

# **Roadside benzene and 1,3-butadiene projections based on the 1997 NAEI road transport model**

A report produced for The Department of the Environment, Transport and the Regions, The National Assembly for Wales, The Scottish Executive and The Department of the Environment for Northern Ireland

John R Stedman

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# Executive Summary

The 1997 National Air Quality Strategy (NAQS) included the following specific objectives for benzene and 1,3-butadiene, to be achieved by the end of 2005:

- benzene: 5 ppb, measured as a running annual mean
- 1,3-butadiene: 1 ppb, measured as a running annual mean

The recently completed review of the NAQS included a proposal to bring the date for achievement of these objectives forward to the end of 2003.

The Commission of the European Communities has published a proposal for a Directive in relation to limit values for benzene and carbon monoxide. This is the second Daughter Directive to be brought forward by the European Commission under the Framework Directive on Ambient Air Quality Assessment and Management. The proposed limit value for benzene is  $5 \mu\text{g m}^{-3}$  (1.542 ppb), as an annual mean, to be achieved by 1 January 2010.

The projections of roadside benzene and 1,3-butadiene that have been published in the review of the NAQS (DETR *et al*, 1999, Stedman and Dore, 1998) and for comparison with the EU Daughter Directive limit value (Stedman, 1999) were based on emissions projections derived from the 1996 National Atmospheric Emissions Inventory (NAEI) road transport model. Emissions projections based on the 1997 NAEI road transport model are now available and estimates of roadside concentrations have been re-calculated using these revised projections.

The estimates of concentrations of benzene and 1,3-butadiene calculated on the basis of the 1996 NAEI indicate that current national policies are likely to be sufficient to reduce roadside concentrations to below the objectives for the end of 2003 proposed in the review of the NAQS (DETR *et al*, 1999). No road links were predicted to have benzene concentrations higher than the objective in 2003 and only one road link was predicted to have a roadside 1,3-butadiene concentration higher than the objective in 2003. The projections calculated here, based on the 1997 NAEI road transport model, confirm this conclusion.

Projections based on the 1996 NAEI indicate that very few road links are expected to have concentrations higher than the proposed EU limit value of  $5 \mu\text{g m}^{-3}$  by the end of 2006 and very few are expected to have concentrations greater than  $5 \mu\text{g m}^{-3}$  with a 20% safety margin by the end of 2008. A total of 12 road links are projected to have an annual mean benzene concentration in excess of  $5 \mu\text{g m}^{-3}$  in 2009 for the predictions based on the 1997 NAEI, and a total of 75 road links are expected to have concentrations greater than  $5 \mu\text{g m}^{-3}$  with a 20% safety margin. The majority of the road links with the highest estimated benzene concentrations are in inner London and are also expected to be at risk of exceeding the proposed EU limit value for annual mean  $\text{NO}_2$ .



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# 1 Introduction

The 1997 National Air Quality Strategy (DoE *et al*, 1997) included the following specific objectives for benzene and 1,3-butadiene, to be achieved by the end of 2005:

- benzene: 5 ppb, measured as a running annual mean
- 1,3-butadiene: 1 ppb, measured as a running annual mean

The recently completed review of the NAQS (DETR, *et al*, 1999) included a proposal to bring the date for achievement of these objectives forward to the end of 2003.

The Commission of the European Communities has published a proposal for a Directive in relation to limit values for benzene and carbon monoxide. This is the second Daughter Directive to be brought forward by the European Commission under the Framework Directive on Ambient Air Quality Assessment and Management. The proposed limit value for benzene is  $5 \mu\text{g m}^{-3}$  (1.542 ppb), as an annual mean, to be achieved by 1 January 2010.

