

**WHO Air quality guidelines  
for particulate matter,  
ozone, nitrogen  
dioxide and sulfur dioxide**

*Global update 2005*

**Summary of risk assessment**



**World Health  
Organization**

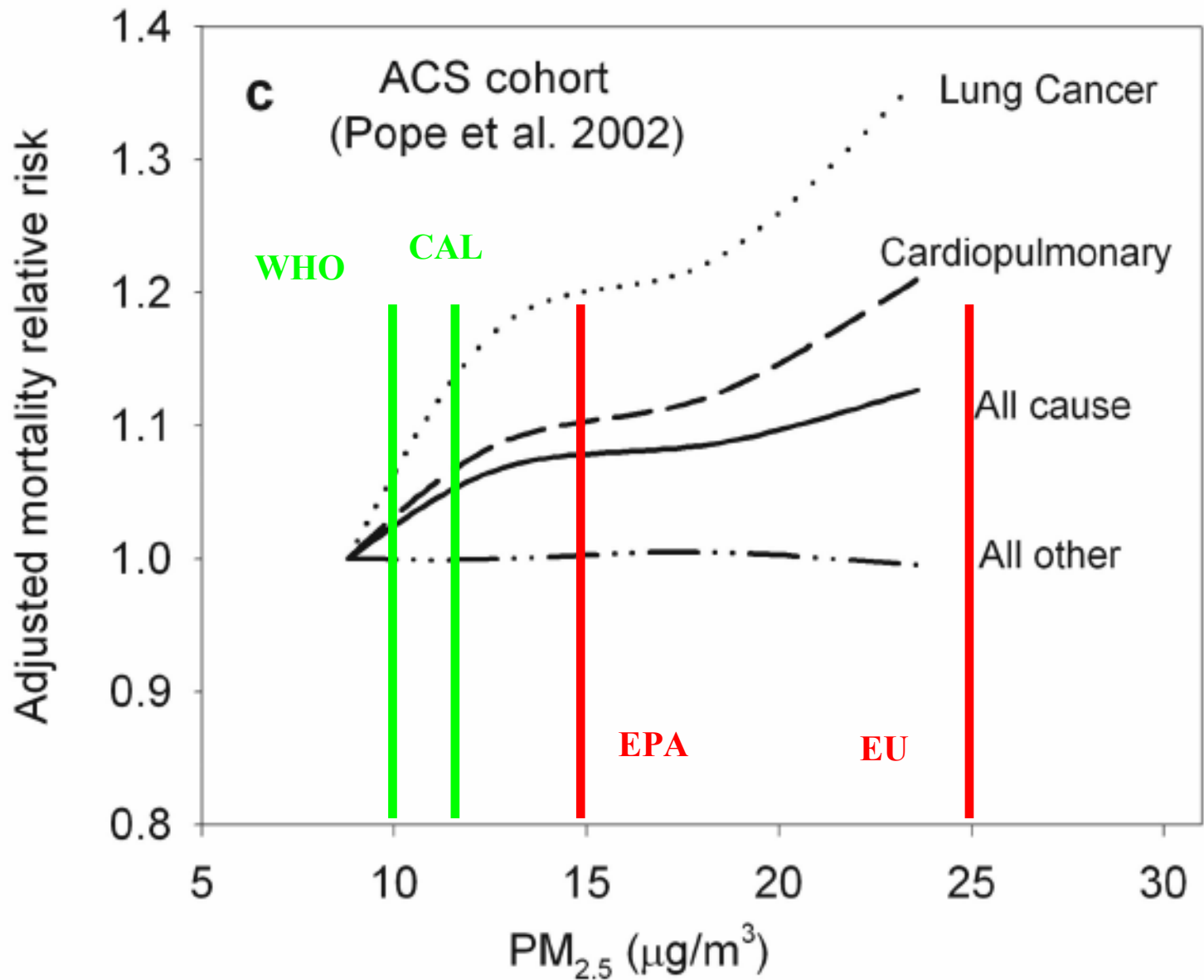
## **Role of the guidelines in protecting public health**

The WHO air quality guidelines (AQGs) are intended for worldwide use but have been developed to support actions to achieve air quality that protects public health in different contexts. Air

