ArupTransport

Tyne and Wear Passenger Transport Authority

New Tyne Crossing

Proof of Evidence on Air Quality

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APPENDICES

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APPENDICES

APPENDIX A

Air Quality

A1. EXISTING AIR QUALITY

A1.1 DEFRA Air Quality Monitoring Data

The recorded concentrations of carbon monoxide, nitrogen dioxide and PM_{10} at the DEFRA Urban Centre monitoring station in Newcastle are presented in Table A1.

TABLE A1 : MONITORING RESULTS FROM DEFRA AUTOMATIC MONITORING STATION AT NEWCASTLE CENTRE (URBAN CENTRE)

Pollutant	Statistic	Reading				Air Quality Strategy Objectives
		1997	1998	1999	2000	
Carbon monoxide	Maximum 8 hour mean (mg/m^3)	3.5	2.6	2.2	1.9	11.6 mg/m^3
Nitrogen dioxide	Annual Mean ($\mu g/m^3$)	40	36	31	29	40 $\mu g/m^3$
	Hourly mean - no of exceedences of 200 $\mu g/m^3$	0	0	0	0	18 exceedences
PM_{10} #	Annual Mean ($\mu g/m^3$)	27	24	21	17	40 $\mu g/m^3$
	24 hour mean – number of exceedences of 50 $\mu g/m^3$	20	6	6	0	35 exceedences of 50 $\mu g/m^3$

Data have been converted from TEOM units to gravimetric units by multiplying monitoring data by a factor of 1.3

The concentrations of nitrogen dioxide recorded at the DEFRA diffusion tube monitoring sites in the area of the New Tyne Crossing are presented in TableA2.

TABLEA2: DEFRA NITROGEN DIOXIDE DIFFUSION TUBE SURVEY RESULTS FOR SITES IN THE AREA OF THE NEW TYNE CROSSING

Site Identifier	Grid Ref (NZ)	Site Type	Annual Average NO_2 ($\mu g/m^3$)						
			1995	1996	1997	1998	1999	2000	Mean
Newcastle Upon Tyne 8N	4285,5650	Background	-	17	19	21	13	13	**17**
Wallsend 2N	4298,5664	Intermediate	-	29	27	31	36	33	**31**
Hebburn 4N	4315,5648	Background	23	21	21	27	21	21	**22**
North Shields 1N	4351,5686	Background	9	25	21	23	27	25	**22**
South Shields 2N	4368,5667	Intermediate	28	21	23	-	-	-	**24**
South Shields 7N	4371,5671	Background	24	17	21	33	21	25	**23**
South Shields 9N	4366,5669	Intermediate	-	-	-	38	23	23	**28**

Kerbside - between 1 and 5m from busy roadside (Results from any kerbside sites are not included as none are located close to the development site and therefore not representative of local conditions)
Intermediate - 20 to 30m from busy road
Background - at least 50m from busy road

A1.2 Newcastle City Council Monitoring

The recorded concentrations of benzene and nitrogen dioxide from Newcastle City Council's diffusion tube monitoring programme (November 1999 to April 2001) are presented in Tables A3 to .

TABLE A3: NEWCASTLE CITY COUNCIL BTX DIFFUSION TUBE SURVEY RESULTS – BENZENE CONCENTRATIONS (μg/m^3). NORTH TYNESIDE

Site Number	Location	Average 6 April 2000 to 6 April 2001
4	Lesbury Street	0.6
6	Flatworth Council Depot	0.6
12	54 Firtrees Avenue	0.5
14	Howdon Lane Council Nursery	0.5
16	Tyne View Terrace	0.7

TABLEA4: NEWCASTLE CITY COUNCIL BTX DIFFUSION TUBE SURVEY RESULTS – BENZENE CONCENTRATIONS (μg/m^3). SOUTH TYNESIDE

Site Number	Location	Average 14 April 2000 to 3 April 2001
1	19 Bilton Hall Road	0.7
2	27 Prince Consort Road	0.7
3	Grange Nursing Home	0.7
4	105 High Street	0.7
5	1 Salem Street	0.7

TABLE A5: NEWCASTLE CITY COUNCIL AVERAGE ANNUAL NITROGEN DIOXIDE DIFFUSION TUBE SURVEY RESULTS – NORTH TYNESIDE (μg/m³)

Site Number	Location	1999 4 November 1999 to 6 January 2000	2000 6 January 2000 to 10 January 2001	2001 10 January 2001 to 6 April 2001
01	Howdon Road – opposite. Frater Terrace	19	20	28
02	3 Brinkton Street	18	18	26
03	Meldon Street	27	22	23
04	Lesbury Way	21	18	25
05	95 St. Stephens Way	20	18	25
06	Flatworth Council Depot	19	18	20
07	Malmo Close	16	18	26
08	Narvik Way	18	19	23
09	14 Henley Gardens	21	19	31
10	105 Melrose Gardens	20	22	30
11	98 Rutherford Street	13	17	25
12	54 Firtrees Avenue	22	17	-
13	36 Brunton Avenue	18	12	-
14	Howdon Lane Council Nursery	18	15	30
15	56 Bewicke Road	25	20	28
16	Tyne View Terrace	20	21	23

TABLEA6: NEWCASTLE CITY COUNCIL AVERAGE ANNUAL NITROGEN DIOXIDE DIFFUSION TUBE SURVEY RESULTS – SOUTH TYNESIDE (μg/m^3)

Site Number	Location	**1999** 4 November 1999 to 6 January 2000	**2000** 6 January 2000 to 10 January 2001	**2001** 10 January 2001 to 6 April 2001
01	20 Brixham Crescent	20	18	20
02	35 Salcombe Avenue	19	18	18
03	77 Salcombe Avenue	20	20	15
04	35 Newlyn Drive	21	18	21
05	38 Newlyn Drive	22	17	19
06	Bilton lodge, Newlyn Drive	20	17	22
07	46 Epinay Walk	22	21	25
08	23 Regent Road	18	16	22
09	105 High Street	20	19	26
10	27 Prince Consort Road	19	16	28
11	2 Abbey Drive	18	15	21
12	14 Canon Grove	19	17	25
13	3 Chaytor Street	16	18	25
14	15 Pearson Place	19	18	23
15	21 Ferry Street	25	18	32
16	45 Shakespeare Street	19	17	36
17	57 Priory Road	22	16	-
18	53 Minister Parade	19	13	18
19	8 Hope Street	21	16	22
21	41 Wilberforce Street	21	15	-
22	1 Percy Street	24	18	-
23	1A Wilberforce Street	24	16	-
24	13 Salem Street	24	20	22
25	1 Salem Street	23	21	24
26	5 Stothard Street	17	15	-
27	67 Stothard Street	22	14	-
28	1 Prince Consort Road	20	18	27
29	101 St Paul's Road	10	16	20

A2. SENSITIVITY OF DUST TO DIFFERENT LAND USES

The sensitivity of different land uses to impacts from dust generated during construction activities is presented in Table A7.

TABLE A7 SENSITIVITY TO DUST OF DIFFERENT LAND USES

Insensitive	Low	Medium	High
Undeveloped land Parkland	Isolated residential properties Commercial and industrial sites – including heavy industry, warehousing, factories, scrapyards and farms	Multiple residential properties Commercial and industrial premises – premises including: nurseries and garden centres, car/other showrooms, food retail premises and agriculture Community facilities – doctors' surgeries	High density residential properties Commercial and industrial properties – specialist technical or industrial facilities, such as: double glazing manufacture, electronics factories, paint and finishing workshops. Sensitive Community facilities – Schools, colleges, playgrounds, hospitals and nursing homes

TABLE A8: DUST SENSITIVE RECEPTORS WITHIN 100M OR 250M OF PROPOSED CONSTRUCTION SITE

Receptor	Distance from Construction Activities	Description and Dust Sensitivity
North		
Green space East/West of A19, South of Wallsend Road	<100m	Low/None
Residential areas in Howdon (south of Tynemouth Rd)	100m-250m	Medium
Residential area in East Howdon	<100m	Medium
Playground in East Howdon	100-250m	High
East Howdon Community Centre	100-250m	Medium/High

TABLE A8: DUST SENSITIVE RECEPTORS WITHIN 100M OR 250M OF PROPOSED CONSTRUCTION SITE		
Howdon Yard (Industrial/Commercial)	<100m	Low/Medium
South		
Rohm & Haas	<100m	Low
Bailey's Industrial Estate	<100m	Low
Second Hand Car Lot	<100m	Low
Dunn Street Schools	<100m	High
Residential areas in Jarrow adjacent (east and west) of the tunnel alignment	<100m	Medium
Residential area in Jarrow adjacent to Mercantile Dock, at corner of Priory Road and Chaytor Street	<100m	Medium
Jarrow Community Centre	<100m	Medium/High
Retail/Commercial area in Jarrow Centre	100-250m	Medium
St Mark's Church	<100m	Low/Medium
St Bede's School	<100m	High
Residential area: • Between Howard Street and Metro line (including Epinay Walk and Debussey Court) • Regent Rd south of Metro line	<100m	Medium

TABLE A9: MITIGATION MEASURES FOR INCLUSION IN CODE OF CONSTRUCTION PRACTICE AND EFFECTIVENESS	
Mitigation Measure for inclusion in Code of Construction Practice	**Effectiveness**
• The enclosure of stockpiles of dusty materials and damping down (where possible) during use.	Moderate/High
• The use of hard surfaced areas for easy cleaning and reduction in generation of surface dust.	High
Regular cleaning of hard surfaced areas by brushing and water sprays.	Moderate/High
Hoardings and gates to prevent dust breakout.	Low
Sheeting of vehicles carrying dusty materials.	High
Use of water sprays, and covers, reduction in drop heights and screening during handling and transfer of dusty materials.	High
Location of dust producing activities away from sensitive areas as far as possible.	Moderate/high
Watering of unsurfaced haul roads and consideration of hard surfacing close to sensitive areas.	High
Speed limits on site haul roads.	Moderate
Use of vertically directed exhausts.	Moderate/high

TABLE A9: MITIGATION MEASURES FOR INCLUSION IN CODE OF CONSTRUCTION PRACTICE AND EFFECTIVENESS	
Exposed areas of site to be sealed and revegetated as soon as possible.	High
Mixing of concrete and/or bentonite slurries to be carried out in enclosed/shielded areas where necessary.	Moderate

TABLE A10 GRAPHICAL SCREENING RESULTS, NORTH SIDE

Pollutant	Carbon Monoxide	Benzene	Nitrogen Dioxide		Fine Particulate Matter (PM_{10})	
Averaging Period	**Maximum 8-hour mean (mg/m^3)**	**Annual mean ($\mu g/m^3$)**	**Annual mean ($\mu g/m^3$)**	**99.8th percentile of hourly means ($\mu g/m^3$)**	**Annual mean ($\mu g/m^3$)**	**90th percentile of daily means ($\mu g/m^3$)**
GN1 – 48 Firtrees Avenue						
2000 existing	3.1	1.9	20	89	20	35
2006 w/o scheme	2.2	1.3	17	76	17	30
2006 with scheme	2.4	1.4	19	84	17	31
2021 w/o scheme	1.8	1.1	16	71	16	28
2021 with scheme	1.9	1.1	18	80	16	29
GN2 – 2 Henley Gardens						
2000 existing	3.3	2.0	22	94	20	35
2006 w/o scheme	2.3	1.4	19	83	17	31
2006 with scheme	2.3	1.4	19	86	17	31
2021 w/o scheme	1.9	1.1	17	76	16	28
2021 with scheme	1.9	1.1	18	79	16	29
GN3 – 19 Melrose Gardens						
2000 existing	3.4	2.2	29	116	20	37
2006 w/o scheme	2.4	1.4	23	97	18	31
2006 with scheme	2.5	1.5	24	102	18	31
2021 w/o scheme	1.9	1.1	20	86	16	29
2021 with scheme	2.0	1.2	22	93	16	29
AQS Objective	11.6 mg/m^3	16.25 $\mu g/m^3$	40 $\mu g/m^3$	200 $\mu g/m^3$ not to be exceeded more than 18 times a year	40 $\mu g/m^3$	50 $\mu g/m^3$ not to be exceeded more than 35 times a year

TABLE A11: GRAPHICAL SCREENING RESULTS, SOUTH SIDE						
Pollutant	**Carbon Monoxide**	**Benzene**	**Nitrogen Dioxide**		**Fine Particulate Matter (PM_{10})**	
Averaging Period	**Maximum 8-hour mean (mg/m^3)**	**Annual mean ($\mu g/m^3$)**	**Annual mean ($\mu g/m^3$)**	**99.8th percentile of hourly means ($\mu g/m^3$)**	**Annual mean ($\mu g/m^3$)**	**90th percentile of daily means ($\mu g/m^3$)**
GS1 – 28 Newlyn Drive						
2000 existing	3.0	2.4	18	78	19	35
2006 w/o scheme	2.2	1.6	15	69	17	30
2006 with scheme	2.2	1.6	15	69	17	30
2021 w/o scheme	1.8	1.2	14	66	16	28
2021 with scheme	1.8	1.2	14	66	16	28
GS2 – 21 Bilton Hall Road						
2000 existing	3.2	2.5	24	102	20	35
2006 w/o scheme	2.3	1.6	19	85	17	31
2006 with scheme	2.3	1.6	19	86	17	31
2021 w/o scheme	1.8	1.3	17	77	16	28
2021 with scheme	1.9	1.3	18	80	16	29
GS3 – 74 Salcombe Avenue						
2000 existing	3.4	2.6	28	113	20	37
2006 w/o scheme	2.3	1.6	22	93	17	31
2006 with scheme	2.4	17	22	94	18	31
2021 w/o scheme	1.9	1.3	19	84	16	29
2021 with scheme	1.9	1.3	20	87	16	29
GS4 – 155 Lulworth Avenue						
2000 existing	3.3	2.5	25	105	20	35
2006 w/o scheme	2.3	1.6	20	87	17	31
2006 with scheme	2.3	1.6	20	88	17	31
2021 w/o scheme	1.9	1.3	18	79	16	29
2021 with scheme	1.9	1.3	18	82	16	29
GS5 – 5 Regent Road						
2000 existing	3.4	2.6	30	120	21	37
2006 w/o scheme	2.4	1.7	23	98	18	31
2006 with scheme	2.4	1.7	23	98	17	31
2021 w/o scheme	1.9	1.3	20	88	16	29
2021 with scheme	1.9	1.3	21	90	16	29
AQS Objective	11.6 mg/m^3	16.25 $\mu g/m^3$	40 $\mu g/m^3$	200 $\mu g/m^3$ not to be exceeded more than 18 times a year	40 $\mu g/m^3$	50 $\mu g/m^3$ not to be exceeded more than 35 times a year

A3. DETAILED MODELLING RESULTS

TABLE A12: RESULTS OF DETAILED MODELLING AT SELECTED SITES, NORTH SIDE

Pollutant	Carbon Monoxide	Benzene	Nitrogen Dioxide		Fine Particulate Matter (PM_{10})	
Averaging Period	Maximum 8-hour mean (mg/m^3)	Annual mean ($\mu g/m^3$)	Annual mean ($\mu g/m^3$)	99.8^{th} percentile of hourly means ($\mu g/m^3$)	Annual mean ($\mu g/m^3$)	90^{th} percentile of daily means* ($\mu g/m^3$)
DN1 – 2 Mitford Street						
2000 existing	1.2	0.7	29	102	20	30
2006 w/o scheme	0.9	0.4	25	88	17	27
2006 with scheme	0.9	0.4	23	80	17	26
2010 w/o scheme	-	-	22	78	16	25
2010 with scheme	-	-	21	72	16	25
2021 w/o scheme	0.7	0.3	24	84	16	25
2021 with scheme	0.7	0.3	21	74	16	25
DN2 – 1 Meldon Street						
2000 existing	1.2	0.8	34	119	20	30
2006 w/o scheme	0.9	0.4	30	106	18	27
2006 with scheme	0.8	0.4	25	86	17	27
2010 w/o scheme	-	-	26	92	17	25
2010 with scheme	-	-	22	76	16	25
2021 w/o scheme	0.7	0.3	29	101	16	25
2021 with scheme	0.7	0.3	24	82	16	25
DN3 – 47 Norman Terrace						
2000 existing	1.1	0.6	21	74	19	29
2006 w/o scheme	0.8	0.3	19	66	17	26
2006 with scheme	0.8	0.3	18	63	17	26
2010 w/o scheme	-	-	17	61	16	25
2010 with scheme	-	-	17	59	16	25
2021 w/o scheme	0.7	0.3	19	65	16	24
2021 with scheme	0.7	0.3	17	61	16	24
DN4 – 111 Cumberland Street						
2000 existing	1.1	0.6	24	85	19	30
2006 w/o scheme	0.8	0.4	21	73	17	26
2006 with scheme	0.8	0.3	20	71	17	26
2010 w/o scheme	-	-	19	68	16	25
2010 with scheme	-	-	19	66	16	25
2021 w/o scheme	0.7	0.3	20	72	16	24
2021 with scheme	0.7	0.3	19	68	16	24
DN5 – 48 Telford Street						
2000 existing	1.2	0.6	22	78	19	30
2006 w/o scheme	0.8	0.3	20	69	17	26
2006 with scheme	0.8	0.3	19	67	17	26
2010 w/o scheme	-	-	18	63	16	25
2010 with scheme	-	-	17	61	16	25
2021 w/o scheme	0.7	0.3	19	65	16	25
2021 with scheme	0.7	0.3	18	63	16	25
DN6 – 2/4 Chatton Street						

