Developing an appropriate scientific and decision-making framework for effective air quality management

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Abstract

In local and regional areas where air quality currently exceeds air quality standards, or may do so in the future, there is a need to develop an appropriate scientific and decision-making framework within which effective air quality management may be undertaken. The tools and components of an air quality management framework include health- and environment-based air quality standards, air quality and meteorological monitoring networks, emissions inventories, validated numerical dispersion models to calculate spatial patterns of air pollution concentrations over the short-term (to forecast episodes or smogs) and long-term (future years), regulatory instruments, a system of communicating with the community (to engage the community in decision-making as well as alerting the public to periods of poor air quality) and a cost-effective and feasible Air Quality Improvement Plan (Action Plan) that will reduce emissions from targeted sources and ensure that air quality standards are achieved and then maintained. An appropriate method of costing and evaluating the likely effectiveness of alternative combinations of policies and measures comprising the Action Plan is also needed. Since air quality management is multi-sectoral (environment, transport, planning, energy, industry and health), the development of an Action Plan and its successful implementation depends upon having in place appropriate systems for collaboration between national, regional and local government as well as between these levels of government and other stakeholders (business community, labour unions, non-governmental organisations, health professionals, academic scientists and the public).
1 Introduction

Resolution of local or regional air pollution problems requires the development of an appropriate scientific and decision-making framework within which effective air quality management may be undertaken. The goal of air quality management is to maintain a quality of air that protects human health and welfare. It should also extend to providing protection of animals, plants, ecosystems, materials and aesthetics (e.g. visibility) [1]. In areas where air quality poses a risk to people and the environment due to concentrations of pollutants exceeding standards, the aim of air quality management is to implement a plan that will lead to acceptable levels of air quality as soon as is possible and to ensure that this healthy air is then maintained in a sustainable way [2, 3, 4, 5, 6, 7]. To achieve this air quality goal, it is necessary to develop, evaluate and implement an Air Quality Improvement Plan.

2 Linking air quality improvement with other objectives

Increasingly, the goal of achieving healthy ambient air quality is linked with other environmental goals or objectives. For example, reducing emissions from indoor heating and cooking appliances through the introduction of more efficient systems and appliances will reduce emissions to the ambient atmosphere but will also reduce indoor pollution concentrations and improve the health of occupants. Reducing energy consumption by transport, industry and domestic sources will reduce emissions of pollutants that adversely affect people’s health but this will also reduce greenhouse gas emissions that impact on climate change. Equally, a strategy to improve one goal may worsen another. For example, building a by-pass around a congested city may improve air quality in the city centre but lead to longer journeys for vehicles so increasing fuel consumption and carbon dioxide emissions.

3 Air quality management

3.1 Tools and components

The tools and components of an air quality management framework include:

- health- and environment-based air quality standards
- air quality and meteorological monitoring networks (and topographic database)
- emissions inventories
- validated numerical dispersion models to calculate spatial patterns of air pollution concentrations over the short-term (to forecast pollution episodes or smogs) and long-term (future years)
- regulatory instruments
- system of communicating with the community, that is, engaging the community in decision-making as well as informing the public about the
level of air quality in relation to the health risks posed, especially during pollution episodes or smogs (issuing pollution alerts)

- cost-effective and feasible Air Quality Improvement Plan (Action Plan) that will reduce emissions from targeted sources and ensure that air quality standards are achieved and maintained in a sustainable way. This requires an appropriate method of costing and evaluating the likely effectiveness of alternative combinations of policies and measures comprising the Action Plan.

The integration of these tools and components form the basic scientific and decision-making framework to provide the air quality management capability in specific localities and regions. Figure 1 outlines a general framework for air quality management. It is a dynamic system. It requires regular updating and improvements to the emissions inventories and the numerical dispersion models in order to identify areas where standards are exceeded, or may do so in the future. Continual assessment of air quality is needed using air quality monitoring and modelling calculations to ensure air quality standards are achieved and then maintained in the face of changing pollution problems, emission sources, background pollution levels (pollutants imported into the locality) and climatic conditions. An Action Plan needs continual fine-tuning to reflect changing conditions and situations. If it is not likely to achieve air quality standards in some areas according to the original timetable then it may require a fundamental rethink.

