2.02 MODELLING AIR QUALITY SCENARIOS IN LONDON ARE THE EU LIMIT VALUES FOR NO_2 AND PM_{10} ACHIEVABLE?[H]

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INTRODUCTION

The first daughter directive of the European Framework Directive on Air Quality (*EC Council Directive 1999/30/EC*) requires that concentrations of nitrogen dioxide (NO_2), small particulate matter (PM_{10}), sulphur dioxide (SO_2) and lead are below limit values specified for 2005 and 2010. Monitoring of air pollutants is of primary importance in determining current concentrations at specific points and in determining historical trends in pollutant concentrations which can aid in the determination of future concentrations. However modelling is essential for determining in detail the spatial variation in concentration, for predicting future concentrations, for understanding relevant sources at a particular receptor (source receptor relationships) and for testing scenarios for pollutant reduction. The urban air quality model ADMS-Urban has been developed and designed specifically for these purposes and is used in many countries in the EU and elsewhere to perform such calculations.

In this short summary paper further examples of the use of the model for the purposes determining compliance with the air quality directives are briefly presented for NO_2 and PM_{10}. These are focused on London with an emphasis on road traffic emissions; an example from London Heathrow Airport is also presented. The sections of the paper are as follows: a summary of validation, sensitivity and comparison studies; base case scenarios and source apportionment studies for London including Heathrow Airport; and an example of a road traffic emission reduction strategy.

ADMS-URBAN

The ADMS-Urban model has been described in detail at previous harmonization workshops and in other sources (eg Carruthers et al, 1998 and UK Air quality Expert Group, 2004). In summary it consists of the local dispersion model ADMS nested within a trajectory model. The dispersion model treats all relevant sources explicitly and includes the OSPM street canyon model (Hertel et al, 1990) suitably adjusted to incorporate the ADMS meteorological profiles. The model is linked to the emissions inventory toolkit (EMIT (CERC, 2003)) for storage and manipulation of all relevant input data and is linked with a choice of GIS for case of input and presentation of model calculation. The data handling facilities have been developed for the large emission databases required for larger urban areas.

ADMS-URBAN VALIDATION

Extensive Validation of ADMS 3 (the basic dispersion model within ADMS-Urban) and ADMS-Urban itself has been conducted (eg Hanna et al, 1999, Carruthers et al, 2003a). As an illustration of the model performance we have included Figure 1 which shows comparison between calculations of NO_2 and PM_{10} concentrations at a range of roadside urban centre and urban background sites in London, Manchester and York. This shows generally excellent performance well within the requirements of the EU directive, up to 30% error for annual averages and 50% for peak concentrations (high percentiles). Studies examining the

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sensitivity of model performance to a range of input parameters including emissions and meteorology, surface roughness etc showed that the model exhibited most sensitivity to uncertainties in the meteorological variables and the emissions. Comparison with other empirically based models utilised in the UK show that the models compare well for current emissions but that there is a marked divergence in model performance for future projections (Carruthers et al, 2003b). For NO_2 this may reflect differences in chemistry routines with empirical schemes unable to take account of the impact of changes in the relative quantities of O_3 and NO_x. In the case of PM_{10} source apportionment suggests that this may relate to different relative contributions of different sources.

