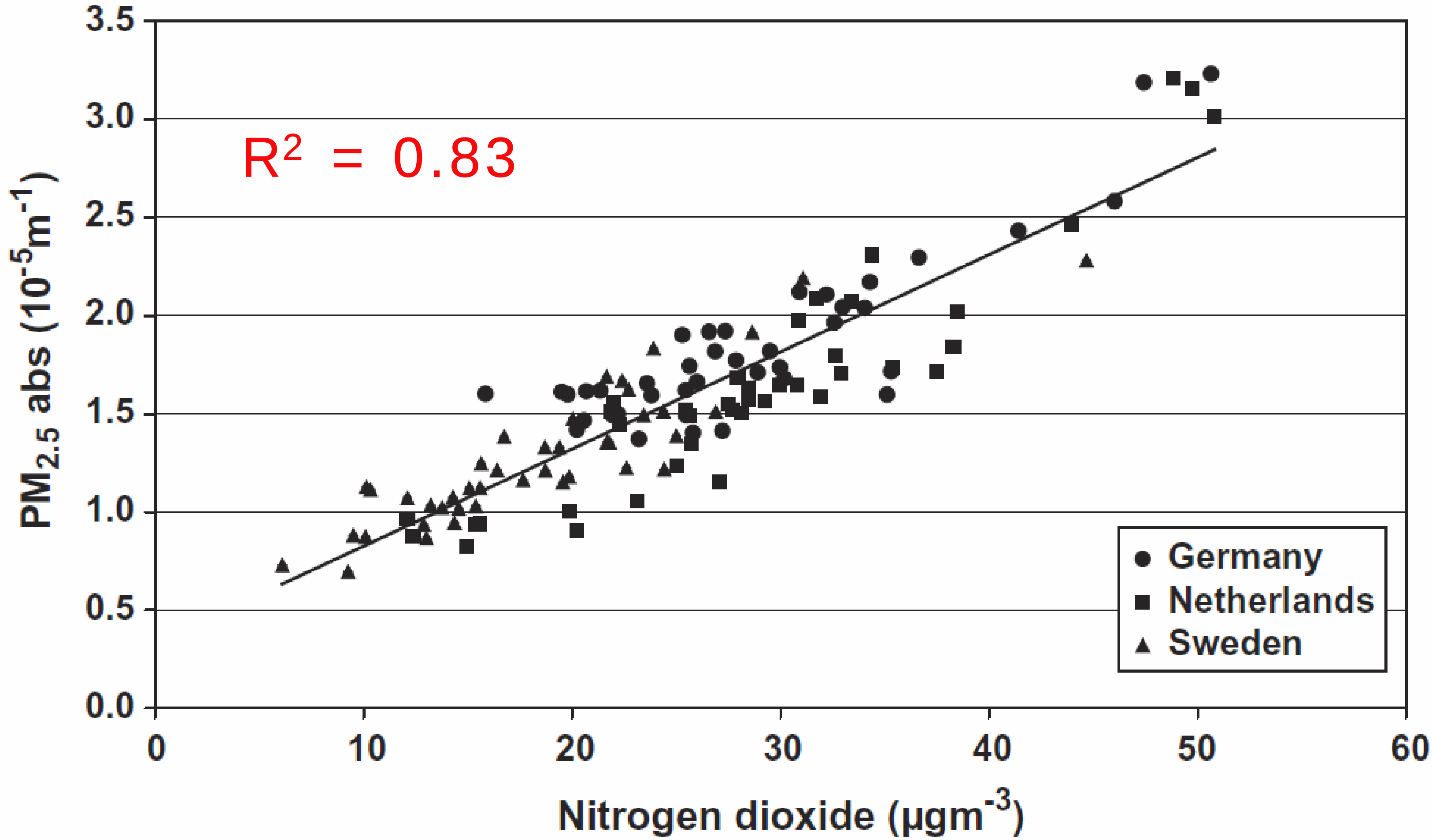
Key NO2 issues
Bert Brunekreef, PhD

- The changing air pollution mix
- How bad is NO2 all by itself?
- How good as representing an outdoor mixture?
- What about the indoor studies?
- Air Quality Standards for NO_2

M. Lewné et al. / Science of the Total Environment 332 (2004) 217–230



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E S C A P E

European Study of Cohorts for Air Pollution Effects

2008 - 2012

SEVENTH FRAMEWORK PROGRAMME

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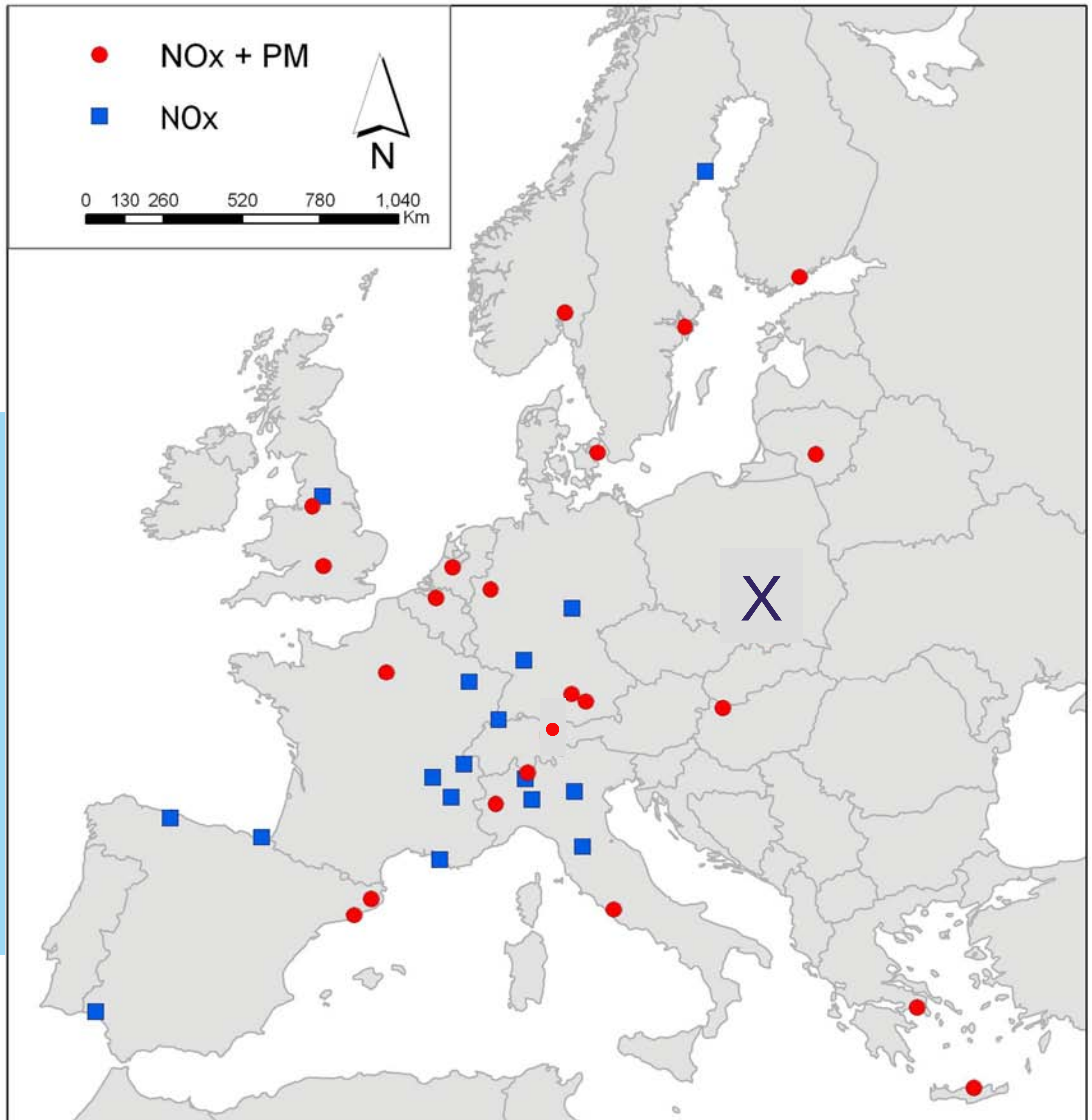
ESCAPE study areas