**PM<sub>2.5</sub>:**                      **10  $\mu\text{g}/\text{m}^3$  annual mean**  
   **25  $\mu\text{g}/\text{m}^3$  24-hour mean**

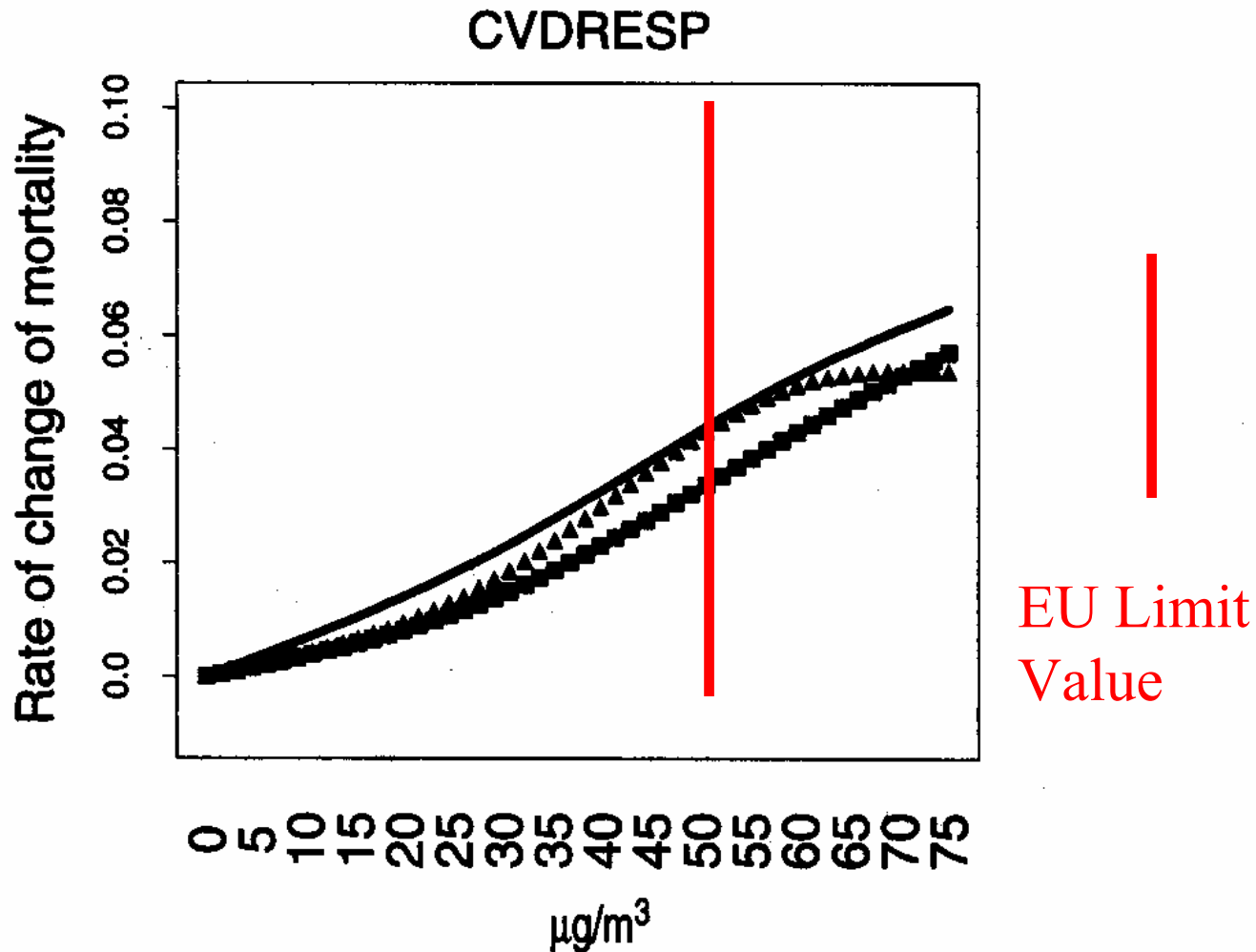
**PM<sub>10</sub>:**                         **20  $\mu\text{g}/\text{m}^3$  annual mean**  
   **50  $\mu\text{g}/\text{m}^3$  24-hour mean**

