A COMPARISON OF AIR POLLUTION MODELLING TECHNIQUES AT A MAJOR UK REGIONAL AIRPORT

H. V. Peace, B. Owen and D. Raper

Dalton Research Institute, Manchester Metropolitan University, U.K.
E-mail address: h.peace@mmu.ac.uk

ABSTRACT

Considerable progress has been made on improving the efficiency of aircraft engines in recent years, with a resulting reduction in emissions. Further improvements are forecast, however any projected emissions improvement is by far outstripped by projected air traffic growth. Therefore, emissions from aviation and related sources will result in higher air pollution concentrations close to airports.

The air pollution impact close to airports' is usually assessed by one of two methods, due to modelling constraints. Method one tends to only model the airport in spatial detail and is used when the airport is the main source of interest, such as in a planning application, and does not normally include spatially disaggregated emissions for the surrounding area. Hence, total modelled concentrations away from the airport tend to be crude. Method two tends to crudely model the airport as a limited number of volume or area sources. This method is normally used when the airport is not the main emission source of interest and therefore is not modelled in detail due to limitations in the number of sources to be modelled. This methodology whilst allowing an element of the airport's emissions to influence ground level concentrations, is not necessarily detailed enough to confidently predict the air quality impact of an airport on the surrounding area. This paper considers the differences in ground level air pollution estimates, that the application these two methodologies results in, and draws conclusions as to how a more robust methodology may be used in the future.

BACKGROUND

The European Union's (EU) 1st Daughter Directive sets limits for a variety of air pollutants including an annual limit of 40ug/m3 (21ppb) for nitrogen dioxide (NO_2) to be achieved by 2010 by EU member states [1]. The United Kingdom (UK) as part of their obligation to achieve the EU air pollution limits have set similar objectives for air pollution, including an annual average NO_2 objective of 40ug/m3 (21ppb) to be achieved by 2005. As part of the UK government's aim of achieving the UK objective local authorities have had to undertake, under *The Air Quality Strategy* [2] and part IV of *The Environment Act* [3], air quality review and assessments. About 124 out of around 450 [4] local authorities in the UK have recently completed a review and assessment of local air quality which has culminated in the declaration of Air Quality Management Areas (AQMAs) in many urban areas, where air pollution objectives are likely to be exceeded. Those local authorities who declare AQMAs are to undertake a further stage of assessment, to identify the major sources of air pollution within these AQMAs [5], such as airports.

At present many areas within the UK and similarly other countries do not have airports which are large enough to significantly affect local air quality at ground level, with the exception of major hub airports. However, as air transport is projected to grow significantly, even taking into account the after affects of September 11th, this situation may not continue indefinitely. Aviation passenger numbers are expected to grow by between 4.5% and 7% from 2001 to 2004, these revised figures were released a year after September 11th 2001 [6]. Air traffic growth figures prior to September 11th were in the region of 5% per annum between 1990 and 2015, resulting in a typical 3% growth in aviation fuel consumption per annum [7]. However, high growth scenarios predicted a growth rate in fuel consumption of up to 9.4% [7]. This fuel increase is likely to lead to similar increases in air pollution emissions. Those emissions close to ground are likely to impact on ground level air quality from aircraft. Additionally, as this increase in air traffic is largely driven by the number of people wanting to be transported by air, these people will need to travel to and from the airports of their origin and destination. This increase in ground travel demand will also affect air quality in the areas surrounding an airport. To summarise, the ground level air pollution impact from airports in the coming years is likely to grow significantly.