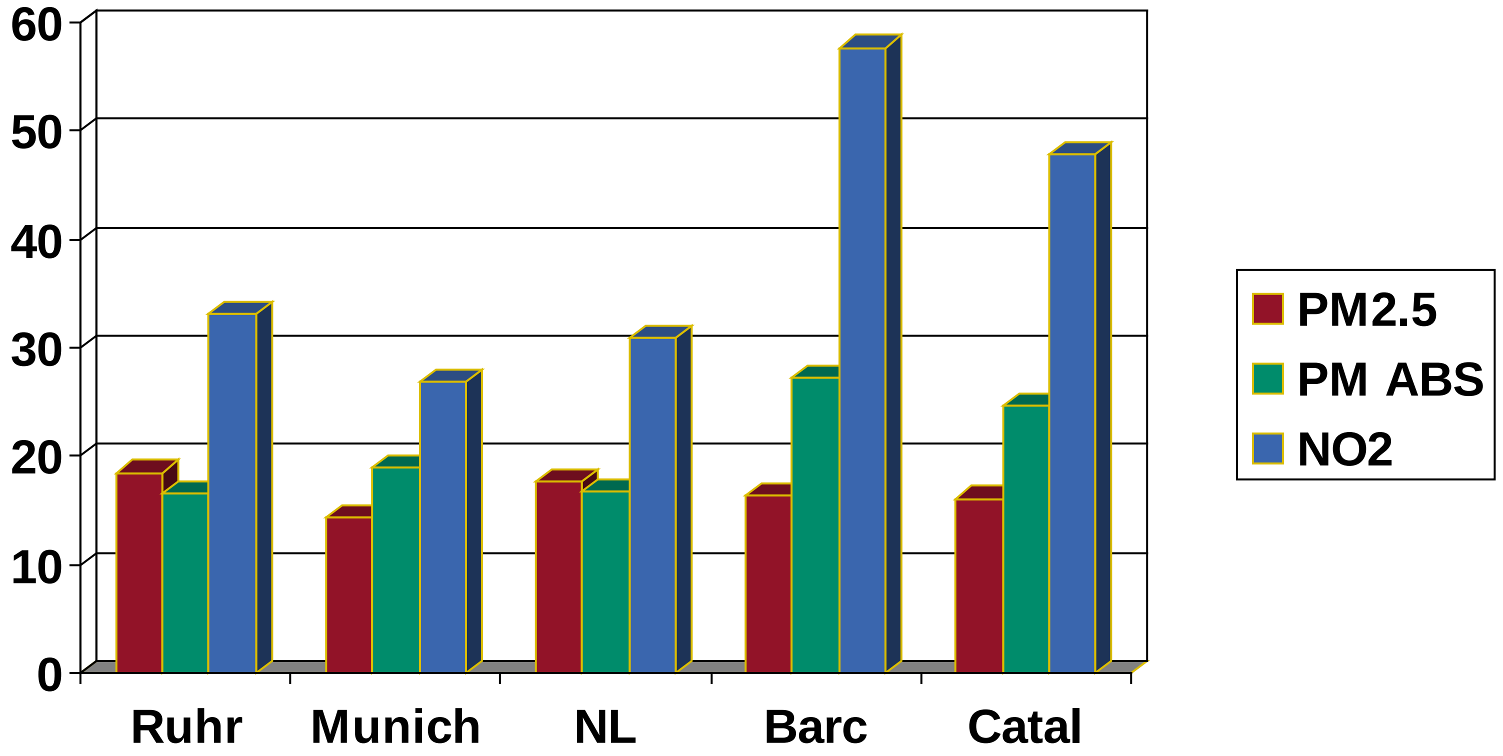
ESCAPE

- ~ 30 existing cohorts
- Birth and pregnancy outcomes
- Respiratory morbidity
- Cardiovascular morbidity
- Cancer & mortality
- PM2.5 & NOx monitoring & modeling in ~ 40 EU areas

Exposure modeling

- PM: 20 sites/area, 3 * 2 weeks hot/cold/intermediate seasons
- NOx: 40 sites/area, same frequency
- Continuous one background site 1 yr/area
- PM2.5 & PM10
- PM2.5 elements XRF, reflectance
- Filters stored for future analyses (PAHs, EC/OC, Oxidative stress markers, …..)
- LUR modeling with local GIS data
- Dispersion model output where available

ESCAPE: annual mean PM2.5, ABS (*10), NO_2



ESCAPE Pearson R^2 annual mean NO_2 with PM2.5 and PM2.5 Abs

	NO2 - PM2.5	NO2 – PM2.5 abs
Catalunya (N = 40)	0.73	0.90
Munich (N = 20)	0.29	0.86
Ruhr area (N = 20)	0.69	0.89
The Netherlands/Belgium (N = 40)	0.56	0.86

Prospective Study of Air Pollution and Bronchitic Symptoms in Children with Asthma

Rob McConnell, Kiros Berhane, Frank Gilliland, Jassy Molitor, Duncan Thomas, Fred Lurmann, Edward Avol, W. James Gauderman, and John M. Peters

TABLE 5. TWO-POLLUTANT MODELS OF WITHIN-COMMUNITY EFFECTS (DIFFERENCE BETWEEN ANNUAL AIR POLLUTANT CONCENTRATION AND 4-YEAR AVERAGE CONCENTRATIONS; n = 48) AMONG CHILDREN WITH ASTHMA

	Adjustment Pollutants								
Main Pollutant	NO_2	O_3	PM_{10}	$PM_{2.5}$	$PM_{10-2.5}$	Inorganic Acid	Organic Acid	EC	OC
NO_2	0.071*	0.057	0.065†	0.054	0.079*	0.085*	0.071†	0.062†	0.039
O_3	0.028	0.055†	0.039	0.029	0.054†	0.067	0.065	0.043	−0.003
PM_{10}	0.034	0.026	0.044	0.010	0.080†	0.056	0.043	0.033	−0.011
$PM_{2.5}$	0.046	0.062	0.070	0.085†	0.080†	0.117†	0.091†	0.084	0.003
$PM_{10-2.5}$	0.046	0.005	−0.070	0.010	0.023	0.019	0.017	0.013	−0.013
Inorganic Acid	−0.295	−0.180	−0.221	−0.333	0.110	0.182	−0.035	−0.299	−0.876†
Organic Acid	−0.025	−0.080	0.019	−0.048	0.150	0.180	0.171	−0.012	−0.253
EC	0.350	0.507	0.503	0.010	0.919	1.463	0.995	0.966	−1.307
OC	0.237	0.356†	0.380†	0.335	0.356*	0.653*	0.479*	0.585*	0.345*