**WHO AQG 2000: no quantitative guidelines**

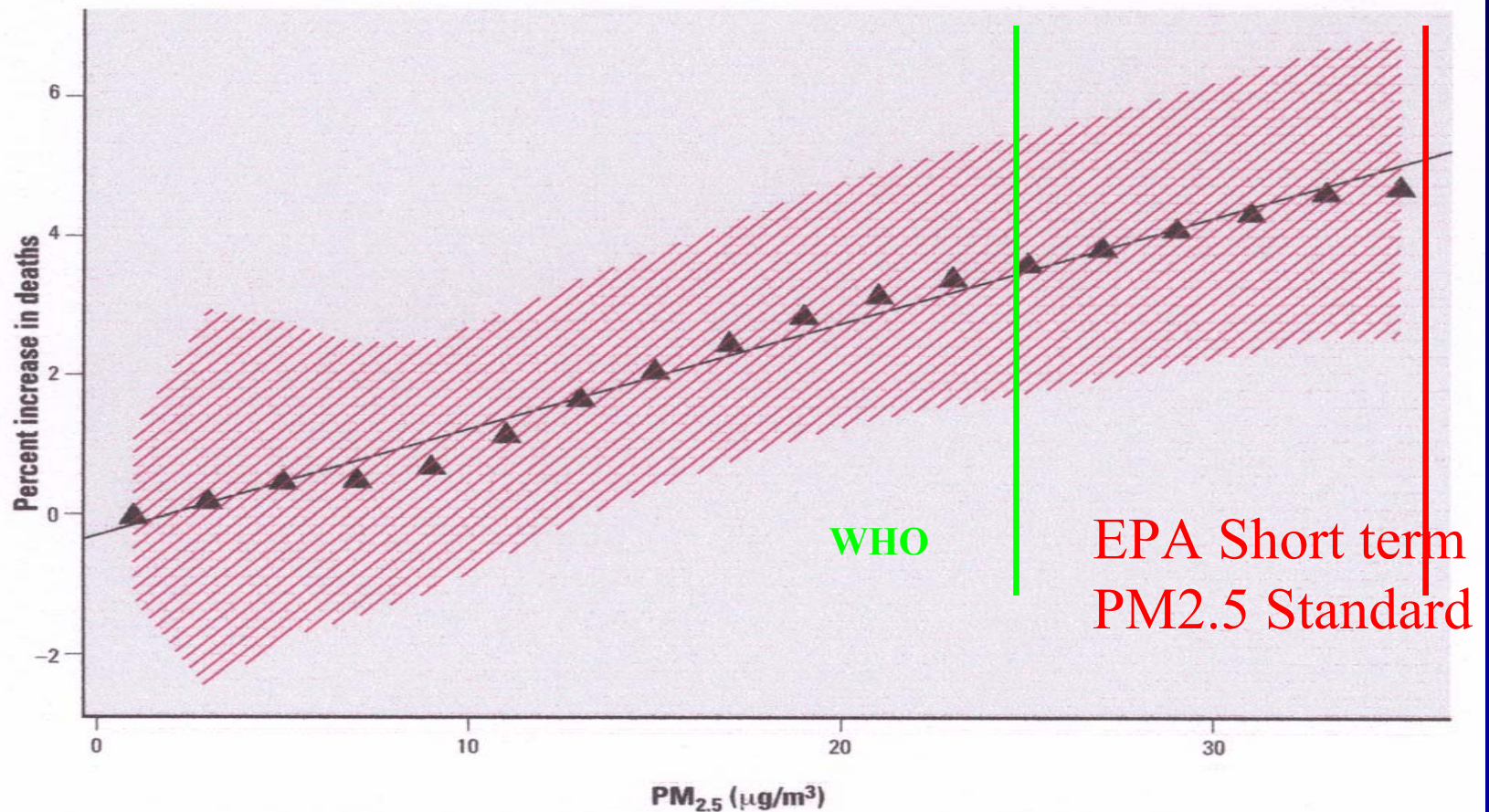


# Relationship between PM10 and daily deaths

Daniels, NMMAPS, Am J Epidemiol 2000



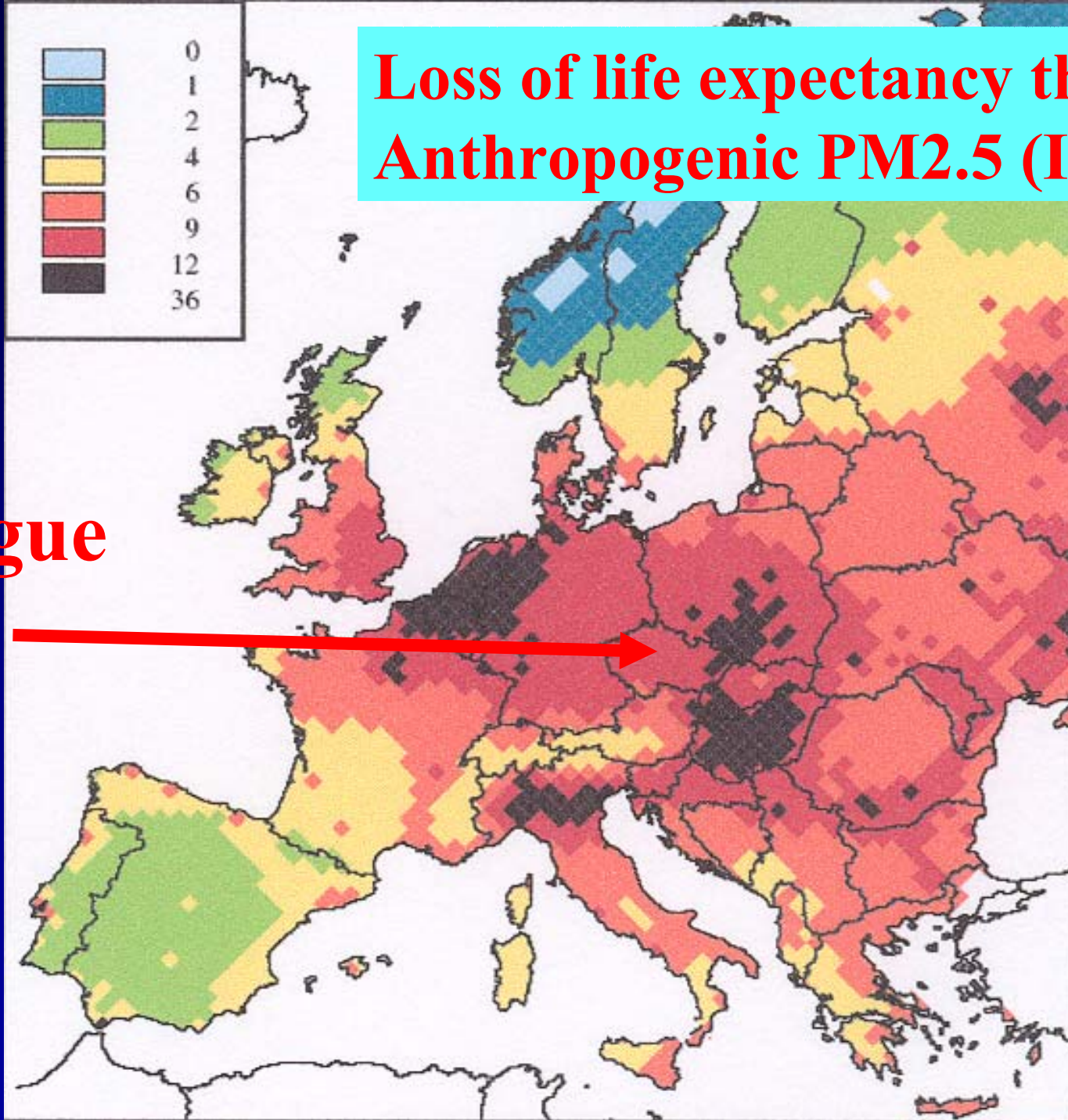
# Schwartz, PM2.5, EHP 2002



**Figure 1.** Overall estimated dose–response relation between total PM<sub>2.5</sub> and daily deaths in six U.S. cities. The estimate is obtained by combining the estimated smoothed curves in each of the cities, after controlling for weather, season, and day of the week. The shaded area indicates the pointwise 95% confidence intervals at each point. The line shown is a least-squares regression line through the estimated points.