The projections of roadside benzene and 1,3-butadiene that have been published in the review of the NAQS (DETR *et al*, 1999, Stedman and Dore, 1998) were based on emissions projections derived from the 1996 National Atmospheric Emissions Inventory (NAEI) road transport model, details of which can be found in Salway *et al*, 1999. Projections of roadside concentrations for comparison with the proposed EU Daughter Directive limit value for benzene (Stedman, 1999) were based on the same emissions projections. Emissions projections based on the 1997 NAEI road transport model are now available and estimates of roadside concentrations have been re-calculated using these revised projections. The 1997 NAEI road transport model incorporates an improved treatment of cold start and evaporative emissions and the likely changes in emissions over time. Tables 1 and 2 show comparisons of UK urban road traffic emissions projections for both benzene and 1,3-butadiene. These tables show that emissions in 2005 as a percentage of 1996 emissions are very similar for 1,3-butadiene for the two emissions projections but a rather smaller decline in benzene emissions is predicted according to the 1997 NAEI. Both the 1996 NAEI and 1997 NAEI based emissions projections are designed to represent the impact of current national policies.

The estimates of roadside benzene and 1,3-butadiene that were published in the review of the NAQS did not include roads in Northern Ireland because the assignment of roads as built up or non-built up was not available. The same model has been used to derive the estimates presented in this report and the results are tabulated for direct comparison with earlier work. Analysis of roadside concentrations of benzene, 1,3-butadiene and other pollutants for subsequent reviews of the NAQS will include roads in Northern Ireland.

**Table 1. Projections of UK urban road traffic emissions of benzene (kTonnes per Year, based on 1996 and 1997 NAEI)**

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1996 NAEI	17.90	15.95	13.98	12.15	10.31	8.71	7.30	6.04	4.99	4.20	3.55	3.14	2.87	2.71	2.61
1996 NAEI percentage of 1996	100%	89%	78%	68%	58%	49%	41%	34%	28%	23%	20%	18%	16%	15%	15%
1997 NAEI	20.36	17.97	16.05	14.27	11.58	10.07	8.79	7.72	6.87	6.1	5.57	5.17	4.85	4.62	4.44
1997 NAEI percentage of 1996	100%	88%	79%	70%	57%	49%	43%	38%	34%	30%	27%	25%	24%	23%	22%

**Table 2. Projections of UK urban road traffic emissions of 1,3-butadiene (kTonnes per year, based on 1996 and 1997 NAEI)**

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1996 NAEI	5.08	4.56	4.02	3.52	3.03	2.58	2.18	1.82	1.52	1.29	1.11	0.99	0.92	0.86	0.83
1996 NAEI percentage of 1996	100%	90%	79%	69%	60%	51%	43%	36%	30%	25%	22%	20%	18%	17%	16%
1997 NAEI	5.86	5.07	4.46	3.88	3.35	2.85	2.43	2.08	1.8	1.58	1.42	1.31	1.22	1.16	1.12
1997 NAEI percentage of 1996	100%	87%	76%	66%	57%	49%	41%	35%	31%	27%	24%	22%	21%	20%	19%

## 2 Benzene projections for comparison with the NAQS objective

Table 3 shows a comparison of the number of urban major road links projected to exceed the NAQS objective for benzene of 5 ppb as a maximum running annual mean. We have taken a threshold for annual mean concentration of 3.5 ppb to represent a risk of exceeding a maximum running annual mean concentration of 5 ppb. This takes into account the difference between annual and maximum running annual means and also provides an approximate safety factor of 20 % for uncertainties in the mapping methods (Stedman and Dore, 1998).

**Table 3. The number of urban major road links projected to exceed the NAQS objective for benzene (7508 road links examined).**

Year	1996 NAEI		1997 NAEI	
	number of road links	max. conc. (ppb)	number of road links	max. conc. (ppb)
1996	571	7.7	571	7.7
1997	292	6.9	282	6.8
1998	129	6.1	140	6.1
1999	38	5.3	53	5.5
2000	15	4.6	15	4.5
2001	2	3.9	2	3.9
2002	0	3.3	0	3.5
2003	0	2.7	0	3.1
2004	0	2.3	0	2.7
2005	0	1.9	0	2.5

Projected concentrations in 2000 and 2001 are very similar for the 1996 NAEI and 1997 NAEI based emissions estimates. Projected concentrations in 2003 and 2005 are higher for the 1997 NAEI based estimates but are still well within the objective.

