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Estimated benzene concentrations in the UK and proposed EU limit value

A report produced for The Department of the Environment, Transport and the Regions, The Welsh Office, The Scottish Office and The Department of the Environment for Northern Ireland

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Executive Summary

The Commission of the European Communities has recently 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 development of empirical models of both background and roadside concentrations of benzene and a comparison of resulting estimated concentration with the proposed amended NAQS objectives has recently been completed (Stedman and Dore, 1998). A comparison of estimated the benzene concentrations with the proposed EU limit value is presented here.

The proposed limit value for benzene is 5 μgm^{-3}, as an annual mean, to be achieved by 1 January 2010. Annual mean benzene concentrations in all background locations at the end of 2009 are predicted to be well within the proposed limit value.

Estimated annual mean roadside benzene concentrations in 2009 are expected to be considerably higher. Very few road links are expected to have concentrations higher than 5 μgm^{-3} 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. The majority of the road links with the highest estimated benzene concentrations are in central London.

Contents

1 Introduction

The Commission of the European Communities has recently 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. A common position was reached on the first Daughter Directive, which will set limit values for sulphur dioxide, nitrogen dioxide, lead and particles.

The proposed limit value for benzene is 5 μgm^{-3}, as an annual mean, to be achieved by 1 January 2010. This is equivalent to 1.542 ppb at the standardisation of 293 K and 101.3 kPa specified in the proposal. This can be compared with both the UK National Air Quality Strategy (NAQS) objective of 5 ppb as a running annual mean to be achieved by 2005 (DoE, 1997) and the proposed amended objectives of 5 ppb as a running annual mean to be achieved by 2003 and an indicative level of 1 ppb running annual mean to be achieved by 2005 (DETR *et al*, 1999).

The development of empirical models of both background and roadside concentrations of benzene and a comparison of resulting estimated concentration with the proposed amended NAQS objectives has recently been completed (Stedman and Dore, 1998). A comparison of the estimated benzene concentrations with the proposed EU limit value is presented here. A report on 'A method for predicting roadside CO concentrations in the UK' (Stedman and Linehan, 1999) is also being prepared and will include a comparison of estimated concentrations with the proposed EU limit value for CO.

2 Mapping methods

2.1 BACKGROUND LOCATIONS

Maps of estimated annual mean background benzene concentration have been calculated for 1996 and 2009. Full details of the methods used to calculate the 1996 map are given in Stedman (1998). A brief description of these methods is provided in Stedman and Dore (1998) along with a description of the methods used and assumption that have been made in order to project this map forward to provide estimates for 2009.

A map for 1996 was calculated from a combination of a map of rural NO_2 concentration and estimates of low level VOC emissions on a 1 km square basis from the National Atmospheric Emissions Inventory (NAEI, Salway *et al*, 1997, Goodwin *et al*, 1997). The relationship between ambient annual mean benzene concentration and emission rates was calibrated using data from the national monitoring networks (Broughton *et al*, 1998). The relationship between rural benzene and NO_2 concentrations was derived from measurements at the Harwell site.

A map for 2009 has been calculated by scaling the 1996 map by the changes in emissions that current policies are likely to deliver. Projected emissions were taken from the NAEI road transport model (Murrells, *pers. comm.*, 1998). Road traffic emissions have been assumed to contribute 90% of the benzene concentrations measured during 1996. The remaining 10% of non-traffic benzene emissions have been assumed to remain constant in future years.

2.2 ROADSIDE LOCATIONS

The development of an empirical model of roadside benzene concentrations has been described by Stedman and Dore (1998). Current benzene measurement data from both automatic and diffusion tube monitoring programmes were examined to find the relationship between the 'roadside enhancement' of concentrations and the road link vehicle emissions estimated from the NAEI. Annual mean roadside benzene concentrations for 1996 throughout the UK were then estimated from the sum of background concentrations and this enhancement. The definition of roadside locations in this context is provided by the locations of the monitoring sites used to calibrate the model (typically 1 to 5 m from the edge of the road). Future annual average roadside concentrations have been predicted by applying the NAEI emission reduction factors for these years to the modelled roadside concentrations.

2.3 UNCERTAINTIES

The estimates of benzene concentrations in background locations have been compared with measurements at automatic sites and the difference between estimated and measured concentrations in 1996 were generally considerably less than 0.5 ppb (Stedman, 1998). The estimated background benzene concentrations have therefore been compared directly with the proposed EU limit value of 1.542 ppb (5 μgm^{-3}) in the maps presented in this report.

The estimates of benzene concentrations at the roadside are subject to additional uncertainties in the relationship between the roadside enhancement of concentrations and the emissions from each road link. The uncertainty in estimates of annual mean benzene concentrations at the roadside in 1996 was found to be about 1 ppb (20%) at concentrations of about 5 ppb (Stedman and Dore, 1998). Estimated roadside benzene concentrations have therefore been compared with both 1.542 ppb (5 μgm^{-3}) and 1.234 (5 μgm^{-3}, with a 20% safety margin) in the analysis presented here.