The air pollution impact close to airports' is usually assessed by one of two methods, due to modelling constraints. Method one tends to only model the airport in spatial detail and is used when the airport is the main source of interest, such as in a planning application, and does not normally include spatially disaggregated emissions for the surrounding area. Hence, total modelled concentrations away from the airport tend to be crude. Method two tends to crudely model the airport as a limited number of volume or area sources. This method is normally used when the airport is not the main emission source of interest and therefore is not modelled in detail due to limitations in the number of sources to be modelled. This methodology whilst allowing an element of the airport's emissions to influence ground level concentrations, is not necessarily detailed enough to confidently predict the air quality impact of an airport on the surrounding area. Depending on the layout of the airport, in relation to local sensitive receptors such as schools, hospitals and housing, the major source of ground level air pollution concentrations for these sensitive receptors needs to be defined as otherwise the major source affecting the receptor may not affect it.

The local authorities within the study area have declared AQMAs mainly based on predicted annual average nitrogen dioxide (NO_2) exceedances, this is one of the main objectives to be exceeded by many local authorities in the UK. This pollutant is also one of the main pollutants of concern associated with aviation. In most industrialised countries the major source of NOx is from road traffic, typically 40-50% [8], in the UK 44% of NOx emissions come from road transport [9] and only 1.2% from aviation sources [9]. As NO_2 is unstable in the atmosphere dispersion modelling of the effect of the different sources associated with the local regional airport were not undertaken for NO_2, but instead for NOx, to act as a precursor for NO_2. Dispersion modelling has been undertaken using ADMS-Urban; a second generation gaussian dispersion model [10] designed to model a large number of sources typical of an urban area.

METHODOLOGY

The Greater Manchester and Warrington (non-airport emissions) and the Airport (airport emissions) emissions inventories have been utilised in this study [11, 12]. Descriptions of the methodologies used to compile these inventories are described in various papers [13, 14]. Emissions were calculated for a two project years, 2005 and 2010. Emission and dispersion modelling were also carried out for a base of 2001 for verification purposes [15], which are not reported here. Spatially resolved emissions for the Airport were calculated using the ICAO [16] database of emission factors, supplemented with data from the USA FAA [17]. The inventories do not take account of how pollutants are dispersed in the atmosphere and therefore do not provide an estimate of ambient ground level air pollution concentrations resulting from the emissions. Estimates of ambient pollutant concentrations resulting from the Airport's emissions have been made by using the spatially resolved emissions data to carry out dispersion modelling. This paper is mainly concerned with the dispersion modelling of the estimated emissions.

Five main sources (emissions) of air pollution have been modelled in this study. Road traffic, which includes road traffic travelling to and from the Airport both on the local road network and on the Airport's internal road network have been modelled as line sources, none airport related road traffic was modelled separately. Additionally, aircraft exhaust emissions have been modelled as line sources (landing, takeoff, approach, climbout and taxi). Industrial sources for the surrounding area and the Airport (i.e. boilers) have been modelled as point sources. Other sources have been modelled as volume sources, such as: auxiliary power units (APUs); helicopter emissions; aircraft engine testing; and Airport service vehicles and ground support equipment (airside only). Additionally, gridded emissions from the surrounding area (over 1000km^2) have been modelled on a kilometre square volume source basis. In addition to emission input data diurnal variations in emissions were input into the model for both aircraft and road traffic, where these were modelled discretely. Additional, seasonal variation of aircraft was taken into account in the modelling when the airport was modelled discretely.

The dispersion model was run for three airport scenarios:

1. All airport sources modelled discretely as described above;
2. All airport sources modelled as part of the grid of 1 km^2 volume sources (height 10m);
3. Only aircraft exhaust emissions modelled discretely, other airport sources modelled as part of the grid of 1 km^2 volume sources.

Sequential hourly meteorological data for 1999 from the UK Meteorological Office Ringway station has been used in conjunction with the emissions and the ADMS-Urban dispersion model to determine ground level concentrations at specified receptor point locations for 1999. This meteorological data site is the most representative meteorological station which supplies the relevant input for ADMS-Urban for the study area.

None modelled sources have been accounted for by adding background concentrations. These have been derived from a local automatic background continuous monitoring site at Tranmere, Wirral. Hour by hour concentrations have been added to the hour by hour model predictions made by the model for the short term concentrations (i.e. hourly), however for long term concentrations the annual average has been added directly.

