The impacts of road transport on urban air quality - a case study of the Greater Manchester region

J.W.S. Longhurst, D. Rayfield, D.E. Conlan
Atmospheric Research and Information Centre, Department of Environmental and Geographical Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK

ABSTRACT

Within the context provided by one of the UK's major commercial, industrial and population centres, transport induced air quality problems are discussed and potential solutions identified. The problem is defined in terms of economic and social factors leading to the development of a car based economy allied to macro scale changes in industrial activity and decentralisation of population. The resultant impacts of transport emissions on the natural and built environment and human health are discussed. The administrative, legislative and pollution control responses to the problem are examined. The nature of this growing problem means it will require the integration of policies on traffic management, land use, public transport and pollution control if it is to be addressed satisfactorily.

INTRODUCTION

Transportation, incorporating accessibility and personal mobility is considered by many as an essential component of modern living. The challenge in transportation planning is reconciling supply and demand whilst minimising the costs which a transport system imposes on the environment. Many of the environmental challenges faced by urban environments result from an inability to reconcile these issues [1].

Recently a consortium of local authorities in the UK and others have undertaken a unique integrated study of the causes and consequences for urban areas of continuing our current transport policies. The work co-ordinated by a regional body, the Manchester Area Pollution Advisory Council, brought together planners, engineers, and environmental health personnel from a group of 16 local authorities plus specialist air quality academics and the regional health authority to address the environmental issues and to begin the process of identifying solutions [1]. This co-operative integrated approach adopted by the participants can be viewed as an immensely valuable building block in the move towards integrated local air quality management.

Transactions on Ecology and the Environment vol 3, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

HISTORY OF GREATER MANCHESTER

The study area contains the conurbation of Greater Manchester together with Cheshire and parts of Derbyshire and Lancashire. The area has a total population of around 4.5 million [1]. It is well served by motorway and 'A' roads and contains some of the most heavily trafficked stretches of road in the UK. It is home to the largest UK airport outside of London. It is well served by main line and local rail services and is the location of the U.K.'s first modern urban tram system, Metrolink. In the context of the U.K. the area is well served by bus and coach services. The area developed rapidly during the 19th century when it contained the "workshop of the world" and today has a rich industrial heritage from the Victorian era. The face of the area has changed significantly over the last two decades. The previous concentration on heavy industry has been replaced by a much more diverse economy and an urban structure which has changed in response to wider changes in society. The popular image of the Manchester area with its "smokestack" industry is today no longer matched by the reality of the 1990s. Major improvements have been made to the quality of the area's atmosphere over recent decades, largely as a result of the clean air legislation and partly as a result of de-industrialisation [2]. Over more recent years, however, in common with other heavily populated regions, the air quality has begun to deteriorate again as a result of the rapidly growing use of motor vehicles and in particular the private car [1].

DEFINITION OF THE PROBLEM

Motor vehicles are amongst the largest contributors to air pollution. It is estimated that nationally transport contributes approximately 19% of carbon dioxide, 41% of hydrocarbons and 51% of nitrogen dioxide [3]. Public concern has now reached the stage where there is a growing consensus of the need to develop cleaner engine technologies and for a change in driving patterns and more effective transportation systems. National road traffic forecasts from the Department of Transport show total traffic is expected to increase by between 27-47% by 2000 A.D. and between 83-142% by 2025 A.D. compared with 1988 [4,5]. Between 1979 and 1991 there has been an increase of 65% in the amount of traffic on Greater Manchester's motorways and 36% on local 'A' roads [1,6]. This compares with a national increase of 75% and 33% respectively. It becomes immediately apparent that building more roads is not the answer. This realisation has placed transportation at the forefront of political and public debate and it has become clear that our growing dependance on the private car will have to cease.

Technological changes in the combustion of fuel and the design of engines, including lean burn technology, unleaded petrol and catalytic converters will reduce the pollution emitted by an individual road vehicle. However, with the predicted increase in the volume of road traffic and urban congestion it may be only fifteen years before the reductions in the levels of pollutants brought about by these changes will be over-shadowed by the increase in both vehicle numbers and the kilometres driven by each vehicle [1]. The changes in technology are thus only a short term solution to the problem. However, they provide a window of opportunity within which society can develop the policies and practices leading to sustainable transport. Many of the causes of the transport induced air quality problems we now confront are in fact driven by broader scale societal changes operating at the national and regional scale. These include:

1) decentralisation of population and employment
2) de-industrialisation
3) rising car ownership and journeys undertaken
4) lack of investment in, and patronage of public transport
5) more leisure time
6) changes in pattern and location of retailing

The consequence of these changes in transport terms is that the frequency and length of individual journeys is now much greater than was the case twenty or thirty years ago.