Figure 1: Air quality management framework.
At the outset, locations need to be identified where concentrations of specific pollutants currently exceed air quality standards or are predicted to do so in the future. Many air quality management systems are concerned with identifying all areas of exceedances to which an Action Plan should then be applied. Others, such as in the UK, focus only on locations within areas of exceedances where people may expect to be exposed in relation to the averaging time of each pollutant standard. This reflects the view that to pursue a strategy to achieve air quality standards at all places without regard to whether or not the public might be exposed would be inappropriate and highly inefficient [8]. The focus on locations only where members of the public are regularly present ensures maximum resources can be targeted where they are needed. This approach does not mean the same persons need to be regularly present, even for short-term standards such as the 15-min sulphur dioxide standard. Nevertheless, a single exposure of an individual above the standard is to be avoided. Local authorities in the UK are advised they should assess exposure for annual means at residential building facades (the link between pollution concentrations measured both inside and outside a building point to the building façade being representative of relevant public exposure), schools and hospitals but not workplace facades where the public do not have regular access. 24-h and 8-h means are assessed at the same locations as annual means plus residential gardens, but not kerbsides. 1-h means are assessed where the longer-term means are assessed plus kerbsides of shopping streets, car parks and bus stations (though not those fully enclosed).

![Review and Assessment stage = SCIENTIFIC PROCESS](image)

![Action Plan stage = DECISION-MAKING PROCESS](image)

Figure 2: Process stages in air quality management.

### 3.2 Developing the Air Quality Improvement Plan

Having identified the locations to target, and having understood the causes (sources, chemistry) of the pollution problems, it is then necessary to develop, evaluate and implement the Air Quality Improvement Plan to ensure that a healthy and environmentally acceptable air quality is achieved and then sustained in the future. This poses a major challenge for all those involved in air quality management. The early stage of the process, the review and assessment of the pollution problems, is largely a scientific process. It relies on a limited amount of co-operation (such as commerce and industry allowing access to emissions data) and is largely undertaken by a single professional group, that is, environmental scientists. In contrast, the subsequent stage of developing, evaluating and then implementing an Action Plan is largely a decision-making process (involving...
policy, politics and planning) and one whose success is dependent on extensive collaboration across a wide range of professional groups and stakeholders (Figure 2). Integrating the two stages can be a challenge as this involves bringing together different groups of professionals who have different skills, priorities and approaches.

3.3 Local, regional and national government co-operation and collaboration

A strategy to improve air quality rarely comprises a single measure. Rather a wide range of measures is needed. Even where one source, such as motor vehicle emissions, is the primary cause of poor air quality, an effective action plan requires a combination of measures. This increases the number of stakeholders that need to be involved and poses considerable organisational challenges. Formulating and implementing a comprehensive and effective strategy to improve air quality requires close co-operation, co-ordination and collaboration between national, regional (state, province, county) and local (municipal) government representing the various jurisdictions in environment, transport, planning, energy, industry and health. Air quality problems and solutions are multi-sectoral. Consequently, air quality management strategies are more readily achieved if mechanisms already exist for co-ordinating responses to issues which cross different areas of government policy [1]. A metropolitan area, comprising a large number of local authorities, will need to ensure mechanisms are in place to enable effective collaboration between local authorities as well as with regional and national government agencies.

Mechanisms to encourage successful collaboration may vary between countries because structures of local, regional and central government differ markedly. Differences may exist even within the same country. For example, in England, local government is structured in two contrasting ways [9]. In some areas, a single all-purpose council, known as a unitary council, metropolitan borough council, or London borough council, is responsible for all local authority functions. The other structure uses a two-tier system in which responsibilities are divided between district and county councils. District councils run local planning, environmental health, and economic development functions but strategic-level transportation planning and land use planning are undertaken by county councils.

The challenge for air quality management is co-operation within and between local authorities as well as with regional and national government agencies. Significant difficulties and tensions may exist within local authorities with departmental insularity sometimes leading to a lack of co-ordination between departments [10]. Equally, difficulties of co-operation amongst the different professions within an authority arise because of the differences in their goals, priorities and experience of air quality issues. Whereas environmental health departments have long been concerned with air pollution problems, this may not be the situation for some planners. Transport planners may already be involved in transportation policies and programmes that consider air quality as one of several issues to take into account, but this may not necessarily be the case for land use planners or economic development officers. Moreover, land use planners and economic development officers may never have received any training in dealing with air pollution issues. Within a local authority many of the potential cross-
departmental collaboration problems may be overcome where an air quality ‘champion’ emerges either through their position as leader of local government or simply through their own determination to push through initiatives.

A lack of communication and collaboration between neighbouring authorities may place another limitation on the effectiveness of air quality management. At the least it may result in a duplication of effort where significant sources of air pollution affect more than one authority area. At the worst, differences in practice (monitoring equipment, emissions inventories, model), expertise, assumptions made in assessment of the problem, and the choice of measures to tackle the problem can undermine its likely success. For example, at a technical level, differences in the numerical dispersion model chosen, and the assumptions made, by neighbouring local authorities may lead to areas defined as likely to exceed air quality standards simply reflecting local authority boundaries. When this is translated into proposed emission reduction measures, such as vehicle access restrictions, this may lead to questions of credibility of the whole process amongst stakeholders. Generally, co-operation between neighbouring local authorities tends to be more effective where there is already a history of such co-operation on other issues [10].