RESULTS

Table 1: 2005 NOx (μg/m3) receptor point results

Receptor	**Airport discrete Average**	**Airport discrete 99.8%ile**	**Airport as grid Average**	**Airport as grids 99.8%ile**	**Airport as grids and lines Average**	**Air port as grids and lines 99.8%ile**
R2, Stand	72.38	399.30	68.68	411.96	68.66	411.97
R3, Stand	64.66	373.95	55.46	372.15	54.76	366.44
R4, Building	79.66	421.00	66.25	399.53	65.94	398.49
R5, Stand	104.86	499.19	83.44	457.18	83.04	456.87
R6, Terminal	148.80	824.51	116.96	543.78	79.74	464.38
R7, Terminal	85.46	444.02	65.07	397.50	64.82	395.40

R8, Traffic crossing	86.78	440.63	65.72	401.39	65.41	397.45
R9, Terminal	112.32	575.17	65.73	400.59	65.46	397.33
R10, Stand	122.76	659.39	66.75	404.37	66.38	404.29
R11, Met. Station	109.38	594.96	69.38	412.75	68.74	407.37
R12, College	54.72	389.05	47.87	372.54	47.57	371.07
R13, Clinic	45.28	351.57	45.00	351.93	44.90	351.75
R14, Primary School	48.43	354.04	47.56	354.12	47.08	353.81
R15, Road	48.49	356.25	47.64	357.40	47.44	357.40
R16, Park	57.37	365.15	49.71	359.62	49.60	359.62
R17, High School	63.14	378.04	57.33	381.83	57.03	380.89
R18, Bus Park	52.86	365.64	51.22	380.69	50.64	378.97
R19, AURN	52.53	365.84	50.49	377.15	49.90	372.91
R20, Road	51.49	365.78	49.28	375.28	48.85	374.85
R21, Road	50.41	366.51	49.19	375.50	48.68	375.71
R22, Road	70.77	410.70	69.20	414.90	64.56	406.42
R23, Health Centre	47.80	362.87	46.85	371.86	46.64	369.60
R24, Station	49.92	371.31	48.66	384.77	48.09	382.46
R25, Road	43.17	348.74	42.42	348.73	42.42	348.73
R26, School	44.87	350.82	41.61	350.33	41.60	350.33
R27, Road	39.47	338.89	38.84	347.37	38.84	347.37
R28, AURN	39.49	339.50	38.52	347.12	38.51	347.12
R29, Terminal	49.13	352.15	49.24	375.27	48.82	374.84
R30, Terminal	115.94	585.51	93.50	524.74	87.97	499.70
R31, Taxi way (80m)	93.69	490.12	69.06	418.76	68.39	412.09
R32, Runway (120m)	94.45	479.97	82.55	452.15	82.49	451.48
R33, Cargo Centre	89.58	447.00	82.47	451.02	82.42	450.38
R34, Motorway junction (15m)	68.66	376.14	52.70	365.60	52.31	363.73
R35, Residential	117.84	715.12	115.54	728.93	104.63	626.45
R36, Residential	58.07	372.58	52.25	376.55	51.70	375.53
R37, Minor road	63.87	382.34	57.16	377.56	56.83	378.79
R38, Motorway junction (100m)	70.89	402.60	69.23	414.06	69.20	414.10
R39, Road	69.68	424.27	65.68	410.40	65.30	409.96
R40, AURN	49.38	372.78	46.69	390.21	46.57	389.21
R41, Motorway (100m)	51.37	365.43	49.11	374.95	48.71	374.50
R2, Stand	79.90	452.94	68.81	392.14	68.77	392.14

