. Moreover, action plans merely had to ensure a gradual return to compliance.

THE AMBIENT AIR QUALITY DIRECTIVE

Germany was not alone in having difficulties in meeting the limits laid down by the 1999 directive. Severe and widespread breaches of the PM_{10} limit values, in particular the daily limit, were a common occurrence in member states across the EU after 2005. One of the difficulties was that breaches were often caused by unfavourable weather conditions, which transported pollution and dust from long distances, and which member states were powerless to do anything about. member states also projected that they would similarly struggle to comply with the limit for NO_2 by 2010.

So when the Commission proposed a new directive, member states lobbied for flexibility. The 2008 directive on ambient air quality and cleaner air for Europe was a case of 'one step forwards, two steps back'. Out went the requirement to produce short-term action plans – unpopular and seen as ineffective by many. Member states were given power to introduce them but were not required to do so. However, the obligation to produce air quality plans was strengthened with a new obligation to ensure that where breaches of limits occurred after the expiry of the relevant deadline, a plan was drawn up to ensure that the limits were achieved in the shortest time possible[4].

Another small step forward was the introduction of new controls on particulate matter with a diameter of 2.5 µm or less ($PM_{2.5}$) – a limit value and an exposure reduction obligation. However the $PM_{2.5}$ limit was very weak – 25 µg/m^3 compared to the 10 µg/m^3 recommended by the WHO, which greatly reduced the value of such a move.

However, the protection of public health was seriously undermined by the introduction of the possibility of delaying compliance with the limits (to 2011 for PM_{10}, and to 2015 for NO_2 and benzene) on condition that the Commission was satisfied that certain conditions. The Commission was given a role in approving or rejecting applications from member states. The conditions were:

- The member state had taken all appropriate measures for compliance by the original deadline;

In the case of PM_{10}, the failure to achieve compliance was the result of factors beyond the control of member states, e.g. unfavourable weather conditions or 'street canyons' which prevented dispersion of pollution from busy roads; and

- The member state had a plan in place to achieve compliance by the new, extended deadline.

THE AIR QUALITY STANDARDS REGULATIONS 2010

The 2008 EU directive was transposed into UK law, almost word for word, by the Air Quality Standards Regulations 2010. Unusually, the Secretary of State assumes responsibility for all obligations, including ensuring compliance with the limit values throughout the UK, monitoring and assessing air quality, disseminating information about air quality and crucially, drawing up plans where breaches of limits occur.

Limit values under the Air Quality Standards Regulations are, for all intents and purposes, identical to those laid down by the Environment Act 1995. Instead of being mere objectives which local authorities and the Secretary of State must work towards, they impose a strict duty on the Secretary of State to ensure compliance by the relevant date. However, in practice the Secretary of State continues to rely, at least in part, on local authorities to deliver local air quality improvements through the system of air quality management laid down by the Environment Act 1995.

SUCCESS OR FAILURE?

There remains widespread breaches of both PM_{10} and NO_2 limits in urban areas throughout the EU, 14 years after the limits and deadlines were first laid down in the Daughter Directive. Despite significant reductions in emissions of PM, there was no discernible downward trend in the size of the population exposed to levels of PM_{10}. In 2010, 21 per cent of the EU urban population lives in areas where the daily limit value for PM_{10} was exceeded[5]. The picture for NO_2 is similarly discouraging: despite significant overall decreases in emissions of NO_x, concentrations of NO_2 have actually increased at some roadside locations, with seven per cent of the EU population living in areas in breach of the NO_2 annual limit in 2010[5].

This failure is to some extent mirrored in the UK, although the UK has had some success in achieving the limits for PM_{10}. According to the most recent official data submitted by the UK to the European Commission, there were no breaches of the PM_{10} limit value in 2011. However, London remains very close to the daily limit value. In any event, compliance with the PM_{10} limits is probably as much a reflection on the weakness of the limits as evidence that great strides have been made in improving air quality: the limits for PM_{10} are double WHO guidelines.

By contrast, the limit value for nitrogen dioxide is equivalent to the WHO guidelines, and there are widespread breaches of the NO_2 limit values in urban areas throughout the UK. Often these are by huge margins: in London's Brixton Road and Putney High Street, annual mean concentrations are between three and four times the legal limits. The picture is similar in major urban centres, with roadside measurements and modeling showing levels of NO_2 around double the legal limits. Current plans show that compliance in 15 air quality zones will not achieve compliance until 2020. For one zone, Greater London, compliance is not expected until 2025.

REASONS

There have been a number of well-documented policy failures that have contributed to the breaches of the NO_2 limits. Examples of these include: dieselisation of the fleet, failure to achieve modal shift away from road transport and the failure of planning authorities to prevent development that has a negative impact on air quality. However, this article will focus on the legal aspects of these failures.

A crucial factor has been the failure of EU emissions legislation, particularly the Euro standards for diesel vehicles. These have failed to deliver real-world emissions reductions and in some cases measures such as the fitting of Diesel Particulate Filters has actually increased primary emissions of NO_2. The main problem with air pollution from road traffic is in urban areas, but the test cycles used to check that engines comply with the Euro standards greatly favour vehicles being driven under motorway or other open road conditions rather than the low-speed, stop–start conditions prevalent in towns and cities. In addition, there has been a lack of ambition in EU measures to tackle emissions from other sources such as agriculture, shipping and non-road mobile machinery, and member states, supported by extensive lobbying from industry, have watered down and delayed proposals.

But the failure of EU emissions legislation is only half the story. A lack of political will means that too often central government, which has the deepest pockets and its hands on the main policy levers, has failed to take timely action to tackle urban air pollution. For example, the UK Government does not have an up-to-date, coherent and holistic plan to address air quality. The current national air quality strategy dates back to 2007. Plans submitted to the Commission at the end of 2011 contain very little in the way of effective new measures, and address only breaches of nitrogen dioxide. The only hint of a major national initiative is a very weak commitment to "investigate the feasibility" of a national framework of low-emission zones, which has until now seen little progress.

From a legal perspective, the most obvious reason for the lack of political will is the absence of an effective enforcement mechanism. Limit values can be breached without any real consequences for those charged with ensuring compliance: Defra can produce plans that show that compliance with nitrogen dioxide limits will not be achieved until 2025; Local Authorities can get away with failing to designate Air Quality Management Areas or giving development consent to new projects that worsen already poor air quality by increasing flows of traffic to polluted areas.

There is a long-standing legal maxim that "every right must have a remedy, and without a remedy, there is no right". Any notion that we have a right to clean air must be viewed with this in mind.

LACK OF ENFORCEMENT BY THE COMMISSION

The European Commission is the guardian of the EU treaty, with the power to refer member states to the ECJ where they fail to properly implement EU directives[6]. There is a particular onus on the commission to enforce environmental directives such as the ambient air quality directive. However, this is a role that the Commission is poorly equipped to carry out. It lacks not only the necessary numbers of expert staff to scrutinise and process the data submitted by member states, but also the powers, procedures and institutional autonomy it needs to effectively enforce the directive.

First, the Commission has no powers of inspection, relying instead on information provided to it by member states to establish whether compliance has been achieved. This is compounded in the air quality directive as member states are given nine months after the end of a calendar year to report breaches to the commission.

Second, the Commission's enforcement procedure takes too long. Infringement action under Article 258 is a three-stage process. First the Commission sends the member state a written warning, known as a 'letter of formal notice'. Then, the Commission must send a final written warning, known as a 'reasoned opinion', setting out the basis for the alleged breach of EU law and requiring the member state to take certain steps by a certain deadline. Only at the expiry of this deadline can the Commission refer the member state to the ECJ. But even assuming that the Commission successfully persuades the ECJ of the member state's failure to comply, this does not lead to fines. At this stage the ECJ only has the power to issue a declaration: a written statement confirming that the member state has broken EU law. It is only once a member state has failed to heed this declaration, and continues to be in breach of the Court's judgment, that the Commission can use its powers under Article 260 to refer the member state back to the ECJ with a recommendation for a fine, even then only after issuing a new letter of formal notice and reasoned opinion. This is a long and complex process which is also notable for a lack of transparency (for example, the letters of formal notice and reasoned opinion are not made public).

A recent run of disastrous ECJ judgments in commission infringement cases illustrates perfectly how these problems render the air quality directive virtually unenforceable by the Commission. To take the most recent example, in December 2012 the ECJ gave judgment in *Commission v Italy*[7]. The ECJ declared that Italy had breached its obligations under the 1999 Daughter Directive by failing to ensure compliance with PM_{10} limits in 2006 and 2007, but refused to take a view on whether Italy was in ongoing breach after this date. This was because when the case was referred to the ECJ, the latest data the Commission had at its disposal was that for the years 2006 and 2007, which was provided by Italy in 2009. The Commission first wrote to Italy to warn it of its intention to bring infringement action in June 2008 – four-and-a-half years before the court gave judgment.

As a result of judgments like this, which make it impossible for the Commission follow up with proceedings under Article 260, the Commission has had to go back to the drawing board and change the way it brings these cases[8]. Rather than merely stating that member states were in breach at a certain date and calling on the court to infer continued breach from that, it will now try to prove to the court that the member state is in ongoing breach of the directive based on its air quality plans. This is a much more complex and labour-intensive way of bringing cases which will stretch the Commission's already limited resources to breaking point. Crucially, the Commission has had to go right back to the very start of the process with these member states, so we will probably not find out whether this strategy is successful until as late as 2017.

ENFORCEMENT IN MEMBER STATES

Enforcement of the Directive is not solely the responsibility of the European Commission. Member states' domestic courts are required to ensure compliance by providing effective remedies for breaches of EU law. The *Janecek* case was heralded by campaigners and environmental lawyers alike as a powerful precedent that would give citizens and concerned groups such as NGOs the right to go to court and demand action where limit values were breached. The reality is that accessing the courts remains very difficult in most member states, but especially the UK. Legal action is expensive. Would-be litigants must not only fund their own lawyers (a profession not renowned for its reasonable hourly rates) but also face the prospect of paying the defendant's legal fees if they lose (although some limits are now set on this potentially liability). Even if a claimant is successful in proving that there has been a breach of EU law, this does not guarantee success. In 2011 ClientEarth brought a case against the Secretary of State for the Environment, Food and Rural Affairs before the High Court. Despite forcing the Secretary of State to admit that she was in breach of her obligations under the Directive, the court declined to give any remedy, ruling that it was for the Commission to take action against the Secretary of State. ClientEarth fared no better in the Court of Appeal and to add insult to injury were ordered to pay £10,000 towards the Secretary of State's legal costs[9]. A further appeal was heard by the Supreme Court in March 2013.

THE 2013 REVIEW

So at the beginning of the EU's Year of Air[10], the EU air pollution law is in something of a mess. The limits in the Directive are far too lax to adequately protect human health, as confirmed by a recent report by the WHO, which recommended that its own guidelines be tightened, with the implication that, at least from a health point of view, the EU should follow suit[11]. Despite this, limits are being breached across the EU and are projected to continue to do so for many years to come. EU emissions legislation is failing to deliver real-world emissions reductions, giving member states the perfect excuse to justify prolonged breaches of the limit values. Some, including the UK, are even calling for 'flexibility' in the application of limits. Faced with this, the Commission understandably wants to focus on improving the emissions legislation for now, rather than opening up the ambient air quality directive and risking further time extensions or a weakening of standards to be forced on it by member-state lobbying.

In the long term, limit values are the key to delivering clean air. However, they need to be aligned with the latest scientific data and they need to be faithfully respected by national and local authorities. Where they are breached, plans must be produced that lay down additional measures to tackle the problem, with clear timetables for implementation. The public must be given the opportunity to participate in the formulation of those plans – this is not only a legal requirement but also an important tool for raising awareness and garnering support for local air quality measures. Ultimately, where the authorities fail to produce adequate plans or implement them in good time, both the Commission and concerned citizens within member states must have the ability to go to court and obtain effective remedies that force them to live up to their legal and moral responsibilities. ES

Alan Andrews is a lawyer with ClientEarth, a not-for-profit environmental law organisation. Alan's work focuses primarily on air pollution issues, and particularly on promoting better compliance with European air quality standards in the UK. He also sits on the stakeholder expert group for the EU's "Year of Air" air policy review.

SOURCES

1. Council Directive 82/884/EEC of 3 December 1982 on a limit value for lead in the air.
2. Case C-59/89 Commission v Federal Republic of Germany [1991] ECR I-2607.
3. Case C-237/07 Dieter Janecek v Freistaat Bayern [2008] ECR I-06221.
4. Article 23.
5. European Environment Agency (2012) *Air Quality in Europe – 2012 Report*; EEA Report No 4/2012. European Environment Agency, Copenhagen. www.eea.europa.eu/publications/air-quality-in-europe-2012.
6. Article 258 Treaty on European Union.
7. Case C 68/11 Commission v Italy [2012] (unreported).
8. Europa (2013) *Environment: a fresh legal approach to improving air quality in Member States*. Press release, 24 January 2013. europa.eu/rapid/press-release_IP-13-47_en.htm
9. I don't think this needs referencing – it was made by order of the Court of Appeal dated 30 May 2012, which is not published.
10. European Environment Agency (2013) *2013: Kicking off the Year of Air*. Press release, 8 January 2013. www.eea.europa.eu/highlights/2013-kicking-off-the-2018year.
11. World Health Organisation (2013) *Review of evidence on health aspects of air pollution – REVIHAAP Project: First results*. www.euro.who.int/__data/assets/pdf_file/0020/182432/e96762-final.pdf [Accessed: 26th March 2013].

Air quality legislation and practice – a practitioner's perspective

David Muir analyses the effectiveness of the various Clean Air Acts and the Environment Act 1995 in resolving urban air pollution.

Legislation on air quality, and in particular local air quality, has a long history in the UK: in the 13th century there are references to Henry III's queen (Eleanor of Provence) leaving Nottingham during a meeting of a parliament because of smoke, and the first smoke abatement law was passed in the year after Henry's death (1273). In 1306 a Royal Proclamation banned coal burning in London. This must have been 'forgotten' with the passing years, as Queen Elizabeth I also banned coal burning in London, though only when Parliament was sitting.

Further similar measures were introduced from time-to-time between the 17th and 20th centuries. The effectiveness of such measures can be judged by reference to such publications as John Evelyn's 1661 tract *Fumifugium*[1], and in the 19th and early 20th centuries, the frequent references to London fogs and smogs in the novels of Charles Dickens and Arthur Conan Doyle, and the London paintings of Claude Monet and Sir William Blake Richmond. The latter was so frustrated by poor light caused by winter smoke in London that in 1898 he founded the Coal Smoke Abatement Society to campaign for cleaner air.

THE CLEAN AIR ACTS

The key event leading to legislation to address the issue of urban air pollution was the Great London Smog of 1952, during which at least 4,000 people died as a result of air pollution. Even then, the Government was reluctant to act. The Clean Air Act 1956 was the result of a private member's bill that was eventually accepted by the government of the day. This was followed by the Clean Air Act 1968, and both, along with some related legislation, were consolidated into the Clean Air Act (CAA) 1993.

These Acts approached the problem from a number of directions. The measure that was most evident to the general public was the power given to local authorities to establish Smoke Control Areas (SCAs) where only approved fossil fuels (i.e. 'smokeless' coal, coke, gas or oil) could be burnt on domestic premises. Another power included assessing smoke emissions from steam locomotives, especially when on shed, i.e. when in storage. This is because other emissions (when trains are in motion) are transient whereas on shed the emissions could be prolonged especially when raising steam from an initially cold boiler. (There is a particularly interesting discussion of the railway emissions in the 1975 history of the King's Cross locomotive depot, *Top Shed*[2]). Local authorities also gained powers to prosecute small industrial smoke emitters such as scrap yards (they burnt cable and other waste materials). These measures were supplemented by a shift from production of electricity in small power stations located in urban areas to large coal-fired power stations in (supposedly) more rural locations.

▼ Table 1. Current air quality management areas in the UK[3]

Source	Number of current AQMAs by source				
	England	Northern Ireland	Scotland	Wales	London
Road transport, unspecified	167	22	20	10	26
Country or unitary authority road	155		4	16	1
Mixture of road types	79		3	4	2
Highways agency road	43			1	
Industrial source	11		1	1	
Transport and industrial source	10		1		4
Transport, industrial and domestic sources	8				
Not defined	3	1			
Domestic heating	2	5	1		
Total	478	28	30	32	33

Superficially the CAAs were a spectacular success in that there have been no more smogs on the scale of the 1952 London smog, though there were lesser episodes in 1956, 1957, 1957–8 and 1962, all involving black smoke and sulphur dioxide. Just how much of the overall success can be directly attributed to the legislation is more questionable. There can be little doubt that the legislation assisted in the improvements achieved but other factors, notably social factors, also made a major contribution. In addition the legislation had some weak points, especially that the declaration of SCAs was at the discretion of local authorities.

PHASING OUT COAL

A major social factor behind the improvements achieved was the growing discontent with the inconvenience of domestic coal burning, in particular with the lower-grade coals in general use, which normally produced larger quantities of residual ash than the 'smokeless' fuels. The CAAs did assist considerably in the move away from using low-grade coal by making grants available to subsidise the installation of smokeless grates and heating systems using alternative fuels.

Air quality problems also increased over the years in part because some local authorities failed to declare SCAs, but also because large local authorities had to stagger the process over a number of years. Typically a city would declare SCAs in its central areas, followed by the western side of the city, finishing in the eastern side. A major consequence of this was that by the time the last SCAs were being declared, the areas in question were benefiting from earlier declarations of SCAs, with the result that there were more challenges to the SCA programmes and less willingness to cooperate. On the other hand, any new build in those areas usually contained heating systems that would comply with the CAA requirements.