TABLE A12: RESULTS OF DETAILED MODELLING AT SELECTED SITES, NORTH SIDE

2000 existing	1.2	0.6	22	78	19	30
2006 w/o scheme	0.8	0.3	20	69	17	26
2006 with scheme	0.8	0.3	18	65	17	26
2010 w/o scheme	-	-	18	63	16	25
2010 with scheme	-	-	17	61	16	25
2021 w/o scheme	0.7	0.3	19	67	16	25
2021 with scheme	0.7	0.3	17	61	16	25
AQS Objective	11.6 mg/m^3	16.25 $\mu g/m^3$	40 $\mu g/m^3$	200 $\mu g/m^3$ not to be exceeded more than 18 times a year	40 $\mu g/m^3$	50 $\mu g/m^3$ not to be exceeded more than 35 times a year

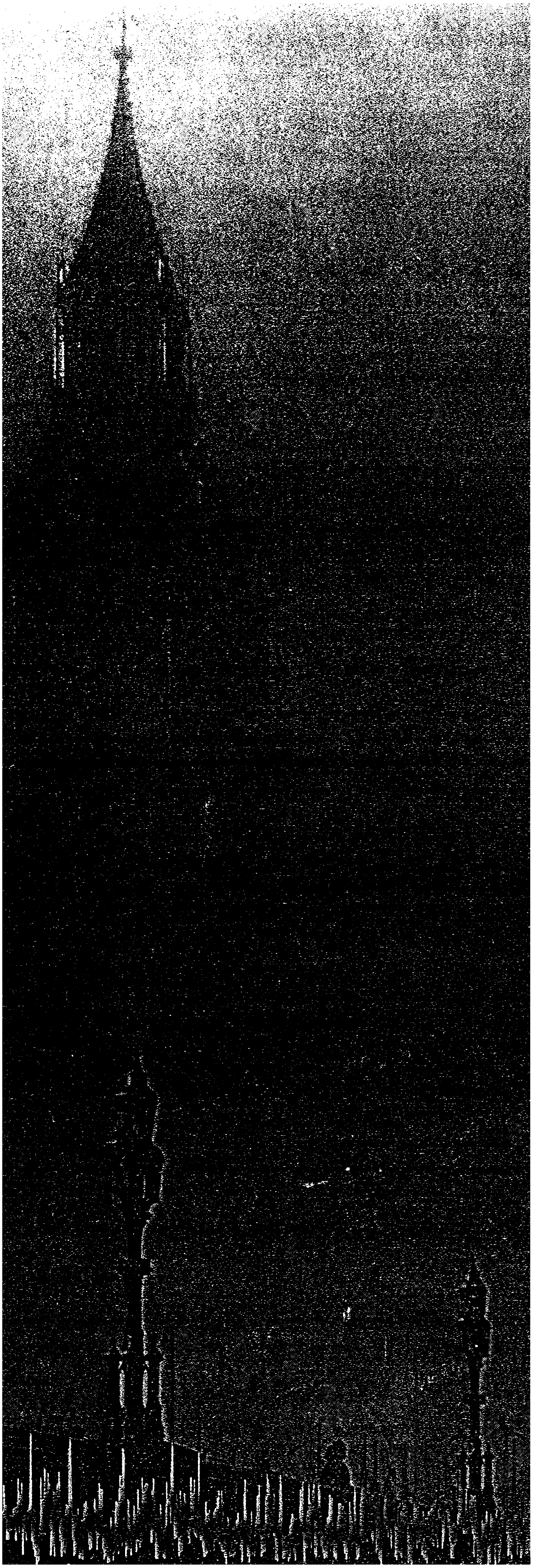
TABLE A13: RESULTS OF DETAILED MODELLING AT SELECTED SITES, SOUTH SIDE						
Pollutant	**Carbon Monoxide**	**Benzene**	**Nitrogen Dioxide**		**Fine Particulate Matter (PM_{10})**	
Averaging Period	**Maximum 8-hour mean (mg/m^3)**	**Annual mean (µg/m^3)**	**Annual mean (µg/m^3)**	**99.8th percentile of hourly means (µg/m^3)**	**Annual mean (µg/m^3)**	**90th percentile of daily means (µg/m^3)**
DS1 – 40 Epinay Walk						
2000 existing	1.1	0.8	23	81	19	30
2006 w/o scheme	0.8	0.4	21	73	17	26
2006 with scheme	0.8	0.4	22	76	17	26
2010 w/o scheme	-	-	19	65	16	25
2010 with scheme	-	-	19	68	16	25
2021 w/o scheme	0.7	0.4	20	72	16	26
2021 with scheme	0.7	0.4	21	75	16	25
DS2 – 46 Debussey Court						
2000 existing	1.1	0.9	28	98	20	30
2006 w/o scheme	0.8	0.5	25	88	17	26
2006 with scheme	0.8	0.5	25	86	17	26
2010 w/o scheme	-	-	22	78	16	25
2010 with scheme	-	-	22	78	16	25
2021 w/o scheme	0.7	0.4	25	88	16	26
2021 with scheme	0.7	0.4	25	87	16	25
DS3 – 45 Harold Street						
2000 existing	1.2	0.8	25	89	20	30
2006 w/o scheme	0.8	0.5	22	77	17	26
2006 with scheme	0.8	0.4	21	74	17	26
2010 w/o scheme	-	-	20	70	16	25
2010 with scheme	-	-	19	68	16	25
2021 w/o scheme	0.7	0.4	22	78	16	26
2021 with scheme	0.7	0.4	21	72	16	25
DS4 – 3/5 Stothard Street						
2000 existing	1.2	0.9	27	93	20	30
2006 w/o scheme	0.8	0.5	24	84	17	26
2006 with scheme	0.8	0.5	23	81	17	26
2010 w/o scheme	-	-	21	74	16	25
2010 with scheme	-	-	21	73	16	25
2021 w/o scheme	0.7	0.4	24	85	16	26
2021 with scheme	0.7	0.4	23	80	16	25
DS5 – 35/37 Stothard Street						
2000 existing	1.2	0.9	31	110	20	30
2006 w/o scheme	0.8	0.5	27	96	17	26
2006 with scheme	0.8	0.5	27	95	17	26
2010 w/o scheme	-	-	24	85	16	25
2010 with scheme	-	-	24	85	16	25
2021 w/o scheme	0.7	0.4	29	100	16	26
2021 with scheme	0.7	0.4	27	94	16	25
DS6 - 67 Stothard Street						

TABLE A13: RESULTS OF DETAILED MODELLING AT SELECTED SITES, SOUTH SIDE

2000 existing	1.2	1.1	39	138	21	31
2006 w/o scheme	0.8	0.6	34	120	18	26
2006 with scheme	0.8	0.6	35	123	18	26
2010 w/o scheme	-	-	30	104	17	25
2010 with scheme	-	-	30	106	17	25
2021 w/o scheme	0.7	0.4	36	126	17	26
2021 with scheme	0.7	0.5	35	122	17	25
DS7 – 12 Raglan Street						
2000 existing	1.2	0.8	21	74	19	30
2006 w/o scheme	0.8	0.4	20	69	17	26
2006 with scheme	0.8	0.4	18	65	17	26
2010 w/o scheme	-	-	18	63	16	25
2010 with scheme	-	-	17	61	16	25
2021 w/o scheme	0.7	0.3	19	65	16	26
2021 with scheme	0.7	0.3	18	63	16	25
DS8 – 55/57 Priory Road						
2000 existing	1.2	0.8	24	85	19	30
2006 w/o scheme	0.8	0.4	21	75	17	26
2006 with scheme	0.8	0.4	21	74	17	26
2010 w/o scheme	-	-	19	68	16	25
2010 with scheme	-	-	19	67	16	25
2021 w/o scheme	0.7	0.3	20	69	16	26
2021 with scheme	0.7	0.4	21	72	16	25
DS9 – Commercial Priory Road						
2000 existing	1.2	0.8	22	78	19	30
2006 w/o scheme	0.8	0.4	20	71	17	26
2006 with scheme	0.8	0.4	20	70	17	26
2010 w/o scheme	-	-	19	65	16	25
2010 with scheme	-	-	18	64	16	25
2021 w/o scheme	0.7	0.3	19	67	16	26
2021 with scheme	0.7	0.4	19	67	16	25
DS10 – 21 Ferry Street						
2000 existing	1.2	0.8	24	85	19	30
2006 w/o scheme	0.8	0.4	21	73	17	26
2006 with scheme	0.8	0.4	21	72	17	26
2010 w/o scheme	-	-	19	67	16	25
2010 with scheme	-	-	19	66	16	25
2021 w/o scheme	0.7	0.3	20	69	16	26
2021 with scheme	0.7	0.4	19	68	16	25
AQS Objective	11.6 mg/m^3	16.25 µg/m^3	40 µg/m^3	200 µg/m^3 not to be exceeded more than 18 times a year	40 µg/m^3	50 µg/m^3 not to be exceeded more than 35 times a year

APPENDIX B

Extract from the first report of the Quality of Urban Air Review Group



Urban Air Quality in the United Kingdom

January 1993

First Report of the
Quality of Urban Air Review Group

Prepared at the request of the
Department of the Environment

B1

Table 3.5 Ratios of 98th Percentile to Annual Mean for NO_2 Concentrations at Sites Operated by Warren Spring Laboratory

Site	Ratio of 98th Percentile/Annual Mean 1987	1988	1989	1990
London, Victoria	2.18	2.11	2.16	2.14
London, Earls Court	2.40	2.49	2.60	2.23
Cromwell Road	-	-	2.33	2.36
Stevenage	2.67	2.21	2.24	2.24
Glasgow	2.23	1.90	2.26	2.04
Manchester	2.24	2.39	2.48	2.64

There is also a marked variation in the diurnal NO concentrations between weekday and weekends, as can be seen in Figure 3.15. Not only are concentrations of NO lower during the daytime at weekends as compared to weekdays, but the peak concentrations associated with peak vehicle flows during weekday mornings is absent at the weekends.

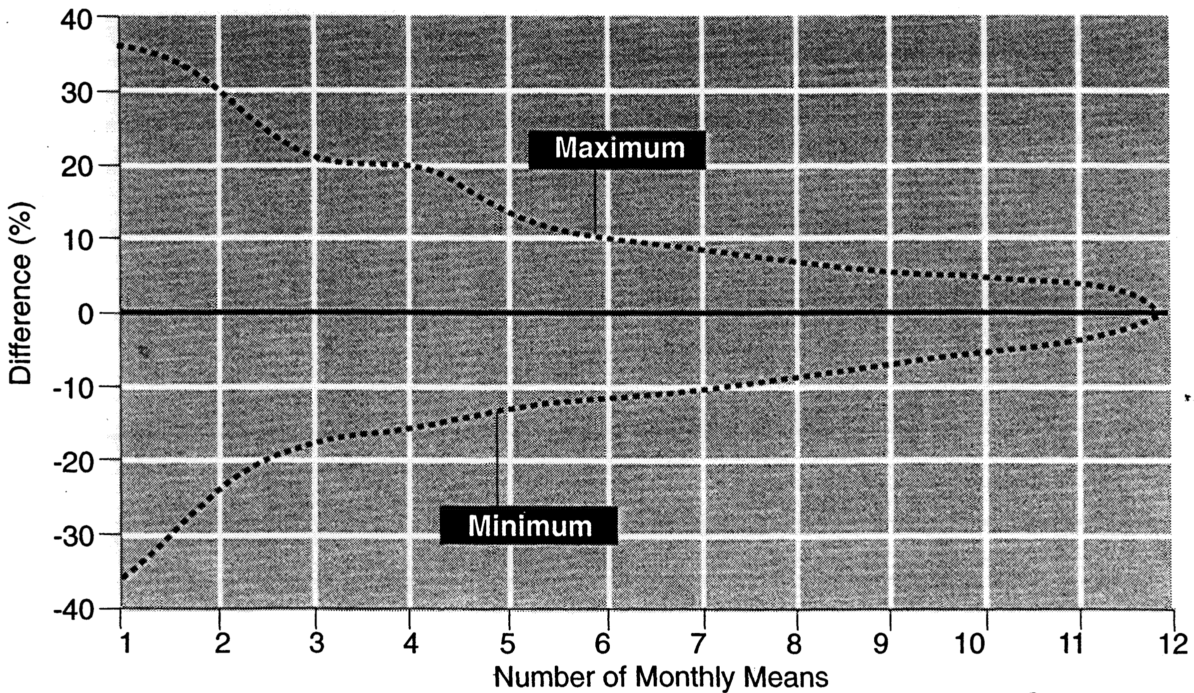
Diffusion tube surveys often include a mix of roadside and background sites. In the 1991 diffusion tube survey carried out by Warren Spring Laboratory, sites were classified according to their distance from the nearest road. 'Near road' sites were defined as 'facing directly on to a major road' of which there were 19. 'Background' sites were those over 50 m from a major road. Not surprisingly, it is the near-road sites which consistently show higher concentrations, when compared with background sites in the same urban area. The three sites with the highest mean concentration over the six month period were all near-road sites in London.

