DISPERSION OF AIR POLLUTION IN URBAN AREAS IN THE UK

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INTRODUCTION

The Air Quality Strategy in the UK and the EU Air Quality Framework Directive and subsequent Daughter Directives set out objectives and limit values for the major polluting species. Particularly challenging for the UK are the annual average objectives and limits for NO_2 (40μg/m^3) to be achieved in 2005 (Air Quality Strategy) and 2010 (EU limit values) and the annual mean limit value for PM_{10} of 20μg/m^3 to be achieved by 2010. These levels will be achieved across much of the UK because of reductions in industrial emissions and the significant improvement in road transport emissions arising from clean fuels and the implementation of EURO standards for vehicle emissions. However concentrations of NO_2 and PM_{10} remain a problem in large urban areas and more especially in London. This paper presents the application of the ADMS-Urban model (*Carruthers et al*. 1998) to determine likely areas of exceedence of the levels in London for the target years.

METHODOLOGY

The key components of the study are model set-up, validation, a sensitivity study, comparisons with other prediction techniques and calculation of contour maps for the base year (1999) and target years (2004, 2005, 2010).

The emissions database has been constructed by the Environmental Research Group at King's College London (ERG) and the Greater London Authority (GLA). It includes high resolution road data consisting of road segments as little as 10m in length, and 11 vehicle classes with vehicle flows and speeds based mainly on traffic counts rather than models, a comprehensive dataset for industrial emissions explicitly detailed as point sources, and a grid 1km × 1km resolution of other sources. Meteorological data were obtained for Heathrow Airport and the London Weather Centre, whilst rural background pollution concentration data were obtained from four sites around London.

Comparisons between ADMS-Urban and observation and model sensitivity

London has an extensive network of continuous monitors including approximately 30 which constitute part of the UK national (AURN) network and many other sites operated on behalf of local authorities. The model data comparison was performed using the AURN sites; these comprise a combination of roadside, kerbside and background sites. An example for PM_{10} is shown in Table 1. The statistics shows that ADMS-Urban generally performs well.

Sensitivity of concentration statistics to meteorological data site and model set-up (minimum Monin-Obukhov length, grid source height, surface roughness) were also performed. Sensitivity was found to be greatest to the location of the meteorological data site.

Table 1. Monitored and calculated PM_{10} concentrations ($\mu g/m^3$)

	Annual average		90.4th percentile of 24 hr average		98.1th percentile of 24 hr average		Standard deviation		NMSE (objective 0)	Correlation (objective 1)	FA2 (objective 1)	Normalised bias (objective 0)
	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated	Monitored	Calculated				
A3 roadside	29.6	31.4	46.0	43.8	59.3	59.1	16.4	13.0	0.15	0.707	0.897	-0.06
Bexley suburban	25.2	26.2	41.9	37.7	60.9	47.9	16.4	11.9	0.22	0.679	0.888	-0.039
Bloomsbury urban centre	28.4	28.7	42.2	40.6	59.1	53.5	14.4	12.6	0.14	0.686	0.941	-0.009
Brent urban background	23.1	26.3	37.6	37.8	45.6	52.0	13.8	11.8	0.21	0.651	0.898	-0.129
Camden roadside	34.2	33.2	49.6	46.6	67.7	62.3	18.2	14.5	0.19	0.607	0.934	0.03
Eltham suburban	22.6	26.6	35.4	38.1	47.1	48.3	12.1	12.2	0.19	0.672	0.917	-0.162
Haringey roadside	28.4	28.5	41.7	40.7	59.4	53.4	14.6	12.4	0.13	0.714	0.951	-0.006
Hillingdon suburban	26.9	29.0	41.8	41.2	58.2	58.6	16.8	13.0	0.22	0.645	0.879	-0.076
Marylebone roadside	46.0	48.9	66.7	67.6	108.6	82.9	42.4	20.4	0.71	0.361	0.897	-0.06
North Kensington urban background	27.0	27.2	42.2	39.4	59.0	52.9	14.5	12.2	0.14	0.725	0.945	-0.004
Sutton roadside	25.8	26.2	39.6	38.6	48.2	51.2	14.4	12.0	0.21	0.599	0.94	-0.016