It should also be noted that the model of roadside benzene concentrations has been calibrated with monitoring data from sites in built up areas. Sites with a more open aspect, such as those adjacent to motorways or major roads in rural areas will not conform to this relationship. Emissions from vehicles travelling on these roads are generally more effectively dispersed than emissions on built up urban roads. Roadside mapping has therefore been restricted to urban major roads (a total of 7508 road links), where the relationship is reliable. A distinction between built up and non-built up major road links is not currently available for roads in Northern Ireland. All roads in Northern Ireland have therefore been excluded from the current analysis.

It is likely that the considerations for the siting of fixed measurement stations within the Daughter Directive for benzene will be similar to those given in the first Daughter Directive.

Monitoring for the protection of human health is therefore expected to be restricted to areas in which the population is likely to be directly or indirectly exposed for a period which is significant to the averaging time of the limit value. Individual road links which have no housing, hospitals, schools or similar buildings within about 10 m of the roadside are therefore unlikely to be of concern.

3 Comparison of mapped estimated with the proposed limit value

3.1 EMISSIONS PROJECTIONS

The emissions projections used in the mapping work are given in Table 1. Road traffic emissions of benzene are expected to fall to a small fraction of their 1996 value by 2009 as a result of current policies.

Table 1. Benzene emission projections used in the mapping work (relative to 1996)

year	1996	1997	1998	1999	2000	2001	2002	2003
background	1.00	0.90	0.80	0.71	0.62	0.54	0.47	0.40
roadside	1.00	0.89	0.78	0.68	0.58	0.49	0.41	0.34
year	2004	2005	2006	2007	2008	2009	2010	
background	0.35	0.31	0.28	0.26	0.24	0.24	0.23	
roadside	0.28	0.23	0.20	0.18	0.16	0.15	0.15	

3.2 BACKGROUND LOCATIONS

Maps of estimated annual mean background benzene concentrations for 1996 and 2009 are given in Figures 1 and 2. Concentrations in 1996 were greater than 1.542 ppb in the centres of several cities, such as London, Birmingham, Leicester, Manchester and Liverpool. Concentrations in all areas in 2009 are predicted to be well within the proposed limit value. The maximum estimated concentration is in central London and is 2.6 ppb in 1996 and 0.6 ppb in 2009.

3.3 ROADSIDE LOCATIONS

Figures 3 and 4 shows that the estimated roadside benzene concentrations in 1996 and 2009 are expected to be considerably higher than in background locations. Table 2 gives a detailed analysis of the estimated roadside benzene concentrations in all the years from 1996 to 2010. Very few road links are expected to have concentrations higher than 1.542 ppb by 2006 and very few are expected to have concentrations greater than the limit value with a 20% safety margin (1.234 ppb) by 2008. Table 3 shows that the majority of the 15 links with the highest

estimated benzene concentrations are in central London. Figure 5 shows the road links in this area in more detail.

Table 2. Estimated annual mean roadside benzene concentrations (ppb) for urban built up roads (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

* equivalent to limit value of 5 μgm^{-3} with a 20% safety margin (or a limit value of 4 μgm^{-3} with a no safety margin)
** equivalent to limit value of 5 μgm^{-3} with a no safety margin

Table 3. Fifteen major road links with the highest estimated annual mean benzene concentrations (ppb)

rank	id	conc. in 2007 (ppb)	road number	location	road name
1	17639	1.6	A4202	Mayfair	Park Lane
2	36119	1.4	A4	Hammersmith	Talgarth Road
3	28505	1.4	A4	West Kensington	West Cromwell Road
4	48251	1.4	A501	Paddington	Marylebone Road
5	36109	1.4	A3	Kennington	Kennington Park Road
6	57537	1.4	A4	Knightsbridge	Knightsbridge
7	48489	1.3	A46	Leicester	Burleys Way
8	6121	1.3	A4	Hammersmith	Hammersmith Flyover
9	38466	1.3	A4	South Kensington	Cromwell Road
10	18496	1.3	A4	Hammersmith	Great West Road
11	27087	1.3	A406	Hendon	North Circular Road
12	18468	1.3	A3211	Blackfriars	Embankment
13	46120	1.3	A501	Baker Street	Marylebone Road
14	46121	1.3	A4	Hammersmith	Great West Road

15	47245	1.2	A501	Marylebone	Marylebone Road

4 Conclusions

Annual mean benzene concentrations in all background locations in 2009 are predicted to be well within the proposed limit value of 5 μgm^{-3}.

Estimated annual mean roadside benzene concentrations in 2009 are expected to be considerably higher. Very few road links are expected to have concentrations higher than 1.542 ppb by 2006 and very few are expected to have concentrations greater than the limit value with a 20% safety margin (1.234 ppb) by 2008. The majority of the road links with the highest estimated benzene concentrations are in central London.

5 Acknowledgement

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Appendices

CONTENTS

Appendix 1
Title

CONTENTS

Appendix 2
Title

CONTENTS

Appendix 3
Title

CONTENTS

Section 1
Title of section

CONTENTS

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