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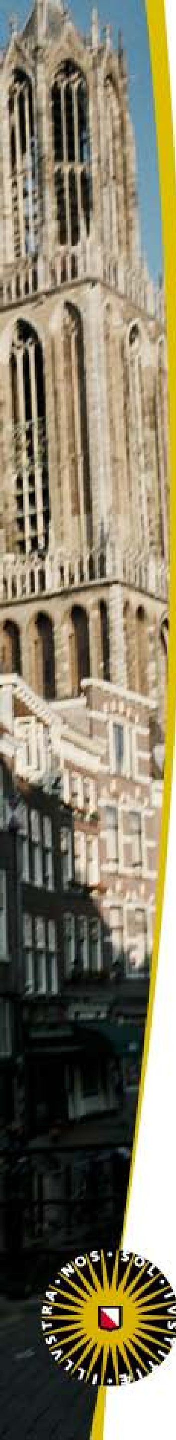
AJRCCM 2003



Health effects of air pollution observed in cohort studies in Europe

BERT BRUNEKREEF

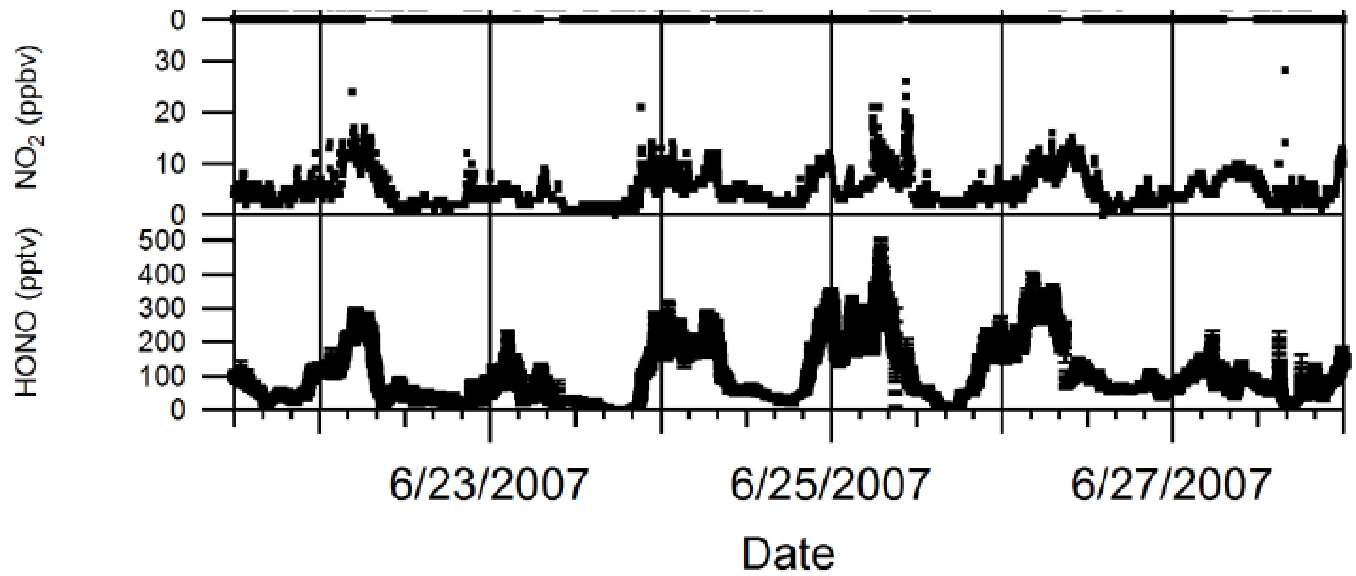
Table 2. Effect estimates from European cohort studies on air pollution and mortality, expressed per 10 $\mu g/m^3$ NO_2 or NO_x.

Source	All-cause mortality	Cardiopulmonary deaths
Hoek et al. (2002) (NO_2) 1986-1994	1.12 (0.98–1.33)	1.27 (1.00–1.78)
Nafstad et al. (2004) (NO_x) 1975-1998	1.08 (1.06–1.11)	1.08 (IHD) (1.03–1.12)
Filleul et al. (2005) (NO_2) 1974-1998	1.14 (1.05–1.17)	1.27 (1.04–1.56)
Gehring et al. (2006) (NO_2) 1990-2002	1.11 (1.01–1.21)	1.36 (1.14–1.63)
Naess et al. (2007) (NO_2)		1.05 (51–70 year olds)

JESEE 2007

Measurements of HONO during BAQS-Met

J. J. B. Wentzell[1,2,*], C. L. Schiller[1,2,**], and G. W. Harris[1,2]



HONO/NO2 Canada **0.02**

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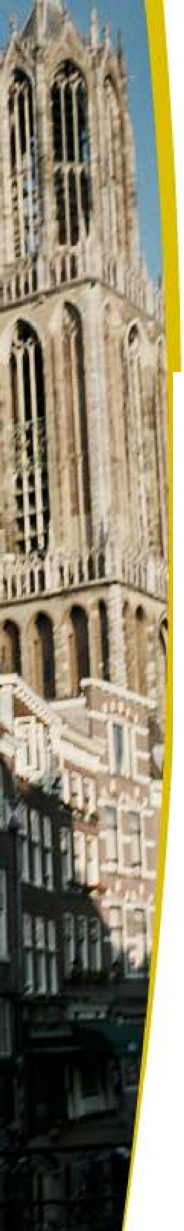
ACP 2010



Effects of Low-Level Winter Air Pollution Concentrations on Respiratory Health of Dutch Children

Gerard Hoek*,† and Bert Brunekreef*

TABLE 2

Distribution of Air Pollution Concentrations (μg/m³) on the Day Before the Pulmonary Function Tests (N = 86)

Component	Mean	Standard deviation	Minimum	Maximum
SO_2 [a]	14.9	14.5	0.4	94.3
NO_2 ←	36.6	15.8	2.1	69.7
PM_{10}	44.9	23.3	14.1	126.1
SO_4^{2-}	6.7	6.7	0.0	29.7
NO_3^-	7.3	6.9	0.9	36.8
HONO ←	2.8	2.2	0.1	10.6
T_{min} [b]	3.7	4.1	−7.3	15.6

HONO/NO2 Netherlands **0.08**

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Env Res 1994

Correlation between Concentration of Air Pollutants on the Day before thi Pulmonary Function Test Days and Ambient Temperature of the Same Day

	SO_2	NO_2	PM_{10}	SO_4^{2-}	NO_3^-	HONO
SO_2						
NO_2	0.46[a]					
PM_{10}	0.50	0.64				
SO_4^{2-}	0.41	0.59	0.78			
NO_3^-	0.39	0.50	0.71	0.77		
HONO	0.40	0.69	0.57	0.58	0.61	
T_{min}	−0.21	−0.26	−0.16	−0.09	−0.07	−0.38