Table 9.3: 2010 NOx (μg/m3) receptor point results

Receptor	**Airport discrete Average**	**Airport discrete 99.8%ile**	**Airport as grid Average**	**Airport as grids 99.8%ile**	**Airport as grids and lines Average**	**Air port as grids and lines 99.8%ile**
R2, Stand	70.75	363.95	65.13	347.12	65.11	347.07
R3, Stand	56.53	309.03	45.29	302.56	44.82	298.57
R4, Building	70.05	344.53	60.14	340.89	59.92	338.54
R5, Stand	108.34	492.76	81.29	410.88	80.93	410.57
R6, Terminal	161.59	694.58	108.56	500.32	77.70	440.84
R7, Terminal	80.42	379.29	59.51	336.46	59.30	334.14
R8, Traffic crossing	81.37	380.96	60.02	340.90	59.77	336.70

R9, Terminal	152.64	634.58	59.96	338.62	59.75	336.23
R10, Stand	181.65	765.13	60.71	343.69	60.43	342.84
R11, Met. Station	152.21	708.67	62.61	354.28	62.14	350.10
R12, College	48.42	341.44	41.26	311.23	40.96	309.60
R13, Clinic	37.56	283.77	36.81	287.98	36.74	286.38
R14, Primary School	40.02	284.81	38.87	284.11	38.50	283.27
R15, Road	40.41	285.99	38.99	289.91	38.85	289.91
R16, Park	46.97	295.62	40.39	291.83	40.32	291.60
R17, High School	57.18	321.02	51.20	315.98	50.95	314.34
R18, Bus Park	43.94	298.09	41.95	303.36	41.55	302.18
R19, AURN	43.93	294.58	41.49	304.16	41.08	301.47
R20, Road	43.65	303.16	41.47	300.36	41.18	300.25
R21, Road	41.54	293.60	40.09	297.41	39.73	297.39
R22, Road	48.92	309.85	47.81	317.55	45.93	312.19
R23, Health Centre	39.48	290.40	38.34	297.43	38.22	297.77
R24, Station	40.42	290.14	39.68	300.27	39.37	300.33
R25, Road	36.85	279.67	35.63	279.90	35.62	279.90
R26, School	38.51	282.93	34.93	281.76	34.93	281.76
R27, Road	33.14	274.57	32.13	278.58	32.13	278.58
R28, AURN	33.12	275.88	31.84	278.35	31.84	278.35
R29, Terminal	43.63	303.25	41.45	300.35	41.16	300.24
R30, Terminal	118.68	529.04	89.71	503.58	85.12	475.09
R31, Taxi way (80m)	93.92	451.21	62.63	353.97	62.10	348.56
R32, Runway (120m)	97.84	468.31	80.60	406.97	80.56	406.53
R33, Cargo Centre	92.37	438.35	80.54	406.15	80.50	405.70
R34, Motorway junction (15m)	60.67	308.78	43.48	298.51	43.21	296.37
R35, Residential	94.61	545.81	91.37	561.25	83.19	480.10
R36, Residential	51.09	305.34	43.68	305.04	43.25	302.20
R37, Minor road	58.24	327.75	51.39	316.25	51.05	314.45
R38, Motorway junction (100m)	68.38	350.88	65.53	347.96	65.51	347.93
R39, Road	59.09	328.77	53.23	323.93	52.98	322.89
R40, AURN	43.40	318.71	40.09	320.75	40.04	320.71
R41, Motorway (100m)	43.61	303.43	41.39	300.31	41.11	300.21
R2, Stand	62.89	353.19	53.96	315.94	53.93	315.93

CONCLUSION

To summarise, the results in general are higher for the discretely modelled airport sources. There is little difference between the two scenarios where the airport is not discretely modelled. If the results for Scenario 1 (all airport sources modelled discretely) are taken as the benchmark (this assumes these results are more likely to be correct), then it could be argued that the results of Scenarios 2 and 3 underpredict. This possible underprediction is likely to be due to the airport sources being modelled as diffuse volume sources and therefore any receptor placed near or in these volume sources is likely to predict lower concentrations due to the already diffuse nature of the source. Consider for example a motorway; if the motorway is modelled as a volume source then the motorway's emissions are already diluted across the volume source. However, if the same motorway is modelled as a line source and a receptor placed close to this source, the motorway emissions are not diluted prior to modelling and the receptors prediction is likely to be higher. This is what appears to be happening in this study. It is therefore suggested that any modelling including airports as volume sources considers whether the airports sources contribution is likely to be significantly diluted before reaching any receptor points of interest. If it is thought that the receptor points are likely to be influenced by airport source then the airport should be modelled discretely.