COMPARISONS WITH OTHER METHODOLOGIES

In addition to the ADMS-Urban system two other methodologies have also been used routinely to calculate current and future air pollutant concentrations across London. These have been developed by NETCEN (e.g. *Stedman*, 2001) and by ERG (*Carslaw et al*., 2001). The NETCEN mapping methodology is designed to allow rapid testing of policy scenarios and their impact across the whole of the UK. Concentrations are considered as comprising up to three component parts: a rural background, an urban background and roadside. The rural background is determined from rural monitoring sites. The urban background is characterised by dispersion modelling of emissions across a significant area e.g. 25 × 25km with the magnitude of the concentration determined by a correlation analysis using background monitoring sites; the road contribution is determined directly from a simple algorithm relating emissions to pollutant concentrations. The annual average NO_2 is derived from NO_x annual average using empirically based curves. The ERG methodology is designed specifically for London and uses a combination of local data and modelling and a multiple repression technique using the monitoring sites across London. The modelling includes explicit considerations of local sources whilst more distant sources are considered as grid sources treated in a separate model run of ADMS 3 (*Carruthers et al*., 1994).

An example of comparisons for annual mean NO_2 is shown in Table 3. This shows roadside and background sites listed consecutively and the prediction of each of the methodologies. Two different Atmospheric Emissions inventories (AEI) were used for the NETCEN runs, the London Atmospheric Emissions Inventory (LAEI) and the National Atmospheric Emissions Inventory (NAEI). At the specific sites listed in the table there is a reasonable correspondence between ADMS-Urban, NAEI and ERG predictions, however further analysis reveals a different picture. Table 2 shows the total road length in London exceeding threshold concentrations for NO_x, NO_2 and PM_{10} for 1999 and 2005. Significant differences are for example apparent for exceedence of 40µg/m^3 by the NO_2 concentrations. Figure 1 compares annual average roadside PM_{10} for ADMS-Urban with the NETCEN methodology.

Table 2. Annual average NO_2 concentrations for 1999 with typical meteorological data (1999) (µg/m^3)

	Measured Value	ADMS-Urban	NETCEN NAEI Background	NETCEN NAEI Roadside	NETCEN LAEI Background	NETCEN LAEI Roadside	NETCEN Site Specific	ERG
A3 roadside	58	67	41	-	35	-	-	61
Camden roadside	66	71	46	69	42	44	66	63
Cromwell roadside	93	76	54	70	46	49	92	73
Haringey roadside	51	55	45	49	39	41	48	50
Hounslow roadside	60	53	44	60	39	39	-	-
Marylebone roadside	91	88	59	83	49	83	92	80
Southwark roadside	75	67	51	66	44	55	-	-
Sutton roadside	44	42	39	-	34	-	44	-
Tower Hamlets roadside	70	71	48	58	42	55	67	61
All roadside sites mean	68	66	-	-	-	-	-	-
NAEI/LAEI roadside sites mean	72	69	-	65	-	52	-	-
ERG roadside sites mean	72	71	-	-	-	-	-	65
Bexley suburban	37	40	37	-	32	-	-	40
Bloomsbury urban centre	67	57	63	-	50	-	67	65
Brent urban background	37	44	42	-	38	-	-	36
Bridge Place urban background	63	53	57	-	48	-	-	57
Eltham suburban	36	44	41	-	35	-	-	-
Hackney urban centre	60	55	46	-	40	-	-	53
Hillingdon suburban	50	63	45	-	39	-	-	55
Lewisham urban centre	54	55	43	-	37	-	-	-
N Kensington urban background	46	52	48	-	43	-	-	48
Southwark urban centre	56	50	47	-	40	-	-	61
Sutton suburban	35	38	39	-	34	-	-	-
Teddington urban background	32	34	40	-	35	-	-	36
Wandsworth urban centre	52	59	45	-	39	-	-	-
West London urban background	55	50	47	-	42	-	55	57
All background sites mean	49	50	46	-	39	-	-	-
ERG background sites mean	50	50	47	-	41	-	-	51
All AURN sites mean	**56**	**56**	**46**	**-**	**40**	**-**	**-**	**-**

Table 3. Percentage road length exceeding specified annual mean values

	ADMS-Urban		NETCEN LAEI		ERG	
	1999	2004/2005	1999	2004/2005	1999	2004/2005
NO_x >30 µg/m^3	100	100	100	100	100	100
NO_x >40 µg/m^3	100	98	100	97	100	98
NO_x >50 µg/m^3	99	83	98	85	100	82
NOx >60 µg/m^3	90	56	91	71	98	61

