Application of ADMS-Urban to a large urban area: Model sensitivity to selected input parameters

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1 Introduction

A study was undertaken to model levels of pollutants in the Greater Manchester conurbation in the North West of England using the multi-source dispersion model, ADMS-Urban (McHugh et al, 1997). The emissions inventory used in this study is based on the same model and methodologies as the urban scale emission inventories developed for the UK Department of Environment Transport and the Regions. The meteorological data is input via files obtained from the UK Meteorological Office supplied in formats specifically derived for ADMS-Urban model users. These inputs provide close to standard modelling inputs for users in the UK.

The aim of the study is firstly to examine the performance of the model by comparison of the base year model predictions with monitored data building upon previous evaluation studies. The second aim of the study was to examine the effect of certain model parameters and modelling approaches on model results.

Concentrations of oxides of nitrogen (NOx) and nitrogen dioxide (NO_2) were modelled to future assess compliance with the UK Air Quality Objectives laid down in the Air Quality Strategy for the UK (DETR, 2000). The modelled values for the initial base year are compared with monitored data at seven continuous monitoring sites in the conurbation and a statistical comparison is used to discuss the overall model performance. Secondly, sensitivity analyses have been undertaken which pay particular attention to parameters that must be determined by the model user such as a minimum Monin-Obukhov length, surface roughness value and grid source depth.

This study was undertaken as part of the research programme funded by the Greater Manchester local government authorities as part of their review and assessment of air quality required by the UK Environment Act, 1995.

2 Study Methodology

2.1 Study Approach

Concentrations of NOx were modelled for a base year of 1997 and 2005 (the year for which the Air Quality Objectives apply). For this extended abstract only the results for NOx in 1997 are shown. The predicted concentrations for the base year were compared with monitored concentrations at the automatic continuous national monitoring sites located at seven locations throughout the conurbation. The monitoring site locations are described in Table 1. Modelled and measured time series data have been compared. Statistical analyses were carried out to assist in the comparison of model predictions with monitored data. This work builds on existing validation and evaluation studies of the ADMS-Urban model (e.g. Owen et al, 1999 and 2000).

Model runs for the sensitivity analyses were undertaken for the central City of Manchester area. Two continuous monitoring sites are located in the city centre area; Manchester Town Hall and

Piccadilly Gardens. The sensitivity analyses investigated the parameters shown in Table 2. To investigate the effect of these parameters on model results a simple parametric analysis has been undertaken whereby the outputs of a base case are compared to outputs from additional simulations with one parameter value changed at a time.

Table 1 AURN sites in the Greater Manchester area 1997.

Site	Type
Bolton	Urban background
Bury	Roadside
Manchester Piccadilly	Urban background
Manchester South	Sub-urban
Manchester Town Hall	Urban background
Salford Eccles	Urban background
Stockport	Urban background

Table 2 Parameters for uncertainty analysis.

Parameter	Base Case	Range
Minimum Monin-Obukhov length	30 m	100 m
Surface roughness	1 m	2 m
Grid source depth	20 m	50 m, 150 m
Size of area of detailed treatment of sources	2 km x 2 km	1.5 km x 1.5 km
Meteorological data	Hourly (for 1997)	Percentage frequency (10 yr summary 1987-97)

The parameters considered are varied within the range of uncertainty of the values for this application.

Sensitivity of the model to the type of meteorological data used has also been investigated. ADMS-urban in common with many dispersion models such as ISC and AERMOD can use sequential hourly met observations or longer term observations in a percentage frequency format to calculate annual average concentrations.

2.2 The model

The Atmospheric Dispersion Modelling System (ADMS) model has been subjected to a number of validation studies (Bennet and Hunter, 1997 and Carruthers *et al,* 1996). ADMS-Urban is a development of the ADMS model (Carruthers *et al*, 1994) including a line source algorithm to enable the calculation of pollutant concentrations from road traffic.

3 Results

3.1 Comparison of modelled and monitored data

A standard set of statistics (Hanna and Paine, 1989 and Hanna *et al,* 1991) was produced to compare the modelled and monitored data sets including means, standard deviations (ó), bias (B), fractional bias (FB), normalised mean square error (NMSE), correlation (R) and the fraction of data within a factor of two (F_2). Percentile values for monitored and modelled data sets have been calculated.

For the majority of sites the NOx predictions are within +/-5 or 6% of the measured annual average values. However, for the Manchester Piccadilly site the modelled annual average value is 12% higher than the measured annual average value and for the Bury roadside site the modelled value is about 24% lower than the measured annual average value. This site is the only roadside monitoring site included in this study and the modelled values are significant underestimates when compared with the measured values.

Table 3 Modelled and observed NOx concentrations (ppb) at AURN sites in 1997.

