Key air pollution problems in the early 21st century

Peter Brimblecombe[1]

[1] *School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK*

This paper explores not only emerging scientific problems but also the difficulties communicating air quality issues into an increasingly sensitive the public and policy arena. The public understanding and trust in air pollution information and indices may be very different to the notions of validity or accuracy that are important for a scientist. We operate in a world where openness requires us to reveal both the difficulties and disagreements in our understanding of the polluted atmosphere. Yet this can be confusing and increase complexity in situations where clear political and social decisions are required. I am going to examine these issues, starting with questions of what substances we regard as pollutants and the difficulties of getting the correct balance of concern given the broadening the base of chemicals emitted to the environment. There are also questions of exposure particularly in terms of vulnerable populations, who may spend large amounts of time indoors, where air is rarely monitored. In contemporary society there are pollution problems that extend far beyond urban areas and we have to consider regional issues such as windblown dusts, smoke from forest fires along with issues of the emission of green house gases and ozone depleting substances. Finally I will discuss the issues of communicating with a concerned public and sceptical politicians and the troubling interface between technological and sociological control. Such complexity is often missed in a maze of seemingly stronger political and social needs.

Key words : indices, monitoring, perception, policy

1. Introduction

The twentieth century required us to see air pollution as a complex issue. I don't mean this in the strictly scientific sense, but as I will illustrate in this brief review there is a need to take issues that are ones within science and integrate them with the world of policy. Although many textbooks treat air pollution as though it was simply a problem of chemistry or meteorology, it is as much a product of social and political perceptions. Thus my paper will often seem to be closer to sociology than science, but science is at its heart.

This paper has to explore, not only emerging scientific problems, but the difficulties in communicating of air quality issues in an increasingly sensitive public and policy arena. The public understanding and political trust in air pollution information may be very different to the notions of validity or accuracy that are important for a scientist. It may influence the types of pollutants monitored and where they are measured. We operate in a world where openness requires us to reveal both the difficulties and disagreements in our understanding of the polluted atmosphere. Yet this can be confusing and increase complexity in situations where clear political and social decisions are required[1].

I am going to examine these issues, starting with questions of what substances we regard as pollutants and the difficulties in getting the correct balance of concern given the broadening the base of chemicals emitted to the environment. One of the important questions about where comes under the area of indoor air where we spend so much of our time. However, in contemporary society pollution extends far beyond urban areas and we have to consider regional problems such as windblown dusts along with issues of the emission of greenhouse gases and ozone depleting substances. At the end I will consider the issues of communicating with a concerned public and sceptical politicians and the troubling interface between technological and

---

Corresponding author: Peter Brimblecombe, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK
Phone: 44(1603)593003
E-mail p.brimblecombe@uea.ac.uk

sociological control.

2. The broadening base of pollutants

Our concern about air pollutants widens and we see more air pollutants of concern. The problem with this is that it can dilute the focus. The new EU chemicals agency will register some 30,000 substances in use under various regulations e.g. *Regulation on the Evaluation and Control of the Risks of Existing Substances*. The UK's Royal Commission on Environmental Pollution has just published a report: *Chemicals In Products: Safeguarding The Environment And Human Health,* which requires toxicity, persistence and accumulation to be evaluated for these chemicals. This seems an enormous task. However, it can be managed by screening, with the use computer-based molecular modelling the scientific literature searches. In this way one can balance the amounts of chemical produced against the likely risk of public exposure.

However even those pollutants we consider traditional and relatively well understood are worth revisiting. Sulfur dioxide has been in decline in many countries and often levels have been reduced by an order of magnitude. Nevertheless SO_2 is now so low that its effects are decoupled from those of particulate matter. However, at high concentrations SO_2 still seems to have impacts through short-term exposure and a there is a significant correlation with health effects in Europe.

By contrast ozone has seen less substantial improvements, because it is a secondary pollutant and found over wide continental areas. It seems to be increasing at a global level, which hampers local and regional attempts at control.