### 3 1,3-butadiene projections for comparison with the NAQS objective

Table 4 shows a comparison of the number of urban major road links projected to exceed the NAQS objective for 1,3-butadiene of 1 ppb as a maximum running annual mean. We have taken a threshold for annual mean concentration of 0.7 ppb to represent a risk of exceeding a maximum running annual mean concentration of 1 ppb. This takes into account the different between annual and maximum running annual means and also provides an approximate safety factor of 20 % for uncertainties in the mapping methods (Stedman and Dore, 1998).

**Table 4. The number of urban major road links projected to exceed the NAQS objective for 1,3-butadiene (7508 road links examined).**

Year	1996 NAEI		1997 NAEI	
	number of road links	max. conc. (ppb)	number of road links	max. conc. (ppb)
1996	1228	2.1	1228	2.1
1997	876	1.9	751	1.8
1998	493	1.6	403	1.6
1999	249	1.4	191	1.4
2000	104	1.2	75	1.2
2001	30	1.1	25	1
2002	12	0.9	10	0.9
2003	1	0.8	1	0.8
2004	0	0.6	0	0.7
2005	0	0.5	0	0.6

Projected concentrations in 2000, 2001 and 2002 are slightly lower for the 1997 NAEI based emissions estimates. Projected concentrations in 2003 and 2005 are similar for the two different emissions projections and are within the objective for all except one road in 2003.

## 4 Benzene projections for comparison with the proposed EU limit value

Tables 5 and 6 show a comparison of projected roadside benzene concentrations based on the 1996 NAEI and the 1997 NAEI with the proposed EU limit value of  $5 \mu\text{gm}^{-3}$  as an annual mean. Only 2 road links are projected to have an annual mean benzene concentration in excess of 1.234 ppb ( $5 \mu\text{gm}^{-3}$  with a 20% safety margin) in 2009 for the predictions based on the 1996 NAEI. A total of 75 road links are projected an annual mean benzene concentration in excess of 1.234 ppb in 2009 for the predictions based on the 1997 NAEI, including 12 with concentrations higher than 1.542 ( $5 \mu\text{gm}^{-3}$  with no safety margin). The 75 road links with the highest predicted concentrations are listed in Table 7 along with estimates of roadside benzene concentrations in 2009 based on the 1996 NAEI and the 1997 NAEI. Estimates of roadside annual mean  $\text{NO}_2$  concentrations in 2009 are also listed for these road links and are all higher than 21 ppb (the proposed limit value for annual mean  $\text{NO}_2$  in 2009), although the exact ranking of concentrations is different. These estimates of roadside  $\text{NO}_2$  concentrations have been taken from the work carried out for the review of the NAQS (Stedman, *et al*, 1998) and were based on the 1996 NAEI and the mapping methods adopted in the review of the NAQS. 1996 NAEI emissions projections for  $\text{NO}_x$  have been used in preference to 1997 NAEI emissions projections for consistency with published estimates.

**Table 5. Estimated annual mean roadside benzene concentrations (ppb) for urban built up roads, 1996 NAEI (7508 road links examined)**