Association between Same- and Previous-Day (Lag) Air Pollution Concentration and Pulmonary Function

	FVC ($ml \cdot \mu g^{-1} \cdot m^3$)	FEV$_{1.0}$ ($ml \cdot \mu g^{-1} \cdot m^3$)	PEF ($ml \cdot sec^{-1} \cdot \mu g^{-1} \cdot m^3$)	MMEF ($ml \cdot sec^{-1} \cdot \mu g^{-1} \cdot m^3$)	N[b]
PM_{10}	0.01[a] (0.06)	−0.10 (0.06)	−0.82* (0.29)	−0.52* (0.17)	782
PM_{10} lag	0.07 (0.07)	−0.06 (0.08)	−0.93* (0.34)	−0.43* (0.21)	759
SO_4^{2-}	−1.15* (0.53)	−0.97** (0.53)	−5.12* (2.51)	−0.54 (1.11)	300
SO_4^{2-} lag	−0.65* (0.33)	−0.84* (0.34)	−4.04* (1.54)	−1.50** (0.87)	531
NO_3^-	−1.00* (0.45)	−1.06* (0.47)	−1.81 (1.93)	−1.67** (0.96)	300
NO_3^- lag	−0.32 (0.36)	−0.58** (0.34)	−1.45 (1.49)	−1.33 (0.85)	531
SO_2	0.26 (0.21)	0.15 (0.20)	−0.83 (1.07)	−0.58 (0.53)	775
SO_2 lag	0.54* (0.18)	0.21 (0.17)	−0.54 (0.87)	−0.44 (0.44)	856
NO_2	−0.01 (0.09)	−0.05 (0.10)	−0.62 (0.49)	−0.44** (0.24)	846
NO_2 lag	0.08 (0.09)	−0.03 (0.09)	−1.38* (0.42)	−0.34 (0.23)	842
HONO	−1.93 (1.38)	−2.48** (1.33)	−5.91 (5.54)	−4.77** (2.65)	288
HONO lag	−0.40 (1.26)	−1.31 (1.30)	−10.33 (6.27)	−3.20 (3.28)	438

Indoor nitrous acid and respiratory symptoms and lung function in adults

D L Jarvis, B P Leaderer, S Chinn, P G Burney

HONO/NO2 UK **0.24**

	Min	25th centile	Median	75th centile	Max
Indoor HONO (ppb) (n = 255)	0	2.05	3.10	5.09	20.55
Indoor NO_2 ($\mu g/m^3$)	5.40	14.55	24.55	42.00	113.70*
Indoor NO_2 (ppb) (n = 240)	2.80	7.57	12.76	21.84	59.12

Table 4 Prevalence (%) of respiratory symptoms and mean lung function parameters by quartile of HONO (random sample only)

	Quartile 1 (n = 51) (0–2.11 ppb)	Quartile 2 (n = 50) (2.17–3.08 ppb)	Quartile 3 (n = 50) (3.09–4.80 ppb)	Quartile 4 (n = 50) (4.84–20.55 ppb)	p for trend across categories
Symptoms in last 12 months					
Wheeze	25.5	26.0	28.6	33.3	0.19
Wheeze with breathlessness	14.3	18.0	24.0	22.0	0.25
Woken by attack of SOB	7.8	2.0	8.0	6.0	0.98
Woken by coughing	31.3	22.0	32.0	24.0	0.66
FEV_1 as % predicted	110.2	106.9	106.6	105.3	0.09
FEV_1/FVC ratio (%)	79.7	79.0	78.5	76.2	0.007

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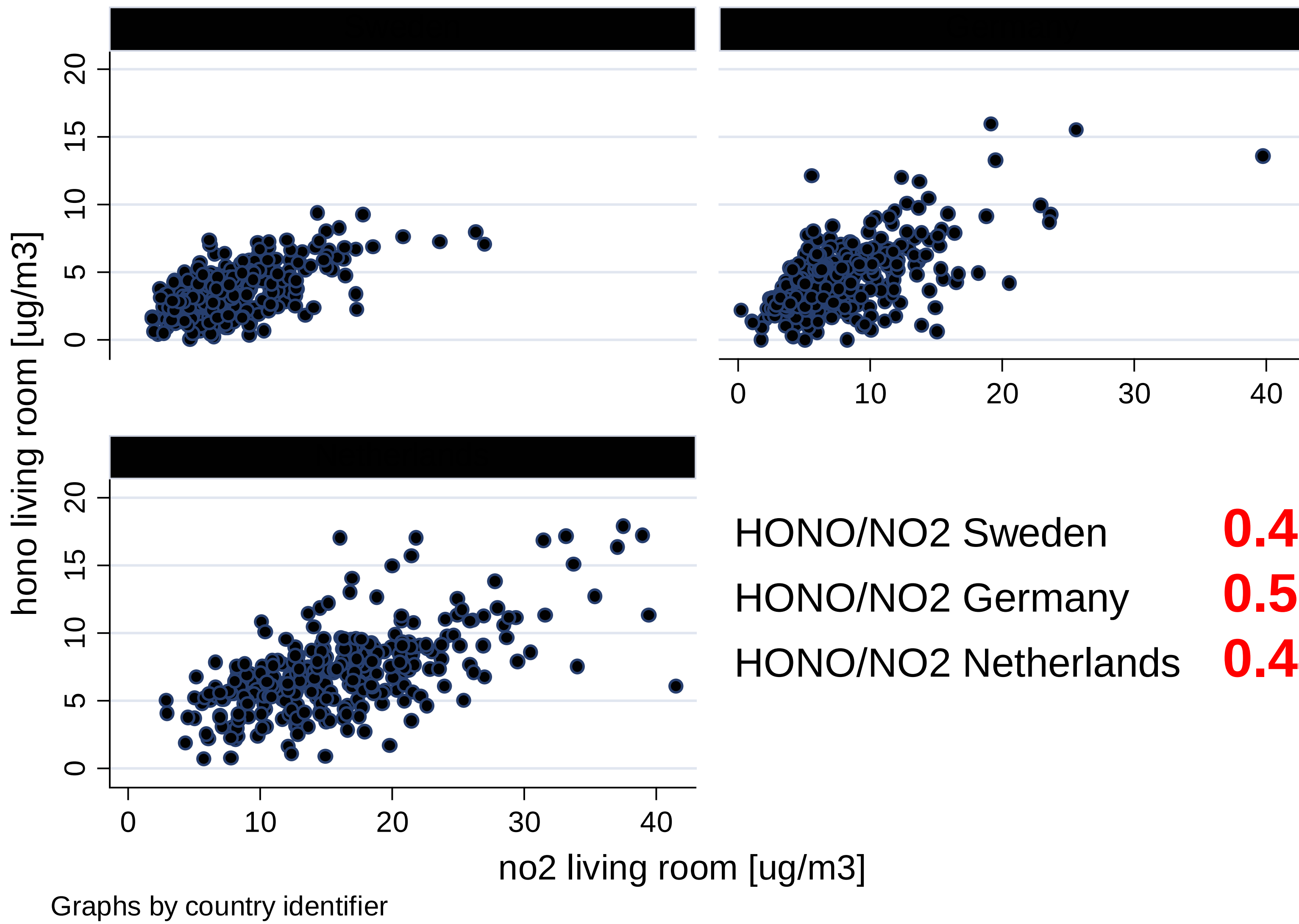
Thorax 2005