THE COPA AND THE EPA

The Control of Pollution Act (COPA) 1974, although important in its own right, has only limited applicability in relation to general urban air pollution. There are provisions in relation to the composition of fuel, both for furnaces and motor vehicles, and it makes cable burning a specific offence. It also confers powers on local authorities to obtain information relating to air pollution.

The Environmental Protection Act (EPA) 1990 is also more important in the wider context. The two main airquality elements relate to integrated pollution control (IPC) by the Environment Agency and Air Pollution Control (APC) by local authorities as a means of regulating emissions from industry and statutory nuisance.

Although both of these pieces of legislation appear to have been reasonably effective, their relevance to local air quality is low.

▼ Table 2. Revoked air quality management areas in the UK[3]

Source	Number of revoked AQMAs by source				
	England	Northern Ireland	Scotland	Wales	London
Road transprt, unspecified	55	5		2	
Country or Unitary Authority rd	23				3
Industrial source	7				
Mixture of road types	5				
Transport and industrial source	1				
Not defined	1				
Domestic heating	1	6			
Highways agency road	1				
Total	94	11	0	2	3

ENVIRONMENT ACT (1995)

Potentially the most important recent piece of legislation relating to local air quality is Part IV of the Environment Act (EA) 1995. (A curious parallel with the original Clean Air Act is that Part IV was originally introduced in the House of Lords as an amendment to the Government's Environment Bill.) The key elements of the legislation are that all local authorities are required to review and assess air quality against specified criteria called air quality objectives (AQOs) and, if these are not being met or are unlikely to be met by the specified date, to declare one or more Air Quality Management Areas (AQMAs) and develop an action plan to work towards meeting the criteria within the AQMAs.

One element of the legislation that was a clear success was that most majority local authorities carried out the first part of the process (the review and assessment), although many did not meet the original time scale for this process. Given that many local authorities had little or no experience of air quality, this was perhaps a better outcome than might have been anticipated. The development of action plans was far patchier and possibly reflects the fact that this process involves a number of parties, within and outside the local authority, for whom air quality might not be a priority.

FAILING LEGISLATION

The main point at which the legislation fails appears to be in implementing the action plans and achieving the AQOs. There are a number of possible reasons, probably acting in combination, why this is the case. One is the sheer size of the problem. **Tables 1** and **2** show the numbers of current and revoked AQMAs in the UK as of February 2013[3] and **Table 3** shows the pollutants responsible for the declarations.

There are two main factors illustrated by the data in the tables. The first is the large number of AQMAs declared. Although the actual number of local authorities declaring AQMAs is lower than **Table 1** might suggest (due to some declarations coming from the whole authority or a single part of it and others coming from multiple discrete parts within authority areas), there is a very strong belief that it is much greater than Government had originally expected. The second factor is that only about 4 per cent of the declarations have no transport component.

The significance of these two main factors is that dealing with the problem of air pollution will involve far more action than had been anticipated, and this implies the allocation of greater resources than had been anticipated. In addition, much of that action will have to focus on transport, which will need to involve the general public.

A third factor is that implementation of local authority action plans involves a number of agencies, both inside and outside the authority declaring an AQMA. These problems can be exacerbated in two-tier authorities where action on transport requires the co-operation of a county council as the highways authority.

A further point, albeit a small one, is that some AQMAs were declared on the grounds of domestic emissions. This would appear to be a consequence of the Clean Air Acts not being implemented in these areas. There are, of course, a number of additional factors such as the apparent failure of Euro standards for emissions from road vehicles to deliver their promised benefits, and the more general issue of apparently reduced emissions failing to translate into significant reductions in concentrations in real-life measurements.

SUCCESS OR FAILURE OVERALL?

There can be no doubt that the Clean Air Acts did have some effect in improving air quality in those UK towns and cities where they were implemented. On the other hand, the lack of universal application did mean that the benefits were not enjoyed by all the population. There was also some success, albeit in the longer term and not necessarily 100 per cent, in controlling smoke emissions from industrial premises such as scrap yards. A key element in the successes is the fact that, at least in the earlier stages, the legislation brought benefits to the general public in those areas where it was fully implemented. However, unforeseen and negative consequences came about because of the emissions from large coal-fired power stations contributing to acid rain.

Although it might be wrong to describe the Environment Act as a failure, there can be no doubt that it has not achieved the desired improvements in urban air quality. There is probably no single factor responsible for this; rather it is a combination of factors. The resource implication is one that seems to stand out in spite of the apparent benefits that could accrue from improvements in public health. The fact that air-quality management needs the co-operation of a number of agencies, not all of which may regard air quality as one of their priorities, is also important.

However, probably the major factor is the general public. There are certainly two main elements here. Firstly, the facts that air pollution is now largely invisible and the effects may be described as a 'trickle effect' (in contrast to the 1952 London smog) mean that recognition of the scale of the problem is greatly reduced. Secondly, effective action in the majority of AQMAs will involve some measure of action on road traffic, which is likely to be unpopular with the majority of drivers.

CONCLUSIONS

There are two main elements to all legislation: enactment and implementation/enforcement. In the case of the two main pieces of legislation considered here, the Clean Air Acts have, to a large extent, been effectively implemented, whereas the Environment Act Part IV has proved far more difficult, in spite of an apparently greater awareness of environmental issues.

Although there are many possible reasons why implementation of the Environment Act has not been effective there are two that stand out. The first is the lack of political will to commit resources to achieve the aims of the legislation, allied to a probable belief that there is no major problem to address. The second is that although there is superficial support for better air quality, there appears to be little public will to achieve improved air quality, by means of individuals taking action themselves to reduce air pollution arising from road traffic. ES

David Muir has worked in the air quality field for 37 years, with Bristol City Council from 1976 to 2009 and as an independent consultant/researcher since 2009. He gained a PhD from the University of the West of England in 2003. He has been a member of IAQM since its foundation and serves both on its committee and on the IES Council.

Table 3. Current air quality management areas by pollutant[3]

Pollutant	Benzene	Nitrogen dioxide	Particulate matter	Sulphur dioxide
England		456	43	7
Northern Ireland		22	6	
Scotland		20	20	1
Wales		31	1	
London		33	29	

SOURCES

1. Evelyn, J. (1661) *Fumifugium or The Inconveniencie of the Aer and Smoak of London Dissipated.* Together with some remedies humbly proposed by J.E. Esq; to His Sacred Majestie, and To the Parliament now Assembled. Gabriel Bedel and Thomas Collins, London.
2. Townend, P.N. (1975) *Top Shed*. Ian Allan Ltd, Shepperton.
3. Defra www.defra.gov.uk/environment/quality/air/air-quality/laqm.

Clean Air in London

Simon Birkett reviews a long campaign to build public understanding of air pollution.

"Don't drink the water and don't breathe the air!" I can still remember the brutal satire of the Tom Lehrer song 'Pollution'[1] in the 1960s. I guess that was what got me interested in the environment. But lots of things have come together to make the Clean Air in London campaign what it is today. From a personal perspective, the best part has been creating something, delivering results and working with such a large, diverse and wonderful network of supporters and others.

The story began over 20 years ago when I jumped at an opportunity from my employer to attend a 12-month programme with Common Purpose (a leadership training organisation) which introduced me to nearly a dozen different aspects of society, including health, housing, transport and the environment. It was inspiring. A few years later, I joined my local residents' association. Before long I was helping the association and my work mentor, who was by then a near neighbour, run a campaign against the City of Westminster (a London borough) that ended up in the High Court with a finding in our favour. However, I learned that there is little point trying to persuade politicians to do things they do not want and do not have to do. I decided it would be easier to ask them to comply with public health laws.

Perhaps by chance or to try another route, the same mentor suggested air pollution was bad in our area and encouraged me to set up and chair a new Transport and Environment Committee for the Knightsbridge Association (KA; a local organisation in Westminster) in 2006. Before long, and wanting to start at the top, the new Committee had written to the then-Mayor of London Ken Livingstone, urging a bolder low-emission zone. Next thing, the Committee was responding on behalf of the KA to the Department for Environment Food and Rural Affairs (Defra) consultation on a new Air Quality Strategy with support from every official amenity society in the City of Westminster. Each of these letters was laboriously printed and posted until I realised the power of email.

THE LAUNCH OF THE CAMPAIGN

It was beginning to become administratively cumbersome to encourage others to support each committee letter. That was when Dr Charles Tannock, a Conservative MEP, suggested I set up a campaign that people could support. This culminated in February 2007 in the launch of the cross-party Campaign for Clean Air in London with a group of Honorary Founder Supporters who are still involved in the campaign. Ken Livingstone wrote personally in support of the aims of the campaign.

By then the campaign had a blog on the BBC Action Network to publish its letters and announcements, and I was starting to be interviewed by the press and television. Perhaps annoyingly for the Government, I had then figured out, largely by trial and error, the BBC search engine algorithm and the campaign was appearing top in searches on the BBC's global website. Ned Temko of *The Observer* had also written the first big press story, 'Chelsea choked by its tractors'[2].

▲ **Photo credit: ©2013 Simon Birkett**

Most of 2006 and 2007 was spent lobbying on a proposed new Air Quality Directive that would replace several existing directives dating back to 1996 and 1999. At one stage, it seemed the process was logjammed. So the campaign wrote to the then European Commissioner for the Environment, Stavros Dimas, copying in MEPs and many others, urging the European Commission, the European Parliament and the Council of Ministers to accept the highest common denominator – in health and environmental terms – proposed by each of them. Combined, later in the process, with an insistence that three 'red lines' had to be met if a new Directive was to be better than the previous legislation, that is more or less where the new Directive ended up. Writing those letters and emails may have been Clean Air in London's most valuable contribution to air quality and public health.

AT A GLANCE: 3 RED LINES

1. no 'burden of proof' before member states can take action to improve air quality;
2. the Directive must make clear that all limit values will continue to apply everywhere (as they do currently) with no let-out possible, e.g. no let-outs through the inclusion of a clause allowing member states not to measure these limit values everywhere; and
3. any time extensions must not, in any circumstances, include so-called 'two-stage' time extensions which would have the (inevitable practical) consequence of making any first stage ineffective.

THE CAMPAIGN PRINCIPLES

Underpinning the campaign has been a vision. It was obvious the campaign needed to be London-wide, health-based and cross-party if it was to get established and remove hurdles to acceptance. Several other principles emerged:

- **The London Matrix:** a table with two columns labelled 'Air pollution' and 'Greenhouse gases' (or 'Sustainability') and two rows labelled 'London' (or any other city) and 'Rest of the world'. The vision is to comply with air quality laws and health standards for air pollution in London and show how wider air pollution and sustainability issues can be tackled successfully everywhere through a mixture of political will, technology and behavioural change. This is a powerful tool in discussions with policy makers to put the issue in context and communicate a positive vision.

- **The London Principle:** accept a one-per-cent increase in greenhouse gases (e.g. carbon dioxide) if a measure can achieve a 10 per cent reduction in air pollution (e.g. oxides of nitrogen) and vice versa (provided air pollution laws are complied with in full). The ratio is not precise or fixed but the principle allows, for the first time, practical trade-offs between

climate and air quality issues with diesel exhaust being the classic example.

- **The London Circles:** measures to tackle transport typically fall into one of two overlapping circles. Emission measures, like the low-emission zone, which tackle primarily emissions at source and may reduce congestion; and congestion measures, like road-user pricing, that tackle congestion and may reduce emissions. Each measure usually offers secondary benefits for the other.

From a personal perspective, I have learned that air pollution problems are best tackled at their source rather than through offsetting (by tree planting or creating green walls, for example), and it is not so much a question – in air pollution terms – of how big a vehicle is but rather how much fuel it burns in total. More recently, I have begun to understand the danger of scientific research being used (by others) to manufacture uncertainty. Also the danger that policy-makers and legacy industries use specious arguments to defend the status quo, e.g. we must not reduce sulphur emissions from shipping because they have a short-term cooling effect in the atmosphere! We need to keep thinking holistically and remember that emissions are the problem and that we need to get on with reducing them; Janez Potočnik, current European Commissioner for the Environment, wisely calls it 'resource efficiency'.

THE VITAL ELEMENTS

A campaign needs a compelling vision backed by data, pressure and support (which is similar to the approach recommended by human resources professionals to change the personal behaviour of employees). More particularly, a campaign needs:

1. **Governance**. Clean Air in London, for example, is now a legal entity and is answerable primarily to its Honorary Founder Supporters, sponsors and clients. It is also important to carry your supporters with you. Earlier the campaign operated under the auspices of the KA.

2. **Content.** What are the big issues? Who is responsible for what and when are the milestones? Are there consultations to reply to? Are there cover-ups? Are there shocking failures or omissions? Use Google alerts to warn you about news or developments on the web. What are the top solutions? For example, Clean Air in London proposed 45 measures in its manifesto for the Mayoral and London Assembly elections in 2012. and at the top of the list was political leadership.

3. **Prioritise**. Don't be a 'busy fool'. Identify the objectives, focus on mission-critical milestones and do not be distracted or broaden your remit just because it might seem more fun. Spend 80 per cent of your time doing 'moving ahead' things and 20 per cent on maintenance. Focus on return on effort and outputs. Achieve something important every single day, in one place, for years. Measure your performance, e.g. number of media articles including a mention of your organisation. Never give up.

4. **Marketing and communication**. No one is under any obligation to listen to you or read what you write. Make it easy for people to access your content and share it. Set up a website with as much bandwidth as you can afford. Apart from anything else, it saves you looking for things and having to email everything to people. Repeat, again and

again, your most important messages, e.g. the World Health Organisation has classified diesel exhaust as carcinogenic for humans. Your first foray on the internet can be frightening, so go at your own pace and take basic precautions, but remember there is nothing more powerful for campaigners.

5. **Legal pressure**. Research the legal constraints and insist they are complied with in full. Make the most of access to environmental information laws which are narrower but much more powerful than freedom of information laws, especially when enquiries relate to emissions to the environment. Clean Air in London has taken the Government to the Court of Appeal, with pro-bono support from Friends of the Earth's Rights and Justice Centre and two excellent barristers, Gerry Facenna and Laura Elizabeth John. We lost the case but won numerous concessions from the Government that are now enshrined in law. A new challenge might achieve more.

6. **Empower others.** Clean Air in London writes its letters and publishes key resources so that, as far as possible, others can tailor them to their own circumstances. The campaign has also increased its productivity by publishing guides that help others and allow you to say 'Please read [it], then call me back'. There is a call to action, '10 steps for Clean Air in London'. Clean Air in London is also celebrating its first Clean Air in London Awards to recognise a wider circle of contributors.

7. **Be constructive, positive and upbeat.** Your campaign has a vision to save the world, e.g. by using The London Matrix. Always be ready to propose solutions and try to end on a positive note. Don't get bogged down by negativism or distractions, about European fines, for example, as they are necessary but final sanctions, like jail.

8. **Celebrate and enjoy your successes.**

WORKING WITH THE MEDIA

The important role of the media deserves a special mention. Media professionals have a very demanding occupation. The best and almost all are incredibly rigorous. Occasional mistakes are inevitable because they operate under near-impossible deadlines. If they contact you, you must respond immediately. You could offer or ask to send campaign quotes by email. Be willing to give robust quotes but weigh your potential liability. Build reciprocal relationships: suggest ideas to reliable media contacts. Bear in mind that you can spend days or weeks without any success, despite even thinking you have the best story in the world, then 'all hell breaks loose' and everyone wants to speak to you. Remember that the media is often fobbed off and managed by a large organisation's media office, prevented from speaking to decision-makers, so direct access to campaigners is valuable to them.

Each media channel has different characteristics. Online can reach many people, is there forever (more or less) and can be corrected, if wrong. Everyone likes seeing something in the paper. Radio is often live and allows slightly longer comment. Television is perhaps the most powerful medium but you only get a sound bite and it is usually recorded and therefore edited. Remember a sound bite is roughly one sentence, not a headline. It can take me up to a day beforehand to distill a complex issue and myriad facts into one sentence and make notes of other points to answer or offer. Then, of course, you have to be lucky to be included! Do not make the mistake of thinking the television or radio can afford to let you ramble on.

Social media has a vital role to play too. It builds real relationships with a vast number of potential contacts and it is cheap. It is ideal for campaigners and often used by the media to source ideas and identify trends. Facebook is better for longer items. Twitter is fabulous for offering small inputs for big outputs and immediacy. Make sure that you use hashtags, lists, searches and people's usernames: no one can follow their timeline once they are following more than 20 people! Ask questions: some followers asked Clean Air in London to tweet shorter messages (to allow others to add comments, make it easier to retweet and do less to help others, i.e. 'spoonfeeding' some followers). The power of Twitter is shown by people often referring to the campaign by its username, CleanAirLondon, (because Twitter does not allow space for 'in').

WHY IS AIR QUALITY STILL BAD?

With all these weapons at our disposal, why is something not being done about air pollution now it has been identified as the biggest public health risk after smoking? Why does the public not know about it? The answer to both questions is that successive Governments have not understood the health evidence or wanted to be asked what they are doing about air pollution or wanted to take action to deal with it (e.g. banning the oldest diesel vehicles from cities as Germany has done in over 45 cities). Scientists have only discovered in the last 10 years or so that the health impacts of long-term exposure to dangerous and invisible airborne particles dwarf those from short-term exposure to visible air pollution as we saw during the Great London Smog of 1952. Scientists are as certain now about these risks as they are of those from smoking.

Air Quality Ministers have sometimes displayed their ignorance and been reshuffled within weeks. But it is worse than that.