The last decade of the 20^{th} century saw the rapid emergence of concern over suspended fine particulate material in the atmosphere. In the early 1990s it appeared from the work of Dockery *et al*[2]. that there was a clear relation between daily mortality in an urban population and the presence of fine particles, typically categorised by their diameter in microns as PM_{10} and $PM_{2.5}$. Particle loads in urban atmospheres have been exacerbated by the increasing use of diesel vehicles and the production of secondary particles in photochemical smog. The striking correlation between fine particles and health effects that emerged in the 1990s that politicians and regulatory agencies rapidly saw the significance. In particular the idea that the number of deaths from air pollution could be determined on a daily basis raised the spectre of considerable public concern.

This concern over fine particles arose with such rapidity that it affected developing legislation, which tried to incorporate new research as it developed. This presented many difficulties for legislators even in terminology as within the European Commission particles were variously referred to as: (1) suspended particulate matter (2) fine suspended particulate matter and (3) PM_{10} and $PM_{2.5}$. The European Directive 96/62/EC on *Air Quality Monitoring and Management*: included: sulfur dioxide, nitrogen dioxide, PM10/2.5, lead, ozone, benzene, carbon monoxide, PAH, cadmium, arsenic, nickel and mercury.

So much for the traditional compounds and those included under the European Directive In Europe some countries tried to have air pollutants such as fluoride and 1,3-butadiene included, without success.. They probably represented local concerns rather than those of all across Europe. However, it is worth reflecting on some of these air pollutants not included:

SULFIDES
Hydrogen sulfide from automotive catalytic converters, mercaptans - pulp mills and thiophenes and benzothiophenes from tyres, combustion processes

ACETONITRILE
Forest fires, automobile exhaust and manufacturing facilities. Acute exposure causes irritation of mucous membranes, while chronic exposure affects central nervous system e.g. headaches and tremors.

ORGANIC ACIDS
Dicarboxylic acids - oxalic and malonic acids common in photochemical smog. Pinic, sesin acids and abietic acids acids arise from monoterpene oxidation and forest fires. Humic acid like substances (HULIS) may have soil sources or derive from the oxidation of soot.

ALDEHYDES
Formaldehyde: forest fires, automobile exhausts and indoors resins used in particleboards. Acetaldehyde: wood combustion, vehicle exhaust fumes. Acrolein and crotonaldehyde forest and wildfires, as well as vehicle exhaust, acrylic acid manufacture

ETHYLENE OXIDE
Hospital sterilizers – principal source, but also from the manufacture of textiles, detergents, polyurethane foam, antifreeze, adhesives. Carcinogenic action from chronic exposure to low concentrations - but conflicting results

QUINOLINE
From metallurgical processes, in the manufacture of dyes, petroleum refining, coking. It is a likely liver carcinogen.

SIMPLEHALOGENATED COMPOUNDS
Carbon tetrachloride once widely used in dry cleaning. Chloroform widely used, chlorinated water, paper mills, waste sites. Ethylene dichloride production of vinyl chloride. Tri/tetrachloroethylene landfills. Vinyl chloride industrial emissions include the discharge of exhaust gases, landfills.

CHLORONATE DIBENZO-COMPOUNDS
Dioxins/Furans fugitive dusts, waste incinerators, cement production, and pulp/paper production, "preserved" wood combustion. Polychlorinated biphenyls (PCBs) released to the air from disposal sites.

3. Indoor-outdoor exposure

A pre-occupation of the late 20th century was the development of fine air pollution monitoring networks in many countries. Automated equipment is now available that has allowed these to be reliable and accurate and give good records of the ambient concentrations of pollutants. The location of monitoring stations has always been difficult. Regulation has usually required them to be placed in large cities (typically with populations of a quarter of a million), rather than in rural areas. In cities resources are available and the monitoring record might reasonably represent the exposure of large populations. Siting is inevitably a problem, as some favour urban background sites, while others favour their presence at sites with the greatest pollution. There are also local public and administrative and public pressures that influence the location of monitors.