ROAD TRANSPORT EMISSIONS

Individual motor vehicles are not particularly important as a source of pollution, but collectively they represent one of the largest sources of atmospheric pollution [3]. Vehicle emissions are estimated from a combination of fuel consumption data, an analysis of U.K. vehicle driving patterns and the application of appropriate emission factors. Such emission factors are specific to the type of pollutant, the class of vehicle and the driving cycle e.g. urban (low speed) or motorway (high speed). Emissions from individual vehicles are expressed as the grammes of pollutant emitted per kilometre travelled, and are available for petrol and diesel cars, buses, light and heavy goods vehicles and motorcycles [7]. The combustion of liquid fossil fuel releases a range of primary pollutants, the mix of which will be determined by the fuel type, the engine management system, the load an engine is being asked to apply and the pollution control technology installed on the vehicle. Primary pollutants include sulphur dioxide, black smoke, nitric oxide and nitrogen dioxide, volatile organic compounds and carbon monoxide. Secondary pollutants such as nitrogen dioxide, ozone and other organic compounds are formed as a result of chemical reactions between the primary pollutants and other chemicals present in the atmosphere. This is influenced by prevailing meteorological conditions.

IMPACTS

Health Effects

There has been concern by both medical and non-medical professionals that the prevalence of respiratory disorders, primarily asthma, has risen in recent years [8,9]. In an attempt to explain this, some research has considered the question whether environmental pollution has made a contribution to this apparent increase. The main respiratory conditions thought to be affected by environmental pollution are asthma, hay fever and respiratory infection. In addition some studies have suggested a link between polluting agents in the atmosphere and cancer, in particular leukaemia [10]. In looking at the effect of air pollution on asthma incidence, it is necessary firstly to consider the way in which air pollutants affect the respiratory system. Airborne pollutants have a direct irritant effect on the upper airways leading to bronchial constriction and decreased ability to breath deepily [11]. They may also have a direct toxic effect and aggravate existing asthma. Finally they may modify the immune response and thereby increase specific response to inhaled allergens [8]. In the MAPAC area hospitalisation rates for asthma per thousand population are above 1.5, and in four districts above 3.0 and in one, greater than 4.0 per thousand [1]. Diesel particulates are believed to damage the lining of the lungs and enable inhaled allergens to pass through to deeper tissues and activate the immune defences, thus triggering an asthma attack [12]. Long term exposure to air pollution aggravates respiratory and cardiovascular illnesses and reduces the lungs ability to exhale air and increase the rate at which the lungs lose capacity due to age.

Environmental Effects

Probably the most significant vegetation change in the UK as a result of air pollution has occurred in the North West. The upland peat areas east of Greater Manchester have suffered immense vegetation damage in the past 200 years. *Sphagnum* moss which forms the dominant species in most peatlands was severely affected in the Southern Pennines due to air pollution from industry. Loss of *Sphagnum* moss increases erosion. More recently emissions from vehicles have contributed to this problem and also affected grasslands, arable and horticultural crops. Also ozone can cause damage to various vegetation types [13]. The primary impact of vehicle emissions on freshwaters in the north west is from nitrogen oxides. NO_X is one of the precursors to acid deposition which is detrimental to fish and other freshwater fauna and flora. Under acid conditions aluminium maybe released from soils and reach water courses. Aluminium exposure will impair gill and lung physiology in fish. Increased acidity in freshwaters effects riparian bird and small mammal populations in such areas [14]. The most important of the emissions from vehicles to impact on buildings and materials are nitrogen oxides, black smoke and sulphur dioxide. Various stones and materials are more susceptible to damage from such pollutants than others. Limestone, marble, carbon-steel, nickel, paint and some plastics are most vulnerable. Stone decay can take several forms which includes removal of detail from carved stone and the build up of black gypsum crusts in sheltered areas. Corrosion of materials occurs when atmospheric pollutants such as sulphur dioxide react with water vapour to form dilute acids [15].