In CAL's view, the current Government is still failing to warn people and may be misleading them with statistics such as: "air pollution has declined significantly in recent decades"; air quality is "good across 99% of the UK"; and "air pollution still reduces life expectancy by an average of six months" (if averaged over 60 million people alive at the moment).

When asked about legal breaches, the government says it is concerned and has plans in place to reduce air pollution. Of course, Governments have omitted to mention that scientists have only known about the longer-term health impacts in the last decade or so. No wonder that the general public does not understand the importance of this issue.

WHAT NEXT?

The European Commission has named 2013 the Year of Air. The number of organisations actively campaigning on air pollution has mushroomed and media interest is rising exponentially. So far this year media interest is running two or three times that of last year, which was itself a record year. We need continuity and the further tightening of health and legal protections from new EU and UK legislation.

In my view, the solution lies in building public understanding of the dangers of air pollution, enforcement and tightening of existing laws, new legislation on sources of pollution.

Clean Air in London has had many successes in the last seven years. Together, we might just 'save the world' in the next seven! **ES**

Simon Birkett founded the cross-party Campaign for Clean Air in London in 2006. In 2009, Simon accused the previous British Government of one of the biggest public health failings or 'cover-ups' in modern history for not publishing an estimate for the number of deaths attributable to long-term exposure to dangerous airborne particles.

The campaign won the City of London's inaugural Sustainable City Award for outstanding contributions to improving air quality. Simon is Founder and Director of Clean Air in London.

SOURCES

1. Lehrer, T. (1965) 'Pollution'. Reprise Records, Burbank, CA.
2. Temko, C. (2006) Chelsea choked by its tractors, *The Observer*, 20 August. www.guardian.co.uk/news/2006/aug/20/transportintheuk.travelsenvironmentalimpact.

AQE 2013: monitoring emissions and ambient air

This article summarises the subjects covered by the speakers at this year's air quality and emissions show.

Many of the UK's major towns and cities are failing to meet EU air-quality targets, so several of the AQE speakers and workshop leaders looked at ways in which monitoring could help the UK and other countries to do better. The fact that air quality is also a global concern was reflected in the fact that there were visitors from 38 countries.

AMBIENT AIR QUALITY

The focus of the first day of the conference was ambient air quality. Brian Stacey from Ricardo-AEA spoke on behalf of Defra, providing his interpretation of UK and EU air quality policy, and how this interacts with monitoring and modelling. Looking forward, he speculated that very fine particles and dark particles are likely to be the focus of attention.

Professor Frank Kelly from King's College London explained the need for a new approach to monitoring. His colleague, Dr Ben Barratt, has used portable aethalometers to continuously measure the black carbon exposure of a variety of people, highlighting the advantages of portable monitors and showed that the main risks occur during travel on busy roads.

Professor Roy Harrison from Birmingham University delivered a presentation in which he explained how to gain added value from monitoring data by understanding air pollution processes. His talk illustrated some of the scientific advances that have been derived from the analysis of routinely collected data.

Whilst the demand for environmental monitoring data grows, the funding for doing so is under pressure, and Ruth Fain from Golder Associates explained how section 106 agreements (section 75 in Scotland) can be used to secure the implementation of air-quality monitoring programmes or other mitigation as part of the granting of planning permission.

Emphasising the importance of commonality of monitoring amongst EU member states, Emily Jarvis from SIRA closed the first day by explaining the role of instrument equivalence and MCERTS certification of continuous ambient air quality monitoring systems (CAMs).

EMISSIONS MONITORING

The second day addressed emissions monitoring, and Richard Vincent, Head of Industrial Pollution Control at Defra, explained that the Industrial Emissions Directive (IED) applies to around 10,000 installations in England and Wales, including a wide variety of processes, from power stations to dry cleaners. Importantly, the IED tightens the implementation of Best Available Techniques (BAT) through the progressive adoption of the BAT conclusions reached in the BREFs (Best Available Techniques Reference Documents).

In the next presentation Michelle Gallagher from the Environment Agency (EA) explained that odour is a form of pollution and any EA-regulated process that creates an odour needs to develop an Odour Management Plan.

Also from the EA, Rick Gould outlined the development of Operator Monitoring Assessment (OMA), which provides a systematic tool for auditing the monitoring provisions required by an operator's permit and scoring the degree of risk.

In the afternoon session, Carsten Röllig from TÜV in Germany discussed EN 15267, which is a European Committee for Standardisation (CEN) standard for testing and certifying automated measuring systems (AMS), which applies to AMS for both stack emissions and ambient-air monitoring.

In the final conference presentation, Rod Robinson from the National Physical Laboratory provided an outline of the emissions-monitoring methods standardised in Europe, explaining how these fit with European Directives, BATs and BREFs.

The next AQE show will take place on 22–23 April 2015. Visit www.aqeshow.com for further information. ES

Air pollution and health: past, present and future

Robert Maynard outlines what is known and what is yet to be discovered about the causes of ill-health associated with air pollution.

It is now widely accepted that air pollution imposes a heavy burden on public health. That this was the case in the 'bad old days' of coal smoke smogs, when annual average concentrations of particles monitored as black smoke in London ran to several hundred μg/m³ was hardly surprising. That this is still the case when levels of many air pollutants are now lower in UK cities than perhaps at any time since the Industrial Revolution is remarkable. The use of soft coal for domestic heating in urban areas has been banned, emissions from motor vehicles are very substantially lower than they were a few decades ago, emissions of sulphur dioxide from power stations burning fossil fuels have been much reduced and as a result annual average concentrations of particulate matter monitored as PM_{10} are now down to 20–25 μg/m³, and of $PM_{2.5}$ down to about 10–12 μg/m³.

Yet the burden on public health remains large. The magnitude of this was estimated by the UK Departments of Health's Committee on the Medical Effects of Air Pollutants in 2010[1]. The committee, using a large US cohort study, took coefficients linking long-term average concentrations of $PM_{2.5}$ and the risk of death from all non-accidental causes, and applied these to a life-table for the UK. This approach allowed both an estimate of the current burden imposed on health by $PM_{2.5}$ and a calculation of the impact on health of policies designed to reduce concentrations of particulate matter.

The results were surprising; current concentrations of $PM_{2.5}$ imposes a burden equivalent to nearly 29,000 deaths per year in the UK population and an associated loss of life expectancy of about 340,000 life years. How this effect is distributed across the population is not known but, on average, there is a loss of about six months of life expectancy. By any standards this is a large effect.

CARDIOVASCULAR DISEASE

Perhaps even more surprising is the fact that the majority of this effect is due to an increase in the risk of death from cardiovascular disease rather than from an effect on respiratory disease, with the notable exception of lung cancer. That deaths from cardiovascular disease comprised a large proportion of the deaths associated with high concentrations of smoke was, in fact, known as a result of analyses of the effects of the London smog of 1952 but at the time the focus was on the acute effects of exposure to very high concentrations.

It is accepted that long-term exposure to comparatively low concentrations also has a large effect, indeed a much larger effect than that imposed by day-to-day variations in concentrations. The effects of the latter may be estimated by the use of coefficients derived from time-series studies. For 10 μg/m³ PM_{10} the time series coefficient is 0.6 per cent but size of those derived from cohort studies that look at the effects of long-term exposure is 6.0 per cent.

WHAT ARE PARTICULATES?

Ambient particulate matter comprises a complex mixture of inorganic and organic components. In UK cities, about a third of material monitored as PM_{10} is produced by the combustion of fuel by motor vehicles, about a third is made up of secondary particles (largely sulphates and nitrates) and the rest is mechanically generated particles largely of crustal origin. It is unlikely that particles from all these sources have the same toxicological potential. It follows that reducing concentrations of particles generated by these various sources is likely to have variable effects on the burden of disease imposed by the ambient aerosols. The desirability of reducing concentrations of the more active components is obvious.

Which are the more active components? It seems likely that some components, for example sodium chloride (common salt) are unlikely to be very active. Secondary particles, for example, ammonium sulphate, would also not be expected to be, per se, toxicologically active, though the compound may act as a surrogate for more active species that are produced in the chain of reactions linking sulphur dioxide with ammonium sulphate. In fact none of the components of the ambient aerosol seems likely to be sufficiently active, at least in terms of classical toxicology, to produce the effects noted above. How odd this is!

"Anyone who reads the current evidence linking exposure to ambient particles with effects on health will be struck by how closely the effects resemble those of cigarette smoking."

We know that the aerosols have significant effects on health, and yet we cannot point to any one component, or indeed group of components, that is present in sufficient amounts to produce these effects. This has led some critics to take the view that we are being misled by the results of epidemiological studies. Such a view has now been discarded by the majority of experts working in the field, and more interesting suggestions as to how very low mass concentrations of particulate matter might produce significant toxicological effects are being put forward.

NUMBER VERSUS MASS

One suggestion is that we should not be confined to thinking about *mass* concentrations; perhaps it is the *number* of particles, rather than the mass of particles, per unit volume of air that is the important factor. If this is so then very small particles that make up the majority of the number but contribute only a small fraction of the mass concentration are an obvious target for research. It should also be noted that very small particles contribute a large surface area per unit mass. This theory, the 'ultrafine hypothesis', was put forward more than 15 years ago and remains in play.

The very limited monitoring of particle number concentrations has delayed progress in testing the hypothesis. Epidemiological studies are impossible without monitoring, and few epidemiological studies are sufficiently well funded to allow monitoring networks to be set up and maintained. However, some work has indeed shown that number concentrations of particles are more strongly linked with some effects on health than are mass concentrations. As far as effects on cardiovascular disease are concerned, the current focus is on $PM_{2.5}$ rather than PM_{10}, and it has been suggested that ultrafine particles might be especially involved with producing effects on the cardiovascular system. The suggestion has been put forward that significant numbers of ultrafine particles might find their way into the blood, where they might have effects. This links with the rapidly developing area of nanotoxicology though, perhaps surprisingly, it has been shown that only a small percentage of nanoparticles that are deposited in the lungs actually find their way into the bloodstream.

THE LINK WITH INFLAMMATION

Another, more general, theory suggests that particles deposited in the lungs set up an inflammatory cascade, perhaps triggered by and certainly involving free radicals. Once the cascade is triggered, the particles will have induced a much larger reaction than could be explained by their mass alone. Yet another theory suggests that metals present on particles act as catalysts and by so doing 'punch above their weight'. If it is admitted that inflammation plays an important role, then effects on the cardiovascular system are more easily explained. Secondary production of what are known as 'acute phase reactants' by the liver (including fibrinogen) might affect the clotting properties of the blood and could lead to the accumulation of blood clots on the surface of plaques of atheromatous material found in, for example, the coronary arteries. It has also been suggested that such plaques might be destabilized and undergo surface rupture. The potential link with heart disease becomes explicable if these theories are correct. Important support for this theory has been produced by epidemiological studies which have correlated the rate of development of atherosclerotic disease with long-term exposure to ambient particles.

VARYING EFFECTS WITH VARYING COMPOSITIONS

One of the important implications of theories that focus on specific components of the ambient aerosol is that because the mixture of material that makes up fine particles ($PM_{2.5}$) varies in composition from place to place, we should not expect identical effects to occur in all areas. This is a very important deduction and one that will cause much difficulty for those responsible for regulating concentrations of particles. What has been so impressive about the results of epidemiological studies linking particle concentrations with effects on health has been the consistency of the results. This very consistency has buttressed the argument that the associations described by the studies are in fact causal in nature and that they indicate real effects.

Having accepted that the associations are causal, perhaps we should now begin to look at why the associations are not identical. This may throw light on the components that are producing the effects. If it turns out that the effects of the composition of $PM_{2.5}$ vary from place to place, then it is clear that there will have to be some rethinking about methods of estimating the burden of disease imposed by exposure to such particles. The use of a single coefficient linking mass concentrations with effects may be found to be unsatisfactory. The need for more epidemiological studies with much better characterisation of the particles studies is obvious.

GASEOUS POLLUTANTS

Progress with thinking about the effects on health of gaseous air pollutants, such as nitrogen dioxide and ozone, has lagged behind thinking about particles. But recent work has suggested that nitrogen dioxide may be having important effects of its own even at rather low concentrations. This, too, requires rethinking of some of our assumptions. It has been argued, for example, that nitrogen dioxide acts as a surrogate for fine particles, and thus controlling concentrations of nitrogen dioxide without also controlling concentrations of fine particles would be of little benefit to health.

The latest World Health Organisation (WHO) review of the problem suggests that this may not be correct and that nitrogen dioxide may be, itself, playing a role in causing effects on health. This raises an interesting question: to what extent are studies of the effects of nitrogen dioxide reflecting the effects of closely correlated concentrations of particles and to what extent are studies of particles reflecting the effects of nitrogen dioxide? This question has not yet been answered. That nitrogen dioxide better reflects the activity of some component of the ambient aerosol than does any currently available measure or index of the ambient aerosol if also possible. Once again the need for more and better focused research is obvious.

SMOKING

Anyone who reads the current evidence linking exposure to ambient particles with effects on health will be struck by how closely the effects resemble those of cigarette smoking:

- effects on the risk of death from cardiovascular disease;
- effects on the rate of development of atherosclerotic disease;
- effects on the risk of death from lung cancer; and
- effects on birth weight.

Only effects on the risk of chronic obstructive pulmonary disease (chronic bronchitis and emphysema) appear to be lacking or, at least, not yet well described at low ambient concentrations. Such an effect has been described in studies of the effects of exposure to very high concentrations of particles found where cooking over open fires is done indoors in developing countries. Like cigarette smoke the ambient aerosol is a complex mixture; the aerosols have much in common.

Reducing the effects of exposure to cigarette smoke is, at least in principle, easy: stop smoking! Reducing the effects of ambient air pollution is much more difficult: complete prevention of exposure to the ambient aerosol is impossible, though the extent of exposure can be reduced by reducing the concentration of that aerosol. But levels are already low and further significant reductions in mass concentration will be costly. Finding and reducing exposure to the active components of that the ambient aerosol are now the priority. ES

Professor Robert Maynard qualified in physiology and medicine in Cardiff and, having completed junior appointments as a hospital doctor, was appointed as a lecturer in the Department of Physiology at University College Cardiff. He has undertaken research in the mechanisms of injury and toxicology and, for the last 20 years of his career, led work on air pollution within the UK Department of Health and the Health Protection Agency.

SOURCES

1. Committee on the Medical effects of Air Pollutants (2010) *The Mortality Effects of Long-term exposure to particulate air pollution in the United Kingdom*. Health Protection Agency, Didcot. www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317137012567.
2. Arden Pope III, C., and Dockery, D.W. (2006) Health effects of fine particulate matter: lines that connect. *Journal of the Air & Waste Management Association*, 56 (6) pp709–742.
3. Committee on the Medical effects of Air Pollutants (2009) *Long-term Exposure to Air Pollution: Effect on Mortality*. Health Protection Agency, Didcot.www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317137020526.
4. World Health Organisation (2013) *Review of the evidence on health aspects of air pollution – REVIHAAP Project. First Results*. WHO Regional Office for Europe, Copenhagen.

IAQM
Institute of Air Quality Management
Be part of the collective voice of the air quality community
Gain professional recognition by being a member of the professional body for air quality scientists and managers
Attend events from our busy calendar for free or a heavily reduced fee
Use of post-nominal letters
Chance to contribute towards our guidance and reports
WWW.IAQM.CO.UK

Air quality and the water environment

Mark Everard explores the way that the air and water systems profoundly influence each other.

The biosphere of planet Earth is a seamless continuum of energy and matter, circulating primarily under the influence of incident solar radiation significantly modified through the agency of organic life. The sustainability of the Earth system depends upon finely tuned and adaptive interactions of living and non-living elements that have been shaped by evolutionary pressures over billions of years.

We may split this continuum into soil, air, water and living organisms, but the depth of their interdependence is exemplified by the water cycle. Water runs from and through land, shaping it, modifying its structure and ecology, transforming chemicals, and bearing solutes and suspended matter into underground and surface water bodies. From water bodies, wetlands and soils, water evaporates or is transpired into the atmosphere, from where it may be captured and recirculated locally, for example as mist in forests or complex vegetation, or else conveyed over scales from the local to the global by meteorological systems.

BETWEEN WATER AND AIR

Air and its quality affects the water environment in profound ways. Precipitation is an obvious pathway from air to water, as chemicals (including contaminants) dissolve into precipitation, thereby affecting both quantity and quality and, as a consequence, geomorphology, ecology and the many human benefits that flow from the water environment. Aerial emissions have been found to have significant and widespread eutrophication impacts on important or threatened habitats in the UK, both aquatic and terrestrial, particularly through nitrogen enrichment.

Furthermore, acidification of both freshwater and terrestrial habitats rose significantly in public profile and political concern from the 1970s, largely driven by aerial emissions of sulphur dioxide (SO_2). The scale of this impact was not immediately appreciated, expressed as it is over long distances, yet tracing widespread and significant acidification in Scandinavia to UK emissions highlighted the scale of the problem. This lead to a variety of technological fixes combined with international protocols designed to improve the management of emissions at source.

Welsh uplands remain a British 'hot spot' of acidification impacts, exacerbated by topography, their location downwind of industrial emissions, pollutant capture by coniferous plantations and low buffering capacity. (Active monitoring of acidification impacts on UK waters arising from air pollution is undertaken by the Acid Waters Monitoring Network.)

The multiple influences of the aquatic environment on air are equally substantial. Obviously, evaporation from water bodies and water films, as well as evapotranspiration from vegetation, are significant pathways by which water enters the atmosphere, where it has significant impacts on atmospheric humidity, chemistry and climate systems.