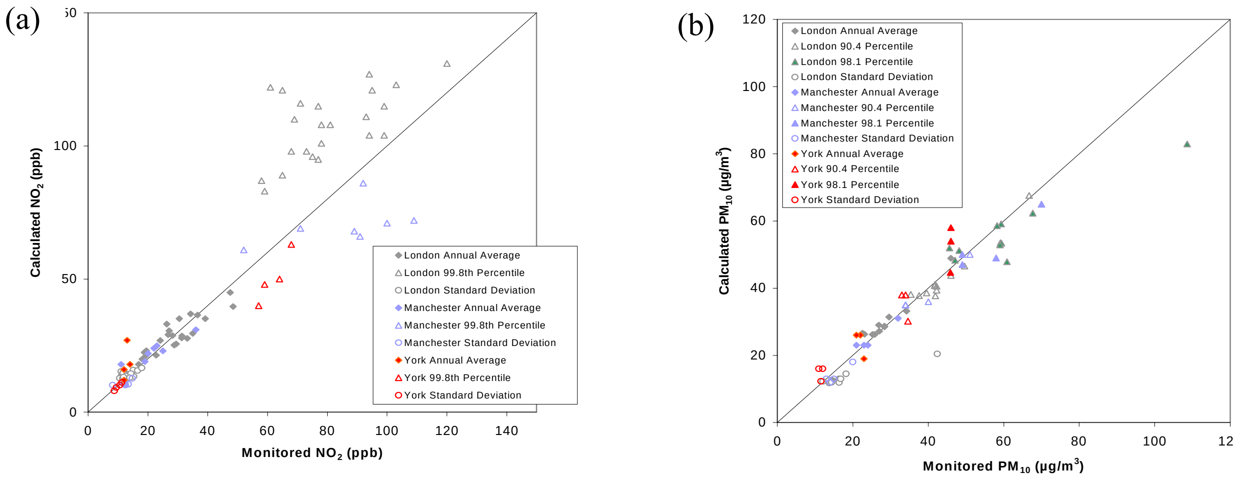

Figure 1. Comparison of Measured and Calculated Annual Average, Percentile and Standard Deviation Data Pairs calculated using ADMS-Urban (a) NO_2, (b)PM_{10}.

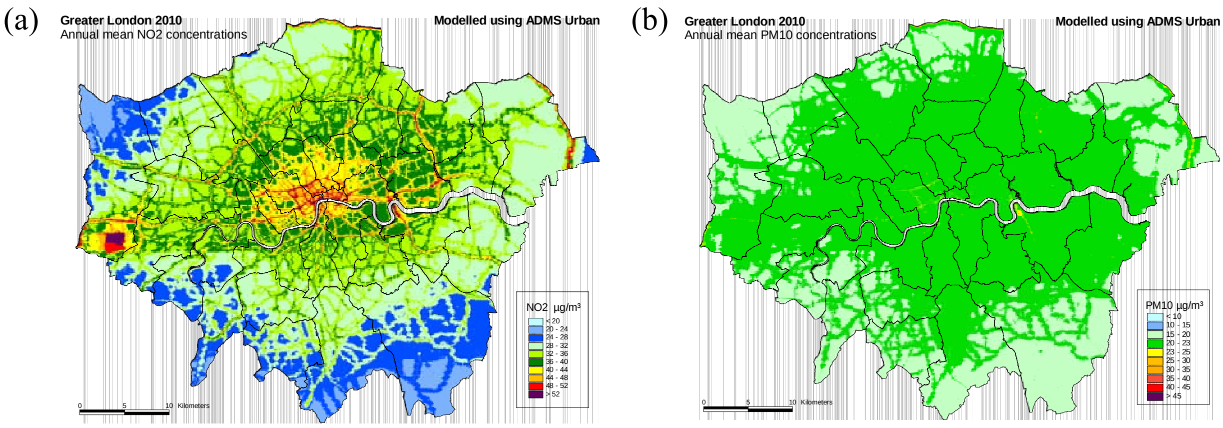

Figure 2. Calculated annual average concentrations across London for 2010 (a) NO_2, (b) PM_{10}.

BASE CASE SCENARIOS

Figure 2 and Table 1 show examples of concentrations across London of NO_2 and PM_{10} calculated from base case emissions; that is cases where no additional mitigation scenarios to those already being introduced or due to be introduced (eg EURO 4 vehicle emissions). Annual average maps of NO_2 and PM_{10} are shown for 2010 whilst the table presents projections for averaging time corresponding to the EU limit values for 2005 and 2010 at various receptor points in London. It can be seen that a significant area of London will fail to achieve either the NO_2 or PM_{10} annual average limit values in 2010 (respectively 40µg/m^3

and 20μg/m^3). In the case of PM_{10} the Table shows that worst case meteorological conditions also lead to exceedence of the daily average limit values for 2005. Note also that there is less spatial variation in PM_{10} across London this showing the relative importance of PM_{10} advected into the London area.