The second report of the Photochemical Oxidants Review Group presents the results from diffusion tube studies of NO_2 concentrations adjacent to busy roads. One study demonstrated that for a road with traffic flows of 50,000 vehicles a day, the NO_2 concentrations varied as follows:

Table 3.6 Peak Hourly Average NO and NO_2 Concentrations (ppb) Recorded at Two Roadside Sites in London

	1986		1987		1988		1989		1990	
Site	NO	NO_2	NO	NO_2	NO	NO_2	NO	NO_2	NO	NO_2
Cromwell Road	1,126	195	N/A	N/A	N/A	N/A	1,767	271	1,336	245
Central London	N/A	468	N/A	264	N/A	345	N/A	212	-	-

Figure 3.11 Difference Between True NO_2 Annual Mean and Average Over Different Numbers of Monthly Means



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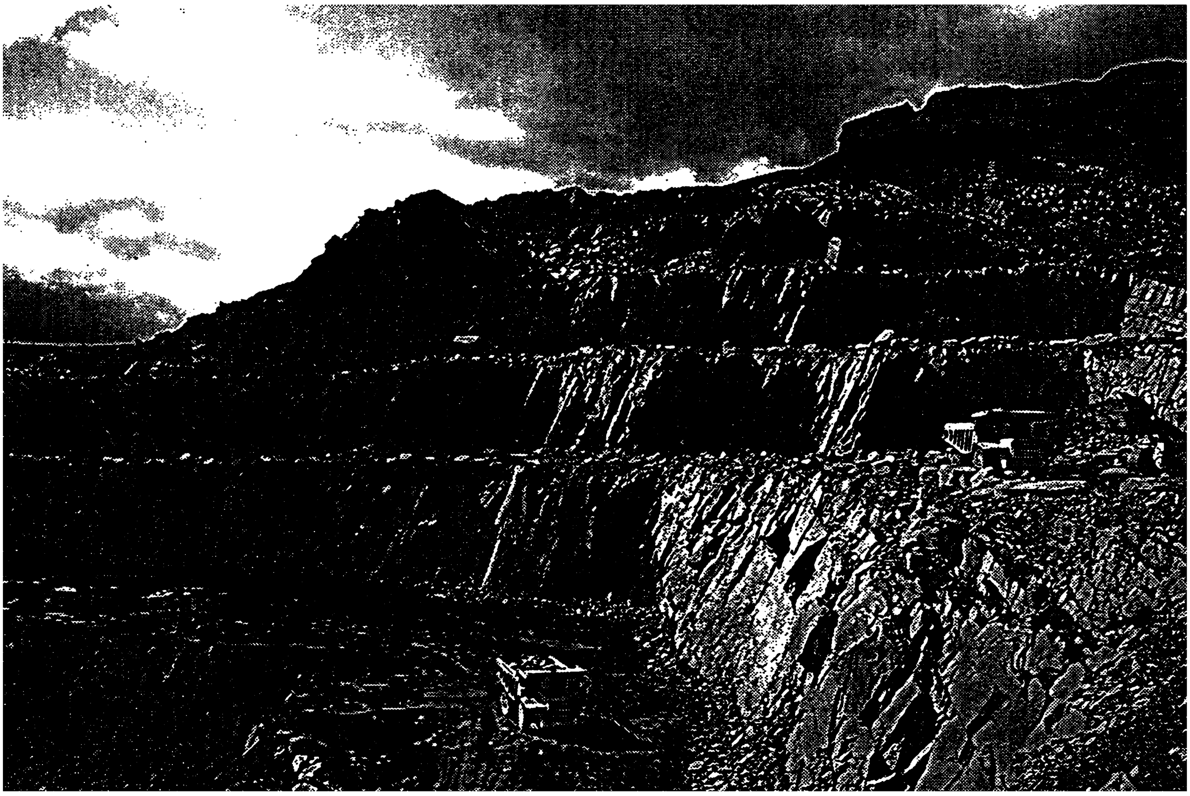
APPENDIX C

Extract from the DoE reoirt The Environmental Effects of Dust from Surface Mineral Workings

Department of the Environment
Minerals Division

The Environmental Effects of Dust from Surface Mineral Workings

Volume 1
Summary Report & Best Practice Guides



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MITIGATION OPTIONS FOR MINERAL EXTRACTION

POSSIBLE ACTION	RELATIVE COST	EFFECTIVENESS
1. Locate away from sensitive land uses.	**LOW** - if considered during site design. **HIGH** - if mineral reserves cannot be worked, or if activities have to be moved.	**HIGH** Not always practical due to locational or operational constraints.
2. Water sprays to maintain dampness of material during dry weather.	**MODERATE** - if equipment is already available for use. **HIGH** - if new equipment has to be purchased.	**MODERATE to HIGH** Appropriate for sites located in high and medium sensitivity areas where mineral material is to be worked in a relatively dry state. Requires an adequate water supply. Water sprays must be used in dry condtions to maintain a damp surface although excessive use should be avoided to minimise problems of over watering. May be necessary to spray dry material prior to loading.
3. Reduce drop heights when loading material into trucks or onto conveyors.	**LOW** .	**MODERATE** Effective when carried out appropriately but not always practical, and is highly dependent on staff understanding/training.
4. Minimise unnecessary handling of material.	**LOW** .	**MODERATE** Effective when carried out appropriately but not always practical.
5. Protect from wind.	**HIGH** - if trees have to be planted and maintained, or if wind barriers or fences are erected, otherwise if natural features already exist and can be exploited, then **MODERATE to LOW.**	**MODERATE** Effective within a deep quarry voids, or where surface features such as woodland provide shelter. There may be implications for patterns of working or site design.

MITIGATION OPTIONS FOR SITE HAULAGE

POSSIBLE ACTION	RELATIVE COST	EFFECTIVENESS
1. Hard surface permanent site roads, particularly those used heavily.	**HIGH**	**HIGH** Not always practical especially if roads are in temporary use.
2. Temporary surface site roads - for example with geotextiles.	**HIGH**	**MODERATE** Frequently impractical, particularly with sites requiring use of heavy/large vehicles and other equipment and where steep gradients on site roads are necessary. Unpopular with operators.
3. Improve surface of unpaved site roads by regular grading.	**HIGH**	**HIGH** Needs to be undertaken regularly especially after heavy road usage.
4. Restrict vehicle access to treated road surfaces.	**HIGH to MODERATE**	**HIGH** Restrictions need to be monitored and enforced, otherwise **MODERATE to LOW.**
5. Restrict vehicle speeds.	**HIGH to MODERATE**	**MODERATE** If restrictions are monitored and enforce, otherwise **MODERATE to LOW.**
6. Design site roads to avoid the need for sharp corners (and need for intense vehicle breaking).	**MODERATE to LOW -** if undertaken at site design stage.	**MODERATE** If well designed but not always practical.
7. Design roads to take advantage of natural protection (screening) afforded by other site features.	**MODERATE to LOW**	**MODERATE** If natural protection is available, otherwise **LOW.**
8. Water road surfaces in dry weather to maintain damp surfaces.	**HIGH to MODERATE**	**HIGH** If applied very regularly during hot dry weather, otherwise **MODERATE to LOW.**
9. Use dust suppressant chemicals on road surfaces.	**MODERATE** - if means of application already on site otherwise **HIGH.**	**HIGH to MODERATE** If used and applied appropriately otherwise **MODERATE to LOW.**
10. Planting between site roads and off-site sensitive land uses to provide shelter.	**MODERATE to HIGH** - depends on extent of planting, after-care and species used.	**HIGH** But considerable time is required for plants to mature and provide protection.

movement is greatly decreased by reducing the speed of vehicle movements, and by the watering of dry haul road surfaces (Cowheard, Muleski and Kinsey 1988).

In addition, if the exhaust gases from site vehicles are allowed to blow downwards, onto a surface, this lifts dust into suspension. This is easily prevented by using vehicles which vent exhaust gases upwards away from surface, and this is the advice provided by Process Guidance Note PG 3/8 (91) issued in support of LAAPC specified the Environmental Protection Act (EPA) 1990.

The EPA has identified site haulage as requiring control under the local authority air pollution control system (LAAPC). Guidance is provided in Process Guidance Note PG 3/8 (91), but it is unclear from the advice whether all site haulage is prescribed for control, or only that haulage of crushed or processed mineral. Since the guidance notes are currently undergoing review prior to re-issue, this uncertainty may be presently resolved.

d) Blasting

Blasting can also be a source of dust from mineral workings. Hard materials may require blasting, with explosives, to disrupt the physical structure of the rock face, since blasting loosens material and breaks the material into fragments of manageable size for subsequent handling. The explosives are placed in bore holes drilled into the working face, and the construction of these by means of drill rigs, generate considerable quantities of dust. Many drill rigs used at modern mineral sites use air to flush the bore holes free of debris. Dust emission can be minimised by employing equipment fitted with dust extraction and collection equipment (e.g. bag filters), and this is the advice given in PG 3/8 (91).

2.2.3 Dust Dispersion and Deposition

The ability of suspended atmospheric dust to disperse is determined by how well the dust remains airborne, and is intimately associated with dust deposition processes. Dispersion and deposition are affected by:

- drag, lift and movement resulting from the flow of air on particles;
- weight of the particles;
- interparticle cohesion of particles (Merefield et al 1994).

Kinetic energy must not only be applied to dust particles to initially lift into suspension but, once in suspension, more energy is required to keep the particles suspended in air. Without this energy, the suspended dust will gradually return to surface.

The dispersion of dust is highly weather dependant, driven by surface winds, as suspended dust disperses 'downwind' of the source. In very general terms, suspended dust forms a plume (or cloud) above the emission source. This plume expands, to entrain surrounding air, becoming larger in volume but diluted in concentration. The plume moves in the direction of wind blow, gradually losing dust as the suspended material fails to remain suspended and drops back to surface. This depletion of the dust plume results in the deposition of dust onto the surface that the wind driven plume is blown over.

Research studies are not conclusive on the distance dust particles travel. There are four main sources of such information:

1) research undertaken by the US-EPA at surface mineral sites:

2) research undertaken for the West German government;

3) research undertaken by British Coal at UK opencast coal sites;

4) research reported by IEA Coal Research

Research undertaken for the US-EPA concluded that large particulate matter, that is particles over 30µm in diameter, return to surface quite rapidly. Under average wind conditions, that is winds of mean speed 2-6 m/sec, these particles, which comprise around 95% of total dust emissions were found to return to surface within 60-90m of the emission source (Cowheard et al 1990).

Research undertaken by the Earth Resource Centre at Exeter University for British Coal Opencast (at Pwll Du in South Wales) found that, under normal meteorological conditions, medium sized particles (size range of 10-30µm) will generally travel up to 100-250m from their source before returning to surface. Only occasionally, when winds are stronger, will they travel beyond this (Merefield et al, 1994).

Other research has found that smaller particles are less sensitive to gravity, and remain airborne for much longer. Research by British Coal Opencast at Opencast coal sites in South Wales, indicates that such particles may travel very long distances before eventually returning to surface. The research also shows that levels of PM10, that is particulate matter less than 10 microns in diameter, are much the same upwind and downwind of study sites, indicating that relatively little dust in this size range is produced by

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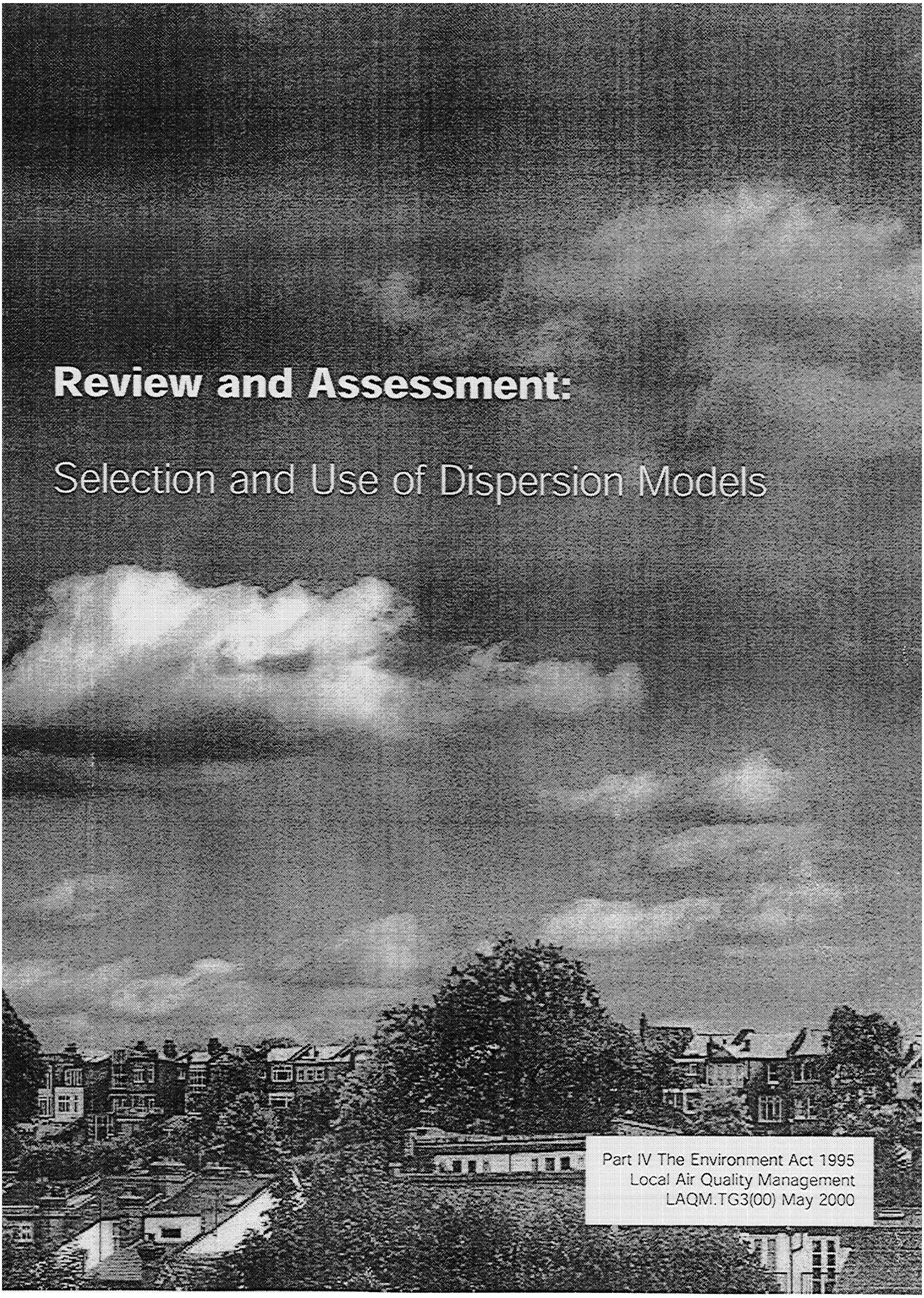
APPENDIX D

Extract from LAQM TG3 Selection and Use of Dispension Models



Review and Assessment:

Selection and Use of Dispersion Models

Part IV The Environment Act 1995
Local Air Quality Management
LAQM.TG3(00) May 2000

A.12 **ALMANAC** – This model was developed by the Central Electricity Generating Board (CEGB) and has been widely used for assessing the impact of power stations. Normally only a single stack can be modelled. ALMANAC can calculate maximum 1-hour mean, 98th percentiles and annual average concentrations. It is not supported commercially by any organisation.

A.13 **R91** – This Gaussian model was developed by a Working Group led by the National Radiological Protection Board (NRPB) in 1979. It has been used in the past by UK regulatory bodies (especially the nuclear industry) as a reference model. R91 originally consisted of nomograms, but a PC version called DISTAR is commercially available; other PC versions include STACKS (encoded by the Meteorological Office) and PLUMES (used by the Environment Agency). DISTAR can treat only flat terrain and cannot model building wake effects, although reports by NRPB show how the basic R91 model can include these effects. The model calculates 1-hour, monthly and annual averages, but there is no percentile post-processor. It uses statistical meteorological data. DISTAR can treat both dry and wet deposition.

A.14 **OSPM** – (Operational Street Pollution Model) This is a street canyon model on which the AEOLIUS model and the street canyon module in ADMS-Urban are based. Its purpose is to provide an easy method for estimating pollution from traffic. It makes use of a very simplified description of the flow and dispersion conditions in a street canyon. Concentrations in a street are calculated by adding the plume from vehicle exhausts to recirculating exhaust gases in the street. The model has been tested against extensive monitoring data from a number of European city streets.

Advanced Models

A.15 **CAL3QHC** – This US Environmental Protection Agency (EPA) model is designed to handle near-saturated and/or over capacity traffic conditions and complex intersections. It predicts 1-hour mean concentrations, for up to 120 road links and 120 receptors. The model runs on a PC. Generally, in the UK, the CALINE model described below is used for road traffic calculations.

A.16 **California Line Source Model (CALINE)** – This model was developed by the California Department of Transportation and the US Federal Highways Agency (FHA). It is a Gaussian model designed for the assessment of traffic emissions from roads. It can model junctions, street canyons, parking lots, bridges and underpasses; it includes a photochemistry model to predict downwind concentrations of NO_2 from NO_X emitted by vehicle exhausts. CALINE predicts 1-hour mean concentrations and is therefore useful for investigating episodes of high NO_2 and CO concentrations. Hourly meteorological conditions are user-defined, and line source emission rates must be calculated independently by the user based on vehicle speeds, HGV mix, traffic flows and published emission factors. CALINE4 requires details on the site configuration, and ambient NO_2, NO and ozone levels if the photochemistry simulations are to be used. The model can handle up to 20 road links and 20 receptors. The model runs on a PC.

A.17 **BREEZE ROADS** – This is a modelling package which includes the CAL3QHC, CAL3QHCR and CALINE4 models developed in the USA. In combination with an emissions model it has versatile applications for calculating roadside concentrations of all the pollutants of interest in many complex road situations. The model can account for hourly, daily and seasonal variations in traffic flows and can provide output for a range of averaging periods comparable with the air quality objectives.