# Loss of life expectancy through Anthropogenic PM2.5 (IIASA)

Prague



# Table 1

## WHO air quality guidelines and interim targets for particulate matter: annual mean concentrations<sup>a</sup>

	PM <sub>10</sub> (µg/m <sup>3</sup> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Basis for the selected level
Interim target-1 (IT-1)	70	35	These levels are associated with about a 15% higher long-term mortality risk relative to the AQG level.
Interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% [2–11%] relative to the IT-1 level.
Interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% [2–11%] relative to the IT-2 level.
Air quality guideline (AQG)	<b>20</b>	<b>10</b>	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to PM <sub>2.5</sub> .

<sup>a</sup> The use of PM<sub>2.5</sub> guideline value is preferred.

### WHO air quality guidelines and interim targets for particulate matter: 24-hour concentrations<sup>a</sup>

	PM <sub>10</sub> (µg/m <sup>3</sup> )	PM <sub>2.5</sub> (µg/m <sup>3</sup> )	Basis for the selected level
Interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over the AQG value).
Interim target-2 (IT-2)	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over the AQG value).
Interim target-3 (IT-3)*	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase in short-term mortality over the AQG value).
Air quality guideline (AQG)	<b>50</b>	<b>25</b>	Based on relationship between 24-hour and annual PM levels.

<sup>a</sup> 99<sup>th</sup> percentile (3 days/year).

\* For management purposes. Based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means. The frequency distribution of daily PM<sub>2.5</sub> or PM<sub>10</sub> values usually approximates to a log-normal distribution.

## Ozone

Guideline

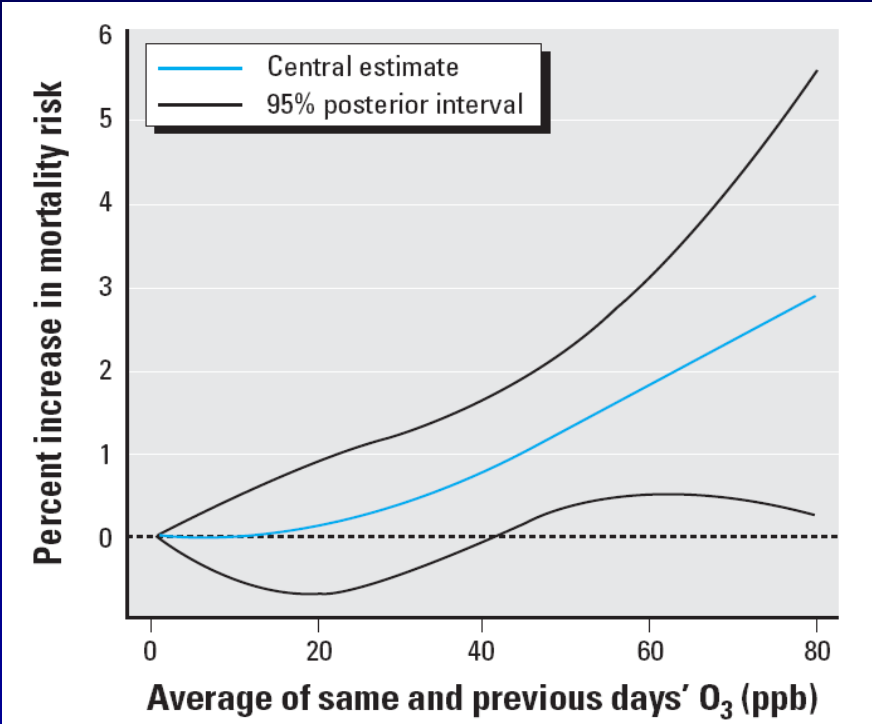
**O<sub>3</sub>: 100  $\mu\text{g}/\text{m}^3$  8-hour mean**

WHO AQG 2000: 120  $\mu\text{g}/\text{m}^3$  8 hour mean

# The Exposure–Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations

Michelle L. Bell,<sup>1</sup> Roger D. Peng,<sup>2</sup> and Francesca Dominici<sup>2</sup>

<sup>1</sup>School of Forestry and Environmental Studies, Yale University, New Haven, Connecticut, USA; <sup>2</sup>Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA



**Figure 3.** Exposure–response curve for O<sub>3</sub> and mortality using the spline approach: percentage increase in daily nonaccidental mortality at various O<sub>3</sub> concentrations.