However an even more difficult question emerges when we consider that the main purpose is often said to be to reflect the health impacts on an exposed human population. Typically the monitors do not reflect air pollution exposure of individuals. Surveys indicate that people spend large amounts of time indoors[3] and even in attractive climates such as California, residents spend, on average, 87% of their time indoors, 7% in enclosed transit and 6% outdoors. This is most especially true of vulnerable groups such as the old, young and unwell. In addition to this some gender differences remain whereby women are more likely to spend more time in domestic settings and often polluted parts of the house, such as the kitchen. Other indoor problems such as sick building syndrome raise sociological issues as they can affect those who are disenfranchised users of the interior air spaces most severely.

Energy conservation in cold countries imposes requirement for lower amounts of heating and has led to lower air exchange rates. Thus indoor concentrations are expected to be higher under very cold conditions when the exchange rates are low and the heating requirement is highest. The use of novel materials in the construction and furnishing of new buildings has introduced a range of compounds into the indoor environment. These have typically been organic compounds from simple carbonyls such as formaldehyde through to more complex compounds that originate from glues and polymers. Carpets have been an especially problematic material.

Governments have often found indoor air a problem to deal with; partially because it provokes the issue of personal freedom and the potential of numerous transactions in a regulatory sense. However, beyond this it frequently crosses departmental boundaries, which makes administration especially difficult. It so often demands attention from a combination of departments of environment, housing, health, worker safety and even cultural heritage. In Europe the new programme from the European Commission that will direct air pollution concerns, CAFÉ (Clean Air For Europe) will unfortunately only look at indoor issues where they relate to advected outdoor pollutants.

4. "Natural" sources - dust forest fires

Acid rain, was a popular environmental issue in the 1980's, but is has now moved along with sulfur emissions to become a serious problem in other regions, perhaps most notably along the Asia-Pacific rim where vast quantities of coal are burnt in expanding economies. However, even in areas where deposited sulfur is in decline the decreases aren't matched by equivalent improvements in the amount of acid brought down in rain[4]. Lower sulfur emissions have not always been accompanied by lower emissions of the nitrogen oxides, which give rise to atmospheric nitric acid. These differences and the mode of oxidation mean that nitric acid rain has a different distribution to sulfuric acid rain. Furthermore, calcium was once more abundant and hence available to neutralise some of the acidity. In recent decades, the amount of alkaline particulate material has declined, perhaps because there is less dust from unsealed roads and less grit from industry and power generation. In Europe and North America such changes are underway at many locations.

Not all that has been learnt in temperate regions is easily applicable in the tropical context. Research and regulation needs to face a different acid rain problem here. Entirely new ecosystem will be confronted by acidic deposition, although we have to recognise some of the novel factors in these regions have been present for many centuries. In places such as Japan and Korea, alkaline dust offers the potential to buffer acids in rainfall. Forest fires can produce acids, but also liberate large amounts of alkaline material that disperses along with the acids. However, such neutralisation processes are not always well understood. The greater extension of acid rain into the tropics, where soils are often deeply weathered, makes available new routes for mobilizing toxic metals within ecosystems.

In the last years of the 20^{th} C it became clear that hazes were widespread across continents. Most recently there has been much comment on the Asian brown-haze. This seems a product of emissions from forest fires, wind blown soil dusts, cooking smoke and industrial emissions. The concern about this does not arise simply from its broad scale, but it also reminds us of the belief that particles from any source, natural or anthropogenic that may impose health risks. In addition to this particulate material, pollutants from forest fires are making increasing impacts on the air quality in cities

In the last fifty years air pollution problems have also been more global. There is a wide social awareness of the enhanced greenhouse effect, acid rain and the ozone hole . Nevertheless these are difficult issues to keep on social and political agendas. People interpret air pollution from local perceptions and it may be difficult to maintain interest in larger spatial scales, and over long time periods.

5. Local vs Global

Although there can be a huge gulf between the perceptions of issues at local and global levels, there are ways in which policy decisions can be integrated. One of the most studied areas has been the effect that the reduction of green house gas emissions has on air pollution on smaller spatial scales. Hans Martin Seip, at the University of Oslo has assembled groups explore the co-benefits of measures with the primary aim to reduce greenhouse gases .These approaches are often called "no regrets policies".