Site	Data	Mean	R	Bias	FB	MSE	Stdev	90th %tile	98th %tile
Bolton	Modelled	40	0.37	-1.92	-0.05	1.33	59	89	228
	Measured	42					51	87	210
Bury	Modelled	154	0.33	-40.8	-0.24	1.08	202	331	867
	Measured	192					133	383	521
Mcr Picc	Modelled	59	0.47	6.41	0.12	1.00	78	131	346
	Measured	52					52	103	211
Mcr T.H.	Modelled	49	0.48	-3.21	-0.06	0.87	64	109	277
	Measured	53					58	102	238
Mcr Sth	Modelled	32	0.43	1.28	0.04	1.28	54	69	191
	Measured	31					41	63	163
Salford	Modelled	49	0.51	-2.66	-0.05	0.87	67	114	267
	Measured	52					66	110	260
Stockport	Modelled	49	0.46	-0.42	-0.01	1.06	72	107	274
	Measured	50					60	94	330

3.2 Effects of model approach and user determined parameters

The model runs and user determined parameters are shown in Table 4. Table 5 shows the percentage change in base NOx predictions caused by the targeted parameter changes as measured by annual average modelled NOx (1); and annual average total NOx including background concentration (2).

It can be seen that most of the targeted parameter changes result in lower predicted values of NOx and thus poorer predictions when compared with monitored data. Using a surface roughness value of 2 m rather than 1 m results in modelled values of NOx 22% lower than the base case. Using a minimum Monin-Obukhov length of 100m rather than 30m gives values of NOx 27% lower than the base case. Altering the grid source depth from 20m firstly to 50m gives 6.5% lower values and secondly to 150 m gives 45% lower values than the base case. Selecting a grid source depth of 150m as in the London studies thus significantly effects the model predictions and the 20 m value selected for the base case provides a better comparison with monitored values in this application. To determine the sensitivity of the model to the area of detailed source description, areas of 2 km by 2 km (the base case) and 1.5 km by 1.5 km within which roads were modelled as distinct line sources, beyond these areas road traffic emissions are aggregated to the grid source level. Predicted values between the 2 model runs were not significantly different.

The type of meteorological data used, either sequential meteorological data or percentage frequency data, has a significant impact on the model predictions. The use of percentage frequency data produces significantly higher predictions that the hourly sequential data set. This is due largely to the lack of diurnal variation in the emission rates which is included for the sequential data runs but not the percentage frequency data. This clearly should be borne in mind when calculating concentrations from emission sources with significant temporal variations such as road traffic.

Table 4 Description of model runs and parameters used.

File name	surface roughness (m)	min MO (m)	grid source depth (m)	area of detailed source description	meteorological data	temporal variations
base	1	30	20	2km x 2km	Sequential	yes
A	2	30	20	2km x 2km	Sequential	yes
B	1	100	20	2km x 2km	Sequential	yes
C	1	30	50	2km x 2km	Sequential	yes
D	1	30	150	2km x 2km	Sequential	yes
E	1	30	20	1.5km x 1.5km	Sequential	yes
F	1	30	20	2km x 2km	% frequency	no

Table 5 NOx predictions from selected model parameter uncertainty tests.

File name	Annual average NOx		%change from base	Annual average NOx + Background		%change from base
	Mcr Picc	Mcr TH		Mcr Picc	Mcr TH	
Monitored				***52***	***53***	
Base case	100.6	82.1		58.6	49.2	
A	78.4	65.3	-22.1	47.6	40.9	-18.8
B	73.1	60.1	-27.3	45.5	38.8	-22.4
C	94.1	78	-6.5	55.4	47.1	-5.5
D	55.4	40.9	-44.9	36.8	29.6	-37.2
E	99.9	83.8	-0.7	58.2	52.2	-0.7
F	109	101	8.3	65.2	61	11.3

4 Discussion

The ADMS-Urban model was used to predict concentrations of NOx and NO_2 in 1997 (the base year) and 2005 (the objective year). Model predictions for the base year show a reasonable comparison with monitored data at six of the seven sites although the predicted values tend to be lower than the measured values. The model significantly under-predicted values of NOx at the roadside side (near the M60 motorway).

The sensitivity analyses for the selected parameters showed that the model predictions were between 20 and 30% lower when values of surface roughness and minimum Monin-Obukhov lengths recommended for large conurbations were used. Values of NOx were approximately 40% lower than the base case when a grid source depth of 150m was used. Modelled values were not significantly affected by varying the area of detailed source description between 1.5 km by 1.5 km to 2 km by 2 km. Using percentage frequency meteorological data produced annual NOx averages approximately 8% higher than those produced using hourly sequential meteorological data.

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