Air quality management demands a substantial financial investment in equipment (initial purchase, operational budgets), facilities (communication links, accommodation) and staff (with appropriate training). Whether assessing and understanding the problem (e.g. installing a pollution monitoring network, compiling emissions inventories, modelling) or implementing control strategies (e.g. vehicle emission standards for new vehicles, new fuel specifications to be used by industry), all require considerable numbers of skilled personnel and systems. Initially, local authorities may lack the necessary tools and expertise to undertake air quality management such that state or national government will need to make resources available which local authorities may draw on. Such resources may include technical and policy guidance documents, fit-for-purpose models, internet-based information including monitoring data and emissions inventories, and telephone and email help desks [4, 11]. Some investment in air quality management may come from environmental taxes or certification payments by transport and industrial sector emission sources, that is, the ‘polluter pays policy’. In developing countries, the development of local air quality management capacity together with the implementation of a strategy to improve air quality may require such substantial financial support that this can come only from international organisations such as the World Bank. In some developing countries, such as Bangladesh, where air quality management has only recently been initiated, very large investments will be necessary to create and sustain a high quality of air quality management capability.

Strategies need enforcement to ensure they are fully implemented and complied with. This is one aspect that often needs strengthening, especially in developing countries, where the institutional capacity for enforcement is limited and where communities are not used to strict enforcement of environmental standards. Although new powers may need to be given to local government for this purpose, it is the provision of adequate resources (trained staff, systems, equipment) that may determine whether strategies can be implemented effectively. In some countries, there may be potential conflict with regard to
authorisation and enforcement responsibilities between local, regional and national government. Similarly, differences in emphasis in policies and priorities between the three tiers of government may need to be resolved.

3.4 Involvement of stakeholders

The business community, academic scientists (universities), labour unions, non-governmental organisation (NGOs) and the public all need to be involved in the development and final selection of the mix of policies and measures adopted to improve air quality (Figure 3). The government, whether local, regional or national, has to recognise it does not have the monopoly on formulating solutions to air pollution problems. Instead, it needs to become a facilitator and co-operative partner [12]. Consultations and discussions amongst all stakeholders are vital to encourage a shared responsibility or partnership approach to improving air quality so as to arrive at an effective and acceptable Action Plan to be implemented within an agreed timetable.

![Figure 3: All stakeholders need to be involved to ensure shared responsibility and partnership in air quality management.](image)

Hong Kong’s experience highlights the importance of creating a successful public-private partnership. In 1995 the government proposed a scheme offering grants to the owners of 18,000 diesel taxis and 4,350 diesel public light buses to convert their vehicles to petrol within five years, after which diesels would be banned. The consultation paper was published without prior estimation of the impacts or reactions of those affected, and the consultation period was only three months. It prompted strong objections from stakeholders and generated a lack of trust and confidence in the government. Consequently, the scheme was withdrawn. In 1997, learning from this experience, the government initiated a new scheme to convert the 18,000 diesel taxis to run on LPG, only this time it involved all parties
and a 12-month trial programme was to be implemented involving 30 LPG taxis, old and new. All key stakeholders, including the taxi operators, fuel suppliers and manufacturers, were part of a panel that evaluated the results of the trial. They were also invited to discuss the fuel tax relief and capital subsidy that would be needed to make the programme successful. Following these discussions, in 2000, the government introduced the scheme and set a target date for phasing out all diesel taxis by 2005. However, the programme was so successful that by 2002 over 90% of taxis had converted to LPG [13].

Since the major driver of air quality management is the protection of health and welfare, then it is only right that the community at risk should have some input concerning the choice of actions and timetable intended to deliver healthy air quality. Some measures (e.g. restrictions on the type of domestic heating system and car access to the city centre) may have significant social and economic impacts on community groups. One cannot divorce the pursuit of healthy air quality from the wider socio-economic impacts of any actions taken. Public consultation and education programmes help increase the community’s ability to understand air pollution problems and the adverse impacts of pollutants on health and the environment. However, it is particularly challenging to find the appropriate means to enable the public to understand the complex science involved in many air quality problems and the levels of uncertainties associated with any ‘answers’ or ‘solutions’. Even so, engaging the community in air quality management may stimulate strong support for the need for measures, help ensure the most appropriate actions are chosen, and lead to greater compliance of implemented measures as well as encourage voluntary actions to reduce emissions. Public education campaigns may influence behavioural choice amongst individuals and groups, such as in transportation decisions, enabling them to make informed decisions. Generally, raising the public’s awareness and understanding of air pollution problems, involving them in the decision-making aspects of air quality management, and communicating information about current and future pollution concentrations to the public is an important part of air quality management. For some people, whose state of health make them particularly sensitive to high pollution concentrations, the provision of short-term air quality alerts is vital.