APPENDIX E

Paper by Jannsen et al

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A CLASSIFICATION OF NO OXIDATION RATES IN POWER PLANT PLUMES BASED ON ATMOSPHERIC CONDITIONS

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Abstract—The NO_2/NO_x ratio as a function of distance from the source has been measured in the stack plumes of Dutch power plants over a period of 10 years, between 1975 and 1985. In this period a large data base was built up, consisting of 60 measuring flights carried out under widely varying atmospheric conditions. It is proposed that the total (cross-wind integrated) NO oxidation rate in power plant plumes can be described approximately by the phenomenological relation:

$$NO_2/NO_x = A(1 - \exp(-\alpha x)),$$

x being the distance from the source. Using the data base, the numerical values for A and α are classified according to atmospheric conditions. Ozone concentration, wind speed and season of the year are the most important parameters in determining A and α. This classification may serve as a first approximation in the development of more accurate analytical models. Variations of measured NO_2/NO_x ratios are explained through natural variations of the ozone background concentration and NO_2 photodissociation rate. Practical application of the classification is illustrated by calculating NO_2 ground-level concentrations for different atmospheric conditions, using Gaussian dispersion equations.

Key word index: NO oxidation rate, classification, atmospheric conditions, stack plumes.

INTRODUCTION

The nitrogen oxides (NO_x) which are emitted in the flue gas of power plants burning fossil fuels consist for the larger part (> 95%) of nitrogen monoxide (NO) and for a small part (< 5%) of nitrogen dioxide (NO_2). After emission from the stack, NO is converted to NO_2, through oxidation with atmospheric ozone (O_3).

Since NO_2 is over 20 times as toxic as NO, it is important from the point of view of public health to be able to predict NO_2 concentrations that may occur at ground level. Conversion products of NO_2, i.e. nitrates such as peroxy acetyl nitrate (PAN) and nitric acid (HNO_3), contribute to concentrations of inhalable adverse matter in the air and to acid deposition (Richards, 1983; Brodzinsky *et al.*, 1984; Russell *et al.*, 1985).

The NO oxidation rate in the atmosphere depends on the interaction of chemical kinetics, i.e. the molecular reaction rates, and physical kinetics, i.e. the processes of dispersion and mixing of the plume with ambient air. Chemical and physical kinetics depend on meteorological conditions such as wind speed and solar radiation and on concentration of the reactants. The interaction between chemical and physical kinetics was discussed by Donaldson and Hilst (1972), Hegg *et al.* (1976), Elshout and Beilke (1984) and Janssen (1986).

Recently Vermeulen (1983) made an inventory of well-documented measurements of NO conversion in stack plumes, described in the literature. These data were used to develop and evaluate a reactive plume model by Builtjes *et al.* (1985, 1986). Elaborate measurements of NO oxidation have been carried out by Melo and Stevens (1981), Richards *et al.* (1981), Hegg and Hobbs (1983) and Elshout and Beilke (1984). These measurements were carried out in the form of measuring campaigns and were related to some meteorological conditions only.

In this study a classification of NO oxidation rates is presented, based on a large data base of NO and NO_2 concentration measurements in the plumes of power plants. The measurements have been carried out under widely varying atmospheric conditions during winter, spring, summer and autumn.

This classification can be used to calculate NO_2 ground-level concentrations and can be used as a guide in developing more accurate reactive plume models.

EXPERIMENTAL METHODS

NO oxidation rates are inferred from measured NO_2/NO_x ratios as a function of distance from the source. The measurements were carried out by means of a specially equipped aircraft at distances between 0.5 and 30 km downwind of a limited number of oil-, gas- and coal-fired power plants in the Netherlands.

The aircraft, a Piper Navajo Chieftain, was equipped with a TECO 14D NO, NO_x chemoluminescence monitor and a Bendix 8002 chemoluminescence O_3 analyser. R-C times of both instruments were set at 1 s. SO_2 concentrations were measured with a TECO 43 SO_2-pulsed fluorescence analyser with an R-C time of 4 s. The data were sampled by a Monitor

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Labs datalogger using a sample frequency of 2 Hz, and stored on cartridges. After the flights the data were processed by computer and concentration profiles were plotted in a fixed coordinate system.

From the measured concentration profiles the NO, NO_2, O_3 and SO_2 concentrations integrated over the plume (ppm m) and the plume widths (m) were determined.

Sampling took place during several horizontal crossings at different altitudes perpendicular to the plume axis. At each distance about 4–10 crossings were made which took 15–30 min. The flight speed of the aircraft during the measurements was 70 m s^{-1}.

During the measurements NO, NO_2, O_3 and SO_2 background concentrations and in some cases the inversion height from temperature data were also obtained. The wind speed at plume height (several hundreds of metres) was calculated by means of the power law $u(z_2)/u(z_1) = (z_2/z_1)^p$ based on measurements of the wind speed at an altitude of 10 m ($u(z_1)$), and z_2 being the average altitude of a number of crossings at one distance. The value for p depends on atmospheric stability. For each measuring day atmospheric stability was determined on the basis of meteorological information from nearby weather stations. Values for p, as recommended by the Royal Dutch Meteorological Institute (KNMI) for atmospheric conditions in the Netherlands, were taken as: Pasquill classes A and B: $p = 0.10$ and Pasquill classes C and D: $p = 0.16$ (KNMI, 1979).

Plume crossings were carried out in the middle of the day between 1100h and 1600h at altitudes between 200 and 700 m. The effective plume heights were between 200 and 500 m. Because the mixing heights during the measurements were at least 500 m (KNMI, 1979) the entire plume was considered to be in the mixed layer of the atmosphere.

The results of 60 measurements made between 1975 and 1985, in different seasons and under widely varying weather conditions, were gathered in a computer data base and supplemented with emission data of the power plants and meteorological information from nearby weather stations.

A description of the total data base is presented by Vaessen (1985).

RESULTS AND ANALYSIS

Description of the NO_2/NO_x *ratio as a function of distance from the source*

In the atmosphere an important pathway for formation of NO_2 is the second-order reaction of NO with O_3. In a homogeneous mixture this reaction can be written as:

$$d[NO_2]/dt = k_1[NO][O_3]. \quad (1)$$

From the equation:

$$NO_x = NO + NO_2 \quad (2)$$

and the wind speed u:

$$u = dx/dt \quad (3)$$

assuming a constant O_3 concentration, the NO_2/NO_x ratio becomes:

$$NO_2/NO_x = A(1 - e^{-\alpha x}) \quad (4)$$

and

$$\alpha = (k_1[O_3])/u. \quad (5)$$

Laboratory determination of the reaction rate constant k_1 gave a value of 29 ppm^{-1} min^{-1} (Becker and Schurath, 1975). Substituting this value, a wind speed of 0.01 km s^{-1} and an O_3 concentration of 35 ppb, a value for α of 1.7 km^{-1} is found. Since the plume, in contrast to laboratory conditions, is an inhomogeneous mixture of NO and O_3, this is not valid. This simplified scheme leading to Equation (4) implies a spatially constant O_3 concentration (a flat profile) which can exist only if the 'replacement' of reacting O_3 by transport processes proceeds at a rate much faster than the chemical reaction rate. However, for the problem under consideration it holds that at some distance from the stack the time scales of the mixing and dispersion processes are larger than the chemistry time scales (Hegg *et al.*, 1976). Therefore, Equation (4) has to be regarded as a first approximation to handle NO oxidation processes in the atmosphere.

Apart from the reaction of NO with O_3, photodissociation of NO_2 influences the NO_2/NO_x ratio during the day:

$$d[NO_2]/dt = -k_2[NO_2] \quad (6)$$

the photodissociation rate k_2 depends on the intensity of solar radiation and lies between 0 in the dark and 0.55 min^{-1} in full sunlight (Parrish *et al.*, 1983).

From measurements of NO oxidation rates in power plant plumes, reported by Janssen (1986), it has been deduced that photostationary equilibrium exists in the plume in the daytime and at a larger distance from the source (> 10 km), determined by Equations (1) and (6) according to:

$$\lim_{x \to \infty} \psi = \frac{k_1[NO][O_3]}{k_2[NO_2]} = 1. \quad (7)$$

The constant A in Equation (4) can then be determined using expressions (1), (2), (6) and (7). For the relation between NO and NO_2 Equation (8) applies:

$$\lim_{x \to \infty} [NO] = (k_2[NO_2])/(k_1[O_3]). \quad (8)$$

Using (2), (4) and (8), we can derive the expression for A:

$$A = \left(\frac{k_2}{k_1[O_3]} + 1\right)^{-1}. \quad (9)$$

After substitution in Equation (4) the description of NO_2 formation in the atmosphere is given by the equation:

$$NO_2/NO_x = \left(\frac{k_2}{k_1[O_3]} + 1\right)^{-1}(1 - e^{-\alpha x}). \quad (10)$$

Formation of NO_2 takes place during mixing of a smoke plume with its surrounding air. Hegg *et al.* (1976) and Janssen (1986) discussed the NO oxidation process in an inhomogeneously mixed plume in the atmosphere. Therefore the relations (1) and (4) are not exactly valid and the value for α in expressions (5) and (10) cannot be derived directly from O_3 concentration and wind speed.

Equation (10) should therefore be regarded as a phenomenological way to describe NO_2 formation in a

E2

plume. Values for α for varying meteorological conditions in different seasons are determined through measurements of NO_2/NO_x ratios as a function of distance from the source. The value for A can be calculated using Equation (9), the value for the photodissociation rate k_2, and the O_3 concentration in the background air.

The power plants under investigation had an installed capacity of between 500 and 1500 MWe and used oil, gas or coal for fuel. Variations in NO concentrations in the flue gases are due to these differences in fuel type and to variations in load. The NO concentrations for this kind of installation range from 150 to 450 ppm. The NO_2/NO_x ratio, however, is independent of this source of noise.

The results show that using Equation (10) may result in a fair description of the oxidation process.

Selection of atmospheric parameters

To be able to use Equation (10), knowledge of the value for the photodissociation rate k_2 is needed. An estimation of this value may be obtained from concentration measurements of background NO, NO_2 and O_3 during the plume flights, assuming photostationary equilibrium in the background air (Van Egmond and Kesseboom, 1985). By using Equation (7) a value for k_2 can be calculated:

$$k_2 = \frac{k_1 [NO][O_3]}{[NO_2]}. \quad (11)$$

We observe that both plume measurements and background concentration measurements have been carried out in the middle of the day from about 1100 to 1600 h. Therefore, values for k_2 will not differ greatly with variations of the solar angle (Parrish *et al.*, 1983). Results of the background concentration measurements, solar radiation data and the calculated k_2 values are presented in Table 1. Values for k_2 under typical mid-day meteorological conditions in the Netherlands, namely 0.15 min^{-1}, 0.25 min^{-1} and 0.35 min^{-1} in winter, spring/autumn and summer, respectively, have been calculated.

From previous research (Janssen, 1986) it appears that O_3 concentration and wind speed are important parameters in determining the NO oxidation rate.

Therefore, a classification of NO oxidation rates is presented for each season—winter, spring/autumn and summer—using O_3 concentration and wind speed as parameters.

Table 1. Calculated values for the photodissociation constant k_2

Season	Solar radiation ($W m^{-2}$)	σ ($W m^{-2}$)	k_2 (min^{-1})	Range
Winter	400	275	0.15	0.10
Spring/autumn	1200	600	0.25	0.15
Summer	1800	700	0.35	0.10

The values for k_2 have been calculated on the basis of average NO, NO_2 and O_3 background concentrations, assuming photostationary equilibrium. The final column in this table shows the range of k_2 values used in the calculations of the uncertainty limits [Equation (13b)].

The classification of NO *oxidation rates*

On the basis of these numerous measurements the values for A and α are classified according to atmospheric conditions, i.e. season of the year, O_3 background concentration and wind speed. This classification of A and α is presented in Tables 2, 3 and 4. The choice of the class boundaries will be discussed in the next paragraph.

By using Equation (9) values for A have been calculated from the average O_3 concentrations in each class and the season-dependent values of the photodissociation rate k_2 (see Table 1). The values for α have been taken as the best values to describe the measured NO_2/NO_x ratios within one class using Equation (10).

Using these values for A and α and Equation (10), NO_2/NO_x ratios as a function of distance from the source can be calculated for a great number of meteorological conditions.

For some classes measuring data are lacking. Values for α are filled in by inter- and extrapolation from values for α in adjacent classes. These values are shown in brackets in Tables 2, 3 and 4. In this procedure values for α are 'normalized' by multiplying each α by the factor $u\,([O_3]k_1)^{-1}$ in its class. The values for A can always be calculated for each class using Equation (9).

Application of these values for A and α in model calculations using Equation (10), together with

Table 2. The classification of values for A and α (km^{-1}) in winter (November–February)

winter

O_3 background concentration (ppb) \ wind speed at plume height (m/s)	0–5	5–15	>15
120–200			
60–120			
40–60			
30–40	(A = 0.87, α = 0.07)	A = 0.87, α = 0.07	A = 0.87, α = 0.15
20–30	(A = 0.83, α = 0.07)	A = 0.83, α = 0.07	(A = 0.83, α = 0.10)
10–20	(A = 0.74, α = 0.07)	A = 0.74, α = 0.07	A = 0.74, α = 0.07
0–10	A = 0.49, α = 0.05	A = 0.49, α = 0.05	(A = 0.49, α = 0.05)

Table 3. The classification of values for A and α (km^{-1}) in spring/autumn (March–May and September–October)

spring/autumn

O_3 background concentration (ppb)	wind speed at plume height (m/s): 0–5	5–15	>15
120–200			
60–120			
40–60	(A = 0.85, α = 0.10)	A = 0.85, α = 0.15	A = 0.85, α = 0.30
30–40	(A = 0.80, α = 0.10)	A = 0.80, α = 0.10	A = 0.80, α = 0.25
20–30	(A = 0.74, α = 0.10)	A = 0.74, α = 0.10	A = 0.74, α = 0.15
10–20	(A = 0.635, α = 0.10)	A = 0.635, α = 0.10	(A = 0.635, α = 0.10)
0–10			

Table 4. The classification of values for A and α (km^{-1}) in summer (June–August)

summer

O_3 background concentration (ppb)	wind speed at plume height (m/s): 0–5	5–15	>15
120–200	A = 0.93, α = 0.40	A = 0.93, α = 0.65	(A = 0.93, α = 0.80)
60–120	A = 0.88, α = 0.20	A = 0.88, α = 0.35	(A = 0.88, α = 0.45)
40–60	A = 0.81, α = 0.15	A = 0.81, α = 0.25	A = 0.81, α = 0.35
30–40	(A = 0.74, α = 0.10)	A = 0.74, α = 0.15	A = 0.74, α = 0.25
20–30	(A = 0.67, α = 0.10)	A = 0.67, α = 0.10	(A = 0.67, α = 0.10)
10–20			
0–10			

measured results under corresponding conditions, are shown in Figs 2–7.

In most cases a good description of the measurements is obtained. Incidental deviations occur, but their number is surprisingly small. Therefore, the method presented proves to be highly suitable to predict NO_2/NO_x ratios in power plant plumes under widely varying atmospheric conditions.

UNCERTAINTY LIMITS OF MEASUREMENTS AND MODEL CALCULATIONS

Measurements

To determine average NO_2/NO_x ratios in a plume several (4–10) plume crossings have been made at one distance from the source. Every plume crossing is a registration of a momentary plume. Figure 1 shows a typical traverse record for NO_x, SO_2, O_3 and NO_2 concentrations in a plume at a distance of 8.5 km from the source. The NO_2/NO_x ratio of this momentary plume is calculated by dividing the over their plume profiles integrated NO_x and NO_2 concentrations:

$$(NO_2/NO_x)_{\substack{\text{momentary}\\ \text{plume}}} = \frac{\int_{\substack{\text{plume}\\ \text{width}}} NO_2\,dy}{\int_{\substack{\text{plume}\\ \text{width}}} NO_x\,dy}. \quad (12)$$

This value for the momentary NO_2/NO_x ratio therefore represents a spatial average, i.e. a flat NO_2/NO_x profile over the plume width; this assumption was recently discussed by Cheng *et al.* (1986) on the basis of measurements. Every momentary plume is a realization of the ensemble of momentary plumes belonging to a specific atmospheric condition. Variations in the parameters influencing the NO_2/NO_x ratio give rise to a distribution of momentary NO_2/NO_x values. This distribution is determined by the standard deviation σ, if the distribution is Gaussian.