DYNAMIC WETLANDS

Some of the most dynamic aquatic ecosystems occur at the ecotone (the interface) between water and land in the form of wetlands, which are amongst this planet's most productive ecosystems. Reedbeds and other complex wetland systems are extraordinarily efficient for cleaning air. This includes not only the settlement of fine particulate matter of 10µ and 2.5µ (PM_{10} and $PM_{2.5}$) but also the metabolism of other air-quality pollutants (sulphur and nitrogen oxides, ozone, etc.). The cumulative benefits for human health and the economic value of these ecosystem services are substantial.

Wetlands can be highly significant for aquatic processes affecting the exchange of climate-active gases between water and air. The potential of wetlands to sequester carbon as peat and in other forms is significant. However, many other wetland processes, influenced by factors such as redox potential and salinity, may be net sources of such climate-active gases as methane and nitrous oxide, which both have far higher climate-forcing effects albeit shorter atmospheric half-lives. Any wetland creation must therefore be carefully thought through: whilst it may be assumed that the construction of a tidal barrage will generate low-carbon energy, there is also significant, if generally overlooked, potential for creation of large expanses of habitat that may generate substantial amounts of climate-active gases such as nitrous oxide.

The same considerations of carbon sequestration versus generation of climate-active gases also apply to deep lakes, salt marshes and many other aquatic habitats. For example, hydroelectric dams have historically been assumed to provide low-carbon energy, yet recent research has highlighted the potential for methane emissions from deep reservoirs to negate or even significantly exceed the direct climate benefits arising from hydroelectric generation[1,2]. Generalisations that ignore the breadth of interactions between water and air systems may therefore lead to perverse outcomes.

THE HUMAN ELEMENT

The human race is both dependent upon and fully interdependent with natural cycles, supported by and in turn profoundly influencing them. The atmosphere, constituting as it does the planet's biggest environmental system, provides substantial and diverse ecosystem services to people, many of them irreplaceable[3]. It is therefore essential to manage air on a systemic basis, acknowledging its multiple links with other environmental systems and human interests.

For example, in the first four of the five-yearly UK water industry investment cycles following privatisation (1990 to 2010), little consideration was given to the substantial escalation of emissions of climate-active gases associated with energy consumption by wastewater treatment to improve effluent quality. In essence, inadvertent atmospheric damage was the net cost of protecting water quality. There are inherent dangers in efforts to manage any environmental subsystem in isolation.

Even worse outcomes can arise when we adopt a 'silo' approach to the management of any single parameter within a subsystem: for example, the disconnection of the management of climate-active gases from health-related substances (including oxides of sulphur and nitrogen, fine particulates and ozone) in the atmosphere, often in practice undertaken by different tiers of local government with little interaction[4], which can lead to antagonistic outcomes despite the fact that these different categories of gases generally arise from the same emission sources[5]. This is exacerbated by the lack of automatic connection with regulatory actions pertaining to emissions from industrial sites, which are significant sources of acidifying gases in addition to those of health and climate concern.

MAKING THE LINKS BETWEEN AIR AND WATER

The intimate coupling of air and water is exemplified by both the causes and consequences of climate change. A now-widespread saying in the environmental management community is that 'mitigation is about air; adaptation is about water'. The basis for this is that emissions of climate-active gases (requiring mitigation) into the atmosphere are the primary drivers of rising global temperatures, but the consequences of an increasingly energetic atmosphere are most immediately and directly expressed via impacts on the water cycle (requiring adaptation). These impacts include exacerbation of aridity in some regions whilst others experience wetter conditions, generally less predictable weather patterns including the periodicity and intensity of precipitation, and cumulative impacts on food production, disease transmission, flooding, soil erosion, carbon remobilisation and species movement. No largely arbitrary partition of the biosphere operates in isolation. Land cover and land use exert substantial influences on exchanges between air and water systems. Coniferous plantations, for example, can exacerbate acidification, particularly in poorly buffered uplands, whilst forest restoration in upland areas such as India's Western Ghats can do much to restore hydrological regimes, ecosystems and human livelihoods damaged by historic deforestation. Land drainage or re-wetting can significantly influence the tendency of landscapes to retain or to shed water, perform nitrification, denitrification and another nutrient-transformation processes, and influence exchanges between air and water/wetland systems.

SYSTEMIC SOLUTIONS

If we cannot divorce the management of one subsystem from another, we can use this intimate linkage for integrated management. Already, society is innovating a range of multi-benefit solutions addressing multiple ecosystem services, superseding the historic focus on a narrow subset.

Practical examples of such systemic solutions include SuDS (sustainable drainage systems), which emulate natural drainage and infiltration processes through a diversity of engineered solutions. Whilst SuDS techniques can address narrowly prescribed drainage purposes, they can also be adapted to deliver linked benefits typically including water quality regulation, amenity provision and habitat for wildlife[6], and their complex vegetation can also improve air quality and attenuate noise. Extending these principles, Green Infrastructure (GI) is a more generic and flexible approach to the protection, restoration or emulation of natural habitats, potentially achieving similar benefits in addition to creating urban green spaces, natural cooling, low-carbon travelling routes (walking and cycle paths, etc.) and 'scrubbing' particulate matter and other air pollutants[7].

A more radically cross-disciplinary approach to harnessing the multiple values of natural processes is seen in integrated constructed wetlands (ICWs), which seek to optimise the production of a broad range of ecosystem services provided by cascades of shallow, aerobic wetland cells[8]. The same broadening of objectives underlies the evolution of river restoration techniques from an initial focus on habitats and species towards addressing multiple benefits, including natural flood management, provision of attractive and biodiverse landscapes, supporting self-sustaining fish stocks, carbon sequestration and nutrient cycling[9].

Water industry investment in the UK is also undergoing a transition towards a more systemic approach, with the emphasis of investment in the quality of supply of piped water shifting from energy-, chemical- and waste-intensive treatment processes at the point of abstraction towards catchment-scale initiatives (such as SCaMP[10] in the North West of England and Upstream Thinking[11] in the South West) that reduce pollution from farmland at source. The economic and ecological benefits include reduced carbon footprint and, potentially, air-quality improvements through the regeneration of more complex riparian and wetland habitat[12].

As society at large, and political and regulatory communities in particular, engage progressively with the need to address whole complex socio-ecological systems, rather than arbitrary subdivisions in isolation, these systemic solutions will become more commonplace. However, the transition requires a broader culture change entailing not only broader thinking but also planning and policy formulation, the reform of narrow economic analyses and ring-fenced budgets to better account for net benefit to human wellbeing, as well as the 'hearts and minds' of society and environmental management practitioners.

AIR QUALITY: SHOULD WE HAVE ACHIEVED MORE?

From the review of activities in this journal, it is quite clear that health, climate change, acidification, eutrophication

▲ Profile view of sustainable drainage system. (Photo credit © WWT) and other environmental concerns have driven a great deal of environmental management attention. However, "Should we have achieved more?" is a loaded question, given what we know and are learning now relative to what we knew when, with the best of intentions, we formulated the regulations, decisions, technologies and assumptions that drive current practice.

So it is more productive to reframe this into two linked questions: "Could we have achieved, and can we in future achieve, more?" The answer to each is an emphatic "Yes!" But delivering this aspiration will require vision and courage to set aside traditional narrow assumptions. It will also require a respect for the interactions within and between air, water, terrestrial and living systems, and an acknowledgement of the role of all in society as beneficiaries and/or victims as well as change agents.

This is what the ecosystem approach, defined by the Convention of Biological Diversity as "…a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"[13], is all about. This approach, recognising people as interdependent components of inherently integrated subsystems, presents a roadmap to a future relationship between people and the natural world that is essential for our long-term wellbeing, and a spur to the innovations in concepts, policy, tools, and management and market systems required to achieve it. **ES**

Dr Mark Everard, a vice-president of the IES, is a frequent contributor to television and radio. He is the author of 11 books, over 60 peer-reviewed papers and over 200 technical articles, many of which promote sustainable development. Mark works in academic, NGO, business and government sectors, and has a particular interest in ecosystem services in both European and developing world contexts.

SOURCES

1. Lima, I.B.T., Ramos, F.M., Bambace, L.A.W., Rosa, R.R. (2008) Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective. *Mitigation and Adaptation Strategies for Global Change*, **13** (2) pp193–206.
2. Barros, N., Cole, J.J., Tranvik, L.J., Prairie, Y.T., Bastviken, D., Huszar, V.L.M., del Giorgio, P., and Roland, F. (2011) Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. *Nature Geoscience*, **4** pp593–596.
3. Everard, M., Pontin, B., Appleby, T., Staddon, C., Hayes, E.T., Barnes, J.H., and Longhurst, J.W.S. (2012) Air as a common good. *Environmental Science and Policy*, [Volume in press].
4. Baldwin, S.T., Everard, M., Hayes, E.T., Longhurst, J.W.S., Merefield J.R. (2008) 'Integrating local air quality and carbon management at a regional and local governance level: a case study of south west England'. In Brebbia, C.A., and Longhurst, J.W.S. (eds) *Air Pollution XVI*. WIT Press. Southampton and Boston.
5. Baldwin, S.T., Everard, M., Hayes, E.T., Longhurst, J.W.S., Merefield, J.R. (2009) 'Exploring barriers to and opportunities for the co-management of air quality and carbon in South West England: a review of progress'. In Brebbia, C.A., and Popov, V. (eds) *Air Pollution XVII*. WIT Press. Southampton and Boston.
6. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., Shaffer, P. (2007) *The SUDS Manual*. CIRIA C697. Construction Industry Research and Information Association, London.
7. Grant, G. (2012) *Ecosystem Services Come to Town: Greening Cities by Working with Nature.* Wiley-Blackwell, Chichester.
8. Scholz, M., Harrington, R., Carroll, P., and Mustafa, A. (2007) The Integrated Constructed Wetlands (ICW) Concept. *Wetlands* **27** (2) pp337–354.
9. Everard. M., and Moggridge, H.L. (2012) Rediscovering the value of urban rivers. *Urban Ecosystems*, **15** (2) pp293–314.
10. United Utilities. SCaMP. www.unitedutilities.com/scamp.aspx [accessed 18 February 2013].
11. South West Water. Upstream Thinking. www.upstreamthinking.org/ [accessed 18 February 2013].
12. Everard, M. (2009) *Using Science to Create a Better Place: Ecosystem services case studies*. Science Report SCHO0409BPVM-E-P. Environment Agency, Bristol. http://publications.environment-agency.gov.uk/pdf/SCHO0409BPVM-E-E.pdf.
13. CBD. Ecosystem Approach. www.cbd.int/ecosystem/. [Accessed: 27th February 2013].

CASE STUDY

The threats from construction dust and fungal spores

Clare Holman summarises the dangers from airborne particles released during construction and demolition work.

Dust is one on those unglamorous air pollutants that is easily dismissed as 'just' a local amenity issue – does it matter if you have to clean your car slightly more often? In fact, dust can have serious health effects for some individuals, and people who live near a large development or mineral extraction site could be exposed to elevated levels of dust for years.

Dust is defined by the British Standards Institution as particles below 75 microns (µm) in diameter that settle out under their own weight but remain suspended for some time[1]. This includes small particles that may enter the body, such as PM_{10} and $PM_{2.5}$, which are defined as particulate matter (PM) that passes through a size-selective inlet with a 50 per cent efficiency cut-off at 10 and 2.5 µm respectively.

PM_{10} is generally considered to be inhalable particles and $PM_{2.5}$ respirable particles. Inhalable particles are those that enter the body through the nose and mouth and are typically deposited in the trachea and bronchia of the lungs. Respirable particles are deposited deeper in the lungs, in the alveolar region, and are thought to be a better indicator of the health effects of PM than PM_{10}. These small particles are mainly generated during combustion processes or formed in the atmosphere. However, there is evidence that particles in the size range between $PM_{2.5}$ and PM_{10} (denoted as $PM_{2.5-10}$) may also be responsible for some of the observed health impacts[2].

SOURCES OF DUST

A significant proportion of PM is derived from mechanical processes such as weathering, wind erosion of aggregate stockpiles, driving on unpaved roads, or the wearing down of vehicle brakes and tyres. Research undertaken in the USA suggests that up to 90 per cent by weight of the fugitive PM_{10} emissions of from construction sites are $PM_{2.5-10}$, depending on the source[3]. With European legislation essentially requiring the fitting of diesel particle filters to new vehicles to meet the new particle number limits, mechanically derived particles are likely to become a major source of road-transport PM emissions.

This article focuses on demolition and construction sites. These sites are mainly in urban areas, often in localities with high population densities where large numbers of people are exposed to dust in its various forms. Dust emissions can occur during the preparation of the land (demolition and earthworks) and construction. The impacts vary substantially from day-to-day, depending on the specific operations being undertaken, the level of activity, the weather conditions and the mitigation measures being applied. A large proportion of the emissions results from vehicles moving over temporary roads and open ground. If mud is allowed to get onto public highways, dust emissions can occur at some distance from the originating site, a phenomenon known as track-out.

CONSTRUCTION DUST

There is evidence that significant PM_{10} impacts can arise very close to construction sites. For example, data from a monitoring station in a pedestrianised area in the centre of Cardiff shows the effect of adjacent works which included demolition, ground works, laying of concrete foundations, erection of a steel frame and concrete floor slabs, wall and roof construction, and finishing. A significant impact on PM_{10} concentrations was observed (measured using a tapered element oscillating microbalance; TEOM) in the year when most of the work was done. There were 54 days when PM_{10} concentrations exceeded 50 $\mu g/m^3$, with a maximum 24-hour value of 96 $\mu g/m^3$, compared to 12 days and a maximum of 82 $\mu g/m^3$ the following year when there was no construction. The greatest impact was on one-hour PM_{10} concentrations, with 89 hours greater than 200 $\mu g/m^3$ during the works compared 11 hours in the following year. These high short-term concentrations mainly occurred during working hours, when the pedestrianised area was at its busiest. The impact on annual mean values was, however, much smaller, with PM_{10} concentrations of 34 $\mu g/m^3$ during and 25 $\mu g/m^3$ after the works. It should be noted that the mitigation measures used on the site were not recorded[4].

Another study has shown that major construction sites in London can increase the number of days when PM_{10} concentrations exceed the national air quality objective value, as well as increasing the long-term average concentrations[5].

HOW FAR DOES DUST TRAVEL?

The scientific evidence on the distance over which impacts may occur is limited. Extensive monitoring of PM_{10} concentrations around construction sites has occurred since best-practice guidance was first published for London[6], however, the data is collected on a site-by-site basis by developers who have no interest in analysing it and publishing the findings. Probably the best evidence available is in an unpublished BRE study for the Greater London Authority (GLA) commissioned to inform the development of its 2006 guidance. It suggested that the impacts on PM_{10} concentrations from a major construction site with good mitigation occur over a distance of less than 150 m, but due to the locations of its monitoring sites, more precise information is not in place.

There are other potential impacts, such as the release of heavy metals, asbestos fibres or other pollutants during the demolition of certain buildings such as former chemical works, or the release of dust containing toxic pollutants during the removal of contaminated soils.

FUNGAL SPORES

Possibly more unusual is the release of fungal spores during the demolition of old buildings which can give rise to specific concerns if immune-compromised people are likely to be exposed. Demolition dust contains a number of fungal spores, including *Aspergillus*, which when inhaled can cause fatal infections. *Aspergillus* is ubiquitous in the environment and therefore everyone is exposed to it; the vast majority can fight the infection and do not suffer any ill effect. However, for those with a severely compromised immune system the outcome can be very different. Around 4,000 people a year contract invasive aspergillosis in the UK and more than half die of it[7]. Leukaemia patients are one of the most sensitive groups of the population, while others include organ transplant recipients, patients who have undergone major surgery and AIDS patients.

In 1999 three people died in Newcastle General Hospital during demolition on the site, and their deaths were attributed to invasive aspergillosis although post mortems to confirm this were not carried out. Another three were treated for *Aspergillus* infections and recovered[8]. A number of other hospitals around the world have experienced similar outbreaks of the disease, and as a result many NHS Trusts have developed procedures for managing the risks within their estate. However, the threat may be from developments outside their control.

Aspergillus spores in the air are continuously deposited within buildings of all kinds. The presence of moisture on any biodegradable material can lead to fungal growth – wood and other organic materials provide the nutrients essential for the spores to multiply. Older buildings constructed with traditional materials are more susceptible than more modern concrete structures. Inside buildings fungal problems are usually associated with flooding, leaks, condensation, damp basements and bathrooms, and dirty air conditioning systems. However dust and fungal spores can also accumulate in the roof space of buildings, made worst by the ingress of rain due to the loss of any roof tiles. While the building is in use the spores are generally left undisturbed, but they become airborne during demolition.

DUST CONTROL

As excessive dust emissions can adversely affect the amenity and health of the local community, all major construction and demolition sites should be required to adopt measures to control the release of dust, and thereby contribute to ensuring better air quality. Experience of demolition and construction sites suggests that dust control tends to get lost amongst the myriad demands of managing a complex site. The potential risks of dust emissions are not fully understood or planned for, and other issues tend to take higher priority.

The Institute of Air Quality Management (IAQM) has developed guidance on assessing the air-quality risk from construction and demolition sites, to determine the level of mitigation required[9]. In addition, separate guidance on mitigation measures for low-, medium- and high-risk sites was issued, drawing on the soon-to-be-published update to the GLA 2006 guidance[10].

For high-risk sites there must be proactive management of dust by the site management. Experience suggests that this works best when there is a dedicated person responsible for dust management and a detailed dust management plan (DMP). The DMP should include details of the mitigation measures to be applied, which are likely to range from staff training in the importance of dust mitigation to the use of water-based dust-suppression techniques. However, to be effective the main day-to-day management tool should be the measurement of ambient PM concentrations, with the details set out in a dust monitoring protocol. Further guidance issued in 2012 by the IAQM covers measurement methods[11].