3.5 Need to be responsive to changes in pollution problems

The nature and sources of air pollution problems change over time as does our knowledge and understanding of the problems. An air quality management framework needs to be dynamic and incorporate regular assessment and reviews of pollution problems and the measures in place to ensure acceptable air quality is maintained. Action plans to tackle the problems will need continual evaluation, updating and modification to ensure they are, or will be, effective.

The role of research is vital in improving the air pollution science and effects of pollutants on public health and the environment. New research may indicate an urgent need to revise a health-based air quality standard. This has been evident in the case of particulates in which standards for dust or suspended particulate matter have been increasingly replaced or supplemented in many countries by standards for PM$_{10}$ which may, in turn, give way to PM$_{2.5}$ or even PM$_{1.0}$. Increasingly, it is
considered that the number of particles rather than the particle mass may be a better indicator of health effects. Changes to an air quality standard may lead to changes in management strategies and measures. Looking to the future, countries will increasingly seek to, or be encouraged to, adopt common air quality standards such as the World Health Organisation guidelines.

Strategies to improve air quality may need adjusting in light of better quality pollution monitoring data, more complete emission inventories and improved numerical dispersion models as well as more comprehensive evaluations of the cost effectiveness of management strategies. The need to improve the completeness and accuracy of emissions inventories is one major challenge facing developing countries. Sometimes even the simplest vehicle fleet data and emission factors are not available.

4 Evaluating alternative strategies

Following the identification of alternative strategies, comprising a range of measures to improve air quality, there needs to be an evaluation of their potential effectiveness. Evaluation of strategies can be undertaken in terms of air quality and health benefits as well as economic benefits and costs. In Mexico City, a large number of measures for making vehicles and fuels less polluting were evaluated and ranked in terms of cost-effectiveness. In Jakarta, Mumbai, Kathmandu and Metro Manila the Urban Air Quality Management Strategy (URBAIR) evaluated alternative mitigation measures by calculating the health savings and costs of each measure [14]. Evaluation may take into account many considerations. It is about balancing the wide range of costs and benefits as well as technical and institutional feasibility. In Britain’s air quality management approach (Air Quality Strategy), proposed measures are evaluated for the air quality improvements likely to be achieved, time taken to be implemented, cost effectiveness, non-air quality impacts (e.g. noise and socio-economic impacts), and public and political acceptability of the measures. Alternative measures are ranked, scored and prioritised for their potential effectiveness and impacts before the final combination of measures is chosen [8, 15]. In the air quality management plan in Perth, Australia, the criteria used to provide a ranking of the relative effectiveness of the measures include the direct and indirect emission reduction potential, the timing of effectiveness (time frames for an action to have an effect and to be fully implemented), cost effectiveness, equity (identification of the stakeholders who would bear the costs of the action and the individuals or groups within the community who may be disadvantaged), technical feasibility, enforceability, public acceptance and public health benefits [16].

5 Assessing progress of the Air Quality Improvement Plan

Following its implementation, the continued effectiveness of the Air Quality Improvement Plan needs to be confirmed and its progress towards improving air quality assessed. A range of measurable (direct and indirect) indicators are needed to track progress of each key objective against target dates. Air quality
needs to be monitored as do emissions. Improvements in a range of health indicators should be assessed. The impact of specific actions such as traffic management measures may be evaluated by monitoring changes in traffic volumes by vehicle type, traffic speed, bus journey time, reduction in vehicle-kilometres travelled, public transport use, number of vehicles meeting specific emissions standards, number of smoky vehicles, population within a set distance of a bus stop, etc. Indicators of co-related policies may be assessed too such as traffic noise and road accidents.

6 Conclusion

Success in developing an appropriate scientific and decision-making framework within which effective air quality management may be undertaken will depend upon many factors. It is important to ensure effective integration of the initial stage of reviewing and assessing of air quality, often conducted by environmental scientists, to the latter stage of developing and implementing of the Air Quality Improvement Plan, involving the politicians, policy-makers, planners and a wide range of stakeholders. Regular updating and improvements to the system are needed too. Generally, air quality management has been most successful in localities where there is strong political commitment to creating healthy air quality, significant investment in equipment, facilities and trained staff, effective collaboration between the different tiers and sectors of government, and a high level of involvement and commitment of stakeholders, including the public.

References