SOURCE APPORTIONMENT

Some insight into preferred emission reduction scenarios and sources contributing most to the concentration of pollutant at a particular location can be obtained by source apportionment calculations. Because in the case of NO_2 the greater part of the source derives from NO_x emissions for nitrogen oxide source apportionment in this case is calculated for total NO_x rather than NO_2. Source apportionment calculations can be presented by a number of different methods, examples of which are presented below. Table 2 shows examples of source apportionment projections for 2010 presented numerically for a number of sites in London. Pie charts corresponding to two sites Marylebone Road (Roadside) and Bloomsbury (urban centre) are shown in Figure 3 and Figure 4 shows an example from sites around Heathrow airport. Detailed maps of concentration distribution corresponding to different source types can also be calculated from a study conducted for the Borough of Hillingdon.

POLLUTANT MITIGATION SCENARIOS

An example of the use of ADMS-Urban for testing mitigation scenarios is given in Figure 5 which in this case shows the potential impact of further improvements in vehicle technology. Other measures which have been investigated in detail include options for a low emission zone.

CONCLUSIONS

This summary of modelling calculations of air quality in London shows that the EU limit values for NO_2 and PM_{10} are unlikely to be achieved in Central London especially near major roads even with emission mitigation strategies currently being considered.

REFERENCES

Hertel, O., Berkowicz, R. and Larssen, S., 1990: The Operational Street Pollution Model (OSPM). 18th International meeting of NATO/CCMS on Air Pollution Modelling and its Application. Vancover, Canada, 1990. pp741-749.

EC Council Directive 1999/30/EC relating to limit values of sulphur dioxide, nitrogen dioxide and oxides of nitrogen particulate matter and lead in ambient air, 1999

Carruthers, D.J., Edmunds, H.A., Lester, A.E., McHugh, C.A., and Singles, R.J., 1998: Use and Validation of ADMS-Urban in contrasting Urban and Industrial Locations. International Journal of Environment and Pollution, **14**, Nos. 1-6.

CERC, 2003: EMIT Atmospheric Emissions Inventory Toolkit User Guide

UK Air quality Expert Group (2004) Nitrogen Dioxide in the UK (to be published)

Hanna, S.R., Egan, B.A., Purdum, J. and Wagler, J., 1999: Evaluation of the ADMS, AERMOD and ISC3 Models with the Optex, Duke Forest, Kincaid, Indianapolis and Lovett Field Data Sets**.** International Journal of Environment and Pollution, **16**, 1-6.

Carruthers, D.J., Blair, J and Johnson, K, 2003a: Validation and Sensitivity Study of ADMS-Urban for London. (www.airquality.co.uk/archive/reports/cat09/Validation&Sensitivity(22JAN03)10_TR-0191-h.pdf)

Carruthers, D.J., Blair, J and Johnson, K, 2003b: Comparison of ADMS-Urban, NETCEN and ERG Air Quality Predictions for London (www.airquality.co.uk/archive/reports/cat09/Comparison_17jun03_12_TR-0232.pdf)

Table 1. Calculated pollutant concentrations corresponding to the EU limit values for 2005 and 2010; exceedence of the limit are shown in bold.

	Site	NO_2 1999 Meteorology		PM_{10} 1999 Meteorology				PM_{10} 1996 Worst case meteorology		
		2010 Annual Mean	2010 1 hour mean 18 exceedences	2005 Annual Mean	2005 Daily average 35 exceedences	2010 Annual Mean	2010 Daily Mean 7 exceedences	2005 Daily mean 35 exceedences	2010 annual mean	2010 Daily mean 7 exceedences
Roadside	A3	**48**	143	27	37	**22**	39	48	**26**	**54**
	Camden	**55**	178	28	38	**23**	41	48	**26**	**55**
	Harringey	**42**	157	25	36	**21**	38	47	**25**	**52**
	Marylebone Road	**71**	191	37	**50**	**28**	47	**58**	**30**	**62**
	Sutton roadside	29	128	24	34	**20**	37	46	**24**	**52**
Background	Bexley	31	172	24	34	**20**	35	45	**24**	**52**
	Bloomsbury	**46**	172	25	35	**21**	37	47	**25**	**53**
	Eltham suburban	32	176	24	34	**21**	35	45	**24**	**52**
	Hillingdon	**48**	168	26	36	**21**	41	47	**25**	**53**
	North Kensington	**40**	151	24	35	**21**	37	46	**25**	**53**