Site workers are not generally familiar with air quality monitoring equipment and therefore the protocol will only be effective if it is very prescriptive, or the monitoring is undertaken by specialists. The disadvantage of the latter approach is that there may be little buy-in from site managers – it is perceived to be an expensive annoyance.

ALERT AND ACTION LEVELS

There is little value in measuring PM concentrations if there are no alert and actions levels to compare the measurements against. If an alert level is exceeded, the contractor should check that best practice mitigation is being appropriately applied. When the action level is exceeded the contractor should stop work as soon as

practicable (recognising that the site must be made safe before work can cease), identify the cause and rectify it before work resumes. What is important is that the site management is quickly aware of any breaches to these levels so that they can respond quickly. There is no point in monitoring if they do not know the concentrations until a week later. On well-managed sites the action level should not be reached.

The effects of construction on air quality depend to a large extent on the mitigation measures adopted. The IAQM guidance on construction dust emphasises the need to identify the risk of adverse effects, in order to then identify the appropriate site-specific mitigation measures. The guidance defines a development site as negligible, low-, medium- or high-risk, depending on the potential for dust to be released and the distance to the nearest receptors.

Since the IAQM guidance was published, the result of a Transport for London trial has shown that the application of calcium magnesium acetate (CMA) dust suppressant, which binds dust particles together onto surfaces, may be a useful measure to reduce the emissions of PM from construction sites and major roadworks depositing on adjacent roads and being resuspended by passing vehicles and the wind[12]. ES

Claire Holman has worked as an air quality consultant for 30 years and is currently with Brook Cottage Consultants. She is Vice-Chair of the Institute of Air Quality Management (IAQM) and led the IAQM working group on assessment of construction impacts. She is also the chair of the Air Panel of the Chartered Institution of Water and Environmental Management (CIWEM).

SOURCES

1. British Standards Institution (1994) Characterization of Air Quality BS6069:1994 Part 2.
2. World Health Organization Regional Office for Europe (2013) *Review of evidence on health aspects of air pollution – REVIHAAP; First results*. WHO Regional Office for Europe, Copenhagen.
3. Midwest Research Institute (2006) *Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors*. Western Regional Air Partnership (WRAP), Denver.
4. Air Quality Expert Group (2005) *Particulate Matter in the UK*. Defra, London.
5. Fuller, G. W., and Green, D. (2004) The impact of local fugitive PM10 from building works and road works on the assessment of the European Union limit value. *Atmospheric Environment*, **38** (30) pp4993–5002.
6. Greater London Authority and London Councils (2006) *The control of dust and emissions from construction and demolition: Best Practice Guidance*. Greater London Authority, London.
7. Health Protection Agency (2006) Fungal Diseases in the UK – The current provision of support for diagnosis and treatment: assessment and proposed network solution. Report of a working group of the HPA Advisory Committee for Fungal Infection and Superficial Parasites. HPA, London.
8. The Aspergillus Website (2013) The need for Guidelines for UK hospitals for the prevention of Nosocomial (hospital acquired) Invasive Aspergillus infection based on work done during an outbreak at Newcastle General Hospital in 1999. www.aspergillus.org.uk/newpatients/aspergillus_in_hospitals.pdf.
9. Institute of Air Quality Management (2012) *Guidance on the Assessment of the Impacts of Construction on Air Quality and the Determination of their Significance*. IAQM, London.
10. Institute of Air Quality Management (2012) *Dust and Air Emissions Mitigation Measures*. IAQM, London.
11. Institute of Air Quality Management and Institution of Environmental Sciences (2012) *Guidance on Air Quality Monitoring in the Vicinity of Demolition and Construction Sites.* IAQM, London.
12. Barratt, B., Carslaw, D., Fuller, G., Green, D. and Tremper, A. (2012) Evaluation of the impact of dust suppressant application on ambient PM_{10} concentrations in London, Environmental Research Group, King's College London.

CASE STUDY

Partial recovery of shallow acid-sensitive lakes from acidification.

Herman van Dam and **Adrienne Mertens** describe the danger of internal eutophication and how a reduction of sulphur and nitrogen air pollutants has enabled the partial recovery of shallow soft-water lakes.

In the 1970s many poorly buffered Scandinavian lakes appeared to be acidified by the long-range transport of air pollutants, mainly sulphur compounds, from western and central Europe, with fish kills being the first sign of ecological effects. Lower in the food chain, changes in the species composition and abundance of algae and zooplankton were observed[1]. As elsewhere in Europe and North America, these findings have been an impetus for research on acid rain, and have also stimulated the monitoring of acid-sensitive lakes in the Netherlands, which is one of Europe's most acid-impacted regions[2].

SHALLOW SOFT-WATER LAKES

The main water system of the Netherlands consists of rivers, canals and lakes that are alkaline and well buffered, and therefore not sensitive to acidification. However, in the sandy regions in the eastern and southern part of the country there are several thousands of vulnerable, small and shallow poorly buffered lakes, with typical sizes of 0.5–5 ha and typical depths of 1–3 m. They are close to industrial sources of air pollution in the Netherlands, Belgium and Germany and to areas with high emissions of ammonia from intensive cattle breeding (**Figure 1**). There are similar shallow lakes in Belgium, France, Northern Germany, Denmark and Poland. In the Natura 2000 European network they are classified as natural dystrophic lakes and ponds, and oligotrophic waters of sandy plains, containing very few minerals. Many of these shallow lakes (*vennen*) are

▲ **Figure 1.** Map of the Netherlands showing the location of the lakes and the precipitation monitoring stations[7].

included in nature reserves, as they harbour otherwise rare and vulnerable plants and animals.

After a brief survey it appeared that in some well-studied lakes a vast array of acid-sensitive species of algae and water plants was replaced by a small number of acid-resistant species between 1920 and 1976[3,4]. At about the same time national and international action plans for the reduction of air pollutants, including sulphur and nitrogen compounds, were published[5,6].

MONITORING PROGRAMME

In order to monitor the expected recovery of the chemistry and biota, regular sampling of 11 isolated lakes throughout the country was started in 1978[7]. The lakes are in protected areas and are exclusively fed by rainwater or some very local groundwater. They experience relatively minor disturbance from human activities, although Scots pine was planted in or spontaneously colonised the original open landscape of heathlands and sand dunes around many of these lakes in the last century (**Image 1**).

The monitoring programme focuses on chemistry (pH, major ions, nutrients) and diatoms (**Figure 2**). Colonies of diatoms are sometimes visible to the naked eye as a brown biofilm attached to stones or water plants. Other species live on the lake sediments or in the open water (as plankton). They have proven to be excellent bioindicators. As several hundred different diatom species may be found in acid-sensitive lakes, each with different pH-optimum values, they are extensively used to show the impact of acid precipitation of surface waters[8].

Three lakes are monitored intensively (using at least four chemical and two diatom samples each year) and eight lakes are monitored extensively (using at least one chemical and one diatom sample in the early autumn of every fourth year).

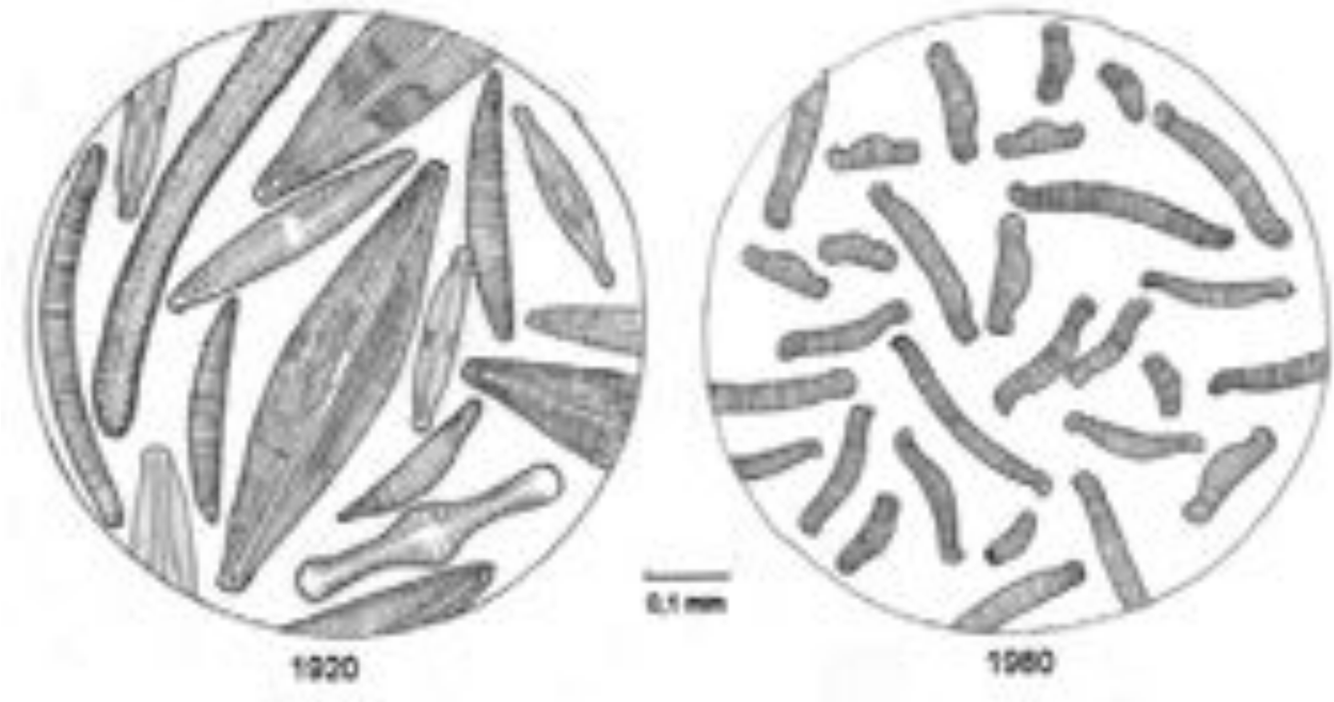
ATMOSPHERIC DEPOSITION AND TEMPERATURE

There are no exact data on the total (potential) acid deposition in Dutch soft-water lakes. Wet deposition seems to provide the best estimates, though probably underestimated by 30–50 per cent for sulphur compounds and 20–30 per cent for nitrogen compounds[9]. Over the period 1978–2010 the wet deposition of nitrate and ammonium decreased by about 50 per cent and that of sulphate by 88 per cent ($p < 0.001$; see **Figure 3**).

Current total nitrogen deposition on the lakes, based on these data, will be about 0.75 kmol/ha/y, while the critical load for poorly buffered lakes in the Netherlands is 0.36–0.71 kmol/ha/y[9]. The current sulphur deposition is about 0.13 kmol/ha/y and well below the critical load of 0.40 kmol/ha/y in 2002[9].

The average air temperature in the Netherlands rose significantly by 2 °C between 1978 and 2010 ($p < 0.001$; see **Figure 3**).

▲ **Image 1.** Sampling diatoms in Goorven in 2004. (Image credit: Martijn Bellemakers)



▲ **Figure 2.** Decrease in diatom species diversity by acidification of soft-water lakes[4].

CHEMICAL RECOVERY

Chemical samples were analysed in different laboratories, but all used comparable Dutch standard methods (NEN). The median concentration of sulphate in water decreased from 230 mmol/m^3 in 1978 to 40 mmol/m^3 in 2010 (**Figure 4**). The concentrations in 1978 were excessively high, due to oxidation of accumulated airborne reduced sulphur in the sediments, which was oxidized when the bottom of the lakes dried out after the extremely dry year 1976[10]. Gradually the sulphate decreased and after other dry periods (e.g. 1996–1997) the increase was much smaller than after 1976. Sulphur was eventually lost from the lake system by discharge to the groundwater during periods of elevated sulphate concentrations after dry years. The average decrease of sulphate (corrected for a change of chloride) in the shallow Dutch lakes between 1978 and 2002 amounts to 6.0 mmol/m^3/y, which was considerably higher than the rates of 0.7–3.4 mmol/m^3/y in the deeper lakes of other European countries[11]. This difference was probably due to the much larger impact of sediment-associated sulphate reduction in the shallower lakes.

Ammonium peaked (parallel to deposition) in 1986 to a median value of 80 mmol/m^3 and decreased later to values of 5 mmol/m^3 (**Figure 4**). The rate of the decrease between 1986 and 2002 (corrected for chloride changes) amounted to 2.4 mmol/m^3/y. Nitrate concentrations were usually below the detection limit of 4 mmol/m^3. In other European lakes nitrogen is mainly present as nitrate, which has decreased in central Europe by about 1 mmol/m^3/y, while almost no changes or even increases were found in the Alps, Scandinavia and the United Kingdom[11].

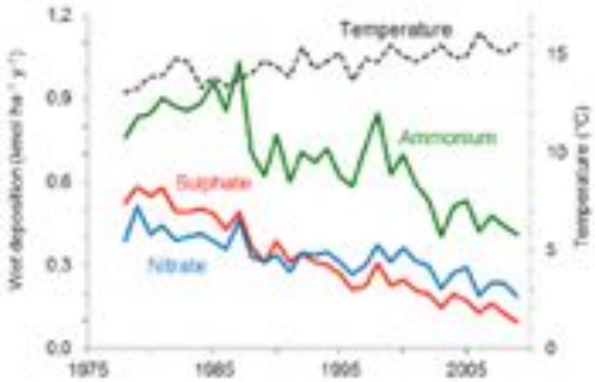
The median pH increased from 4.3 in 1978 to 5.4 in 2010, along with the alkalinity. After correction for chloride changes, the rate of the decrease of the proton concentration is 0.7 mmol/m^3/y, while rates between 0 and 0.3 mmol/m^3/y are recorded for the rest of Europe[11].

Thus the chemistry of the lakes seems to have changed considerably, much more than in other European countries. This is not only a consequence of the policy-mediated decrease of potential acid atmospheric deposition, but also due to the great impact of sediment-related processes of sulphate reduction and denitrification, which are strongly enhanced by increased ambient temperatures, as have occurred over recent decades[12, 13, 14].

INTERNAL EUTROPHICATION

Due to the increased bacterial breakdown, phosphorus release from the sediments has increased, which promotes eutrophication[15]. Maximal total phosphorus concentrations seem to have increased in some lakes (**Figure 4**).

Internal eutrophication is particularly evident in Kliplo, a small, intensively monitored lake that has not been acidified as seriously as the other lakes investigated. Because the shores are comparatively steep and the



▲ **Figure 3.** Mean annual wet deposition at precipitation monitoring stations (data: RIVM) and mean April–September air temperatures in De Bilt (see Figure 1; data: KNMI). Mean water temperatures in shallow lakes are 2 °C higher than mean air temperatures. All changes are significant ($p < 0.001$)[7].

sediments never dry out, a huge amount of organically bound sulphur, derived from atmospheric deposition, has accumulated in the sediments over the years[16]. In contrast to many other shallow soft-water lakes, sulphur loss by discharge to groundwater is small. Monthly measurements indicate that nutrients were released abruptly in 2008. This is not reflected by an increase of total phosphorus, but small green algae have proliferated since then in the plankton, as indicated by the high chlorophyll concentrations, the almost-permanent green colour of the water and high oxygen consumption by the algae (**Figure 5**). The mean pH, which was between 4.6 and 6.1 between 1978 and 2005, increased to 7.1–7.2 in later years, with maximum values up to pH 8.7 in the summer.

Such high values have recently been measured in some of the extensively sampled lakes too. The changes may have been triggered by the high temperatures in 2006–2007, the two warmest years since measurements began in 1706[17]. Signs of internal eutrophication have also been recorded in a set of 68 shallow soft-water lakes from the south of the Netherlands[15].

DIATOMS

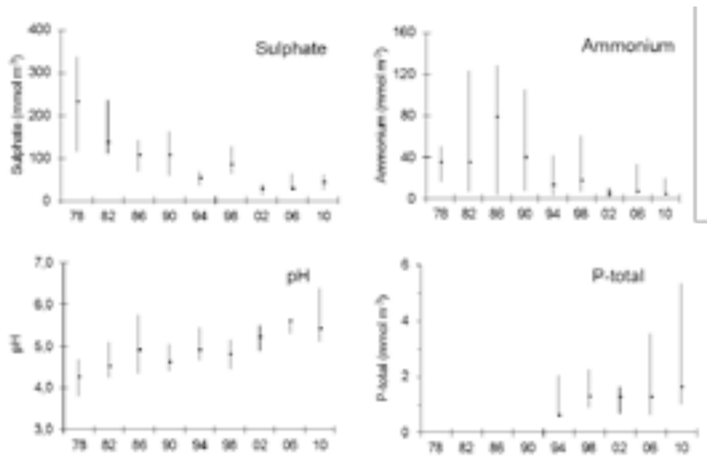
For all lakes, diatom samples taken around 1920 – preserved in the collection of the University of Amsterdam – were studied as a reference. Both the historical and modern samples were taken in the same way (**Figure 1**) and consistent taxonomy[18] was applied over all the years. In each sample 400 diatoms were identified and the relative contribution of each species was calculated, along with diatom-inferred pH values[19] and ecological quality ratios (EQR), as required for the European Water Framework Directive[20].

In total 145 diatom species and varieties were recorded in 130 samples. The species have been split into six ecological groups, listed in the legend of **Figure 6**. In the samples from about 1920, the majority of the diatoms were common acid-water species (e.g. *Frustulia saxonica*) and low-alkalinity species were also well represented. In the latter group rare species from (moderately) nutrient-poor habitats are often present, such as *Brachysira procera*. Species of alkaline eutrophic water and saprophilous species, such as *Nitzschia paleaeformis*, were particularly present in lakes with small-scale human activities (sheep washing, duck decoy, for example).