AIRALLERG QLRT-2000-00073 FINAL REPORT 03 2005



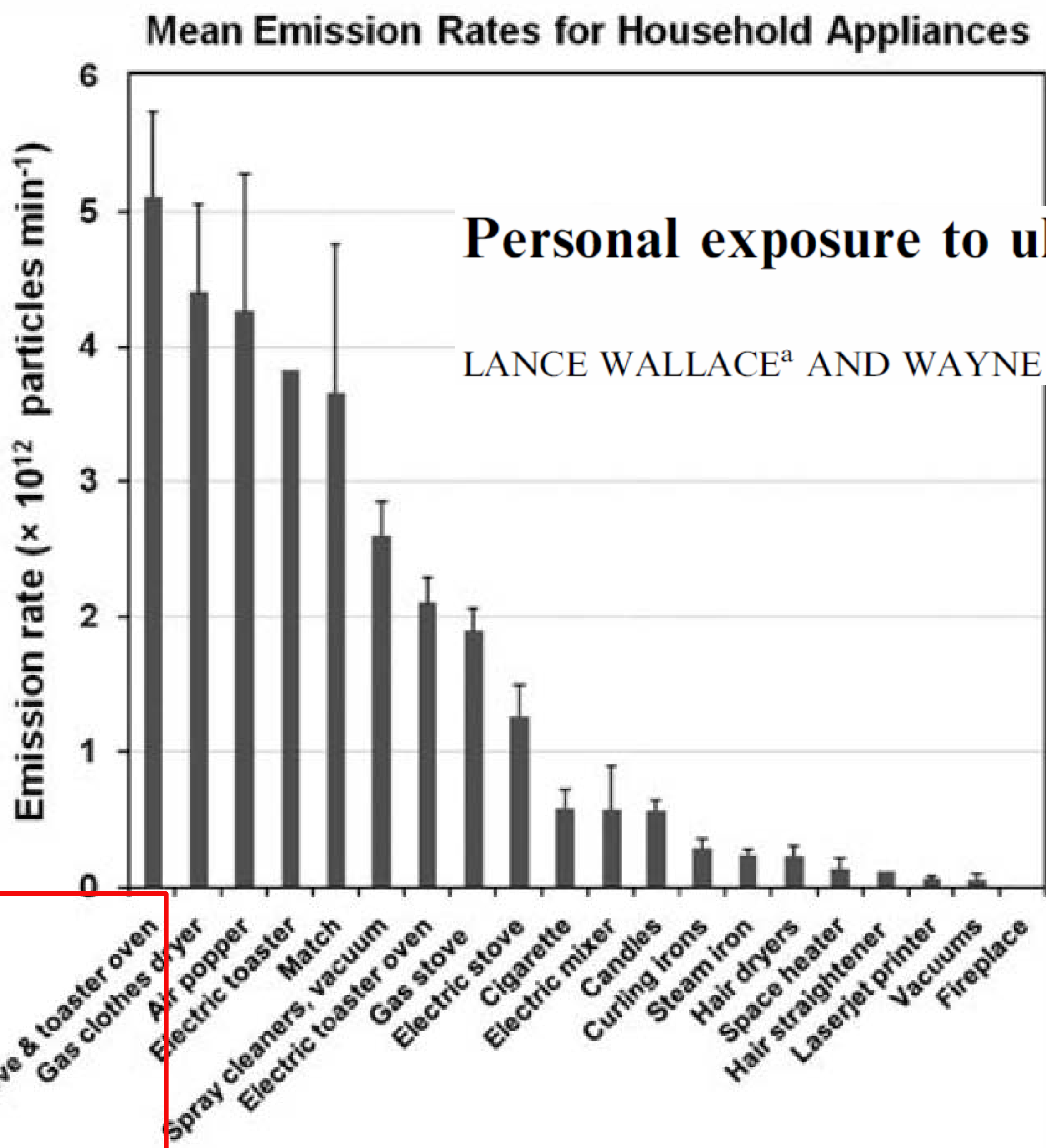
HONO/NO2 Sweden **0.47**

HONO/NO2 Germany **0.55**

HONO/NO2 Netherlands **0.44**

Association between gas stove, HONO and NO_2 and wheezing, nocturnal dry cough, asthma and eczema among children in the AIRALLERG study

	Gas Stove OR* (95% CI)	HONO OR* (95% CI)	NO2 OR* (95% CI)
		IQR=3.7 μg/m^3	IQR=7.2 μg/m^3
Wheeze	0.65 (0.37, 1.14)	0.72 (0.54, 0.95)	0.83 (0.65, 1.05)
Nocturnal dry cough	0.94 (0.55, 1.60)	0.93 (0.76, 1.13)	0.84 (0.68, 1.04)
DD asthma	0.52 (0.25, 1.09)	0.88 (0.64, 1.21)	0.93 (0.74, 1.19)
Eczema	0.98 (0.60, 1.60)	0.97 (0.81, 1.17)	1.04 (0.92, 1.18)



Personal exposure to ultrafine particles

LANCE WALLACE[a] AND WAYNE OTT[b]