Air pollution models can be used together with energy system models to study the impacts of climate change mitigation strategies on air pollution. There has been a study in Finland, by Syri's team[5], of the implementation of the Kyoto requirements. Estimated reductions in SO_2, NO_x, VOC and particulate emissions under various scenarios reduced ground-level ozone and acidification and related environmental impacts. The main contributor to the reductions here were SO_2 emissions from planned restrictions of coal use. In the case of NO_x emissions, a move away from old coal-fired plants with high emission to newer installations caused most reduction. These emission reductions may improve human health, reduce corrosion of materials, and reduce damage to vegetation partly through less acid rain and of lower concentrations of tropospheric ozone. There is a belief that co-benefits mean that the economic gains that accrue are greater than that attributable to greenhouse gas reduction alone.

6. Interfacing with politicians

The complexities of air pollution science have to interface with public perceptions and political decision making. This is especially problematic given the increasing importance of secondary air pollution problems where the pollutants can easily become detatched from their sources. There are also issues with the long-standing preoccupation of political decisions with health being such a dominant factor. Broader issues of environment, aesthetics or cultural landscapes as driving forces in decision making have always been more difficult to bring to the top of agendas.

It has been said that a politician's vision is only as far as the next election. This has meant that democratic structures have problems coping with long-term issues such as global warming which take place over many decades often far outlasting political careers.

Even local air pollution issues are frequently debated over very long periods of time before there is action. The famous Clean Air Act 1956 was the result of four years work after the London Smog of 1952[6] and a long legislative history that went back into the 19th century. The creation of the required clean air zones, after this Act, was often slow even where there was a desire to create them. Some cities that wanted smokeless zones did not complete them until the 1990's. The creation of smokeless zones through persuading people not to use coal in their homes had to confront problems of personal freedom, which worried politicians. This was a challenge in the 1950's just as it is today when the freedom to drive a car equally troubles society.

The interface between science and policy is particularly uncomfortable. Few politicians would claim that they take no cognizance of scientific advice, although ultimately, they may not understand it or choose to ignore it. The reasons why politicians ignore advice of their analysts stems from their different roles and personalities Policy makers are expected to be decisive so they like advice that has universal applicability and is efficient. Absolutisms, clear and definitive answers that ignore uncertainty are preferred. Scientists sometimes feel misgivings about offering opinions completely free of doubt.

7. Providing public information

Public interest groups and the government were keen that air pollution information be made available to the public. Surprisingly little attention is paid to how this information is to be used by the public, or the realisation that many monitoring networks may be ill equipped to provide the appropriate information to the public. People's understandings tend to be localised[7] within the immediate physical, social and cultural landscape. Trust is more likely to derive from personal experiences rather than numerical data. Air quality data would probably need to be more tuned to personal or health interests of individuals at the locations they will occupy if it was to meet public expectations. It would often need to be forward looking and give pollution for the next day rather than the previous. It might be possible via a web-based interrogation, although even this would often fail to pick up short term excursions on a very local level and where this was done it still might not relate the air pollution data to individual experience or feelings.

Government response to the complexity of air pollution data has been to describe it in terms of indices or banding systems. The UK Department Environment Food and Rural Affairs says that "In order to make air quality information more meaningful, a set of criteria are used to classify air pollution levels into bands, with a description associated with each band". These are *low, moderate, high* and *very high* levels of air pollution. The divisions between these bands are defined in terms of the air pollution standard, an information level and an alert threshold. The terms were modified from an earlier system, which raised many objections through the use of emotive or value-laden words such as good or poor. However, like France, the UK has more recently adopted an additional scale that rates air pollution with an integer in the 1-10 range. This is to be similar to pollen indices or sunburn scales. The US Environmental Protection Agency (EPA) had developed a Pollutant Standards Index (PSI) to provide accurate, timely, and easily understandable information about daily levels of air pollution. The indices are meant to provide a uniform system of measuring pollution levels for the major air pollutants. The numerical value of the PSI indicates to public whether air pollution is unhealthy or not.