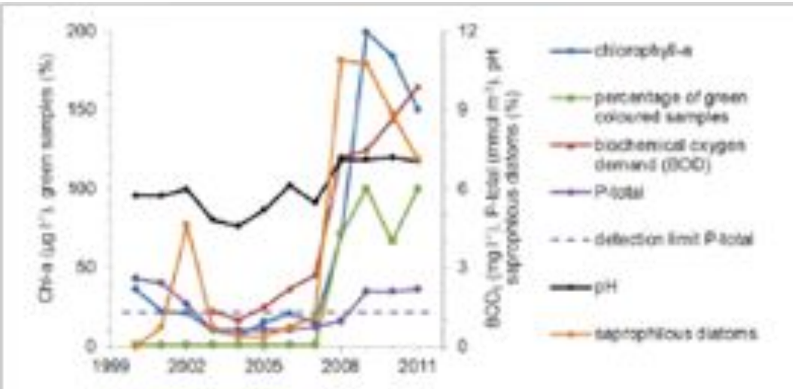
In 1978 and 1982 most lakes were dominated by the diatom *Eunotia exigua*, a well-known indicator of lakes with anthropogenic acidification, including pollution by acid mine-drainage water [21-23]. From 1986 onwards the common acid-water species gradually increased. The low-alkalinity taxa were partly replaced by a group of species characteristic of acid but more or less eutrophic water, such as *E. naegelii*. Species from alkaline eutrophic water and saprophilic preference had generally only low abundance. Recently, these species increased in the substantially enriched Lake Kliplo (**Figure 5**).

Thus, although diatom-inferred pH values and the ecological quality ratios have almost returned to historical values, the changed species composition of the diatom assemblages indicates only a partial recovery from acidification. The lakes have become less acid over the last few decades, but more eutrophic than in earlier times.

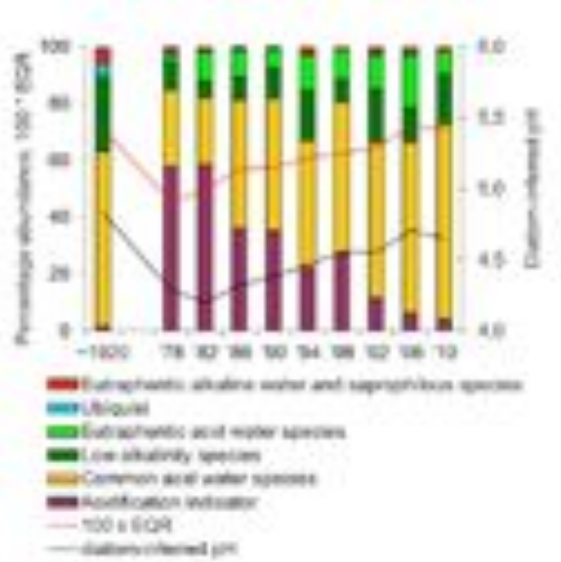
Recovery of diatom assemblages over recent decades has been observed in lakes in south-west Finland and the UK. Some of the 13 Finnish sites had high proportions of



▲ **Figure 4.** Changes of median values and 25th and 75th percentiles of selected chemical variables in the surface water of 11 isolated shallow poorly buffered lakes between 1978 and 2010. With the exception of total phosphate all changes are significant ($p < 0.05$)[7].



▲ **Figure 5.** Changes of annual mean monthly values of selected biological and chemical data from Lake Kliplo.



▲ **Figure 6.** Changes of mean abundance of ecological groups of diatoms, diatom-inferred pH and ecological quality ratio in 11 isolated shallow lakes[7].

the acidification indicator *Eunotia exigua*, which declined between 1985 and 2001. The average diatom-inferred pH increased from 5.6 to 6.1[22]. Significant chemical and biological recovery was observed in the 12 lakes of the UK Acid Monitoring Network in the period 1988–2008, but most sites are still far from reference conditions[23, 24]. However, these lakes were much less acidified than the Dutch shallow lakes, as appears from the much lower proportion of *E. exigua*. Some species (classified in the Netherlands as low-alkalinity species) were rare in the reference UK samples but are more common in the more recent UK samples. Maybe this is a consequence of (slight) eutrophication by atmospheric nitrogen compounds[22,23,24]. In all but one of 10 south Swedish soft-water lakes, chemical data indicated recovery from acidification between 1984 and 1997, but the diatoms did not[25]. Severe eutrophication by increased decomposition of superficial sediments in these countries is not indicated by diatoms.

CONCLUSIONS

Due to national and international policy measures[5,26], the atmospheric deposition of nitrogen and sulphur compounds in shallow Dutch soft-water lakes over the last three decades has decreased by about 50 and 90 per cent respectively. Simultaneously, the concentrations of sulphate and ammonium in the lakes decreased substantially, much faster than in deep lakes in other European countries, due to sediment-related processes of sulphate reduction and denitrification. The increased decomposition of the sediment, also enhanced by climate change, has caused internal eutrophication, particularly in the lakes with steep shores, where the sediments do not desiccate in dry years.

The diatoms indicate a reversal of acidification since the 1980s, but the assemblages do not return to the reference state, due to internal eutrophication. The nutrients are stored in the sediments, as a legacy of excessive atmospheric deposition in the past. Careful removal of accumulated organic matter might prevent further eutrophication. However, this is not a sustainable measure as long as the atmospheric deposition remains above the critical load. A reduction of the atmospheric nitrogen deposition of only 10–15 per cent by 2030 is expected[27]. ES

Dr Herman van Dam is currently a private senior consultant in the fields of water and nature. He has been involved in acid rain research since 1976.

Adrienne Mertens is a senior diatom analyst, currently at the Ecology Team of Grontmij Nederland, and has worked in collaboration with Herman for over 30 years.

The monitoring project was funded partly by the Province of Drenthe and the water authorities Reest en Wieden, Vallei en Veluwe and Dommel. Staatsbosbeheer, Vereniging Natuurmonumenten, Brabant Landscape Foundation, Hoge Veluwe Foundation and the Ministry of Defence allowed access to their properties. Dr. E. van der Swaluw (RIVM, Bilthoven) provided wet deposition data. Professor R.W. Battarbee (UCL, London) and Dr E. Brouwer (B-WARE, Nijmegen) read and commented on the manuscript.

SOURCES

1. Almer, B., Dickson, W., Ekström, C., Hornström, E. (1978) Sulfur pollution and the aquatic ecosystem. In Nriagu, J.O. (ed) *Sulfur in the environment. II. Ecological impact*. Wiley, New York.
2. Hettelingh, J.P., Posch, H., and Slootweg, J. (2008) *Critical load, dynamic modelling and impact assessment in Europe*. CCE Status Report 2008. Netherlands Environmental Assessment Agency, Bilthoven. 200p.
3. Coesel, P.F.M., Kwakkestein, R., and Verschoor, A. (1978) Oligotrophication and eutrophication tendencies in some Dutch moorland pools, as reflected in their desmid flora. *Hydrobiologia* **61** pp21–31.
4. Van Dam, H., and Kooyman-van Blokland, H. (1978) Man-made changes in some Dutch moorland pools, as reflected by historical and recent data about diatoms and macrophytes. *Internationale Revue der gesamten Hydrobiologie* **63** pp587–607.
5. Ministerie van Volksgezondheid en Milieuhygiëne (1976) Indicatief meerjarenprogramma 1976-1980, ter bestrijding van de luchtverontreiniging. Tweede Kamer der Staten-Generaal, Zitting 1976-1977 14314(1/2).
6. UNECE (1979) The 1979 Geneva Convention on Long-range Transboundary Air Pollution. United Nations Economic Commission for Europe, Geneva.
7. Van Dam, H., and Mertens, A. (2011) Monitoring herstel verzuring en klimaatverandering vennen 1978-2010: temperatuur, hydrologie, chemie, kiezelwieren. Herman van Dam, Adviseur Water en Natuur, Amsterdam.
8. Battarbee, R.W., Charles, D.F., Bigler, C., Cumming, B.F. and Renberg, I. (2010) Diatoms as indicators of surface-water acidity. In Smol, J.P., and Stoermer, E.F. (eds) *The diatoms: Applications for the environmental and earth sciences* (2nd edn). Cambridge University Press, Cambridge.
9. Arts, G.H.P., van Dam, H., Wortelboer, F.G., van Beers, P.W.M. and Belgers, J.D.M. (2002) De toestand van het Nederlandse ven. Alterra, Wageningen / AquaSense, Amsterdam / RIVM, Bilthoven.
10. Van Dam, H. (1988) Acidification of three moorland pools in the Netherlands by acid precipitation and extreme drought periods over seven decades. *Freshwater Biology* **20** pp157–176.
11. Skjelkvåle, B.L., Stoddard, J., Jeffries, D.S., Torseth, K., Hogåsen, T., Bowman, J., Mannio, J., Monteith, D.T., Mosello, R., Rogora, M., Rzychon, D., Vesely, J., Wieting, J., Wilander, A. and Worsztynowicz, A. (2005) Regional scale evidence for improvements in surface water chemistry 1990-2001. *Environmental Pollution* **137** pp165–176.
12. Feijtel, T.C., Salingar, Y., Hordijk, C.A., Sweerts, J.P.R.A., van Breemen, N. and Cappenberg, T.E. (1989) Sulfur cycling in a Dutch moorland pool under elevated atmospheric S-deposition. *Water, Air, and Soil Pollution* **44** pp215–234.
13. Holmer, M., and Storkholm, P. (2001) Sulphate reduction and sulphur cycling in lake sediments: a review. *Freshwater Biology* **46** pp431–451.
14. Veraart, A.J., de Klein, J.J.M., and Scheffer, M. (2011) Warming can boost denitrification disproportionately due to altered oxygen dynamics. *PLoS ONE* **6** (3) e18508.
15. Van Kleef, H.H., Brouwer, E., Leuven, R.S.E.W., van Dam, H., de Vries-Brock, A., van der Velde, G. and Esselink, H. (2010) Effects of reduced nitrogen and sulphur deposition on the water chemistry of moorland pools. *Environmental Pollution* **158** pp2679–2685.
16. Marnette, E.C.L., and Stein, A. (1993) Spatial variability of chemical compounds related to S-cycling in two moorland pools. *Water Research* **27** pp1003–1012.
17. Royal Netherlands Meteorological Institute (www.knmi.nl).
18. The principal taxonomical publication used is Krammer, K., and Lange-Bertalot, H. (1986–1991) Bacillariophyceae. In: Ettl, H., Gerloff, J., Heynig, H. and Mollenhauer, D. (eds). Süsswasserflora von Mitteleuropa 2/1-4. Fischer, Stuttgart. Other sources are presented in source 7.
19. Ter Braak, C.J.F., and van Dam, H. (1989) Inferring pH from diatoms: a comparison of old and new calibration methods. *Hydrobiologia* **178** pp209–223.
20. Van der Molen, D.T., Pot, R., Evers, C.H.M., and van Nieuwerburgh, L. (eds) (2012) Referenties en maatlatten voor natuurlijke watertypen voor de Kaderrichtlijn Water 2015-2021. STOWA, Amersfoort. 378p.
21. Battarbee, R.W., Simpson, G.L., Shilland, E.M., Flower, R.J., Kreiser, A., Yang, H., and Clarke, G. (2012) Recovery of UK lakes from acidification: An assessment using combined palaeoecological and contemporary diatom assemblage data. *Ecological Indicators* (volume in press) 10.1016/j.ecolind.2012.10.024.
22. Kwandrans, J. (2007) *Diversity and ecology of benthic diatom communities in relation to acidity, acidification and recovery of lakes and rivers*. Diatom Monographs 9. Gantner Verlag, Ruggell.
23. Say, P.J., and Whitton, B.A. (1981) Chemistry and plant ecology of zinc-rich streams in the northern Pennines. In: Say, P.J., and Whitton, B.A. (eds) *Heavy metals in northern England, environmental and biological aspects*. Department of Botany, University of Durham.
24. Kernan, M., Battarbee, R.W., Curtis, C.J., Monteith, D.T., and Shilland, E.M. (eds) (2010) Recovery of lakes and streams in the UK from the effects of acid rain. UK Acid Waters Monitoring Network 20 year interpretative report. Environmental Change Research Centre, University College London, London.
25. Ek, A.S., and Korsman, T. (2001) A paleolimnological assessment of the effects of post-1970 reduction of sulfur deposition in Sweden. *Canadian Journal of Fisheries and Aquatic Sciences* **58** pp1692–1700.
26. UNECE (1999) Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone. United Nations Economic Commission for Europe, Geneva.
27. Velders, G.J.M., Aben, J.M.M., Jimmink, B.A., Geilenkirchen, G.P., van der Swaluw, E., de Vries, W.J., Wesseling, J. and van Zanten, M.C. (2012) Grootschalige concentratie- en depositiekaarten Nederland. RIVM, Bilthoven. 92p.

Are we losing our sense of values?

Maria Arnold questions the Government's commitment to clean air.

In January 2013 the Healthy Air Campaign met with Lord de Mauley, the Defra minister responsible for air quality. Among others, Frank Kelly from King's College London put forward compelling evidence for urgent action, particularly referencing recent research that indicates that air pollution reduces the lung capacity of children living near busy roads. The primary response was that unless an action can play directly to the Government's growth agenda then there was not much more that could be done. It was entirely what the Healthy Air Campaign had anticipated, and I only began to feel outraged a few days later.

The whole premise of a focus on economic growth is that it is an important indicator of societal wellbeing. But surely the premise ceases to be valid if we become willing to bypass such clear indicators of health problems as reduced lung capacity and premature death, in the name of economic growth. Improving the quality of the air that we breathe can achieve a broad range of benefits, and short-term economic gains surely cannot become the only valid currency for making a case.

One of the Healthy Air Campaign's key recommendations is that the Government delivers a national framework for low-emission zones (LEZs). The Government have been 'investigating the feasibility' of this measure for years and yet progress is sluggish, despite analysis that yields promising indications. The full case for this measures have been set on the Healthy Air Campaign website[1], and we will be engaging local authorities, business and other relevant stakeholders to further explore the issues. Apart from anything else, this particular policy provides an interesting account of how the Government uses economic arguments as a brake to progress rather than as a way of choosing the most efficient way forward.

BUSINESS SENSE

There is a very strong business case for a national framework of LEZs. Defra's Impact Assessment in January 2011[2] weighed up the costs and benefits of a national framework of LEZs and showed very clearly that the benefits outweighed the costs by £155 million. Yet lack of action is defended in the Government's response to the Environmental Audit Commission (EAC)[3] by saying that "while these measures may represent the most cost effective approach to reducing NO_x emissions … the cost to industry were still significant".

Setting aside the question of whether cost to industry should be valued more highly than cost to health, what this fails to take into account is that the cost to *polluting* industries represents a direct boost to the *greener* industries that provide the cleaner technologies. This is entirely ignored in the tally of costs and benefits and therefore entirely undersells the economic benefits of a national framework for LEZs.

Of course there is a complex set of factors to consider about how to design LEZs to be as effective as possible for nitrogen dioxide (NO_2), and why Euro V failed to deliver real-world emission reductions. Especially with Euro VI now in force, there is little question that the UK needs some form of LEZs to achieve legal limits, and yet without a national framework it is likely to be prohibitively costly for local authorities. While there might be some general concerns about LEZs from some local authorities consulted by Defra, they also recognised many advantages of a national framework – creation of a level playing field, making local implementation much easier, and thereby helping to "raise the profile of air quality and the health impacts so as to encourage support for low emission zones and other actions to improve air quality"[3].

Defra's sluggish attitude to a national framework means that in effect they are pushing a patchy bottom-up process, funding a small number of feasibility studies for local areas. This is an almost-perfect recipe for undermining the case for LEZs – if each local authority has to develop their own framework it will become prohibitively expensive, and also lead to inconsistency as well as competition issues across the country.

The Government's inconsistency points to a lack of genuine ambition to reduce emissions. Indeed this seems to be a common view. The European Commission's rejection of time-extension applications for 12 areas of the UK were partly based on the fact that the Air Quality Plans setting out how they would achieve the legal limits referred to measures such as LEZs that were clearly not being pursued with any sincerity. Back in September 2011[4] Defra talked about how the investigations into a national LEZ framework "will continue over the coming months and decisions will be made following the investigation as to whether or not it is feasible..." A year-and-a-half later and the only decision seems to have been to cause as much delay as possible.

A SENSE OF PROPORTION

In their response to the EAC[3] Defra also went on to say "…there was never an intention for any of the [EU] deadlines to force measures that would impose disproportionate costs on society. Deadlines … must reflect both the availability of measures and the affordability of implementation relative to the benefits." (Defra, 2012, p6, para. 23).

'Disproportionate costs' is certainly an apt phrase. Tell that to the most deprived 10 per cent of areas in England, which are subject to 41 per cent higher concentrations of nitrogen dioxide from transport and industry than the average[5]. Or the average Black Briton, who is exposed to 28 per cent higher levels of the pollutant PM_{10} than the average urban white person[6] (PM_{10} is particulate matter that passes through a size-selective inlet with a 50 per cent efficiency cut-off at 10 μm respectively) . Surely if this phrase is to be used it should be in a sentence like this:

"Air pollution is imposing disproportionate costs on the most vulnerable in our society, and so we have no choice but to ask the polluter to pay to clean up the dirtiest vehicles in our towns and cities, at the same time boosting the green economy."

But this would require a broader understanding of the word 'costs' beyond the purely financial. I was struck by a refreshing statement during a conference by John Vandenburg at the US Environmental Protection Agency, who spoke about how it was certainly useful to monetise health benefits, but where it was not possible, the ability to value some things qualitatively should be preserved.