The value for σ has been calculated for each series of 4–10 plume crossings performed at one distance from the source. These 4–10 plume crossings can be completed in 15–30 min. One crossing takes 3–4 min, during which the aircraft is actually in the plume for only 10–60 s. By taking the average of these 4–10

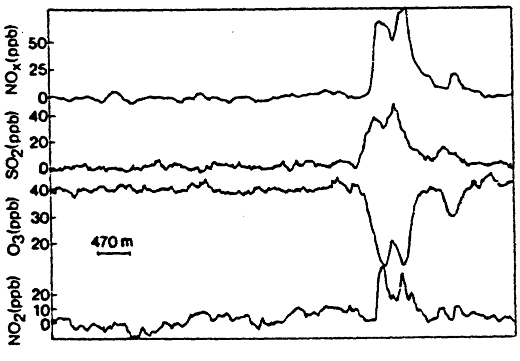

Fig. 1. A typical traverse record for NO_x, SO_2, O_3 and NO_2 concentrations in a power plant plume at a distance of 8.5 km from the source (flight 22, see also Figs 5 and 7).

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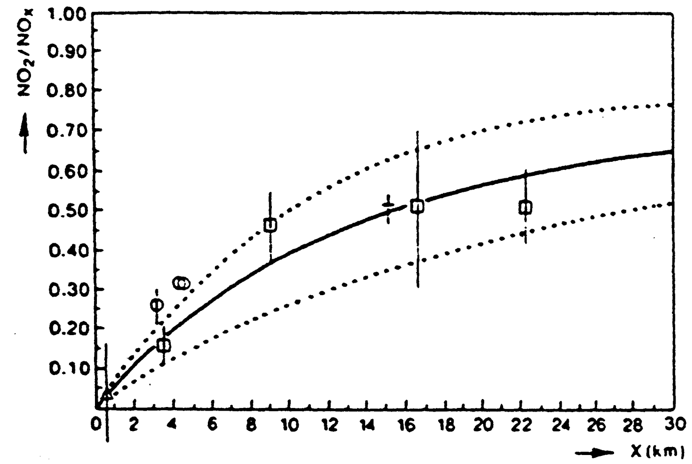

Fig. 2. NO_2/NO_x ratios measured and calculated with their uncertainty limits by using Equation (13b) for some flights in winter: 10 ppb $< [O_3] \leqslant$ 20 ppb; $A = 0.74$, $\alpha = 0.07$; flight 1, □: 5 m s^{-1} $\leqslant u \leqslant$ 15 m s^{-1}; flights 2,△, 3,○, 4,-: $u >$ 15 m s^{-1}. No effect of wind speed on oxidation rate is observed.

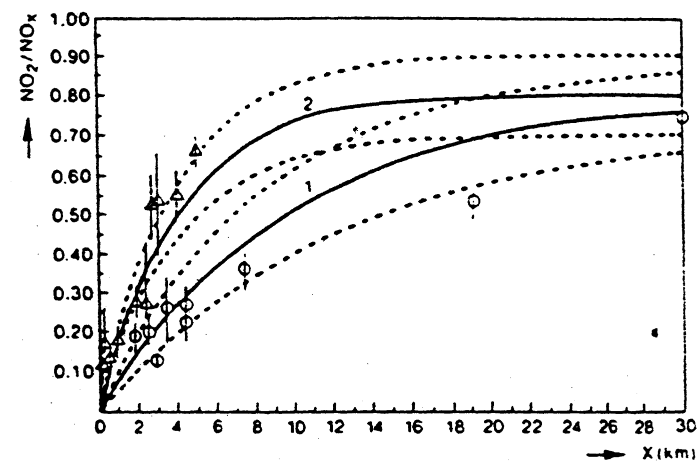

Fig. 3. NO_2/NO_x ratios measured and calculated with their uncertainty limits for measuring flights in spring/autumn: 30 ppb $< [O_3] \leqslant$ 40 ppb; $A = 0.80$; flights 5, 6, 7, 8: 5 m s^{-1} $\leqslant u \leqslant$ 15 m s^{-1}, $\alpha = 0.10$; ○ (1); flights 9, 10, 11, 12: $u >$ 15 m s^{-1}, $\alpha = 0, 25$, △ (2). Increasing wind speed causes increasing NO oxidation rates.

momentary NO_2/NO_x ratios, time averaging has in fact been carried out over a period of approximately 30 min.

These both spatially (flat NO_2/NO_x profiles in the plume) and temporally averaged (averaging period about 20 min) NO_2/NO_x ratios are shown in Figs 2–7.

As we are studying averaged plumes, the standard errors $\sigma/\sqrt{n}$, n being the number of plume crossings, are also shown in Figs 2–7. The standard error of the mean will therefore be a factor of about two–three smaller than the standard deviation.

Model calculations

Equation (10) implies a flat NO_2/NO_x profile over the plume width corresponding with the calculated NO_2/NO_x ratios based on measurements (see the foregoing paragraph). By fitting the best α for the spatially and temporally averaged NO_2/NO_x ratios measured, it is assumed that relation (10) describes spatially and temporally averaged NO_2/NO_x ratios.

To indicate the scatter of the NO_2/NO_x ratios calculated on the basis of Equation (10), we have to keep in mind that this has to be related to the scatter of the mean and not to the instantaneous values of the parameters. We do not take concentration fluctuations (micro-scale mixing) explicitly into account, although this is implicitly incorporated in the values for α if it would systematically influence the NO oxidation rate.

The range of the values for A, k_2, O_3 and α to be discussed in this paper therefore refer to the un-

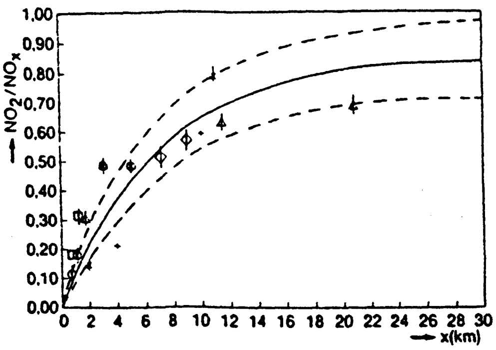

Fig. 4. NO_2/NO_x ratios measured and calculated with their uncertainty limits for measuring flights in spring/autumn: 40 ppb < $[O_3]$ ⩽ 60 ppb; $A = 0.85$, $\alpha = 0.15$; flights 13, □, 14, O, 15, Δ, 16, ×, 17, -, 18, ◇: $5\ ms^{-1} \leqslant u \leqslant 15\ ms^{-1}$.

certainty in the estimation of the mean values, i.e. averaged over the plume and averaged in time.
We distinguish between:

Variation in the values for A caused by taking the middle O_3 concentration in each class and only one k_2 value per season

Variation in the values for α caused by the distribution of NO_2/NO_x ratios measured in each class.

These are thought to be chiefly caused by variations in wind speed.

The variation in the NO_2/NO_x ratios can be defined as:

$$\Delta(NO_2/NO_x)^2 = \left(\frac{\partial(NO_2/NO_x)^2}{\partial A}\right)(\Delta A)^2 + \left(\frac{\partial(NO_2/NO_x)^2}{\partial \alpha}\right)(\Delta\alpha)^2 \quad (13a)$$

using Equation (10):

$$\Delta(NO_2/NO_x)^2 = (1-e^{-\alpha x})^2(\Delta A)^2 + (xAe^{-\alpha x})^2(\Delta\alpha)^2. \quad (13b)$$

Equation (13) is valid if variations in A and α are not correlated. However, this is not entirely true, because A is a function of the O_3 concentration and α is not a function of the wind speed only, but also of the O_3 concentration, as can be seen in Tables 2–4. The differences in α caused by differences in wind speed are, however, of the same order or greater than the differences in α in the adjacent classes. Therefore, covariance of A and α will be neglected for the time being and Equation (13) will serve as a reasonable approximation for explaining variations of NO_2/NO_x ratios within one class.

The ozone parameter A

The distribution of values for A is caused by establishing the discrete parameters of the meteorological conditions: for solar radiation one value for k_2 per season is selected and for O_3 concentration one value of the O_3 concentration per class. Therefore, the boundaries in the distribution of A (ΔA) must be calculated by taking the difference between A minimum ($[O_3]$ minimal and k_2 maximum) and A maximal ($[O_3]$ maximum and k_2 minimum).

The values for ΔA are shown in Table 5. As can be seen in this table, ΔA increases when the O_3 concentration decreases. Therefore, a smaller division of O_3 concentration classes has been chosen when background O_3 concentrations are lower. Nevertheless, values for ΔA are high when O_3 background concentrations are low. A still smaller division in classes of O_3 is not reasonable, considering the usual variations of

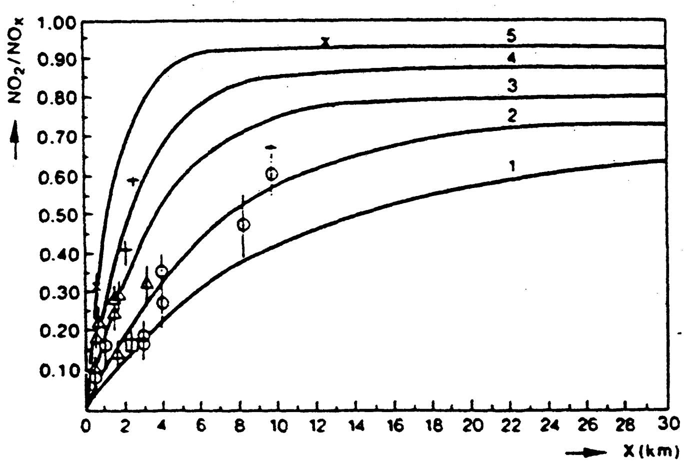

Fig. 5. NO_2/NO_x ratios measured and calculated for measuring flights in summer, showing the effect of O_3 concentration on oxidation rate. Flights 19–31: $5\ ms^{-1} \leqslant u \leqslant 15\ ms^{-1}$; 19, □: 20 ppb < $[O_3]$ ⩽ 30 ppb, $A = 0.67$, $\alpha = 0.10$ (1); 20–22, O: 30 ppb < $[O_3]$ ⩽ 40 ppb, $A = 0.74$, $\alpha = 0.15$ (2); 23–27, Δ: 40 ppb < $[O_3]$ ⩽ 60 ppb, $A = 0.81$, $\alpha = 0.25$ (3); 28–29, -: 60 ppb < $[O_3]$ ⩽ 120 ppb, $A = 0.88$, $\alpha = 0.35$ (4); 30–31, × : 120 ppb < $[O_3]$ ⩽ 200 ppb, $A = 0.93$, $\alpha = 0.65$ (5).

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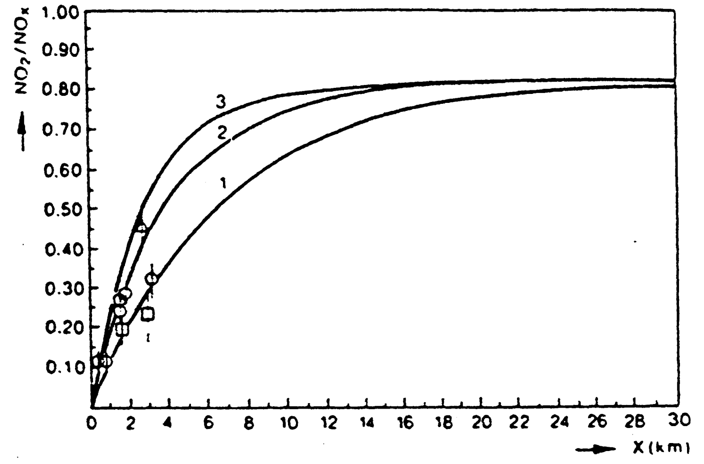

Fig. 6. NO_2/NO_x ratios measured and calculated for measuring flights in summer, showing the effect of wind speed on the oxidation rate. 40 ppb $< [O_3] \leqslant 60$ ppb; flights 32–33: $0\ m\,s^{-1} \leqslant u < 5\ m\,s^{-1}$; □, $A = 0.81$, $\alpha = 0.15$ (1); flights 23–28: $5\ m\,s^{-1} \leqslant u \leqslant 15\ m\,s^{-1}$: O, $A = 0.81$, $\alpha = 0.25$ (2); flight 34: $u > 15\ m\,s^{-1}$, Δ, $A = 0.81$, $\alpha = 0.35$ (3).

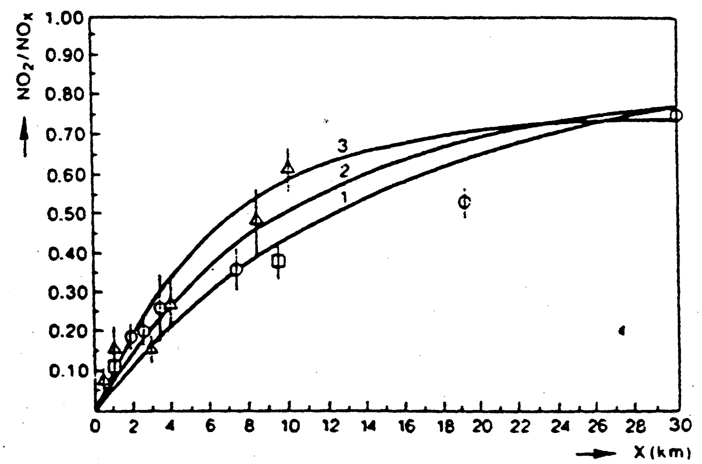

Fig. 7. NO_2/NO_x ratios measured and calculated for corresponding atmospheric conditions, e.g. O_3 concentrations 30 ppb $< [O_3] \leqslant 40$ ppb and wind speed $5\ m\,s^{-1} \leqslant u \leqslant 15\ m\,s^{-1}$ in: winter, flight 35, □, $A = 0.87$, $\alpha = 0.07$ (1); spring/autumn, flights 5–8, O, $A = 0.80$, $\alpha = 0.10$ (2); summer, flights 20–22, Δ, $A = 0.74$, $\alpha = 0.15$ (3).

O_3 concentrations during measurements (about 10 ppb).

The wind parameter α

It is assumed that the parameter α represents the effect of the wind speed on the oxidation rate in one O_3 concentration class. Tables 2–4, however, show no significant effect of wind speed on the NO oxidation rates at low O_3 concentrations. This can be explained by taking the large variations in A into account, caused by variations of O_3 background concentrations at low levels. The effect of wind speed is thus hidden by a normal variation of about 10 ppb in the background O_3. As these variations occur in outdoor air, more precise measurements of the effect of wind speed on the oxidation rate at low O_3 concentration levels are no solution.

In Tables 2–4 values for α are given, differing in discrete steps of at least $0.05\ km^{-1}$. This value proved useful in distinguishing between measurements under different meteorological conditions.

Therefore, a value $\Delta\alpha = 0.03\ km^{-1}$ has been chosen to represent variations of α within one class caused by variations in mean wind speed and other parameters which are not identified here.

Uncertainty limits were calculated using Equation

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Table 5. The variation in values for A caused by variations of the O_3 concentration and the photodissociation rate k_2

Winter (December–February)				
$[O_3]$ (ppb)	A max ($k_2 = 0.10$)	A mean ($k_2 = 0.15$)	A min ($k_2 = 0.20$)	ΔA
1–10	0.74	0.49	0.13	0.25
10–20	0.85	0.74	0.59	0.13
20–30	0.90	0.83	0.74	0.10
30–40	0.92	0.87	0.81	0.05
Spring/autumn (March–May/September–November)				
$[O_3]$	A max ($k_2 = 0.15$)	A mean ($k_2 = 0.25$)	A min ($k_2 = 0.40$)	ΔA
10–20	0.74	0.635	0.42	0.15
20–30	0.83	0.74	0.59	0.10
30–40	0.87	0.80	0.685	0.10
40–60	0.91	0.85	0.74	0.10
Summer (June–August)				
$[O_3]$	A max ($k_2 = 0.25$)	A mean ($k_2 = 0.35$)	A min ($k_2 = 0.45$)	ΔA
20–30	0.78	0.67	0.56	0.10
30–40	0.82	0.74	0.66	0.08
40–60	0.87	0.805	0.72	0.08
60–120	0.93	0.88	0.79	0.08
120–200	0.96	0.93	0.89	0.04

Because the distribution of A values is skewed, indicative values of ΔA as used in Equation (13b) are shown in the final column.