year	number of links < 1.234 ppb*	number of links 1.234 - 1.542 ppb**	number of links >= 1.542 ppb**	highest conc. (ppb)	2nd highest conc. (ppb)	3rd highest conc. (ppb)
1996	1798	930	4780	7.7	7.0	6.8
1997	2250	1073	4185	6.9	6.2	6.1
1998	2805	1258	3445	6.1	5.5	5.3
1999	3502	1299	2707	5.3	4.8	4.7
2000	4378	1250	1880	4.6	4.1	4.0
2001	5227	1135	1146	3.9	3.5	3.4
2002	6070	876	562	3.3	3.0	2.9
2003	6772	541	195	2.7	2.5	2.4
2004	7220	246	42	2.3	2.1	2.1
2005	7424	69	15	1.9	1.8	1.7
2006	7482	24	2	1.7	1.6	1.5
2007	7493	14	1	1.6	1.4	1.4
2008	7504	4	0	1.4	1.4	1.3
2009	7506	2	0	1.3	1.2	1.2
2010	7507	1	0	1.3	1.2	1.2

**Table 6. Estimated annual mean roadside benzene concentrations (ppb) for urban built up roads, 1997 NAEI (7508 road links examined)**

year	number of links < 1.234 ppb*	number of links 1.234 - 1.542 ppb**	number of links >= 1.542 ppb**	highest conc. (ppb)	2nd highest conc. (ppb)	3rd highest conc. (ppb)
1996	1798	930	4780	7.7	7.0	6.8
1997	2281	1078	4149	6.8	6.2	6.0
1998	2745	1267	3496	6.1	5.5	5.4
1999	3263	1381	2864	5.5	4.9	4.8
2000	4464	1242	1802	4.5	4.1	4.0
2001	5183	1135	1190	3.9	3.6	3.5
2002	5852	936	721	3.5	3.1	2.1
2003	6378	757	373	3.1	2.8	2.7
2004	6764	548	196	2.7	2.5	2.4
2005	7084	340	84	2.5	2.2	2.2
2006	7251	222	35	2.3	2.1	2.0
2007	7345	139	24	2.1	1.9	1.9
2008	7404	87	17	2.0	1.8	1.8
2009	7433	63	12	1.9	1.8	1.7
2010	7458	39	11	1.9	1.7	1.7

\* equivalent to limit value of  $5 \mu\text{gm}^{-3}$  with a 20% safety margin

\*\* equivalent to limit value of  $5 \mu\text{gm}^{-3}$  with a no safety margin

**Table 7. Major road links with the highest estimated annual mean benzene concentrations in 2009 (ppb)**

rank	id	road number	1996 NAEI benz. *	1997 NAEI benz. **	1996 NAEI NO <sub>2</sub> ***	region	location	road name
1	17639	A4202	1.3	1.9	28.9	Inner London	Mayfair	Park Lane
2	36119	A4	1.2	1.8	25.1	Inner London	Hammersmith	Talgarth Road
3	28505	A4	1.2	1.7	25.3	Inner London	West Kensington	West Cromwell Road
4	36109	A3	1.2	1.7	24.9	Inner London	Kennington	Kennington Park Road
5	48251	A501	1.2	1.7	25.3	Inner London	Paddington	Marylebone Road
6	57537	A501	1.2	1.6	25.3	Inner London	Knightsbridge	Knightsbridge
7	6121	A4	1.2	1.6	24.8	Inner London	Hammersmith	Hammersmith Flyover
8	48489	A46	1.2	1.6	24.3	England	Leicester	Burleys Way
9	38466	A4	1.2	1.6	24.6	Inner London	South Kensington	Cromwell Road
10	18496	A4	1.1	1.6	25.4	Inner London	Hammersmith	Great West Road
11	18468	A3211	1.1	1.6	24.9	Inner London	Blackfriars	Embankment
12	27087	A406	1.1	1.6	26.6	Outer London	Hendon	North Circular Road
13	46120	A4	1.1	1.5	25.4	Inner London	Hammersmith	Great West Road
14	58173	A404	1.1	1.5	23.7	Inner London	Paddington	Harrow Road
15	47245	A501	1.1	1.5	24.5	Inner London	Marylebone	Marylebone Road
16	46121	A4	1.1	1.5	25.0	Outer London	Hammersmith	Great West Road
17	38465	A4	1.1	1.5	25.6	Inner London	Hyde Park Corner	Duke of Wellington Pl.
18	26429	A501	1.1	1.5	24.6	Inner London	Warren Street	Euston Road
19	16110	A4	1.1	1.5	25.3	Inner London	Hammersmith	Hammersmith Flyover