It would seem that if you add the economic case to the legal and moral case for action, the need to develop a national framework of LEZs is undeniable. However, if we become coerced into valuing only the economic case, and giving far more weight to cost to business than cost to human health, and then within this category valuing cost to polluting businesses more than a boost for green businesses, then we are fighting a losing battle. The Healthy Air Campaign and partners will work to put pressure on the Government to value things consistently and fairly, and take their responsibility seriously.

ACTION

In order to apply pressure we need to build and sustain organisational, public, business and local authority support for action. Low public awareness of the issue is unsurprising, considering the long-term lack of a public campaign from the Government, but the situation is gradually improving. Air quality was a key issue in the London mayoral election, and while Boris Johnson's announcement in February this year of an ultra-low-emission zone in London by 2020 seems to lack substance, it must surely be in response to growing public demand for bold action.

2013 has been designated the Year of Air, with EU air policy due to be reviewed this autumn, and this will bring increased public attention to a neglected area. We are lucky to have a strong and growing set of partners from a range of sectors who recognise the serious impacts of air pollution and are committed to using their influence to raise awareness.

We'll be continuing work in London to engage with communities across the capital to help raise awareness of the importance of healthy air and help people understand how to reduce their exposure and contribution. There are also many local campaigns across the UK and we plan to consolidate these and provide a network within which support can be provided and successes can be learned from.

The new public health framework offers some real potential for mainstreaming air quality within the health sector, with an indicator on air quality in the Public Health Outcome Framework. But Public Health England and others will need to carefully support the change to this new system if we are to achieve a change in the profile of air quality. The National Institute of Clinical Excellence (NICE) is looking into the possibility of developing public health guidance on air quality, a measure that seems to unite support from every part of the air quality community.

Of course we should not forget the business world, often quoted as an obstacle to progress by the Government. I don't think this is necessarily accurate: in many cases business tend to be far more progressive than the Government, more dynamic and prepared for change. Take the New West End Company which represents major retailers and property owners in London's Bond Street, Oxford Street and Regent Street. In advance of the London Mayoral election, it set out ten steps the Mayor should take for the West End, including "commit to meeting legal emission standards within one year by putting in place a Berlin-type low-emission zone for the West End[7]."

If these elements of our society can come together to recognise that some things, such as giving children the chance to develop a good set of lungs, are too important to dismiss out of hand, then perhaps the quality of our air can receive the attention it deserves. ES

Maria Arnold is Health & Environment Advisor at ClientEarth and leads the Healthy Air Campaign. She previously worked at the Sustainable Development Commission advising for the Department of Health and NHS.

You can sign up and support the Healthy Air Campaign at www.healthyair.org.uk/support-us.

SOURCES

1. www.healthyair.org.uk/lezs-in-the-uk.
2. Defra (2011) A Low Emissions Zone framework for inclusion in the Time Extension Notification for compliance with the EU limit value for NO2. IA No: Defra 1341. Department for Environment, Food and Rural Affairs, London. www.archive.defra.gov.uk/environment/quality/air/airquality/docs/ia-no2.pdf.
3. EAC (2012) *Air quality: A follow-up report: Government Response to the Committee's Ninth Report of Session 2010–12.* The Stationery Office Limited, London. www.publications.parliament.uk/pa/cm201012/cmselect/cmenvaud/1820/1820.pdf P14.
4. Defra (2011) Air Quality Plan for the achievement of EU air quality limit values for nitrogen dioxide (NO_2) in Bristol urban area (UK0009). Department for Environment, Food and Rural Affairs, London. uk-air.defra.gov.uk/library/no2ten/documents/UK0009.pdf.
5. Walker, G., Fairburn, J., Smith, G., Mitchell, G. (2003) *Environmental Quality and Social Deprivation. Phase II: National Analysis of Flood Hazard, IPC Industries and Air Quality*. R&D Project Record E2-067/1/PR2. Environment Agency, Bristol. www.geography.lancs.ac.uk/envjustice/downloads/pr2.pdf?version=1%29.
6. The ENDS Report (2009) *UK notification to the European Commission to extend the compliance deadline for meeting PM10 limit values in ambient air to 2011.* Racial Equality Impact Assessment (England). Environmental Data Services, London. www.endsreport.com/docs/20090820a.pdf.
7. New West End Company. *West End Mayoral Manifesto: A shared vision*. www.newwestend.com/about-us/west-end-manifesto.

Monitoring technology will improve air quality management

As the full impact of air pollution on health and mortality becomes better known and many countries fail to meet urban air quality targets, **Jim Mills**, Managing Director of Air Monitors, explains how new monitoring technology can help.

CURRENT MONITORING TECHNOLOGY

A network of monitoring stations routinely measures air quality across the UK employing standard reference methods so that data are comparable spatially and temporally. Data from this network, supplemented by modelling, are available within one hour of each measurement (see http://uk-air.defra.gov.uk/latest/currentlevels). Unfortunately however, these stations are large and expensive to install and operate; so their number is limited. As a result, recent research with both portable and low cost monitors has shown that the measurements from these stations does not always accurately represent the air that people breathe.

NEW TECHNOLOGY

A new concept in air quality monitoring was launched in March at AQE 2013, the air quality and emissions show. Known as 'AQMesh' the new monitors are low cost, small, battery powered, web enabled and suitable for mounting on a normal lamp post. Initially the monitors will measure ambient levels of NO, NO_2, O_3 (ozone), CO, SO_2, humidity and atmospheric pressure. This will dramatically change air quality monitoring, because it will enable the location of accurate monitoring systems at the locations of most interest.

AQMesh will supplement existing networks by enabling air quality to be monitored in the locations that need to be monitored rather than where equipment can be conveniently positioned. The small post-mounted units will be completely wireless, using battery power and GPRS communications. AQMesh 'pods' will wirelessly communicate air quality data to a 'cloud' where sophisticated data management will generate accurate readings. Users will be able to view or download data from up to hundreds of pods via an online portal.

In addition to routine ambient air quality monitoring, AQMesh will also help in the identification of pollution hotspots; often caused by traffic fumes. The pods are quick and easy to install which means that they can be easily moved for specific projects, such as the evaluation of pollution mitigation measures or to support development planning proposals. Other applications include occupational safety investigations and fenceline or fugitive emission monitoring at industrial plants.

New technology will also help in our understanding of particulates. Traditional monitoring techniques have focused on the mass of particulates and for this reason the focus has been on the larger, heavier particles, whereas it is the smaller particles, which have almost no mass, that travel deepest into the lungs and have the most serious health effects. In response, a technology company in Germany, Palas, has developed a new type of particulate monitor; a Fine Dust Analysis Systems (FIDAS), that is able to simultaneously measure all of the most important dust fractions, including the smallest, in addition to providing a reading for particle number concentration.

SUMMARY

Both of the new technologies mentioned above provide substantially improved air quality data at a fraction of the cost of traditional methods; which means that more of them can be deployed; which means that data will be more representative; which means that air quality management will be easier and more effective.

For more information see: www.airmonitors.co.uk

Transforming air quality: reflections on the past, present and future

Roger Barrowcliffe reviews the recent history of the concern about the air we breathe and outlines possible future directions.

Now that the Institute of Air Quality Management (IAQM) is 10 years old, and with a personal career in air quality spanning more than two decades, this is an opportune time for me to reflect on the state of the UK's air quality as I take on the role of IAQM Chair. In this article, I set out my reflections on the changes that have taken place since I began working in air quality and on those we might expect in the future, along with some thoughts on the reasons why we may or may not see improvements.

When I started my career in this area, the priorities and issues were very different than they are today. Smoke and SO_2 control still featured prominently in policy and practice, with the national smoke and SO_2 monitoring network still in place from its beginnings in the 1960s, albeit in decline. Long-range transport of pollutants and acidification was a big issue, sparked in part by Scandinavian indignation at the damage it was said to be causing ecosystems (although the Germans, Czechs, Poles and others were suffering an equal or greater amount of damage, but were also burning coal and thereby contributing to the problem.)

Perhaps the greatest issue of the time was the use of (tetraethyl) lead in petrol, culminating in its reduction and eventual removal from the market. One factor in this transition to better air quality was the very effective Campaign for Lead-Free Air (CLEAR). Other contributing factors were the role of science and, eventually, the introduction of catalytic converters in cars. Intriguingly, there has been a recent echo of this subject in the hypothesis that the phasing out of lead in petrol explains the widespread fall in crime rates since then. This claim is made on the basis of some sound epidemiological evidence)which may yet prove to be a false link), but the topic does remind us that our subject is still capable of surprises.

AIR QUALITY IN TOWNS AND CITIES

One aspect of air quality that was not especially prominent in the 1980s was urban air quality and human health. With the decline of smoke levels and the near-disappearance of SO_2 as an issue for towns and cities, it was assumed that the problem of human health effects was essentially solved. This view changed profoundly in the1990s, not least when it became increasingly clear from epidemiological evidence that air pollution was much more strongly associated with mortality than had been hitherto recognised. In particular, the role of fine particulate matter (PM) prompted a significant re-appraisal of policy and our approach to air quality.

Up to this point, the notion that air quality should be actively managed by monitoring, modelling and specific counter-measures had not properly taken root in the UK. Air-quality standards had not been especially fashionable as regulatory tools in the UK but had been introduced by EU Directives for some pollutants in the 1980s. By the mid 1990s, however, the transformation was complete – the UK became much more active and had begun to set the agenda on air quality. The 1995 Environment Act gave local authorities a mandate to examine local air quality and take action.

The first half of the decade had seen a significant expansion of monitoring activity by national government, providing a real insight into the concentrations of more pollutants in more places than had been the case previously, when resources were focused instead on smoke and SO_2. Local air-quality management had facilitated the continued development of monitoring networks, so that the scale of air-quality problems could be defined. New air-quality objectives introduced by the first national Air Quality Strategy had to be met, so that monitoring and modelling work by local authorities became commonplace.

REDUCED EMISSIONS

The 1990s also saw significant reductions in emissions, both from certain industrial sectors and from road transport. There was a reasonable expectation then that, as we entered the 21st century, everything was in place for a real and continued improvement in air quality, especially in towns and cities where the benefits from the anticipated reduction in emissions from vehicles would be observed most strongly.

Very demonstrably, this has not materialised for all pollutants. Although it is true that concentrations for some pollutants (such as benzene) have diminished, for many people, exposure to some of the key pollutants has remained stubbornly static for the last 10 years or more, as the most recent annual summary by Defra[1] amply demonstrates, most obviously for NO_2 and PM_{10} (particulate matter that passes through a size-selective inlet with a 50 per cent efficiency cut-off at 10 µm). This is particularly true for monitoring stations that have been in operation for the longest time. Even for the most optimistic interpretation of the data, it has to be concluded that any improvements in ambient concentrations have not been commensurate with emission reductions.

If this was a marathon, it would feel very much like the phenomenon runners refer to as 'hitting the wall': the sensation around about the 20-mile mark where fatigue sets in. Lots of effort has been expended, but the finish feels a long way off. Actually, our race is infinite, in that we strive to improve air quality regardless of where we are relative to standards, but in the short term we at least need to make sure that compliance with EU limit values is achieved everywhere. Currently, that represents a huge challenge for our biggest cities where road transport is a major contributor to NO_2 concentrations.

This is a problem on many levels. Clearly, it is not enough to define a required ambient concentration as a target and rely on the increasingly stringent emission concentrations for new vehicles to meet that target. That process has been in place for 20 years and has not delivered air quality that is universally compliant with standards, although it may be true that we are beginning to understand why the emission standards are not working as had been hoped and therefore how they might be redesigned to ensure a better outcome.

STRONGER MEASURES

The reality is that, for some places, more drastic action is required and truly effective action is likely to involve reducing traffic flows substantially, or at least substituting internal combustion engines with a non-emitting drive mechanism. Is this likely to happen? On present evidence, it seems unlikely on any foreseeable timescale. On so many occasions, the public appetite for curbs on the use of vehicles has been found to be very small. This represents a paradox for some. How can we ignore such a large public health problem and why doesn't the Government do something about it?

The answer, I believe, lies in the fact that most members of the public are in fact cognisant, at different levels, of the damage that air pollution causes, but are not willing to make the trade-off with restrictions on the transport system that a radical improvement would require. The problem cannot be framed simply as one in which an external party is imposing a burden on the rest of society. Even if individually we do not own or use a vehicle, we rely on a logistics system that makes extensive use of the internal combustion engine. We expect shops to be full of the things we wish to buy and parcels to arrive at our doorstep. This is a collective issue and change will not happen until a majority recognise that a change is a net benefit for everyone, both in terms of the health outcome and the means to achieve it.

Merely pointing out that the mortality implications are large is not in itself sufficient. After all, the casualty statistics for Britain's roads make for sobering reading, despite improvements over time, but that does not provoke a major re-appraisal of our road transport system. Maybe one reason for this is that deaths and injuries on the roads are not visible as a major event, in the same way as, say, a train or airplane crash is. With air pollution, the same is true. In the infamous London smog event of December 1952, the death toll became highly visible and was a significant spur for legislation. Until that point, only a few people had recognised the scale of the effects of air pollution on health.

LEAD-FREE PETROL

To consider how change comes about, it is worth returning to the story of lead in petrol. The European Environment Agency has recently published an excellent collection of essays under the title of *Late Lessons from Early Warnings II*[2]. In it is a useful summary of the history of the use of lead as an additive in petrol and its eventual removal, both in Britain and around the world. Lead has been recognised as a poison for a very long time, perhaps even as far back as the time of the Roman empire. Throughout the intervening time, however, it has continued to be used in a variety of ways, and many economic interests have sought to downplay its toxic properties, resulting in human exposure. When it was considered for use as an additive to petrol in 1925 (as tetraethyl lead) there was sufficient evidence in the literature to show that lead was a neurotoxin at low doses, but economics and politics prevailed nonetheless, despite the availability of alternatives.

It was not until the 1970s that its use in petrol began to be challenged seriously, first in the USA and then later in Europe. It was only in 1995 that it was finally eliminated from widespread use as a fuel additive. Even then, the reasons for its demise are associated as much with the need to remove lead from fuel so as not to poison catalytic converters as for public health reasons. Having said that, there were at least two factors that assisted in its reduction in, and removal from, petrol sold in the UK, in spite of vigorous industry lobbying for its retention. One was undoubtedly the contribution of CLEAR in the early 1980s. Another was the emotive hypothesis

▼ Photo credit: ©2013 Simon Birkett

that lead was hindering the cognitive development of children and lowering IQ. The idea that children may be harmed is always a powerful one in the human psyche. The point of this brief historical summary is that science and campaigning rarely bring about effective change by themselves, even if the case is a powerful one. The arousal of public conscience is a positive agent for change, but economics and politics are also necessary ingredients. In the case of lead in petrol, what would the outcome have been if catalytic converters had been tolerant of lead?

IMPROVEMENTS AHEAD?

Returning to the core theme of how, or if, our air quality can be improved from where it is now, we need to see several factors aligned if we are to achieve the requisite change in emissions. These factors are public support, political will (which derives from public support or pressure) and economics. We already have much of the science pointing in the right direction. By public support, I do not mean simply recognition that improved air quality is a good thing, but that this state is sufficiently desirable and important that achieving it will entail change that may be costly or inconvenient. We can safely assume that most members of the electorate see improved air quality as a good thing in itself; the crucial factor is mobilising opinion to effect the required changes that will have implications for us all and which might not be comfortable.

As I stated earlier, this recognition needs to embrace the idea that air pollution is a collective problem that we are all partially responsible for. Without that, measures to reduce emissions could be perceived as an external imposition with no personal gain. Contemporary examples of proposals for congestion charging and low-emission zones around the country suggest that, given a free choice, most people opt for the status quo. On issues such as demand pricing for road use, either through tolling of new roads or of charging for using existing roads per mile, the current evidence is that the public is distinctly cool on these ideas. The strength of feeling aroused by fuel prices also suggests that most people are very keen on maintaining, or increasing, vehicle use at present levels. Of course, the problem could be solved instantly if all vehicles on the road were electrically powered, but with the current capital cost of these vehicles being so high and the fact that they are mainly powered with electricity generated from coal or gas, the take-up is inevitably minuscule, even before considerations of style and range are taken into account.

In summary, I believe that urban air quality will improve. In one scenario, it will do so eventually and over a long period of time as economics make it more favourable to use transport modes that are less polluting. With present-day economics and the *relatively* low cost of using vehicles with petrol and diesel as fuels, that could take some considerable time. Alternatively, we can change public opinion to create the political will to intervene in a positive way, resulting in either a reduction in the use of pollutant-emitting vehicles or the substantial rise in the use of non-emitting vehicles.

We can only bring about such a change by changing our approach to persuading the public of the case. To do so, we need to increase our understanding of the barriers to change and how to shift the psychology of the problem from where it is now to one where many more people are both aware of the issue and willing to recognise the overall benefits of action – even taking into account the personal cost. On a 'business-as-usual' scenario, it is difficult to see where the decisive agent of change will come from, barring an unforeseen development in the link between air quality and human health, or an unrelated transformation in transport modes.

That may appear to be a discouraging and pessimistic conclusion, yet if I compare the current state of air quality, and our attitudes towards it, to that which existed when I began my career, I can see that we have taken great strides forward and we experience fewer health effects across the population as result. As in many fields of human endeavour, early progress is relatively easy; later changes are harder. We have not yet exhausted the opportunities for improvement and further advances will be made, but we may need to be more ambitious than hitherto if the progress is not to peter out. ES

Roger Barrowcliffe is a meteorologist by training, and began his career in air quality with the Central Electricity Generating Board (CEGB) in 1988, before going on to spend 21 years as ERM's lead consultant for air quality in the UK. More recently he has established his own company, Clear Air Thinking Limited. In November 2012, he succeeded Bernard Fisher as Chair of the IAQM.