Table 2. Modelled Source Apportioned 2010 Annual Mean NO_x concentration ($\mu g/m^3$)for roadside and background monitoring sites.

		TOTAL	Background	Rail	Shipping	Domestic Gas	Commercial Gas	Industry	Other	Other Road	Car	Taxi	Bus & Coach	LGV	Rigid HGV	Articulated HGV
Roadside	A3	107	12	1	0	5	2	1	4	6	36	1	3	8	18	9
	Camden	117	12	4	0	10	7	2	4	6	25	2	14	7	17	5
	Haringey	69	12	1	0	10	5	2	4	5	10	1	5	3	7	2
	Marylebone Road	223	12	2	0	11	11	3	4	6	38	27	31	17	47	15
	Sutton Roadside	47	12	1	0	6	3	1	3	6	6	0	2	2	3	1
Back-ground	Bexley	50	12	1	0	8	4	3	2	6	4	0	2	1	3	3
	Bloomsbury	80	12	2	0	11	14	3	4	6	8	3	7	3	6	2
	Eltham	55	13	1	0	9	5	4	2	5	6	0	2	2	4	2
	Hillingdon	104	14	1	0	3	1	2	18	7	28	0	4	4	11	11
	North Kensington	66	12	4	0	11	7	2	5	6	7	1	3	2	4	2

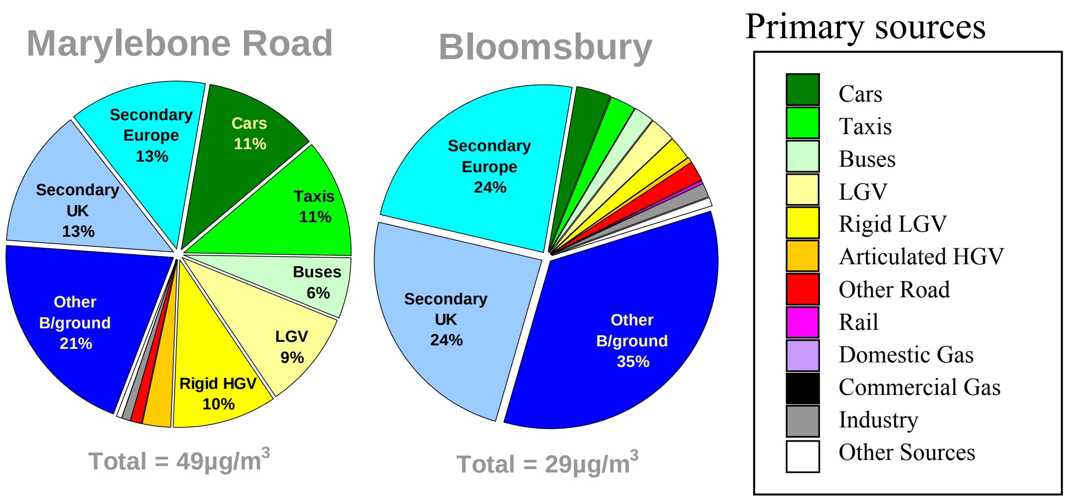

Figure 3. Modelled Source Apportionment of PM_{10} in 1999. Marylebone Road is a roadside site, Bloomsbury an urban centre site.