(13b) and the values for ΔA as shown in Table 5 and $\Delta\alpha = 0.03\ km^{-1}$.

Measurements of α

When using the phenomenological approach as described in this paper it is important to establish the best values for α under different meteorological conditions.

In performing measurements it is therefore useful to know at what distances from the source the maximum variations of the NO_2/NO_x ratio caused by variations of α occur.

This distance can be calculated as:

$$\frac{d[\Delta(NO_2/NO_x)]_z}{dx} = 0 \qquad (14)$$

and using Equation (13b):

$$\frac{d(xAe^{-\alpha x})}{dx} = 0 \qquad (15)$$

which leads to $x = 0$ and $\alpha x = 1$.

Therefore, maximum variations of the NO_2/NO_x ratio occur at distances of $x = 0$ and $x = 1/\alpha$ km, which for the latter means at distances between 1.5 and about 15 km from the source, depending on atmospheric conditions.

To find the best values for α it is advisable to perform measurements close to the source and at distances of about $x = 1/\alpha$ km. We observe here, however, that very close to the source ($500\ m < x < 1000\ m$) NO_2/NO_x measurements may be disturbed by the small dimensions of the plume and the large R-C times of the monitors with respect to the flight speed ($\sim 70\ m\,s^{-1}$) (Janssen, 1986). A distance of 1–2 km appeared to be most practicable.

In our model it is assumed that at a larger distance from the source ($x \gg 1/\alpha$ km) the plume is homogeneously mixed and photostationary equilibrium is established. To verify this, measurements at distances between 15 and 30 km also need to be carried out.

The above considerations have been taken into account in our present research programme, which concentrates on measurements at very high and very low wind speeds and during the night. Measurements of NO_2/NO_x ratios take place at three distances from the source, e.g. 1–2 km, $x \sim 1/\alpha$ km and 15–30 km.

DISCUSSION

Seasonal dependence of the NO *oxidation rates*

From the results of measurements and model calculations it appears that the proposed classification of NO oxidation rates can be a useful tool in predicting NO_2/NO_x ratios in the plume of a power plant.

The values calculated for α, indicating the NO oxidation rate, increase with rising O_3 concentrations, and at O_3 concentrations higher than 30 ppb

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they also increase with wind speed. Figure 7 shows the calculated NO_2/NO_x ratios for the summer, winter, spring/autumn periods at the same range of O_3 concentrations and wind speeds. It is seen that NO_2 formation develops more rapidly in summer than in spring/autumn and is slowest in winter. This may be attributed to differences in turbulence in the atmosphere, considering the differences in solar radiation of the three periods (see Table 1).

At larger distances from the source more NO_2 will be formed in winter because of the lower photodissociation rate in that season; this is also shown in Fig. 7.

Homogeneous and inhomogeneous mixing

Values for α, which are based on measurements, range with atmospheric conditions: 30 ppb $< O_3$ concentration $<$ 40 ppb and 5 m s^{-1} $<$ wind speed $<$ 15 m s^{-1} from 0.07 km^{-1} in winter to 0.15 km^{-1} in summer. These values for α may be compared with the value for α of 1.7 km^{-1} previously calculated for an O_3 concentration of 35 ppb and a wind speed of 0.01 km s^{-1}, by using Equation (5) for a perfect mixed plume. This difference of a factor of 10–20 between measured and calculated values for α can be explained by inhomogeneous mixing of a plume with ambient air.

Inhomogeneous mixing of a plume can take place at two levels, i.e. the structure of the mean concentration fields, also called 'macromixing', and the level of fine scale fluctuations that determines higher-order moments and correlations of these fields, also called 'micromixing'.

Macromixing can be described as follows: in the atmosphere, parcels of NO-rich air, i.e. diluted flue gas, and O_3-rich air, i.e. ambient air mixed into the plume, are spatially segregated. The reaction of NO with O_3 occurs only within a relatively narrow reaction zone between the two regions. Since the bimolecular reaction of NO with O_3 occurs rapidly compared to the mixing times over the scale of the plume, NO_2 formation is retarded. This process of inhomogeneous mixing of a plume was discussed by Hegg *et al.* (1976), and recently by Janssen (1986).

Micromixing plays a role in the conversion of NO into NO_2 if concentration fluctuations of NO and O_3 are correlated. If the correlation between the concentration fluctuations of NO and O_3 is negative, as is probably the case because NO and O_3 have different origins, i.e. flue gas and outdoor air, respectively, NO_2-formation in a plume may be retarded. This is discussed by Donaldson and Hilst (1972), Lamb and Shu (1978) and Builtjes (1981).

If these effects, i.e. macromixing and micromixing, play a role in the oxidation process of NO, they both cause a retardation of the oxidation rate. This causes the values for α based on measurements in the plume to be a factor of 10–20 smaller than values of α calculated in Equation (4), where perfect mixing and zero correlation between concentration fluctuations of NO and O_3 are assumed.

Application of the classification in calculating ground-level NO_2 *concentrations*

The proposed classification of NO oxidation rates can be used in calculating NO_2 concentrations at ground-level by using a Gaussian dispersion model. It is assumed that the NO oxidation rate averaged over the plume traverses also holds for that part of the plume which reaches the ground. The NO_2/NO_x ratio as a function of distance from the source can be added as a source depletion factor according to:

$$C(x,y,z;H) = Q' \exp\frac{(-\frac{1}{2}(y/\sigma_y)^2)}{2\pi u \sigma_y \sigma_z} \times \left\{ \exp\left(-\frac{1}{2}\left(\frac{H-z}{\sigma_z}\right)^2\right) + \exp\left(-\frac{1}{2}\left(\frac{H+z}{\sigma_z}\right)^2\right)\right\}$$

with the source emission factor:

$$Q' = A(1-e^{-\alpha x})Q \qquad (16)$$

Q is the NO_x emission calculated as NO_2.

This is illustrated in Fig. 8 which shows the results of NO_2 concentrations calculated in the centre of the plume at ground level ($y = 0$ and $z = 0$), by using the equation:

$$C(x\,o,o;H) = A(1-e^{-\alpha x})\frac{Q}{\pi u(\sigma_y \sigma_z)}\exp\left(-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right). \qquad (17)$$

The input data of the calculations are given in Table 6. The results show that the positions of the maximum NO_x and NO_2 concentrations are only a few hundred metres to 2 km apart at the most (case 2 in Fig. 8). This means that for practical measuring conditions the position of the NO_x maximum can be considered to be the position of the NO_2 maximum.

CONCLUSIONS

A classification of NO oxidation rates has been presented on the basis of 60 measuring flights in the plumes of power plants in the Netherlands. O_3 background concentration, wind speed and season of the year are the important parameters in determining the oxidation rate. NO oxidation rates increase with rising O_3 concentration, wind speed and solar radiation. By using the classification and assuming that the oxidation reaction with O_3 is the dominant process, the course of the NO_2/NO_x ratio as a function of distance from the source can be described by a sample power of e. With this model a great deal of the variation in NO_2/NO_x ratios measured can be accounted for, provided that allowances are made for naturally occurring variations of the O_3 background concentra-

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APPENDIX F

Summary of Responses to Objectors

F1. OBJECTIONS

OBJ1 Christine Sinnett, 9 Brinkburn Street (OBJ1)

Issue	Description	Response
Air Quality	Christine Sinnett lives within 100m of the construction area near the northern portal. Her concern is that whatever best practice methods are applied, dust would seep in through the current windows. She has asked for sealed double glazed units to be installed as mitigation.	The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period. It can be expected that for Mrs Sinnett, construction dust would have to potential to result in adverse impacts during the construction of the new tunnel portal on the northern side, although the Howdon bypass separates the construction area from the properties. Application of dust control measures will be strictly applied in such areas together with on-site monitoring to ensure that the environmental impacts from dust emissions are minimised. Dust impacts from construction are noted as soiling on surfaces. Inevitably, due to the nature of the emissions, the soiling will occur predominantly on external surfaces. The ability of dust to pass through a closed window, whether single or double glazed is minimal and the provision of sealed double glazing would not be likely to result in any significant difference in internal dust levels.

OBJ14 Mr S Yuen, 5 West Meadow Drive, SR6 7TZ

Issue	Description	Response
Air Quality	Mr Yuen lives in Sunderland. He expresses concern that the new tunnel will create congestion and this in turn will create more pollution. Mr Yuen believes that the money should be spent on making the traffic more free flowing, a toll free crossing, less restrictions and improving tunnel pollution.	Mr Yuen's property is not located near to the development and would not be directly affected by the new tunnel. The air quality impacts of the proposed new crossing are considered in Section 5 of my proof. This shows that the proposals result in changes in air quality in the area but that air quality standards and objectives will be achieved at all locations assessed. An overall assessment described in Section 6.1.13 and 6.1.14 of my proof shows that, overall, there will be an improvement in air quality as a result of the proposals.

OBJ18 Miss A M Allan, 12 Tennyson Terrace, NE29 6LW

Issue	Description	Response
Pollution	Miss Allan's objections include the suggestion that the proposals would 'increase pollution levels, further stretching NHS resources'.	Miss Allan lives in North Shields some 1.5 –2 km from the proposed northern portal and her property would not be directly affected by the proposals. The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant.

OBJ19 Lawrence Scullion, 20 The Foxhills, NE16 5UU

Issue	Description	Response
Pollution	Mr Scullion is concerned about the potential health impacts as a result of the construction of the proposed crossing particularly at his mother's property 35 Epinay Walk, this property is within a few hundred metres of the southern portal. He is particularly concerned as his mother suffers from asthma.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Changes in air quality have been predicted at properties close to the proposal. At properties further away, the changes will be smaller. Detailed air quality modelling has been carried out in 40 Epinay Walk (see table A13 in Appendix A, 40 Epinay Walk is 13m from the nearest part of the scheme whilst 35 Epinay Walk is 29m). This has shown that the predicted changes in air quality in this area are very small and the impact has been shown to be very small.

OBJ21 Celeste Hicks, 2 Carlton Terrace, TS15 9AW

Issue	Description	Response
Pollution	This objection is concerned that "people living near to the site in Howdon, Jarrow and Simonside will be affected by the increase in noise, pollution and dangerous exhaust fumes.	Changes in pollutant concentrations have been described in Section 6 of my proof. The results of this assessment show that some properties will experience an increase in pollutant concentrations although none would result in levels above air quality standards and objectives designed to protect human health. Many properties are predicted to experience a reduction in pollutant concentrations and hence an improvement in environmental conditions. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ28 A Reynard & M Bond, 162 Mowbray Road NE33 3AZ

Issue	Description	Response
Pollution	These objectors live in Mowbray Road some 3-4km from the southern portal. This objection is concerned about the potential increases in pollutant concentrations and its potential to affect children with asthma	Due to the location of their property (3/4 km from the southern portal), this would not be expected to experience any significant changes in air quality as a result of the proposals. Changes in pollutant concentrations have been described in Section 6 of my proof. The results of this assessment show that some properties will experience an increase in pollutant concentrations although none would result in levels above air quality standards and objectives designed to protect human health. Research by the Department of Health has shown that there is not believed to be a causal link between air pollution and the initiation of asthma. In terms of initiation and provocation of asthma factors other than air pollution are much more important in both respects. See Appendix I. .

OBJ86 Mrs M McVeigh, 43 Stothard Street, NE32 3AN

Issue	Description	Response
Pollution	Mrs McVeigh raises a general objection on the grounds of pollution.	Changes in pollutant concentrations have been described in Section 6 of my proof. The results of this assessment show that some properties will experience an increase in pollutant concentrations although none would result in levels above air quality standards and objectives designed to protect human health. In addition, overall atmospheric pollutant emissions are predicted to decrease as a result of the proposed tunnel.

OBJ87 John Strong, 43 Auburn Gardens NE4 0XQ

Issue	Description	Response
Pollution	Mr Strong lives several kilometres from the proposed crossing and is concerned that the proposals will result in the development of new A19 corridor with resulting increased pollution.	Changes in pollutant concentrations have been described in Section 6 of my proof. The results of this assessment show that some properties will experience an increase in pollutant concentrations although none would result in levels above air quality standards and objectives designed to protect human health. In addition, overall atmospheric pollutant emissions are predicted to decrease as a result of the proposed tunnel.

OBJ95 John Richardson, 43 Epinay Walk, NE32

Issue	Description	Response
Pollution	Mr Richardson is concerned that the proposal will result in an increase in air pollution in his house and that pollution levels could rise by 60%	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Changes in air quality have been predicted at properties close to the proposal. At properties further away, the changes will be smaller. Detailed air quality modelling has been carried out in 40 Epinay Walk (see table A13 in Appendix A). This has shown that the predicted changes in air quality in this area are very small (approximately 5%) and the impact has been to be very small.

OBJ110 J SCULLION, 35 EPINAY WALK, NE32 3BJ

Issue	Description	Response
Pollution	Mrs Scullion lives at 35 Epinay Walk close to the proposed development She is concerned that the quality of the air will diminish. Mrs Scullion is asthmatic and is concerned that windows will have to be closed to ensure her condition is not exacerbated by dust.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Changes in air quality have been predicted at properties close to the proposal. At properties further away, the changes will be smaller. Detailed air quality modelling has been carried out in 40 Epinay Walk (see table A13 in Appendix A, 40 Epinay Walk is 13m from the nearest part of the scheme whilst 35 Epinay Walk is 29m). This has shown that the predicted changes in air quality in this area are very small and the impact has been shown to be very small. Research by the Department of Health has shown that there is not believed to be a causal link between air pollution and the initiation of asthma. In terms of initiation and provocation of asthma factors other than air pollution are much more important in both respects. See Appendix I. The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. The mian impact of dust emissions would be soiling on external surfaces and windows should not have to be closed to ensure a reasonable standard of air quality. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period meaning that dust deposition rates would be expected to increase but remain below nuisance levels.

OBJ116 Tynebikes – non-statutory

Issue	Description	Response
Pollution	Tynebikes represents 130 members and their purpose is to promote cycling in and around Tyneside. They are concerned that 'extra emissions created generally as a result of increase in vehicle use would pose a significant health threat'	The effects of the scheme in terms of their effect on emissions is considered in Sections 6.1.15 and 6.1.16 of my proof. This shows that the overall effects of the scheme are a small reduction in pollutant emissions.

OBJ168 Mr Keith Brittan, 36 Epinay Walk, NE32 3BL

Issue	Description	Response
Pollution	Mr Brittan lives in Epinay Walk within a few hundred metres of the southern portal and within tens of metres of construction works. He is concerned that the proposals will 'increase road accident and pollution levels, further stretching NHS resources'. He is also concerned about the impact of air pollution on children, particularly on asthma. He believes that building work within 12/15 metres of his front door will subject him to pollution.	Changes in air quality have been predicted at properties close to the proposal. At properties further away, the changes will be smaller. Detailed air quality modelling has been carried out in 40 Epinay Walk (see table A13 in Appendix A, 40 Epinay Walk is 13m from the nearest part of the scheme whilst 36 Epinay Walk is 20m). This has shown that the predicted changes in air quality in this area are very small (about 5%) and the impact has been shown to be very small. Research by the Department of Health has shown that there is not believed to be a causal link between air pollution and the initiation of asthma. In terms of initiation and provocation of asthma factors other than air pollution are much more important in both respects. See Appendix I. The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period during the construction period meaning that dust deposition rates would be expected to increase but remain below nuisance levels. .

OBJ206 B PAGET, 18 WEST AVENUE, SOUTH SHIELDS, NE34 6QU

Issue	Description	Response
Pollution	Mr Paget is concerned about increasing pollution levels and that NHS resources maybe stretched.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. The overall impact of the proposed scheme is predicted to be a small reduction in emissions of air pollutants.