SOURCES

1. Defra (2012) Air pollution in the UK 2011 http://uk-air.defra.gov.uk/library/annualreport/index.
2. European Environment Agency (2013) *Late lessons from early warnings II: science, precaution, innovation.* EEA Report1/2013 www.eea.europa.eu/publications/late-lessons-2.

Inconsistency undermines progress for air quality

Samantha Arnold exposes the way that variations in our approaches to pollutants make moves towards cleaner air difficult to achieve.

Good-quality air is vital to our own well-being, as well as that of our planet. United by a European Union (EU) Directive on ambient air quality and cleaner air for Europe (Directive 2008/50/EC, currently under review/consultation), Europe has managed to substantially decrease emissions of air pollutants and improve ambient air quality over the past decade. Despite this action, air quality in many areas does not yet meet the EU's long-term objective "to achieve levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment"[1]. Over 80 per cent of people in Europe still live in areas where air-pollutant concentrations exceed World Health Organisation (WHO) limits set to protect their health.

In an increasingly aware society obsessed with healthy lifestyles, why do we continue to fail to prioritise the safeguarding of one of the elements vital to all life – the quality of our air? This, despite poor air quality being strongly linked with health issues and indeed the premature deaths of those exposed. This failure of to adequately act towards the continual improvement of air quality is partly due to inconsistencies that undermine the perception of its importance by the general public, industry, regulators and governments. Examples of such inconsistencies are explored below.

SPATIAL INCONSISTENCIES

Member states across the EU have integrated the overarching EU legislation on air quality into their own country's individual legislative structure. However, significant spatial inconstancies exist, even within a country, in how air-quality requirements are interpreted and applied. This is particularly the case with respect to the demands of the regulatory authorities and/or the process of obtaining a planning consent. Indeed, the failure of the current planning guidance to be fit for purpose has been recently considered in the Lord Taylor's *External Review of Government Planning Practice Guidance*[2] and the on-going consultation process.

Currently, there is huge variability in the requests by the planning authorities for air-quality assessments (and indeed the importance given to the results of any requested air-quality assessments) between areas that are superficially similar but fall under different council boundaries – for example, a rural area with no sensitive habitat sites but in different areas of the UK. For developments of similar scale and nature, recent experience has shown up differences in air-quality assessments in support of planning requests between different areas of the same UK countries, ranging from:

- Full air-quality impact assessment, including air-dispersion modelling, leading to appropriate redesign of the proposed development (e.g. stack height or location analyses, combined stack flues, abatement options, etc) to meet air-quality standards off-site for the protection of human health and habitats (in line with the environmental permitting requirements, even if the facility may not need a permit to operate); to
- Air-quality assessment for habitats, a request often initiated by bodies such as Natural England, even if no assessment has been requested by other bodies for human health (which raises the question that perhaps an air-quality assessment for the protection of human health should also have been required?); to
- Qualitative air-quality assessment and discussion of potential air-quality impacts; to
- No air-quality assessment at all.

These regional inconsistencies in planning-related air-quality assessment requests can mean that the same developer will in some areas have to undertake detailed air-quality assessments and the potential redesign of their proposed facility to meet off-site air-quality standards, whilst in other areas the developer may have to undertake no assessment of air-quality impacts from their proposed facility (regardless of what was learnt about the best design with respect to air quality for the proposed facility for the protection of human health and habitats in other areas).

As air pollutants do not respect arbitrary land boundaries, the protection of the quality of air necessitates spatial consistency in the legislation, and its interpretation and application.

As air pollutants do not respect arbitrary land boundaries, the protection of the quality of air necessitates spatial consistency in the legislation, and its interpretation and application. Air pollutants are transported by air flows across site boundaries, county boundaries and country boundaries. On a European scale this transboundary effect was seen in the 1970s and 1980s when acid rain from other southern European countries fell on Scandinavian countries. Acid rain is rainfall polluted by water-soluble air pollutants, and the acidity is damaging to sensitive habitats.

There is a variable off-set distance (and equivalent time of travel) between where the pollutants are emitted and where acid rain falls. Every area that emits pollutants to the atmosphere will itself be impacted by pollutants from other areas. There will therefore be no net benefit in air quality until every area takes responsibility for its own emissions. This was exemplified by the significant reduction in acid rain achieved when the United Nations Economic Commission for Europe (UNECE) implemented the 1979 Geneva Convention on Long-range Transboundary Air Pollution[3]. The aim of the convention was the reduction of acidic emissions across Europe by predominantly reducing emissions of sulphur dioxide (SO_2).

TEMPORAL INCONSISTENCIES

Temporal inconsistencies in the perception of air quality, and action taken, predominantly concern a mixture of fashionable trends, 'hot topics' often pioneered by research bringing increased understanding to some aspect of the environment and/or technology, and political changes.

In the early 1950s most houses burnt coal for heat. This led to the infamous city smogs and the first significant UK air-quality legislation, the Clean Air Act 1956 (which was consolidated with the Clean Air Act 1968 into the Clean Air Act 1993, and which is currently under review/consultation). The Act introduced a number of measures to reduce air pollution, especially Smoke Control Areas (SACs) in some towns and cities, where only smokeless fuels could be burnt. The introduction of central heating using coal gas followed by natural gas, and the location of oil- and coal-fired power stations away from the densely populated city areas led to a dramatic reduction in the exposure of the general population to air pollution.

Recently, the heating of homes via solid fuel and biomass boilers and burners has increased. One of the reasons for the rise in popularity of biomass burners is the increased public concern over climate change and the

Prioritised behaviours related to air quality will change through time, but these should be driven by scientific understanding and the inter-relationships with existing aims for the benefit of all rather than fashion (political or otherwise).

need to decarbonise our energy supplies. The use of biofuels is also being encouraged by:

- the UKs Renewable Energy Strategy to deliver 15 per cent of the UK's energy from renewable sources by 2020 across electricity, heat and transport (the UK share of the EU target for a 20-per-cent share of renewables in overall EU *final* energy consumption);
- the Renewable Heat Incentive (RHI) to help the UK meet the 80-per-cent reduction in CO_2 emissions from 1990 levels by 2050 under the 2050 Pathways of Department of Energy & Climate Change (DECC); and
- the Climate Change Act 2008 (which requires greenhouse gas emissions to be reduced by at least 80 per cent by 2050, compared to 1990 levels).

Biomass is at present considered carbon neutral due to the simplistic calculation that the carbon emitted when plant matter is burned is equal to that which is absorbed during growth. However, the use of biomass fuel still produces potentially harmful combustion emissions contributing to a decline in air quality, and unsurprisingly, in some urban areas local air quality is being negatively impacted. These emissions are particularly important when multiple biomass-burning sources are clustered in areas where existing concentrations of fine particulates are already quite high. With respect to biomass for local heating, the recognition of the need to address air quality and climate-change issues together has been considered by Environment Protection UK in their biomass and air-quality guidance for local authorities[4]. Within the guidance a screening methodology to consider the cumulative effects of multiple small sources is provided.

Air pollutants such as nitrogen dioxide (NO_2) and particulate matter (PM) as well as greenhouse gases such as carbon dioxide (CO_2) often come from the same sources, including power- and heat-generation activities, emissions from transport, major industry and waste management. Therefore co-ordinated way forward between climate change and air-quality policy is required to produce benefits for both atmospheric areas of concern.

Over the last century, continued scientific research has dramatically changed our understanding of our planet's environment and our interaction with it. The degradation of the quality of the air that we breathe is affecting our health over relatively short timescales: the WHO air-quality standard for NO_2 (adopted by the EU) considers time periods as short as one hour. Over longer timescales emissions into our atmosphere can be seen to be affecting our climate.

Through time our understanding of air quality will continue to evolve. Previous areas of concern may decline as technology changes our behaviours (for example the decrease in smogs with the decrease in domestic coal burning). There will be new areas of discovery and interest (the true impact of PMs, for example). Prioritised behaviours related to air quality will change through time, but these should be driven by scientific understanding and the inter-relationships with existing

aims for the benefit of all rather than fashion (political or otherwise).

LOOKING AHEAD

The 2013 European Year of Air is a fantastic opportunity for air quality to take the spotlight. A number of consultations on existing legislation, within the EU and UK countries, are currently under way, giving everyone the opportunity to provide their points of view and to collectively think about how we can do better to improve the quality of the air around us.

Taking a positive view, actions, even if in response to regulatory requirements, that are integrated across space and time, lead to benefits in improved air quality for all. Some examples of such actions include:

- Adjustments to everyday activities – using public transport, increasing occupancy in vehicles and using well-maintained low-emission vehicles;
- Best-practice management and mitigation options – considering emissions to air as a waste of a potential resource, and redesigning the industrial process to use the emissions, or at least minimise emission impacts through site design;
- Greater consistency in the interpretation and enforcement of appropriate legislation, over various spatial and temporal scales;
- Co-operation to promote and exploit the synergies between related subject areas that can affect the quality of the air; and
- Continued research into understanding the complexities of our atmosphere, and our effects upon our planet's environment as a whole.

Join us in contributing to the European Year of Air 2013 and working together to address inconsistencies in air quality and to improve the quality of the air. ES

Samantha Arnold (CGeog, CSci, MIAQM, MIEnvSc, FRGS, PhD, BSc) is Head of the UK Air Services team at Golder Associates UK Ltd and co-ordinator of their European air-quality teams. (sarnold@golder.com)

Sam would like to thank her colleagues Dan Birkinshaw, Stuart McGowan, Chris Willans and Zhiyuan Yang for their contribution to this article.

SOURCES

1. European Community, 2012.
2. Lord Matthew Taylor of Goss Moor (2012) *External Review of Government Planning Practice Guidance*. Department for Communities and Local Government, London. www.gov.uk/government/uploads/system/uploads/attachment_data/file/39821/taylor_review.pdf.
3. UNECE (1979) The 1979 Geneva Convention on Long-range Transboundary Air Pollution. United Nations Economic Commission for Europe, Geneva.
4. Environment Protection UK (2009). Biomass and Air Quality Guidance for Local Authorities: England and Wales.

Where is the public outcry against poor air quality in the UK?

This issue raises the question of why air quality standards are not yet good enough in spite of attempts to legislate to that effect. This article examines opinions on the role of the public in driving better measures and why it is that the public does not seem to be agitating for more stringent regulation.

Too many cars?

Peter Fryer

There is no doubt in my mind that if petrol- and diesel-engine vehicles had just been invented, they would be closely controlled and would not reach the mass market. The lethal and toxic gases they emit have already been identified and are subject to very strict controls in laboratories and workplaces.

So how has the madness we now suffer arisen? A very powerful mix of the liberating effect of cheap travel, dare I say democratic travel, and two massively powerful industrial concerns – the oil industry and the car manufacturers – so powerful that we measure the strength of our national budgets in terms of car sales and the price of a barrel of Brent crude. These two highly influential lobby groups have the ear of the bankers and industrialists who run the global economy, they use the advertising industry to promote both the glamour of owning a car and just how liberating it is.

Have the last 15 years' work resulted in better air quality management? Or been a cynical ploy to 'park' the problem with those without the resources to solve it? To me the answer is obvious: years wasted gaining more and more data whilst air quality fails to improve and the public just becoming more confused.

We professionals have adopted a particular language to be scientific and precise, but it has no resonance with the general public: 'harvesting effect', 'lost months of life', 'PM^{10}', 'hourly means', '98th percentiles'… We have to reforge the powerful public-health alliance that promoted the Clean Air Acts and smoke control in the 50s, 60s and 70s, we have to employ the advertising industry to best effect to use words and concepts the public can understand, and use arguments that galvanise politicians to action. We must force improved, meaningful vehicle-testing cycles that represent the real-world stop–start and hilly driving conditions of our cities.

Our public-health colleagues tell us that we need to get more exercise – this equates with 'use cars less'. We need to reduce carbon emissions to establish control over a runaway greenhouse effect – this equates with 'use cars less', and we need to reduce emissions of toxic and lethal gases – this also equates with 'use cars less'. Let us focus on the words "toxic and lethal" as the warning and the words "use cars less" as the message.

Pete Fryer (BSc, CMIEH, NEBOSH2, PGDip Mgnt) is a qualified and chartered member of the Institute of Environmental Health, and a NEBOSH qualified safety practitioner. Peter heads up the Environment Team within the Bristol Futures Division of the city council. and is the councils champion for electric vehicles and electric vehicle infrastructure.

Looking back, not forwards?

Jimi Irwin

With increasing evidence about the effects of air pollution on human health, it may seem strange that there is little action on the issue. In the absence of evidence, we can only speculate as to why.

Perhaps a clue lies in our reluctance to look too far ahead. Apart from those suffering respiratory ailments, which may be exacerbated by poor air quality and in themselves justify action, the effects of poor air quality are most likely to manifest themselves in a reduced life expectancy of up to six months. But the loss of a few months of possibly poor-quality life some decades in the future may well seem less pressing than many other issues.

And perhaps we simply agree with Nobel laureate Rita Levi-Montalcini (1909–2012) that "it is better to add life to your days than days to your life"[1].

Jimi Irwin was formerly Head of Risk and Forecasting for the Environment Agency. Before moving to the Environment Agency, Jimi worked at Warren Spring Laboratory, the Government's former environmental research laboratory, where he established the national acid-rain research programme. Jimi has been a member of the IES Council since 2007.

If I can't see it, is it still a problem?

Sasha Englemann

Air is never present. As we grow, we are taught to develop multi-sensory relationships with things around us, and to recognize their status as 'being in the world'. But we are rarely attentive to the fact that, "being in the world is always and without exception … being in the air"[2].

As an environmental scientist and art critic, I see the lack of engagement with issues of air and the atmosphere as a symptom of an inability to engage speculatively and imaginatively with the invisible and transient. Humans find it difficult to maintain an interest in things that are not tangible in everyday experience. In some places, as in present-day Hong Kong, the air is heavy, and a constant reminder of the city's deadly levels of air pollution. In order to prevent such atmospheric conditions, we must find ways to inventively and seamlessly map air-quality science onto urban life. It is for this reason that atmospheric scientists might effectively collaborate with contemporary artists to make their research not only visible, but emotionally present.

Sasha Englemann is a Marshall Scholar pursuing a PhD in geography and the environment at Oxford University, and a freelance writer for Invisible Dust. Sasha's interests lie at the intersection of climate change and contemporary art: her research explores the way atmospheric science is made tangible in art projects.

Lack of understanding?
David Muir

The question of why there is not more public pressure for improving air quality potentially has many answers. One, perhaps rather cynical, view is that the general public do not feel that 'the greenest government ever' would pay much attention to such pressure. Perhaps more realistically, the lack of public feeling reflects a lack of understanding of the scale of the problem.

Many of the issues on which public feeling is strongly expressed are those with a shock factor. Road-traffic accidents, especially those involving children and drunk drivers, frequently lead to demands for punitive sentences, tighter drink–drive limits and more testing of drivers. Rail accidents such as Potters Bar (2002) lead to prominent enquiries and sometimes large fines for the companies involved. So-called binge drinking leads to demands for minimum prices for alcohol, especially from the medical profession When the numbers of deaths per year from these three causes are examined, however, the figures are far smaller than for air pollution. Road-traffic accidents account for about 3,000 per year (10 per cent of these being drink related), rail accidents rarely involve more than 10 fatalities per accident, and the total number of alcohol-related deaths per year was recently given as being about 10,000.

One final thought, again on the cynical side, is that addressing air pollution effectively will mean that people in general will have to make some sort of sacrifice in terms of using their cars. People might vote for 'bread and circuses' but turkeys do not vote for Christmas.

David Muir has worked in the air-quality field for 37 years, with Bristol City Council from 1976 to 2009 and as an independent consultant/researcher since 2009. He gained a PhD from the University of the West of England in 2003. He has been a member of IAQM since its foundation and serves both on its committee and on the IES Council.

Too complex an issue?
Frank Kelly

The majority of individuals do not consider air quality a pressing concern due to poor understanding of what is undisputedly a complex science. There is therefore a pressing need for accessible, easy-to-interpret and engaging information systems designed to communicate the subject. Further, a lack of vested interest in the topic amongst nonsensitive individuals, less likely to be committed to behavioural changes, may also contribute to inadequate engagement. A further explanation is the discrepancy between measured and perceived air pollution, since attitudes and behaviour can be driven by a person's immediate and geographical environment and own experiences rather than data communicated via an advisory service.

Encouraging research does, however, exist that points not only to concern, but also to awareness and compliance, particularly amongst susceptible groups (and, where relevant, their parents), and this must be built upon. Focused education and continued evolution of sophisticated information systems have the potential to achieve a lasting change in public attitude and in turn behaviour, in a way that improves our health as well as the quality of the air we breathe.

Professor Frank Kelly holds the chair in Environmental Health at King's College London, where he is Director of the Environmental Research Group and Deputy Director of the MRC-HPA Centre for Environment & Health. As well as providing policy support to the WHO on air pollution issues, he is Chairman of COMEAP, the Department of Health's Expert Committee on the Medical Effects of Air Pollution.

SOURCES

1. AU (2012) *Rita Levi-Montalcini, great lady of science, dies at 103.* http://atheistuniverse.net/group/science/forum/topics/rita-levi-montalcini-died-at-age-103. [Accessed: 27th March 2013].
2. Sloterdijk, P. (2009) Terror from the Air. MIT Press, Boston, MA.