rank	id	road number	1996 NAEI benz. *	1997 NAEI benz. **	1996 NAEI NO <sub>2</sub> ***	region	location	road name
20	8484	A4	1.0	1.5	25.1	Inner London	Hyde Park Corner	Knightsbridge
21	56464	A46	1.0	1.5	22.8	England	Leicester	Burleys Way
22	48552	A3211	1.0	1.5	23.9	Inner London	Embankment	Embankment
23	17019	A406	1.0	1.4	27.5	Outer London	West Hendon	North Circular Road
24	38443	A40	1.0	1.4	23.8	Inner London	Marble Arch	Cumberland Gate
25	26116	A4	1.0	1.4	24.7	Outer London	Chiswick	Ellesmere Road
26	8509	A40	1.0	1.4	25.5	Inner London	East Acton	Westway
27	46434	A40	1.0	1.4	24.1	Inner London	Marble Arch	Marble Arch
28	56592	A202	1.0	1.4	23.6	Inner London	Vauxhall	Vauxhall Bridge
29	56102	A4	1.0	1.4	24.1	Inner London	Hyde Park Corner	Knightsbridge
30	26185	A3	1.0	1.3	23.0	Inner London	Newington	Newington Butts
31	16403	A40	1.0	1.3	23.0	Inner London	Notting Hill	Notting Hill Gate
32	17689	A5201	1.0	1.3	22.9	Inner London	Old Street	Old Street
33	48428	A4209	1.0	1.3	21.7	Inner London	Lancaster Gate	Westbourne Street
34	47658	A3205	1.0	1.3	22.9	Inner London	Vauxhall	Nine Elms Lane
35	8618	A3211	1.0	1.3	23.7	Inner London	Monument	Upper/Lower Thames St
36	36436	A40	1.0	1.3	22.5	Inner London	Lancaster Gate	Bayswater Road
37	48146	A306	1.0	1.3	21.5	Inner London	Hammersmith	Hammersmith Bridge Rd
38	17569	A3205	0.9	1.3	21.5	Inner London	Euston Station	Euston Road
39	26432	A40	0.9	1.3	22.3	Inner London	Lancaster Gate	Bayswater Road
40	7604	A3220	0.9	1.3	23.2	Inner London	Chelsea	Cheyne Walk
41	8485	A4209	0.9	1.3	22.0	Inner London	Hyde Park Corner	Knightsbridge
42	28003	A58	0.9	1.4	26.1	England	Leeds	Wellington Road
43	37663	A3036	0.9	1.3	22.4	Inner London	Vauxhall	Albert Embankment
44	47244	A501	0.9	1.3	22.5	Inner London	Old Street	City Road
45	48683	A3211	0.9	1.3	23.0	Inner London	Blackfriars	Blackfriars Underpass
46	47247	A503	0.9	1.3	21.2	Inner London	Manor House	Seven Sisters Road
47	7570	A3036	0.9	1.3	22.4	Inner London	Vauxhall	Albert Embankment
48	56614	A201	0.9	1.3	22.3	Inner London	Blackfriars	Blackfriars Bridge
49	7928	A4400	0.9	1.3	24.3	England	Birmingham	St Chads Queensway
50	26115	A4	0.9	1.3	22.9	Inner London	Knightsbridge	Brompton Road
51	16142	A302	0.9	1.3	25.6	Inner London	Green Park	Grovesnor Place
52	16434	A41	0.9	1.3	20.6	Outer London	West Hampstead	Finchley Road
53	48577	A301	0.9	1.3	23.6	Inner London	Waterloo Bridge	Waterloo Bridge North
54	28123	A301	0.9	1.3	23.6	Inner London	Waterloo Bridge	Waterloo Bridge South
55	58282	A118	0.9	1.3	21.6	Outer London	Ilford	Chapel Road
56	19007	A4	0.9	1.3	23.9	Inner London	Hyde Park Corner	Underpass
57	57664	A3212	0.9	1.3	22.5	Inner London	Chelsea	Chelsea Embankment
58	6632	A105	0.9	1.2	20.4	Inner London	Manor House	Green Lanes
59	56093	A2	0.9	1.3	22.3	Inner London	New Cross	New Cross Road
60	27239	A503	0.9	1.2	21.3	Inner London	Manor House	Seven Sisters Road
61	36269	A23	0.9	1.2	22.0	Inner London	Brixton	Brixton Road
62	47667	A3220	0.9	1.2	22.6	Inner London	Kensington	Holland Road
63	36277	A24	0.9	1.2	20.9	Inner London	Clapham C'mon	Clapham Common South
64	28502	A10	0.9	1.2	22.7	Inner London	Tottenham	High Road
65	18077	A501	0.9	1.3	23.2	Inner London	Kings Cross	Euston Road
66	6751	A201	0.9	1.3	22.2	Inner London	Blackfriars	New Bridge Street
67	47999	A4400	0.9	1.3	23.7	England	Birmingham	Bristol Road
68	36502	A46	0.9	1.3	20.9	England	Leicester	Burleys Way
69	37113	A406	0.9	1.2	24.0	Outer London	Neasden	North Circular Road
70	36437	A40	0.9	1.2	23.2	Outer London	Acton	Western Avenue
71	57291	A4032	0.9	1.3	21.9	England	Bristol	Newfoundland Street
72	56394	A38	0.9	1.2	23.8	England	Birmingham	St Chads Queensway