There are technical issues regarding the step function nature of bands, averaging times and synergisms in these types of presentation. However, it has also been possible to argue that bands or indices are used as a mechanism for preventing access to the actual air pollution data. This can be overcome by giving the numerical values of pollutant concentration along side the bands, as seen on text pages created for television transmission. Despite this the UK's system seems widely misunderstood and seen as concealing the real picture by using vague descriptive terms, although the counter view that the numbers are "baffling them with science" It is clear much has to be done in terms of reporting air pollution data and address the severe difficulties of averaging times and spatial scales. Nevertheless it is probable that these will not necessarily meet with public acceptance.

8. Technological vs sociological change

A challenge that faces the 21st century involves the increasing dispersion of air pollution sources. For example, the transitions of last fifty years moved pollution sources from solid fuel based stationary furnaces to liquid fuelled automobiles. This placed pollution generation in the hands of the general public, most particularly the motorist. It has been difficult to approach the sorts of emission reduction required on such wide scales.

Engineers and administrators have often opted for technical fixes, better furnaces or catalytic converters on cars. However, sociological fixes may well be more effective. It might be easier to solve air pollution problems in cities if their citizens did not wish to drive their cars. Traditionally it has been argued such re-education is perhaps effective, but it is too slow for the required pace of change.

In the end we may need to be more imaginative and certainly some industries manage to change public behaviour very rapidly. Fashions in particular change quickly. Enormous campaigns create enthusiasm for new cars, but rarely aim at creating a parallel enthusiasm for public transport, in cities where it is poorly used. Indoor heating accounts for about a third of the UK carbon emission, but between 1970 and 2000 the average temperature in centrally heated homes increases from 14.5 °C to 18.1°C. People now wear fewer clothes indoors, yet if the fashion industry persuaded us to wear warmer clothes indoors a 1°C decrease in indoor temperatures could give a 2% reduction in UK carbon emissions.

9. Conclusion

The complexity of air pollution and its science has created problems for policy making. We have more pollutants to consider and many are secondary products of atmospheric transformations. The science is often so sophisticated that it becomes hard for politicians and the public to interpret. These difficulties come at a time when science is not accepted as the sole source of information on environmental issues. Yet it is also apparent that policy makers like to act in situations where there is agreement and clarity, so the introduction of wider forms of knowledge may make things even more difficult. We may have to concede that scientific and social perceptions play different roles in policy development. Social understandings seem to provide a strategic vision of the kind of society we wish for. The contributions of science may be on a more tactical level, perhaps illustrating the consequences of such visions. This difference may not satisfy those who wish for a fuller integration of all knowledge, but it may represent the practice of environmental management.

Acknowledgements

I would like to thank Kate Preston, Karen Bickerstaff and Mat Cashmore for their ideas, which always provoke much thought.

References

1) Brimblecombe, P. and M. Cashmore, 2002, Air pollution perceptions and policy, *Clean Air Society of Australia and New Zealand, Quarterly Journal* 36(4) 31-34.

2) Dockery, D.W. *et al.*, 1993, An association between air-pollution and mortality in 6 United-States cities', *New England Journal of Medicine*, **329**:1753-1759.

3) Jones A. P. 1999, Indoor air quality and health. *Atmospheric Environment* **33**(28), 4535-4564.

4) Satake, K. *et al.*, 2001, Acid Rain 2000, Water, Air and Soil Pollution, 130, 1-16.

5) Syri, S., N. Karvosenoja, A. Lehtila, T. Laurila, V. Lindfors and J.P. Tuovinen, 2002, Modeling the impacts of the Finnish Climate Strategy on air pollution. *Atmospheric Environment*, 36:3059-3069.

6) Brimblecombe, P., 2002, The great London smog and its immediate aftermath, In Williamson, T. (Ed.) *London Smog 50th Anniversary* NSCA, Brighton, 182-195.

7) Bickerstaff, K. and G. Walker, 2001, 'Public understandings of air pollution: the 'localisation' of environmental risk', *Global Environmental Change-Human and Policy Dimensions*, **11**:133-145.