POLLUTION ABATEMENT TECHNIQUES

There are various technological solutions which can be applied to reduce vehicle emissions. These can be grouped into either modifications to the internal combustion process or alternative fuel sources. Following E.C. legislation all cars sold in Europe from 1993 will require a catalytic converter. The three way catalyst strips oxygen from the NO_X forming nitrogen and uses it to convert CO and HC to CO_2 and water. A two way oxidation catalyst oxidises CO and HC, and in conjunction with a lean burn engine will meet the E.C. Standard (Directive 88/76/EC) on small engines (1.4-2.0 litres) but a TWC is needed for larger engines [1]. Exhaust gas recirculation involves returning the exhaust air to the air fuel inlet which reduces peak engine temperatures, and the levels of NO_X in petrol vehicles. In diesels, the lower oxygen level will simultaneously cause an increase in HC and particulate matter [16]. Introducing hot air into the exhaust system will also reduce the levels of HC and CO. Turbo charging increases the mass of air delivered to the cylinder, thus increasing the power output [17]. However at low speeds misfiring can occur causing the formation of more HC and particulate matter. Overall turbo-charging tends to reduce particulate emissions but increases NO_X. Engine design and management systems enable accurate control of the fuel air ratio which involves using fuel metering systems for catalyst

Transactions on Ecology and the Environment vol 3, © 1994 WIT Press, www.witpress.com, ISSN 1743-3541

equipped cars. Oxygen sensors placed in the exhaust gas, feed back data to a central controller to enable the mixture ratio to be adjusted to meet the driving conditions, ensuring optimum conditions for the catalyst are maintained. Sensors placed on the flywheel can ensure that each cylinder fires at precisely the right time in the engine cycle [16,17]. Lean burn engines operate on a fuel air ratio 18:1 - 21:1 compared to 14.7:1 for normal engines. This affords greater fuel efficiency, lower NO_X and CO levels, but increases the hydrocarbon content. During periods of increased load the fuel mixture is richer producing more NO_X [16]. Ford, in collaboration with Orbital Engine Company of Western Australia have 25 Fiestas on road trials in the U.K. using a revolutionary 2 stroke, 3 cylinder catalyst engine. This system requires only two revolutions per cycle compared to four in the normal engine. This gives the smooth performance of a six cylinder power unit with greater compactness and less complexity.

Of the alternative fuel sources, compressed natural gas (CNG) leads to lower CO and NO_X emissions and because there is no benzene present less polyaromatic compounds are produced. A problem with this fuel is the loss of the greenhouse gas, methane during storage and distribution. Liquid petroleum gas (LPG) is a combination of butane and propane and has the same emission characteristics as CNG [17]. The use of hydrogen as a fuel has many attractions including greatly reduced NO_X emissions and no other pollutants. As its production involves the electolysis of water there is seemingly an endless supply of this fuel. There are question marks though over safety during handling and storage [16]. Alcohol based fuels such as methanol and ethanol have lower emissions of all pollutants. Methanol is produced from natural gas or biomass, whilst ethanol comes from the fermentation of sugar/starch by enzymes. After distillation and water removal, they can then be blended with petrol upto 85% by volume. The major problem with these fuels is the levels of odourous and potentially toxic aldehydes that are emitted. For diesel powered cars there is a substitute derived from rapeseed oil which leads to substantially reduced SO_2 emissions [16]. However sludging of the oil can cause engine failure and there are slightly higher emissions of NO_X. Finally electric vehicles are not only pollution free at the point of use but are very quiet. In providing the power to charge the batteries though, emissions of greenhouse gases are increased at power stations.

SOCIETAL RESPONSES

The technological solutions outlined above may reduce the level of pollutants emitted in the short to medium term. Eventually though, there will need to be changes in the transport habits of society, if the problem of traffic related air pollution is to be tackled effectively. Land use and planning can play an important role. The location of new development relative to transport provision can influence the need to travel. Through development plans, new development can be guided to locations which reduce the need for car journeys and the distances driven, and/or which encourage the use of public transport, cycling and walking. To this end the Government have recently issued new planning guidance to local authorities to minimise car traffic [18].