rank	id	road number	1996 NAEI benz. *	1997 NAEI benz. **	1996 NAEI NO <sub>2</sub> ***	region	location	road name
73	56375	A4044	0.9	1.3	22.2	England	Bristol	Temple Way
74	7055	A406	0.9	1.2	25.2	Outer London	Church End	North Circular Road
75	46111	A3	0.9	1.3	20.9	Outer London	Roehampton	Kingston Road

\* Estimated roadside benzene concentration in 2009 (ppb) 1996 NAEI

\*\* Estimated roadside benzene concentration in 2009 (ppb) 1997 NAEI

\*\*\* Estimated roadside NO<sub>2</sub> concentration in 2009 (ppb) 1996 NAEI

## 5 Conclusions

The estimates of concentrations of benzene and 1,3-butadiene calculated on the basis of the 1996 NAEI indicate that current national policies are likely to be sufficient to reduce roadside concentrations to below the objectives for the end of 2003 proposed in the review of the NAQS (DETR *et al*, 1999). The projections calculated here, based on the 1997 NAEI road transport model, confirm this conclusion.

Projections based on the 1996 NAEI indicate that very few road links are expected to have concentrations higher than the proposed EU limit value of 5 µgm<sup>-3</sup> by the end of 2006 and very few are expected to have concentrations greater than the limit value with a 20% safety margin by the end of 2008. A total of 12 road links are projected an annual mean benzene concentration in excess of 5 µgm<sup>-3</sup> with a 20% safety margin in 2009 for the predictions based on the 1997 NAEI, and a total of 75 road links are expected to have concentrations greater than the limit value with a 20% safety margin. The majority of the road links with the highest estimated benzene concentrations are in inner London. These links are also expected to be at risk of exceeding the proposed EU limit value for annual mean NO<sub>2</sub>.

## 6 Acknowledgements

This work was funded by the UK Department of the Environment, Transport and the Regions, The National Assembly for Wales, The Scottish Executive and The Department of the Environment for Northern Ireland as part of their Air Quality Research Programme.

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**This is an example of how a section page for reports that are split into sections using dividers should look**