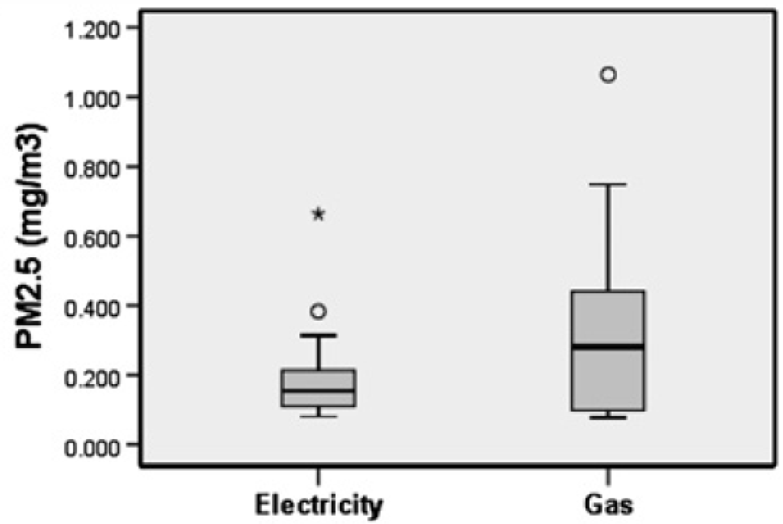
JESEE
2011

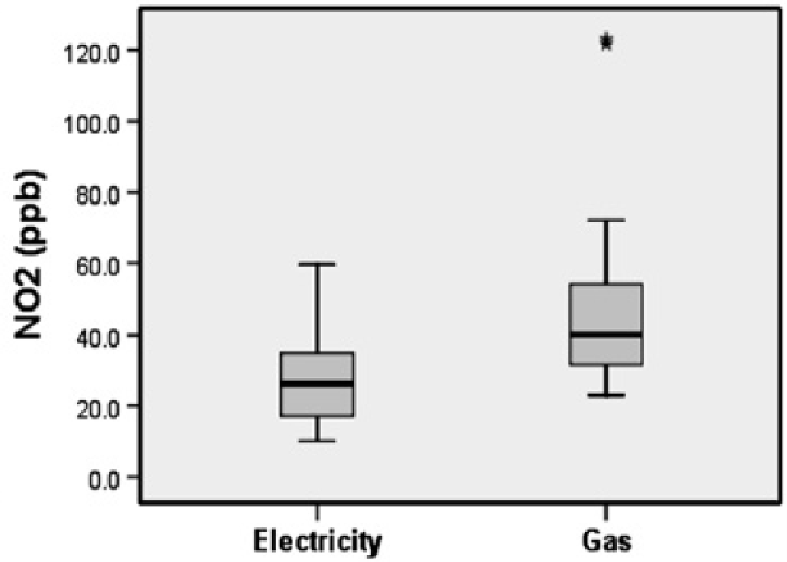
Figure 6. Mean emission rates (with SE) of 19 categories of sources.

Respiratory health and lung function in Chinese restaurant kitchen workers

Tze Wai Wong,[1] Andromeda H S Wong,[1] Frank S C Lee,[2] Hong Qiu[1]

OEM
2011





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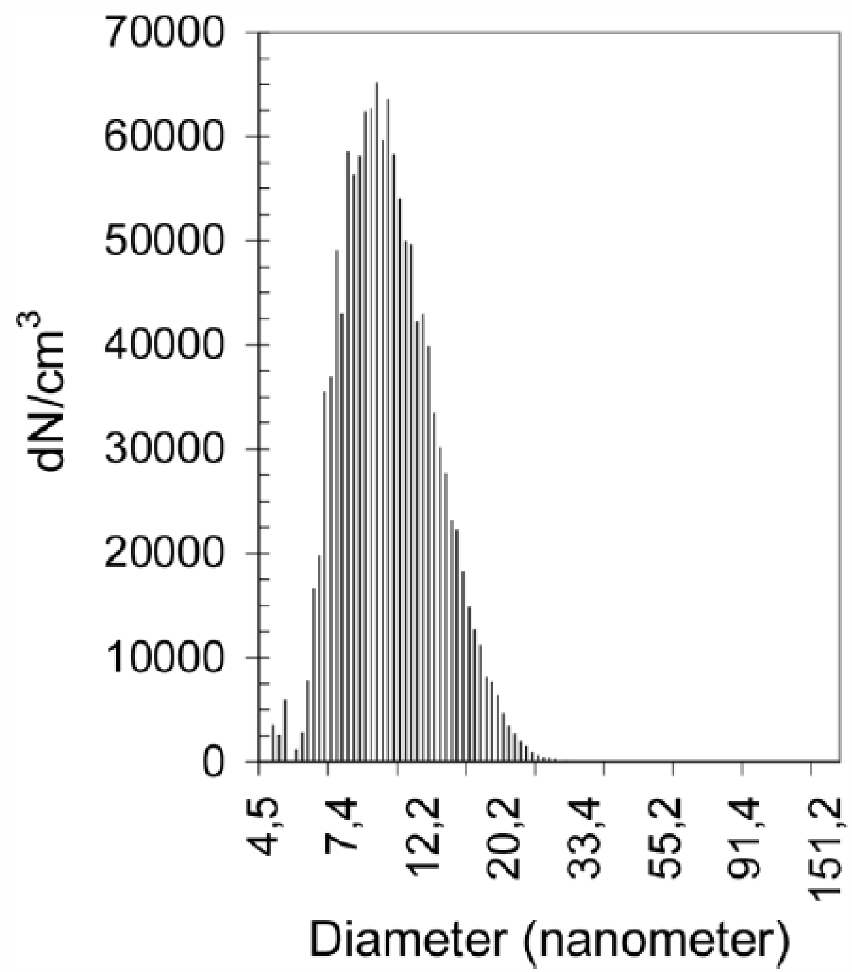
PARTICLE EMISSIONS FROM DOMESTIC GAS COOKERS

Ayten Yilmaz Wagner,[1] Hans Livbjerg,[1]
Per Gravers Kristensen,[2] and Peter Glarborg[1]

CST 2010



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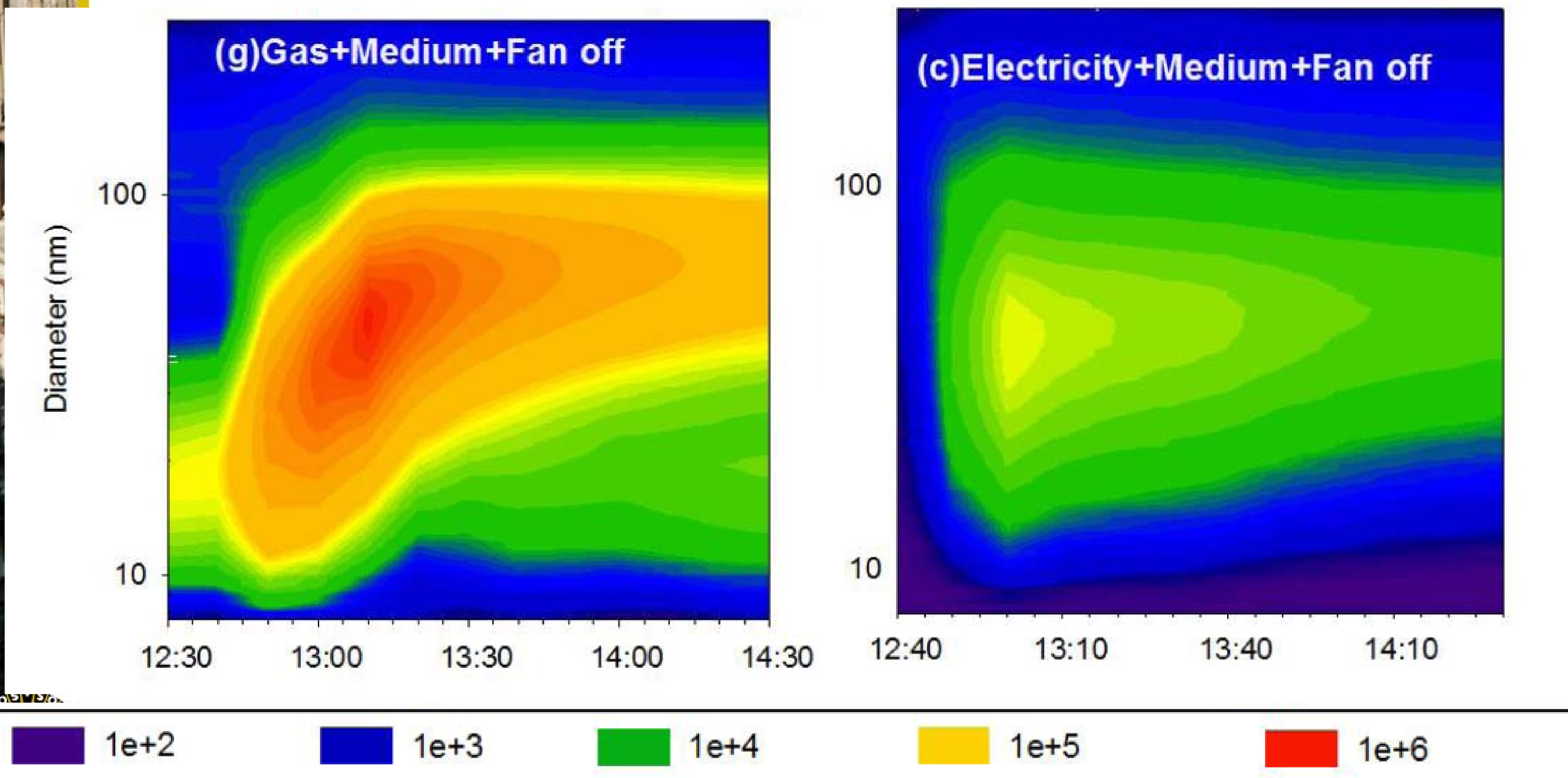
Int. J. Environ. Res. Public Health **2010**