A well used public tansport system is more energy efficient than the use of private cars, particularly for trips to and from town or city centres. For public transport to be an attractive alternative to the private car, it needs to be reliable, efficient, at a reasonable cost, convenient and attractive to use. These objectives can be achieved in a variety of ways including: changes in funding and subsidy from private to public transport; good facilities at railway and bus stations; bus priority measures; good public transport interchange facilities; frequent and extensive "Park and Ride" facilities; upgrading local rail networks; efficient public transport information systems and improving and extending Light Rail systems.

Many trips, particularly in urban areas, are very short and could therefore easily be made on foot or by bicycle [1]. Cycling and walking are the most environmentally attractive options. A wide range of facilities to enable cyclists and pedestrians to travel more safely and in a less-polluted environment can be implemented, many within the existing highway system. It has been clear for some time that town centres cannot take unrestricted traffic growth. Traffic reduction is not only a benefit to those people who live in the urban areas but it enhances the attraction of living in the towns. Traffic restaint must involve more than just the obvious strategies of parking control and road pricing, although they must play a part in the overall strategy [19]. Any traffic restraint policy must also enhance the spaces vacated by the traffic [19]. Options for consideration in the production of an overall traffic restraint policy may include: traffic calming; parking policy; road pricing; planned congestion with priority routes for public transport and traffic free shopping areas [19]. Other measures that can be taken, include encouraging the use of railways and waterways for the carriage of freight, and government grants are available to fund such schemes. Implementing better public information programmes on the effects of traffic and the benefits to be gained from using alternative forms of transport is another measure which can be used to encourage a modal shift in transport choices.

RECOMMENDATIONS ARISING FROM THE MAPAC STUDY

Arising from this are a range of general and specific recommendations that have been formulated. The point of these is to improve air quality but their ramifications are wide ranging and will potentially lead to a radical reorganisation of our urban environments.

<u>General Recommendations</u>

1) A well resourced, integrated and sustainable transport system is a prerequisite of a civilised society. Such a system must be optimised to meet the needs of the travelling public without irreparably damaging the environment.
2) Modes of transport that are best suited to meeting these needs should be encouraged and other forms of environmentally damaging surface transport discouraged.
3) The encouragement of modal shift from private to public transport should be a priority of central and local government.
4) Land use, pollution and other impacts of transport should be better integrated into the environmental assessment process applied to a new development. Comparative environmental assessments should be required to demonstrate that the road, rail or other mode of transport proposed is actually environmentally acceptable and is effective at delivering the level of transport provision required.
5) Road pricing should not be relied upon as an interventionist strategy until a thorough analysis has been performed on its benefits and the distribution of costs in comparison to the cost and benefits of using road fund licensing and road fuel pricing

strategies to restrain traffic.
6) Additional income from road restraint initiatives, (pricing, license or fuel tax) should be used to improve public transportation systems and not directed solely at new road building schemes.
7) Urban congestion problems are best solved by simultaneously encouraging public transport and implementation of appropriate restraint of private vehicle use. It is imperative that enhancement of public transport services is provided prior to the implementation of traffic restraint mechanisms.
8) Education and public information campaigns are required to encourage public transport patronage, to discourage single occupancy trips and to reduce the number of short trips undertaken by private cars.
9) Central government and the European Union must provide the regulatory framework which encourages the manufacture of fuel efficient, low emission vehicles. 10) Central government should support research and development programmes for alternative transport systems and alternative fuels.
11) The regulatory framework should be established which provides specific encouragement for the shift of freight to the railway system. Such a framework of control will cost transport according to the level of its environmental impact.

Specific Recommendations for MAPAC and its Constituent Local Authorities
1) Many pollutants are speed dependent. Emissions can be reduced by road designs which limit speed such as humps and signing
2) Unitary Development Plan development and monitoring procedures, Transport Policies and Programme submissions procedures and air quality monitoring strategies should be reviewed to ensure that the pollution effects of transport are being addressed comprehensively.
3) When considering development proposals the Local Authority should require full details of the local pollution burden to be borne as a consequence of any development and to require that the development be properly connected to public transport systems.
4) Local authorities should conduct long term pollution monitoring for traffic related pollutants and should report the results and the impacts of such pollution to the public.
5) Local authorities should engage in public information and education programmes to improve understanding of traffic and pollution issues and to begin the process of changing car based transport habits.
6) Local authorities should consider providing demonstration projects of alternative fuels such as natural gas or electrically powered vehicles as part of their vehicle fleet provision.
7) Local authorities should re-evaluate their use and need of vehicles and include environmental assessments in the allocation of car user status.