EHP 2006

# On Health Effects of Ozone Exposure and Exposing the Epidemiologic Process

*The Editors*

**W**e are pleased to present in this issue a special supplement on ozone and mortality (see pages 427–468). The unusual history of this supplement deserves explanation. In August 2004, the journal received 3 independent submissions. Each was a meta-analysis of published studies on ozone and mortality. One of the cover letters provided this background:

**Epidemiology 2005**

Ozone Exposure and Mortality  
*An Empiric Bayes Metaregression Analysis*

*Jonathan I. Levy, Susan M. Chemerynski, and Jeremy A. Sarnat*

Associations Between Ozone and Daily Mortality  
*Analysis and Meta-Analysis*

*Kazuhiko Ito, Samantha F. De Leon, and Morton Lippmann*

## **Epidemiology 2005**

A Meta-Analysis of Time-Series Studies of Ozone and  
Mortality With Comparison to the National  
Morbidity, Mortality, and Air Pollution Study

*Michelle L. Bell,<sup>\*</sup> Francesca Dominici,<sup>†</sup> and Jonathan M. Samet<sup>‡</sup>*

## WHO air quality guideline and interim target for ozone: 8-hour concentrations

	Daily maximum 8-hour mean ( $\mu\text{g}/\text{m}^3$ )	Basis for selected level
High levels	240	Significant health effects; substantial proportion of vulnerable populations affected.
Interim target-1 (IT-1)	160	<p>Important health effects; does not provide adequate protection of public health. Exposure to this level of ozone is associated with:</p> <ul style="list-style-type: none"> <li>• physiological and inflammatory lung effects in healthy exercising young adults exposed for periods of 6.6 hours;</li> <li>• health effects in children (based on various summer camp studies in which children were exposed to ambient ozone levels).</li> <li>• an estimated 3–5% increase in daily mortality<sup>a</sup> (based on findings of daily time-series studies).</li> </ul>
<b>Air quality guideline (AQG)</b>	<b>100</b>	<p>Provides adequate protection of public health, though some health effects may occur below this level. Exposure to this level of ozone is associated with:</p> <ul style="list-style-type: none"> <li>• an estimated 1–2% increase in daily mortality<sup>a</sup> (based on findings of daily time-series studies).</li> <li>• Extrapolation from chamber and field studies based on the likelihood that real-life exposure tends to be repetitive and chamber studies exclude highly sensitive or clinically compromised subjects, or children.</li> <li>• Likelihood that ambient ozone is a marker for related oxidants.</li> </ul>

<sup>a</sup> Deaths attributable to ozone. Time-series studies indicate an increase in daily mortality in the range of 0.3–0.5% for every 10  $\mu\text{g}/\text{m}^3$  increment in 8-hour ozone concentrations above an estimated baseline level of 70  $\mu\text{g}/\text{m}^3$ .

## Nitrogen dioxide

### Guidelines

**NO<sub>2</sub>:**                      **40 µg/m<sup>3</sup> annual mean**  
   **200 µg/m<sup>3</sup> 1-hour mean**

**WHO AQG 2000: same values**

their emissions. If, however, NO<sub>2</sub> is monitored as a marker for complex combustion-generated pollution mixtures, a lower annual guideline value should be used (WHO, 2000).

## Childhood Asthma and Exposure to Traffic and Nitrogen Dioxide

*W. James Gauderman,\* Edward Avol,\* Fred Lurmann,† Nino Kuenzli,\* Frank Gilliland,\*  
John Peters,\* and Rob McConnell\**