Table 3. cont'd. Percentage road length exceeding specified annual mean values

	ADMS-Urban		NETCEN LAEI		ERG	
	1999	2004/2005	1999	2004/2005	1999	2004/2005
NO_2 >20 µg/m^3	100	100	100	100	100	100
NO_2 >30 µg/m^3	100	97	98	80	100	87
NO_2 >40 µg/m^3	87	59	53	19	84	36
NO_2 >50 µg/m^3	39	16	16	6	42	10
PM_{10}>20 µg/m^3	100	100	31	5	100	100
PM_{10}>23 µg/m^3	100	98	8	1	100	21
PM_{10}>25 µg/m^3	91	21	5	1	74	7
PM_{10}>30 µg/m^3	8	1	1	0	12	1
PM_{10}>40 µg/m^3	0	0	0	0	1	0
PM_{10}>50 µg/m^3	0	0	0	0	1	0

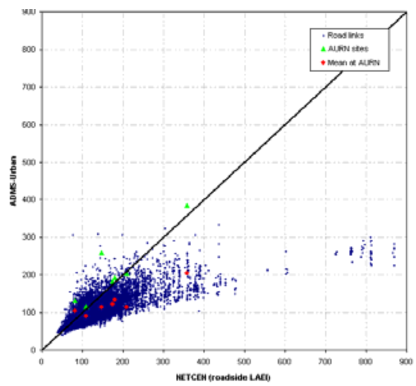

Figure 1. ADMS-Urban and NETCEN LAEI 1999 Annual Average NO_x (µg/m^3)

CONCENTRATION MAPS

An example of a pollutant contour map is shown in Figure 2. This shows annual average NO_2 concentrations projected for 2010. By 2010 the projected area of exceedence of 40µg/m^3 is reduced compared to 1999, however significant areas of central London, roadside sites outside Central London and the area around Heathrow still exceed the limit.

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REFERENCES

Carruthers, D.J., H.A. Edmunds, A.E. Lester, C.A. McHugh and R.J. Singles, 1998: Validation of ADMS-Urban in contrasting Urban and Industrial locations. *Int. Conf. Of Harmonisation of Dispersion Models for Regulatory Purposes, Int. J. Environment and Pollution* 429-436.

Carruthers, D.J., Holroyd R.J., Hunt J.C.R., Weng W-S., Robins A.G., Apsley D.D., Thomson D.J. and Smith F.B., 1994: UK-ADMS: A new approach to modelling dispersion in the earth's atmospheric boundary layer. Journal of Wind Engineering and Industrial Aerodynamics. **52** 139-153 Elsevier Science B.

Carslaw D.C., Beevers S.D., Fuller G., 2001: An Empirical Approach for the Prediction of Annual Mean Nitrogen Dioxide Concentrations in London. *Atmospheric Environment,* Vol 35, 1505-1515.

Stedman J.R., Goodwin J.W.L., King K., Murrells T.P. and Bush T.J., 2000: An empirical model for predicting urban roadside nitrogen dioxide concentrations in the UK. *Atmospheric Environment,* Vol 35, 1451-1463.

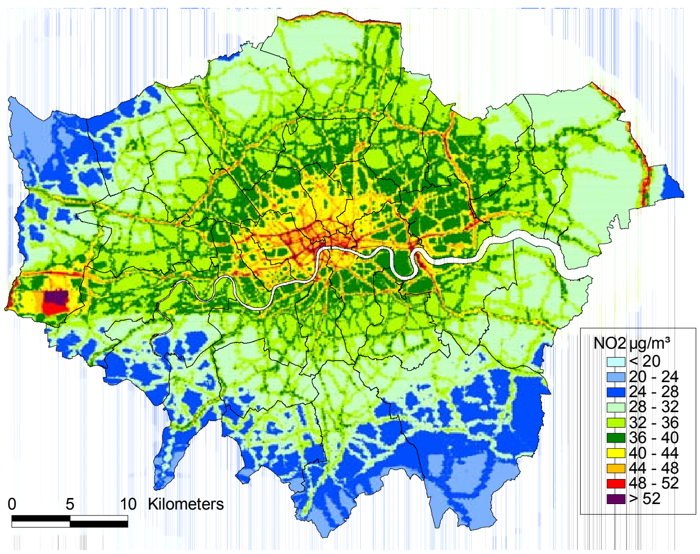

Figure 2. Annual average NO_2 concentrations for 2010 calculated using ADMS-Urban