Measurement of Ultrafine Particles and Other Air Pollutants Emitted by Cooking Activities

Qunfang Zhang [1], Roja H. Gangupomu [2], David Ramirez [1] and Yifang Zhu [1,*]



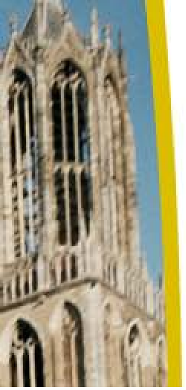
Outdoor NO_2 is NOT indoor NO_2

Location school	Outdoor NO_2 µg/m^3	Classroom NO_2
Very urban (n=33)	37	23
Fairly urban (n=56)	30	13
Non-urban (n=43)	26	11
Very busy road (n=27)	47	24
Fairly busy road (n=39)	37	14
Quiet road (n=44)	33	14

Rijnders, EHP 2001

The US vs. EU AQS approach

Source	Annual standard	1 hr standard
CAL EPA 2007	57 µg/m^3	344 µg/m^3 Max
US EPA 2010	100 µg/m^3	191 µg/m^3 98th percentile
EU	**<u>40 µg/m^3</u>**	200 µg/m^3 18 times (99.8 or 95 percentile??)



Position paper on Air Quality: nitrogen dioxide

WHO has recommended an annual average guideline of 40 Tg/m^3 (WHO, 1996) Although there is no particular study or set of studies that support a numerical value, the WHO's database clearly indicates the need to protect the public from chronic exposures. For example, indoor air studies with strong NO_2 sources (e.g. gas stoves) suggest that an increment of about 30 Tg/m^3 (two week average) is associated with a 20 % increase in lower respiratory illness of children 5 to 12 years old. However, the

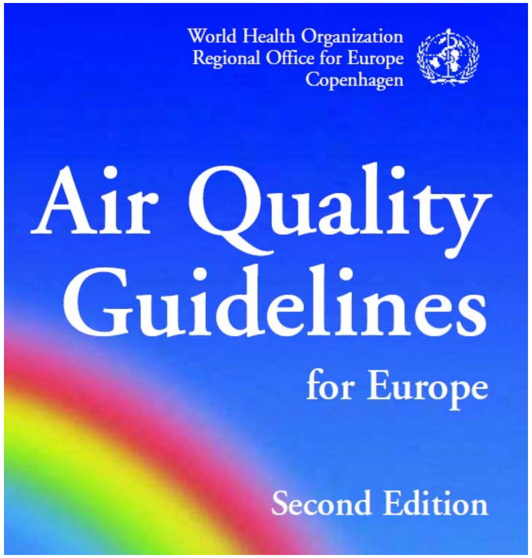
November 1997

Working Group on Nitrogen Dioxide

European Commission
Directorate-General XI

Universiteit Utrecht

1996 - 2000



Furthermore, animal toxicological studies show that prolonged exposures can cause decreases in lung host defences and changes in lung structure. On these grounds, it is proposed that a long-term guideline for nitrogen dioxide be established. Selecting a well supported value based on the studies reviewed has not been possible, but it has been noted that a prior review conducted for the Environmental Health Criteria document on nitrogen oxides recommended an annual value of 40 µg/m^3 *(5)*. In the absence of support for an alternative value, this figure is recognized as an air quality guideline.

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UNITED NATIONS ENVIRONMENT PROGRAMME
INTERNATIONAL LABOUR ORGANISATION
WORLD HEALTH ORGANIZATION

ENVIRONMENTAL HEALTH CRITERIA 188

Nitrogen Oxides

On the basis of a background level of 15 µg/m^3 (0.008 ppm) and the fact that significant adverse health effects occur with an additional level of 28.2 µg/m^3 (0.015 ppm) or more, an annual guideline value of 40 µg/m^3 (0.023 ppm) is proposed. This value will avoid the most severe exposures. The fact that a no-effect level for subchronic or chronic NO_2 exposure concentrations has not yet been determined should be emphasized.

First draft prepared by Drs J.A. Graham, L.D. Grant, L.J. Folinsbee, D.J. Kotchmar and J.H.B. Garner, US Environmental Protection Agency

Universiteit Utrecht

World Health Organization
Geneva, 1997

Synthesis of Environmental Evidence: Nitrogen Dioxide Epidemiology Studies

Vic Hasselblad and David M. Eddy
Duke University
Durham, North Carolina

Dennis J. Kotchmar
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina

Source	N of children	LRI OR per 30 μg/m^3 indoor NO_2
Melia 1980	103	1.53 (1.04-2.24)
Melia 1982	188	1.11 (0.83-1.49)
Neas 1991	1286	1.47 (1.17-1.86)
Dijkstra 1990	775	0.94 (0.66-1.33)
Combined		**1.25 (0.99-1.58)**

JAWMA 1992

Association of Indoor Nitrogen Dioxide with Respiratory Symptoms and Pulmonary Function in Children

Lucas M. Neas,[1] Douglas W. Dockery,[2,3] James H. Ware,[4] John D. Spengler,[2] Frank E. Speizer,[2,3] and Benjamin G. Ferris, Jr.[2]

TABLE 2. Annual cumulative incidences and crude odds ratios (ORs) associated with a major indoor nitrogen dioxide source (gas stove or kerosene heater) and the adjusted odds ratios and 95% confidence intervals (95% CIs) associated with a 15-ppb increase in the annual average indoor nitrogen dioxide exposure by symptom: Harvard Six Cities Study, 1983–1988

	Effect of nitrogen dioxide source category			Effect of a 15 ppb difference in nitrogen dioxide, adjusted*	
	Cumulative incidence (%)		Crude OR	OR	95% CI
	No source	Source			
Shortness of breath	11.5	13.9	1.24	1.23	0.93–1.61
Chronic wheeze	11.3	13.8	1.25	1.16	0.89–1.52
Chronic cough	7.6	9.5	1.29	1.18	0.87–1.60
Chronic phlegm	8.2	10.7	1.35	1.25	0.94–1.66
Bronchitis	7.8	9.4	1.24	1.05	0.75–1.47
Lower respiratory symptoms	22.8	29.0	1.38	1.40	1.14–1.72
Asthma	7.1	5.4	0.75	0.91	0.60–1.36
Hay fever	24.0	24.7	1.04	0.98	0.79–1.22
Earache	34.5	33.0	0.94	1.09	0.90–1.32
Chest illness	10.5	11.0	1.06	1.10	0.83–1.46
Other illness	12.3	12.5	1.02	1.06	0.81–1.40

* Odds ratios adjusted for city, sex, age, parental history of bronchitis or emphysema, parental history of asthma, parental college education, single parent family status, and the measured levels of respirable particulates in the home.