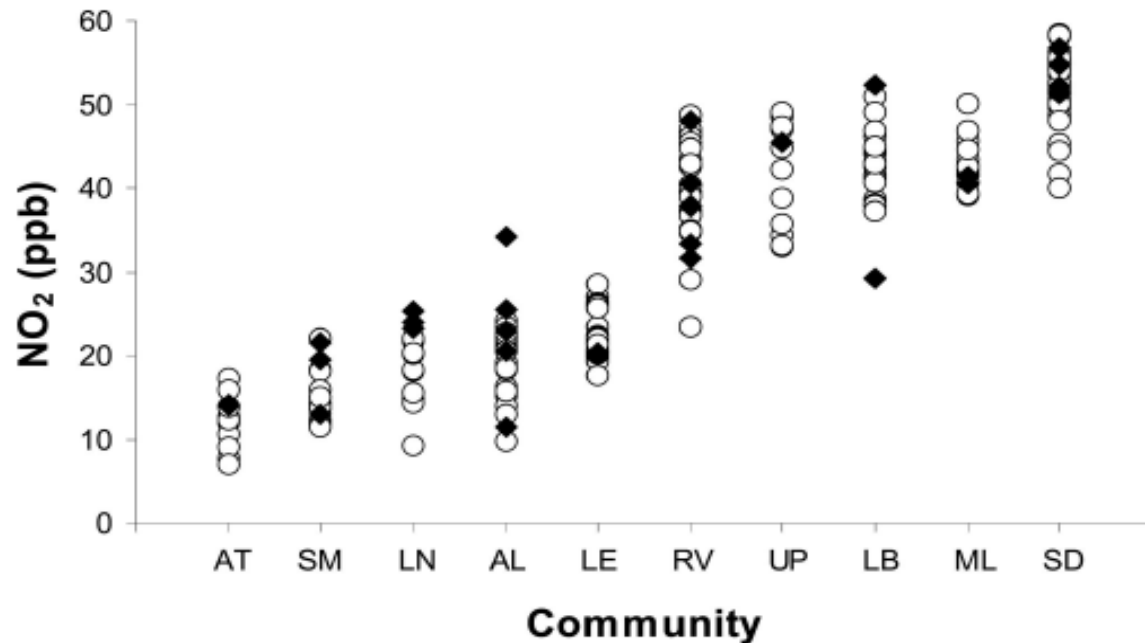


FIGURE 1. Four-week average of nitrogen dioxide measured at homes of asthmatic (solid black diamond) and nonasthmatic (open circle) children in 10 communities. See Table 1 for community abbreviations.

## Childhood Asthma and Exposure to Traffic and Nitrogen Dioxide

*W. James Gauderman,\* Edward Avol,\* Fred Lurmann,† Nino Kuenzli,\* Frank Gilliland,\* John Peters,\* and Rob McConnell\**

# Epidemiology 2005

TABLE 4. Associations Between Measured NO<sub>2</sub> and Asthma-Related Outcomes (n = 208)

Outcome	No.	Measured NO <sub>2</sub> OR* (95% CI)	Distance to Freeway OR* (95% CI)	Model-based Pollution From Freeways OR* (95% CI)
Lifetime history of asthma	31	1.83 (1.04–3.21)	1.89 (1.19–3.02)	2.22 (1.36–3.63)
Recent wheeze <sup>†</sup>	43	1.72 (1.07–2.77)	1.59 (1.06–2.36)	1.70 (1.12–2.58)
Recent wheeze with exercise <sup>†</sup>	25	2.01 (1.08–3.72)	2.57 (1.50–4.38)	2.56 (1.50–4.38)
Current asthma medication use	26	2.19 (1.20–4.01)	2.04 (1.25–3.31)	1.92 (1.18–3.12)

\*Odds ratio per change of 1 IQR in exposure (see footnotes to Tables 2 and 4).