OBJ328 Mrs E Winch, 81 North Drive, Hebburn, NE31 1EW

Issue	Description	Response
Pollution	Mrs Winch is concerned about increasing pollution levels and that NHS resources maybe stretched.	See response to Objection 206 Mr Paget

OBJ185/OBJ348 Teeside Green Party

Issue	Description	Response
Pollution	Teeside Green Party are concerned that the proposed tunnel will increase traffic – and associated pollution and accidents	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. The overall impact of the proposed scheme is predicted to be a small reduction in emissions of air pollutants.

OBJ358 John d'Egville Turvey, 13 Beckenham Avenue, NE36 0EH

Issue	Description	Response
Pollution	This objector is concerned about the health issues from increased pollution. He also believe that the proposals are contrary to Government policy to reduce carbon dioxide emissions.	The effects of the scheme in terms of their effect on global emissions is considered in Sections 6.1.15 and 6.1.16 of my proof. This shows that the overall effects of the scheme are a small reduction in pollutant emissions The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant.

OBJ382 TYNE CROSSINGS ALLIANCE

Objection	Description	Response
Pollution	The Tyne Crossing Alliance argues that the air quality in the locality is already poor and creating major health problems. They are concerned that local residents will not benefit fully from the improvements in vehicle emissions anticipated.	The existing air quality in the area is described in Section 3 of my proof. This section describes the results of an extensive air quality monitoring survey undertaken for this project and the results from other monitoring sites in the area. There is no evidence from these monitoring results that residents are exposed to poor air quality and there is no evidence that air quality in the area is creating a local 'major health problem'. The results of the modelling undertaken are given in Appendix A of the proof. If the results of the DMRB screening assessment are examined, these show that in all cases, future air quality with or without the scheme will be better than existing levels. This is because emission from motor vehicles will decrease in the future as a result of more stringent emission controls. The impact of the scheme proposals can be determined by comparing the predicted concentrations in the future for the situation with the proposed tunnel against the Do Nothing situation. Compared to the do minimum scenario some properties are expected to experience higher concentrations whilst others, a reduction (However, no property is predicted to experience an exceedance of air quality standards or objectives intended to protect human health.

OBJ384 St Paul's Area Residents Association ('SPARA')

Issue	Description	Response
Pollution	The residents association are concerned that a large number of residents in Jarrow already suffer from asthma and that additional vehicles will worsen this problem. They are also concerned about dust during construction.	Research by the Department of Health has shown that there is not believed to be a causal link between air pollution and the initiation of asthma. In terms of initiation and provocation of asthma factors other than air pollution are much more important in both respects. See Appendix I.

		The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ396 NECTAR

Issue	Description	Response
Pollution	NECTAR suggest that the proposal will result in major airborne, sea and land pollution during construction and that it is unacceptable for harmful dust and exhaust emission to be imposed on the communities around the Tyne.	The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period. There will be no significant dust emissions during operation. The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ397 Jarrow Residents Action Group

Issue	Description	Response
Pollution	The Jarrow residents group are concerned that the proposed tunnel 'will cause further pollution'	The results of the air quality assessment described in Section 6 of my proof consider the changes in pollutant levels in the area. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ414 James D Curry, 75 Crowhall Towers, NE10 0NG

Issue	Description	Response
Pollution	Mr Curry is concerned that the roads in the area are already congested polluted and dangerous and that a new tunnel will worsen the affects considerably.	The existing air quality in the area is described in Section 3 of my proof. This section describes the results of an extensive air quality monitoring survey undertaken for this project and the results from other monitoring sites in the area. There is no evidence from these monitoring results that residents are exposed to poor air quality. The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ418 Mrs M Milburn, 57 Beaconside

Issue	Description	Response
Pollution	Mrs Milburn is particularly concerned about the impact of the scheme on her mother who lives in 35 Epinay Walk, Jarrow (see Objection 19). Her mother is asthmatic and Mrs Milburn is concerned that her health will deteriorate if the proposed scheme is implemented. She is concerned that the concentration of roads in one small area will cause greater pollution and will be more damaging to the health of local inhabitants.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Changes in air quality have been predicted at properties close to the proposal. At properties further away, the changes will be smaller. Detailed air quality modelling has been carried out in 40 Epinay Walk (see table A13 in Appendix A, 40 Epinay Walk is 13m from the nearest part of the scheme whilst 35 Epinay Walk is 29m). This has shown that the predicted changes in air quality in this area are very small (about 5%) and the impact has been shown to be very small.

OBJ518 Railway Development Society

Issue	Description	Response
Pollution	The Railway Development Society are concerned that the proposal will generate harmful dust and exhaust emission that will be imposed on the local community. In addition, the extra traffic generated would bring with it air pollution from which local residents would suffer.	The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period. There will be no significant dust emissions during operation. The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

OBJ600 Friends of the Earth

Issue	Description	Response
Geographical Scope too small	Assessment of noise, AQ, severance and safety on routes remote to the scheme e.g. A193, Tynemouth Road, Wallsend Road should be carried out.	Outside the study area of the New Tyne Crossing the impact on air quality was assessed on the A19 corridor, where changes in traffic flows were predicted to be greater than 10%. It was assumed that the impact at properties away from the A19 would be less than the impact at receptors along the A19. No exceedance of air quality standards or objectives were identified in the air quality assessment.

OBJ606 Gareth Ayres, 1 Marden Crescent

Issue	Description	Response
Pollution	Mr Ayres is concerned that the building of more roads will result in more vehicles and hence more pollution.	The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. The effects of the scheme in terms of their effect on global emissions is considered in Sections 6.1.15 and 6.1.16 of my proof. This shows that the overall effects of the scheme are a small reduction in pollutant emissions

F2. RESPONSE TO STATEMENTS OF CASE

Statement of Case 4 – Linda Lambert, 44 Epinay Walk NE 32 3BL —— 58
Statement of Case 5 – Chris Packham, 4 Beaufort Gardens, NE8 3PY
Statement of Case 6 – Alan Careless, 38 Epinay Walk, NE32 3BL —— 390
Statement of Case 7 – William Wilson, 45 Epinay Walk, NE32 3BL —— 100
Statement of Case 10 – Doreen Wilson, 45 Epinay Walk, NE32 3BL
Statement of Case 28 – Brian Atkinson, 98 Broughton Road, NE33 2RS — 372
Statement of Case 32 – Mrs Hassan, 10 Ravel Court, NE32 3BW — 438
Statement of Case 33 – P A Walsh, & Seine Court, NE32 3BP

Issue	Description	Response
Pollution	These objectors have sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives. The air quality standards and objectives have been developed in the UK based on the known health effects of each pollutant. The standards are set at a level where there is either no known health impact or one that could not be discerned in the community. Therefore, there are not expected to be any discernible impact on human health. Indeed, due to the improvements in vehicle emission controls, pollutant concentrations will be lower than at present, even with the scheme. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

F2. RESPONSE TO STATEMENTS OF CASE

Statement of Case 3 - Miss A M Allan, 12 Tennyson Terrace, NE 29 6LW

Issue	Description	Response
Pollution	Miss Allan is concerned about the increase in traffic volume and a subsequent increase in air pollution that will put a strain on the NHS.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 4 – Linda Lambert, 44 Epinay Walk NE 32 3BL

Issue	Description	Response
Pollution	Linda Lambert has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 5 – Chris Packham, 4 Beaufort Gardens, NE8 3PY

Issue	Description	Response
Pollution	Mr Packham has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 6 – Alan Careless, 38 Epinay Walk, NE32 3BL

Issue	Description	Response
Pollution	Mr Careless has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

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Statement of Case 7 – William Wilson, 45 Epinay Walk, NE32 3BL

Issue	Description	Response
Pollution	Mr Wilson has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 10 – Doreen Wilson, 45 Epinay Walk, NE32 3BL

Issue	Description	Response
Pollution	Mr Wilson has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 11 – Eileen Winch, NE31 1EW

Issue	Description	Response
Pollution	Eileen Winch is concerned about the increase in road traffic exacerbating pollution levels with resulting adverse health impacts	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 12 – NECTAR

Issue	Description	Response
Pollution	NECTAR make a general objection of the grounds of air pollution during construction and operation	The potential for dust impacts during construction is discussed in Section 4 of my proof. This section identifies the potential construction activities and suitable mitigation techniques to minimise the dust emissions. With the application of these techniques, the potential impacts of dust have been identified as **minor adverse** during the construction period. There will be no significant dust emissions during operation. The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 15 – North East of England Green Party

Issue	Description	Response
Pollution	This is a general objection on the grounds of air pollution.	The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 25 – Brian Paget, 18 West Avenue NE34 6QU

Issue	Description	Response
Pollution	Mr Paget is concerned that the health effects of the additional extra pollution brought by the extra vehicles have .not been fully explored in the public domain.	The air quality assessment presented in the Environmental Statement is based on the prediction of future air pollutant concentrations and comparing these with air quality standards and objectives. The air quality standards and objectives have been developed in the UK based on the known health effects of each pollutant. The standards are set at a level where there is either no known health impact or one that could not be discerned in the community. Therefore, they are health based standards set to protect public health. The results of the assessment described in Section 6 and Appendix A of my proof demonstrate that no air quality standard or objective is expected to be exceeded and therefore health impacts are not expected to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 28 – Brian Atkinson, 98 Broughton Road, NE33 2RS

Issue	Description	Response
Pollution	Mr Atkinson has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'.	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Changes in air quality have been predicted at properties close to the proposal. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 29 – Joanne Kirby 41 Epinay Walk

Issue	Description	Response
Pollution	This is a general objection on the grounds of air pollution.	The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 32 – Mrs Hassan, 10 Ravel Court, NE32 3BW

Issue	Description	Response
Pollution	Mrs Hassan has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case 33 – P A Walsh, & Seine Court, NE32 3BP

Issue	Description	Response
Pollution	P Walsh has sent a pro forma objection letter that includes the concern regarding 'the environmental and social impact of the proposed tunnel, including .... air pollution'	The results of the air quality assessment described in Section 6 of my proof show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health, therefore health impacts are not predicted to be significant. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

Statement of Case - Tynebikes

Issue	Description	Response
Pollution	Tynebikes have made an objection of the ground that the proposed tunnel would create extra emissions concentrated locally that would have detrimental health impacts which have not been addressed fully	The air quality assessment presented in the Environmental Statement is based on the prediction of future air pollutant concentrations and comparing these with air quality standards and objectives. The air quality standards and objectives have been developed in the UK based on the known health effects of each pollutant. The standards are set at a level where there is either no known health impact or one that could not be discerned in the community. Therefore, they are health based standards set to protect public health. The results of the assessment described in Section 6 and Appendix A of my proof demonstrate that no air quality standard or objective is expected to be exceeded and therefore health impacts are not expected to be significant.

Statement of Case - St Paul's Area Residents Association

Issue	Description	Response
Pollution	The residents association is concerned that the proposals will worsen an existing problem with asthma in the area. They are also concerned about dust during construction.	The air quality assessment presented in the Environmental Statement is based on the prediction of future air pollutant concentrations and comparing these with air quality standards and objectives. The air quality standards and objectives have been developed in the UK based on the known health effects of each pollutant. The standards are set at a level where there is either no known health impact or one that could not be discerned in the community. Therefore, they are health based standards set to protect public health. The results of the assessment described in Section 6 and Appendix A of my proof demonstrate that no air quality standard or objective is expected to be exceeded and therefore health impacts are not expected to be significant. Research by the Department of Health has shown that there is not believed to be a causal link between air pollution and the initiation of asthma. In terms of initiation and provocation of asthma factors other than air pollution are much more important in both respects. See Appendix I.

Statement of Case – E Maguire, 42 Epinay Walk

Issue	Description	Response
Pollution	This is a general objection on the grounds of air pollution.	The results of the air quality assessment described in Section 6 of my proof assess the impact of the exhaust emission. These results show that none of the properties assessed are predicted to result in an exceedance of air quality standards and objectives designed to protect human health. Overall the scheme is predicted to result in a small overall reduction in pollutant emissions.

APPENDIX G

Details of the Derwent Middleton Method

REPORTS

An Empirical Function for the Ratio NO_2:NO_x

R.G. Derwent and D.R. Middleton
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Meteorological Office

This article describes the use of a simple empirical function for the ratio of NO_2 to NO_x. By way of example the procedure as it applies to a simple dispersion model, a box model, which assumes a balance between the rate of pollutant emission and its rate of removal by the wind from the edge of the city is considered.

Introduction

Air quality forecasts are issued every day as part of the Air Quality Bulletin System on behalf of the Air and Environmental Quality Division of the Department of the Environment. The likely concentrations of pollution are calculated a day in advance at the Met Office. They are then sent to NETCEN AEA Technology to be evaluated in the light of monitoring experience and banded into recognised categories. The bandings, such as "Poor" when the hourly mean concentration of nitrogen dioxide is expected in the range 100 to 299 ppb, describe the likely air quality in a shorthand form suitable for use in the media.

Air quality standards are expressed in terms of nitrogen dioxide (NO_2) because it is more closely related to perceived health effects than the total oxides of nitrogen (NO_x). The relative amounts of nitric oxide (NO) and nitrogen dioxide (NO_2) may vary, but their sum $NO_x = NO + NO_2$ is assumed to be conserved. In an urban area the NO_x may be diluted, but not lost from the system; i.e. dry deposition by adsorption to the ground or wet deposition in precipitation are slow and can be neglected when forecasting local NO_x. Air quality forecasts therefore calculate the concentrations of NO_x from which the concentrations of NO_2 must be derived.

Starting with Oxides of Nitrogen (NO_x)

Emissions of NO_x are expressed in their equivalent mass of NO_2 as if all the oxides of nitrogen are in the form of NO_2 (kilotonnes) per unit area (e.g. per 10 km by 10 km Ordnance Survey grid square) per unit time (e.g. per year). In the box model the units for the emissions rate Q are converted to obtain q expressed as $\mu g\ m^{-2}\ s^{-1}$ where $q = 3.171 \times 10^{-4}$ Q. For a slice of the city area that is d m wide across wind, and which extends x m downwind (this may be the size of the city), the NO_x emissions will be obtained as qxd $\mu g\ NO_2\ m^{-2}\ s^{-1}$. From Figure 1, vertical mixing is from the ground up to a height h m, the wind speed is u m s^{-1}, and as before, d m is the cross-wind width of the slice of the city being modelled. The volume of atmosphere into which this emission is mixed per unit time is given by hud. The dilution volume depends on meteorological conditions through h and u. Note that d could be just 1 m, but its value is immaterial because d vanishes in the arithmetic; it is present whilst deriving the box formula for the purposes of keeping the dimensions consistent. We write the concentration of NO_x as c $\mu g\ m^{-3}$. The rate at which the mass of NO_x is removed from the city by the wind is $hudc$, and this equals the rate of emission from the same slice, namely qxd. Setting the rates equal, cancelling the common factor d, and rearranging gives the simple box formula

$$c = (q\,x)/(hu)$$

A conversion factor X is used to convert the units of concentration c from $\mu g\ m^{-3}$ into ppb. The reader will note that just as we expressed emissions data for NO_x in terms of mass of NO_2, so we must invoke the molecular weight of NO_2 when converting the NO_x concentration into ppb. The conversion depends on the molecular weight W of the compound and the absolute temperature T_0 and pressure p:

$$X = 22.41 \times 1013.25 \times T_0/(273.15 \times p \times W)$$

Then $X = 0.487$ for NO_2 where $W = 46$ kg kmole^{-1}, temperature $T_0 = 273.15$ K, and pressure $p = 1013.25$ mbar. QUARG (1993) has a convenient table of values for X and its inverse $1/X$. Once the NO_x concentration $X\,c$ is found in ppb, we can use the following empirical function for the ratio of NO_2 to NO_x.