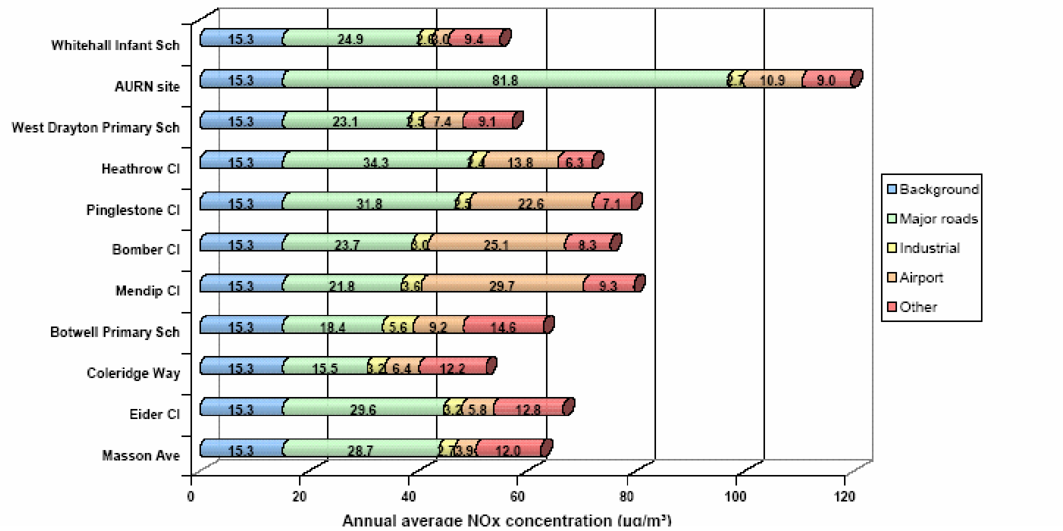

Figure 4. Modelled contribution of major source groups to annual average NO_x concentrations in the neighbourhood of Heathrow Airport (2005)

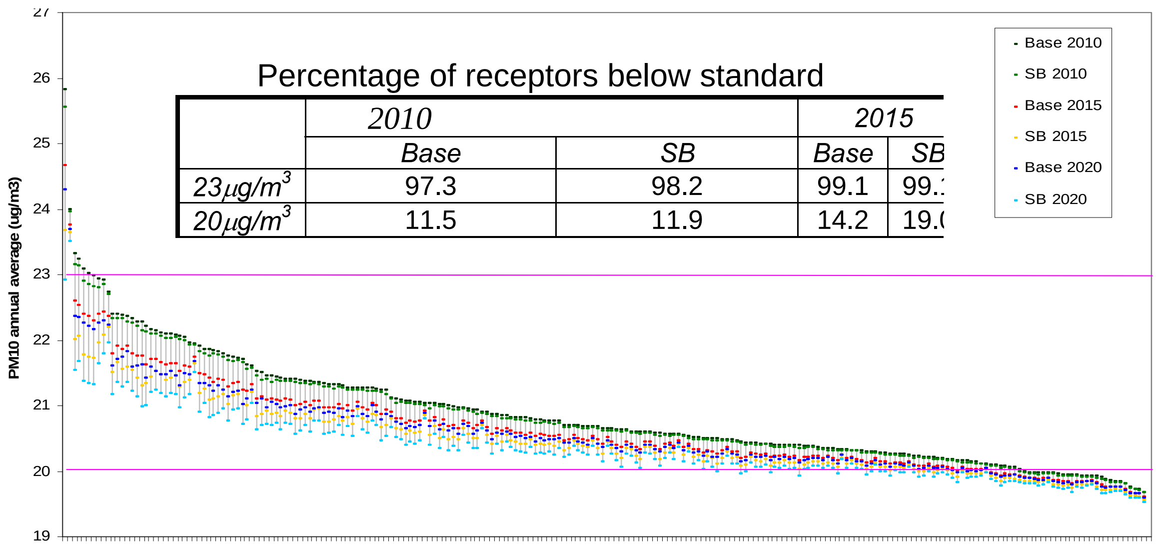

Figure 5. Euro V scenario tests: Base case vs Scenario B (Euro V cars) for 2010, 2015 and 2020 at 100 different receptor points across London.