Universiteit Utrecht

AJE 1991

products with which it is typically correlated. Thus it can be argued that the available scientific literature has not accumulated sufficient evidence to justify revising the existing WHO AQG for annual NO_2 concentrations. Nevertheless, since NO_2 concentrations in ambient air are routinely measured but those of other correlated combustion-derived pollutants are not, it seems reasonable to retain a prudent annual average limit value for NO_2. Such a limit allows for the fact that there may be direct toxic effects of chronic NO_2 exposure at low levels. In addition, maintaining the annual guideline value may help to control complex mixtures of combustion-related pollution (mainly from road traffic)

Thompson 2008 memo

Table 2. NO_2 Daily Maximums and Percentiles for 2004-2006.

2004-2006	NO_2 Daily Maximums								Percentiles	
Location	2nd	3rd	4th	5th	6th	7th	8th	9th	99th	98th
Atlanta	0.083	0.079	0.078	0.074	0.073	0.072	0.070	0.070	0.078	0.071
Boston	0.069	0.067	0.064	0.063	0.062	0.060	0.059	0.059	0.064	0.059
Chicago	0.103	0.094	0.093	0.090	0.090	0.088	0.088	0.088	0.093	0.088
Cleveland	0.075	0.074	0.072	0.070	0.069	0.066	0.065	0.064	0.072	0.065
Denver	0.094	0.089	0.086	0.082	0.079	0.077	0.073	0.072	0.086	0.077
El Paso	0.085	0.080	0.075	0.072	0.071	0.068	0.067	0.066	0.075	0.067
Las Vegas	0.042	0.040	0.039	0.039	0.038	0.038	0.037	0.037	0.039	0.037
Los Angeles	0.110	0.095	0.095	0.089	0.088	0.084	0.083	0.081	0.095	0.083
Miami	0.065	0.060	0.059	0.058	0.057	0.056	0.054	0.053	0.059	0.056
New York	0.112	0.099	0.093	0.090	0.086	0.084	0.082	0.081	0.093	0.083
Philadelphia	0.065	0.062	0.060	0.059	0.058	0.057	0.056	0.054	0.060	0.056
Phoenix	0.107	0.097	0.093	0.090	0.089	0.086	0.084	0.083	0.093	0.085
St. Louis	0.066	0.065	0.064	0.064	0.063	0.063	0.063	0.063	0.064	0.063
Washington DC	0.102	0.088	0.079	0.075	0.072	0.066	0.065	0.063	0.079	0.065

http://www.epa.gov/ttnnaaqs/standards/nox/data/20081124_thompson.pdf

Thompson 2008 memo

Table 3. Ratios of proposed alternatives and the current NO_2 standards.

	2004-2006 Daily			2004-2006 Daily			2004-2006	2005-2006		2004-2006	2005-2006		2004-2006	2005-2006		2004-2006	2005-2006	
	Max	24 hr avg	Rat	Max	24 hr avg	Rat	Daily Max	Ann	Rat	Daily Max	Ann	Rat	24 hr avg	Ann	Rat	24 hr avg	Ann	Rat
Location	99th	99th		98th	98th		99th			98th			99th			98th		
Atlanta	0.078	0.042	1.84	0.071	0.038	1.88	0.078	0.018	4.36	0.071	0.018	4.00	0.042	0.018	2.37	0.038	0.018	2.13
Boston	0.064	0.043	1.50	0.059	0.039	1.50	0.064	0.023	2.73	0.059	0.023	2.50	0.043	0.023	1.81	0.039	0.023	1.66
Chicago	0.093	0.052	1.80	0.088	0.050	1.77	0.093	0.031	3.03	0.088	0.031	2.86	0.052	0.031	1.68	0.050	0.031	1.62
Cleveland	0.072	0.043	1.68	0.065	0.038	1.70	0.072	0.022	3.35	0.065	0.022	3.03	0.043	0.022	1.99	0.038	0.022	1.78
Denver	0.086	0.050	1.73	0.077	0.046	1.68	0.086	0.020	4.22	0.077	0.020	3.78	0.050	0.020	2.44	0.046	0.020	2.25
El Paso	0.075	0.038	1.99	0.067	0.035	1.91	0.075	0.018	4.09	0.067	0.018	3.65	0.038	0.018	2.05	0.035	0.018	1.91
Las Vegas	0.039	0.013	3.04	0.037	0.012	3.10	0.039	0.005	8.65	0.037	0.005	8.21	0.013	0.005	2.84	0.012	0.005	2.65
Los Angeles	0.095	0.061	1.56	0.083	0.055	1.50	0.095	0.031	3.06	0.083	0.031	2.70	0.061	0.031	1.97	0.055	0.031	1.79
Miami	0.059	0.030	1.97	0.056	0.027	2.06	0.059	0.008	7.41	0.056	0.008	7.03	0.030	0.008	3.76	0.027	0.008	3.42
New York	0.093	0.060	1.55	0.083	0.056	1.48	0.093	0.032	2.90	0.083	0.032	2.60	0.060	0.032	1.88	0.056	0.032	1.75
Philadelphia	0.060	0.040	1.51	0.056	0.035	1.61	0.060	0.017	3.62	0.056	0.017	3.34	0.040	0.017	2.40	0.035	0.017	2.07
Phoenix	0.093	0.057	1.63	0.085	0.053	1.60	0.093	0.032	2.95	0.085	0.032	2.70	0.057	0.032	1.81	0.053	0.032	1.69
St. Louis	0.064	0.034	1.91	0.063	0.031	2.03	0.064	0.017	3.82	0.063	0.017	3.74	0.034	0.017	1.99	0.031	0.017	1.84
Washington DC	0.079	0.045	1.76	0.065	0.040	1.61	0.079	0.021	3.70	0.065	0.021	3.02	0.045	0.021	2.10	0.040	0.021	1.88

Average ratio second highest hourly / annual mean: **4.63**

Average ratio 99^{th} hourly / annual mean: **4.13**

Average ratio 98^{th} hourly / annual mean: **3.80**

Average ratio 95^{th} hourly / annual mean: **3.00**

http://www.epa.gov/ttnnaaqs/standards/nox/data/20081124_thompson.pdf

1 hr recalculated to annual mean

Source	RECALCULATED Annual standard	1 hr standard
CAL EPA 2007	74?? > 57 µg/m^3	344 µg/m^3
US EPA 2010	50 < 100 µg/m^3	191 µg/m^3
EU	43 or 66 > 40 µg/m^3	200 µg/m^3