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Estimating Nitrogen Dioxide (NO_2)

Let hourly mean concentration be denoted by square brackets. Concentrations [NO], [NO_2] and [NO_x] were measured by M Goldstone and J Lester of Imperial College, from 20/5/1991 to 30/6/1992, and analysed in Derwent et al (1995). The following expression has been fitted to these data, see Figure 2. Concentrations in Equations 3 to 6 are in ppb. The function gives [NO_2] according to:

$$[NO_2] = 2.166 - [NO_x] (1.236 - 3.348 A_{10} + 1.933 A^2_{10} - 0.326 A^3_{10})$$

where

$$A_{10} = \log_{10}([NO_x])$$

Then the ratio R is

$$R = [NO_2] / [NO_x]$$

By definition of NO_x as total oxides of nitrogen, we have:

$$[NO] = [NO_x]-[NO_2]$$

Tests showed that the function applies in the range 9.0 ppb to 1141.5 ppb of NO_x and the following restrictions apply:

1. Below 9.0 ppb of NO_x, the ratio R is limited to 0.723. This avoids spurious negative values which the above polynomial will generate when near to the origin. It represents most of the NO having been oxidised to NO_2 after large dilution and significant reaction have occurred.
2. Above 1141.5 ppb of NO_x, the ratio R is limited to 0.25. This is the region which spans three orders of magnitude, extending to high concentrations characteristic of tailpipe concentrations. The shape of the curve in this region is open to debate, for there are few data here. The forecast NO_x concentrations are usually in the range 10 ppb to 1500 ppb, so R ranges from 0.73 to 0.25 respectively; the smallest value of R in this range is R = 0.1327 at [NO_x] between 470 ppb and 486 ppb.

This function is used to subdivide the forecasts for [NO_x] into [NO_2] and [NO]. The non-linear character of the function means that it is important for the [NO_x] to be correct if the [NO] and [NO_2] are to be reasonably accurate.

A Nomogram for the NO_x System

The function appears in Figure 3. Concentrations of NO_2 were plotted vertically (top of Figure 3) against those of NO_x horizontally. Subtracting NO_2 from NO_x, the concentration of NO was plotted downwards (bottom of Figure 3). At any NO_x concentration, the amounts of NO_2 and NO can be read from the curves. If we consider an imaginary parcel of air containing oxides of nitrogen, two processes can alter the concentrations in the parcel:

1. The mixture may be diluted, without chemical reaction, in which case the NO_2 and the NO concentrations must remain in constant proportion to each other and to the total NO_x. This would give us a straight line from the starting NO_2 concentration to the origin (i.e. constant [NO_2]:[NO_x]), and a straight line from the starting NO concentration which would also pass through the origin (i.e. constant [NO]:[NO_x]). If parts of such a plot for a parcel containing these gases are straight lines for NO_2 and NO passing through the origin, then the dominant process is just dilution.
2. If chemical reaction takes place, it alters the relative proportions of NO_2 and NO in the parcel. Then the parts of the plot where this occurs will not point to the origin, but will be curved; to change from one line with a particular slope through the origin to another requires chemical reaction i.e. only reaction can vary [NO_2]:[NO_x] and [NO]:[NO_x]. The curved nature of the lines in the nomogram reflect the role of chemistry in changing the yield of NO_2 as the mixture is diluted.

This diagram was constructed from pollution measurements taken throughout the year at a fixed monitor, and shows the behaviour of many air parcels. A special experiment might be imagined to follow the curves for a single parcel. Such a Lagrangian measurement is difficult in practice though as it requires chemical analyses at positions along the many turbulent paths of the mixture. Nevertheless in the absence of other information these curves give a useful and quick guide to the behaviour of the NO_x system in an urban atmosphere over a range of meteorological conditions.

Summary

In forecasting air quality, it is necessary to start from the rate of mass emissions of NO_x (expressed as NO_2), to apply a dispersion model (we used a box model for illustration), and then to convert the mass based concentration of NO_x from $\mu g\ m^{-3}$ to a volume based concentration in ppb. An empirical function then estimates the concentration of NO_2 (ppb) from the value for NO_x (ppb). Similar considerations apply in environmental impact assessments, especially near roads where NO_x and NO concentrations may be high but NO_2 production is restricted by the depletion of O_3. Middleton (1996) has applied the function to NO_2 near roads showing the importance of including background NO_x before reviewing NO_2 impacts in urban areas.

Acknowledgement

This note describes work that was funded by the Department of the Environment, Air and Environment Quality Division under DOE Contract Number EPG 1/3/06. We are grateful for the encouragement and support received during the work.

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Figure 1: Diagram of a Box Model

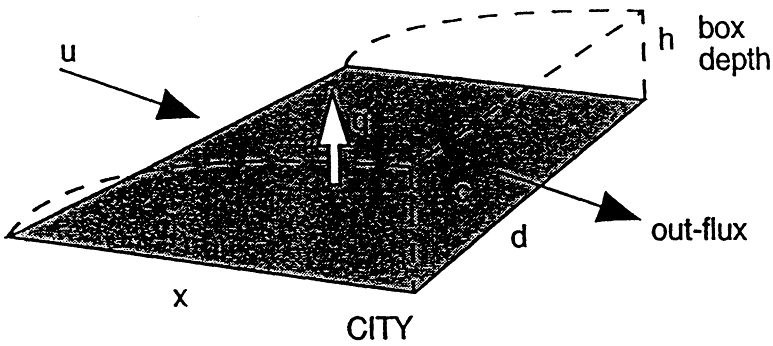

Figure 2: Curve fit to the measurements of the average hourly mean concentration of NO_2 observed for each hourly mean concentration of NO_x in Exhibition Road, London, for the period 1991-2. Concentrations are hourly averages in ppb.

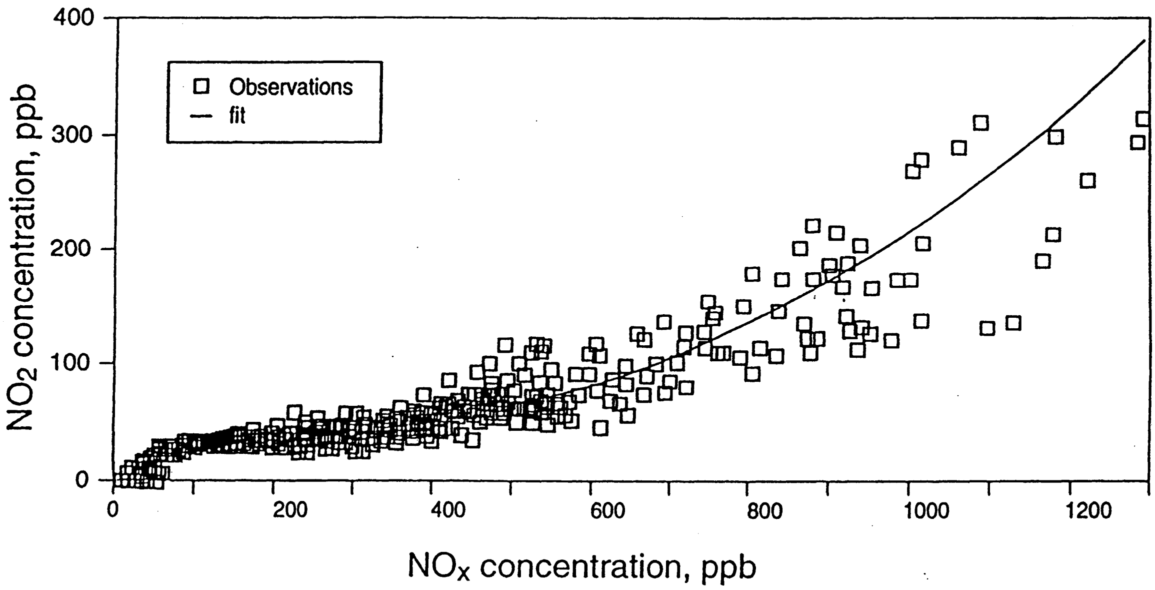

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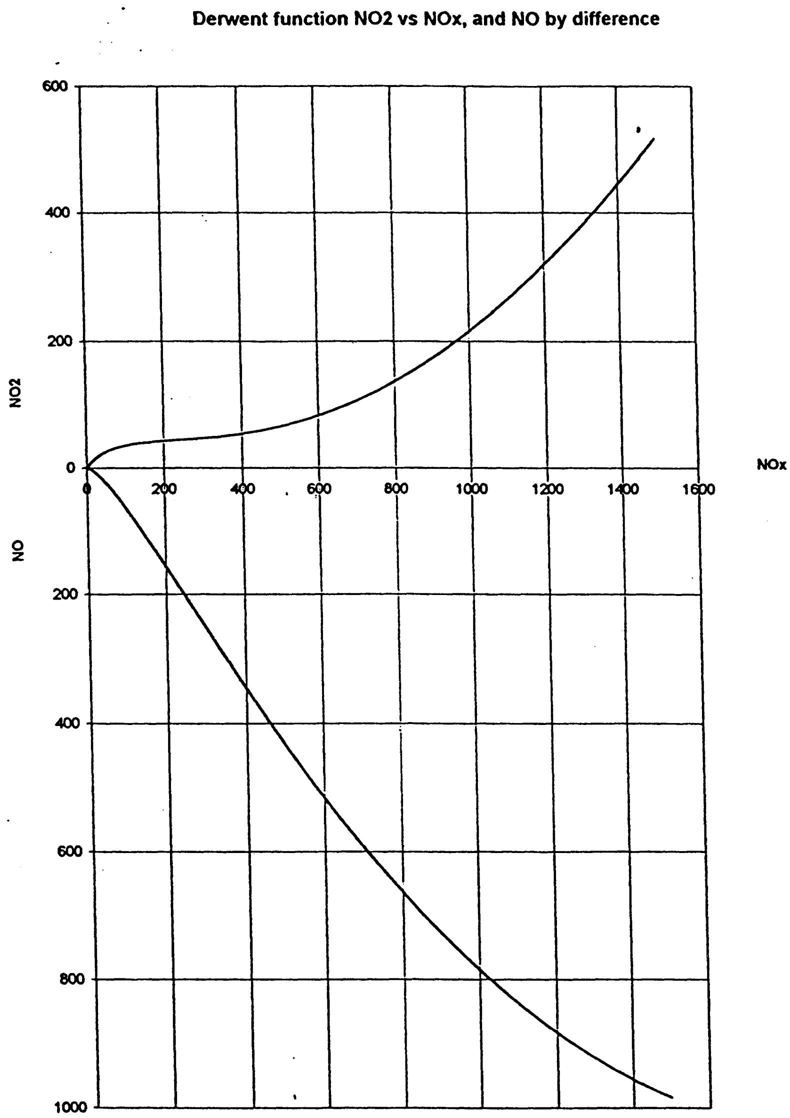
Figure 3: A nomogram for the contributions of NO_2 and NO to total NO_x in an urban atmosphere; concentrations are hourly mean values in ppb. The top curve indicates the likely maximum hourly mean nitrogen dioxide concentration that is expected; the lower curve shows the likely corresponding nitric oxide concentration.



CORRECTION
Clean Air, Vol. 26, No. 2, Summer 1996, page 28:
Please note that the EPAQS recommended standard for carbon monoxide is 10 ppm (and not 10 ppb, as printed).

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APPENDIX H

Extract from the DMRB

A1.5 As a supplement to this local assessment a more generalised appraisal is also required, whereby the local air pollution impact is evaluated and quantified, with reference to distance bands along the corridor of the proposed project. This procedure forces the completion of an effects table, which would subsequently be available for inclusion within a multi-impact assessment and proposal appraisal procedure. The following steps are required to be taken to produce these quantified results:

i. An assessment of the roadside levels of PM_{10} and NO_2, for all affected routes, should be calculated in accordance to the procedure in Section A1.3. This assessment should be carried out for the year 2005, or the project opening year if that occurs after this date, for the do minimum and the proposed scenarios.

ii. For each affected route, calculate the difference in roadside PM_{10} and NO_2 levels between the do minimum and with proposal scenarios. A positive value should be assigned where an increase in concentration has been identified due to the proposal, and a negative value for a decrease in concentration.

iii. For each affected route, the properties should be 'banded', and the number of properties within each band recorded. Four distance bands, up to 200 m from the roadside are specified, as given in Section 7.3. The splits which the bands define closely relate to the diminishing contribution that vehicle emissions make to the local air quality. Beyond 200 m, the contribution of vehicle emissions from the roadside to the local pollution levels is not significant.

iv. To determine the entries for the air quality appraisal summary table, the affected routes should be divided into two groups: those where air quality would be improved (negative results); and those where it would be worse (positive values). The number of properties affected in each group should be calculated by summing over four bands (to give a total number of properties within 200 m of the roadside), then aggregated over all affected routes in the group.

v. These property bands are further subject to a weighting, calculated through the use of the factors in Table A1.3. This weighting compensates for the reduction in pollutant concentration with distance from the road. The total number of 'weighted' properties for each affected route and pollutant, should be recorded.

Table A1.3 Pollutant weightings

Bands	PM_{10}	NO_2
Roadside to 50 m from roadside	1.00	1.00
50 m to 100 m from roadside	0.65	0.80
100 m to 150 m from roadside	0.55	0.65
150 m to 200 m from roadside	0.50	0.55

vi. For each affected route the following values are to be calculated. These values should be calculated for 2005, or the project opening year where that occurs later than 2005:

- (Difference in PM_{10} on the route) x (number of weighted properties on route)
- (Difference in NO_2 on the route) x (number of weighted properties on route)

The PM_{10} and NO_2 assessment value may subsequently be calculated by the aggregation of these values across all affected routes, separately for each pollutant.

A1.6 This quantative assessment procedure, may be supported by a qualitative comment. In particular, a qualitative comment must be provided if either of the following situations applies:

- the proposed project leads to an increase in PM_{10} levels of at least 2 $\mu g/m^3$;
- the proposed project leads to an increase in NO_2 levels of at least 2 ppb and where the road with the proposal is above the NAQS NO_2 objective of 21 ppb.

A1.7 An example of this local air quality assessment methodology and an effects table are provided in Annex 3.

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APPENDIX I

Extract from DoH Report

DEPARTMENT OF HEALTH

Committee on the Medical Effects of Air Pollutants

ASTHMA AND OUTDOOR AIR POLLUTION

Chairman: Professor S T Holgate

Chairman of the Sub-Group on Asthma and Outdoor Air Pollution: Professor H R Anderson

London: HMSO

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10.24 Prevalence studies clearly indicate that indoor sources of pollution, especially tobacco smoke, are significant factors in wheezing illness, particularly in children. It is not clear whether indoor exposure affects mainly the initiation or provocation of asthma. Where indoor air pollution has been taken into account, its influence has usually been greater than outdoor air pollution.

[Chapter 9]

Is the prevalence of asthma higher in urban than in rural environments?

10.25 There is little evidence of variation of asthma prevalence or mortality by degrees of urbanisation whether in urban populations exposed to old or new patterns of pollution.

[Chapter 9]

10.26 Migrants from underdeveloped to developed environments have been found to have increased asthma or bronchial hyperresponsiveness. This could be explained by exposure to elements of western lifestyle, urban air pollution being only one of several possible factors.

[Chapter 9]

Is the prevalence of asthma related to exposure to traffic?

10.27 In most of the few studies so far published, there is a consistent, though modest, association between exposure to traffic and asthma prevalence in children. Assuming that this association is real (and not due to reporting bias, for example) it is unclear whether this is due to an increase in the initiation or provocation of asthma. Air pollution is a plausible explanation though socio-economic and other environmental factors could also play important roles.

[Chapter 9]

Are variations in prevalence within the united Germany consistent with an adverse effect of the "new" pollution on asthma and allergic disease?

10.28 Studies comparing former East and West Germany provide an opportunity to examine cross-sectionally the effects of old and new patterns of pollution within genetically similar populations. Most studies were, however, done after there had already been a major fall in pollution in Eastern Europe.

[Chapter 9]

10.29 Generally, lower levels of skin test allergy have been found in the former East Germany than in the former West Germany. Total IgE concentrations in blood are, in contrast, higher in the East. Bronchitis seems more common and asthma less common in the East. There is no difference in the levels of bronchial hyperresponsiveness. The role of air pollution in explaining these phenomena is uncertain.

[Chapter 9]

Conclusions

10.30 As regards initiation of asthma most of the available evidence does not support an effect of non-biological air pollution.

10.31 As regards worsening of symptoms or provocation of asthmatic attacks, most asthmatic patients are unaffected by exposure to such levels of non-biological air pollution as commonly occurs in the UK. A small number of patients experience clinically significant effects which occasionally require an increase in medication or attention by a doctor.

10.32 Factors other than air pollution are influential with regard to the initiation and provocation of asthma and are much more important than air pollution in both respects.

10.33 Asthma has increased in the UK over the past thirty years but this is unlikely to be the result of changes in air pollution.