ACKNOWLEDGEMENTS

The authors would like to thank Manchester Airport Plc for their co-operation in the production of this paper. Permission for the use of the various emission inventories was obtained by Manchester Airport plc for this study.

REFERENCES

1. Department for Environment, Food & Rural Affairs (DEFRA), 2002. 'Proposed regulations transposing the EC Air Quality Framework Directive and 1st Daughter Directive'. Internet: http://www.defra.gov.uk/environment/consult/aqframe/02.htm accessed May 2002.
2. Department of the Environment, Transport and the Regions (DETR), 2000. 'The Air Quality Strategy for England, Scotland, Wales and Northern Ireland' The Stationery Office (UK).
3. Department of the Environment (DoE), 1995. 'Environment Act 1995. Chapter 25. Part IV. (UK) 1995.' The Stationery Office (UK).
4.NETCEN, 2004. 'Local Air Quality Management' Internet site: http://www.airquality.co.uk/archive/laqm/list.php accessed July 2004.
5. Department for Environment, Food & Rural Affairs (DEFRA), 2001. 'Guidance to local authorities on the further ("stage 4") assessments of air quality required under section 84 of the Environment Act 1995'. Published 2001. Internet: http://www.uwe.ac.uk/aqm/review/stage4g.doc accessed March 2002.
6. ICAO, 2003. 'One Year After 11 September Events ICAO Forecasts World Air Passenger Traffic Will Exceed 2000 Levels In 2003'. Internet: http://www.icao.int/icao/en/nr/pio200210.htm accessed December 2002.
7. IPPC, 2003. 'How are Aviation Emissions Projected to Grow in the Future?' Internet: http://www.grida.no/climate/ipcc/aviation/005.htm accessed December 2002.
8. EMEP, 2002. 'Emissions of nitrogen oxides.' Internet: http://www.emep.int/emis_tables/stab2.html accessed May 2002.
9. NETCEN, 2002. 'National Atmospheric Emission Inventory'. Internet: http://www.aeat.co.uk/netcen/airqual/emissions/database/index.html accessed May 2002.
10. McHugh, C.A., Carruthers, D.J., Edmunds, H.A., 1997. 'ADMS and ADMS-Urban.' International Journal of Environment and Pollution 1997 8(3-6) 438-440.
11. ARIC & GMTU, 2003. 'The Greater Manchester and Warrington Emissions Inventory – 2001 update'. ARIC Report, Manchester Metropolitan University, UK.
12. Manchester Airport plc, 2004. 'GIS Referenced Emissions Inventory 2001'. Manchester Airport plc.
13. Lindley, S.J., Longhurst, J.W.S., Watson, A.R.F., Conlan, D.E., 1996. 'Procedures for the estimation of regional scale atmospheric emissions--an example from the north west region of England'. Atmospheric Environment, 30 (17) 3079-3091.
14. Kalivoda M.T., Kudrna M., 1997. 'Methodologies for estimating emissions from air traffic'. Available from psia-consult@eunet.at Report for COST 319, October 1997.
15. ARIC/CATE, 2004. 'The Manchester Airport dispersion modelling study'. ARIC/CATE Report, Manchester Metropolitan University, UK.
16. QinetiQ, 2001. 'ICAO Engine Exhaust Emissions Databank prepared for the International Civil Aviation Organization (ICAO)'. Internet: http://www.QinetiQ.com/aviation_emissions_databank/index.asp accessed November 2001.
17. US EPA, 1997. 'Compilation of Air Pollutant Emissions Factors'. EPA Report No. AP 42. USA.