SUMMARY AND CONCLUSION

This paper has highlighted the attempts made by one region, to integrate all the various agencies necessary to tackle the air quality problems specific to the area it covers [1]. The nature of this growing environmental problem, its causes and effects, mean that the policies which need to be implemented to solve it will require cooperation by many diverse bodies. MAPAC have made a first attempt to integrate these various agencies into a strategic assessment network specific to Greater Manchester. The experience will be invaluable in pulling together agencies to plan future air quality, but it is vital that there are agreed goals to carry forward and achieve. Unfortunately, this has not happened in this case and the assembled group of agencies has temporarily gone into abeyance. However the scope of local air quality management plans provide opportunities to rebuild this process in the future [20].

REFERENCES

1. Ramsden, P.S., Longhurst, J.W.S., Dinsdale, J.A. and Elliott, R. (eds.) *A Breathing Space. Vehicle related air pollution in North West England.* MAPAC, Manchester, 1993.
2. Longhurst, J.W.S. and Conlan, D.E. 'Changing Air Quality in the Greater Manchester Conurbation' in Air Pollution 2 (Ed. Brebbia, C.A., Baldasona, J.H. and Zanetti, P.) Accepted, *Proceedings of the 2nd Int. Conf. Air Pollution 94* Barcelona, Spain, 1994. Computational Mechanics Publications, Southampton, 1994.
3. Department of the Environment *Digest of Environmental Protection and Water Statistics,* No. 14. H.M.S.O ., London, 1992.
4. Department of Transport *National Road Traffic Forecast (Great Britain),* H.M.S.O., London, 1989.
5. Department of Transport *Transport Statistics, Great Britain 1979-1989,* H.M.S.O., London, 1990.
6. Greater Manchester Transportation Unit *Transport Statistics, Greater Manchester 1991,* GMTU report No.222, Manchester, 1991.
7. Eggleston, H.S. *Pollution in the Atmosphere: Future Emissions from the UK,* LR888 (AP) Warren Springs Laboratory, Stevenage, 1992.
8. Burr, M. 'Is Asthma Increasing?' *Journal of Epidemiology and Community Health.* 41 pp. 185-189, 1987.
9. Fleming, D.M. and Crombie, D.L. 'Prevalence of Asthma and Hay Fever in England and Wales.' *British Medical Journal* 294 pp. 279-281, 1987.
10. Savitz, D.A. and Feingold, L. 'Association of Childhood Cancer with Residential Traffic Density.' *Scandinavian Journal of Environmental Health* 15 pp.360-363, 1989.
11. Lebowitz, M.D. 'The Effect of Air Pollution and Weather on Lung Function in Exercising Children and Adolescents.' *American Review of Respiratory Disease* 109 pp. 262-273, 1974.
12. Quality of Urban Air Review Group *Diesel Vehicle Emissions and Urban Air Quality*, 2nd report, DoE London, 1993.
13. Terrestrial Effects Review Group *The Effects of Acid Deposition on the Terrestrial Environment in the United Kingdom,* 1st report, H.M.S.O., London, 1988.
14. North West Water Authority *Acidification of Surface Waters in Cumbria and the South Pennines,* Final report to the DoE (Contract PECD 7/10/89), NWWA, Warrington, 1987.
15. Building Effects Review Group *The Effects of Acid Deposition on Buildings and Building Materials,* 1st report, H.M.S.O., London, 1989.
16. Watkins, L.H. *Air Pollution from Road Vehicles,* Transport and Road Research Laboratory, DoT, H.M.S.O., London, 1991.
17. Department of the Environment *Acidic Emission Abatement Technologies. Volume 4: Mobile Sources,* H.M.S.O., London, 1991.
18. Departments of Environment and Transport *Planning Policy Guidance: Transport,* 13, H.M.S.O., London, 1994.
19. Manchester City Council *Personal Communication,* Planning Department, Manchester, 1993.
20. Longhurst, J.W.S., Lindley, S.J. and Conlan, D.E. 'Local Air Quality Management' in Air Pollution 2 (Ed. Brebbia, C.A., Baldasona, J.H. and Zanetti, P.) Accepted, *Proceedings of the 2nd Int. Conf. Air Pollution 94* Barcelona, Spain, 1994. Computational Mechanics Publications, Southampton, 1994.