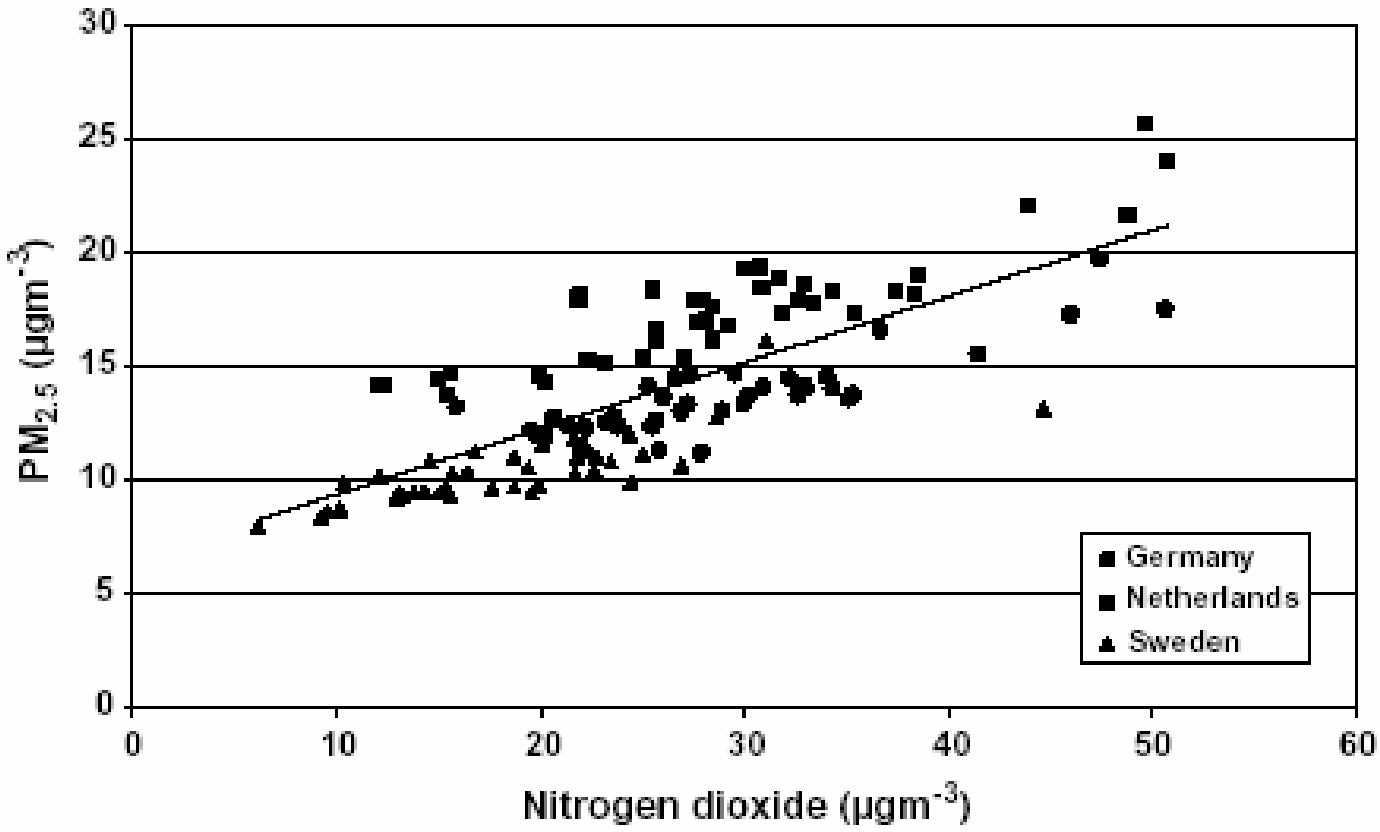
<sup>†</sup>Within the last 12 months.

IQR = 5.7 ppb NO<sub>2</sub> = 10.8 μg/m<sup>3</sup>

# Comparison of effect estimates of European Cohort Studies, for NO<sub>2</sub> or NO<sub>x</sub> per 10 µg/m<sup>3</sup>

	All cause	Cardio pulmonary
Hoek (NO <sub>2</sub> ) 2002	1.12 (0.98 – 1.33)	1.27 (1.00 – 1.78)
Nafstad (NO <sub>x</sub> ) 2004	1.08 (1.06 – 1.10)	1.23 (resp) (1.13 – 1.35)
Filleul (NO <sub>2</sub> ) 2005	1.14 (1.05 – 1.17)	1.27 (1.04 – 1.56)
Gehring (NO <sub>2</sub> ) 2006	1.11 (1.01 – 1.21)	1.36 (1.14 – 1.63)

# Lewne, Sc Total Environ 2004



**R<sup>2</sup> Stockholm**  
**0.64**

**R<sup>2</sup> Munich**  
**0.71**

**R<sup>2</sup> Netherlands**  
**0.80**

# Sulfur dioxide

## Guidelines

**SO<sub>2</sub>:**

**20  $\mu\text{g}/\text{m}^3$  24-hour mean**

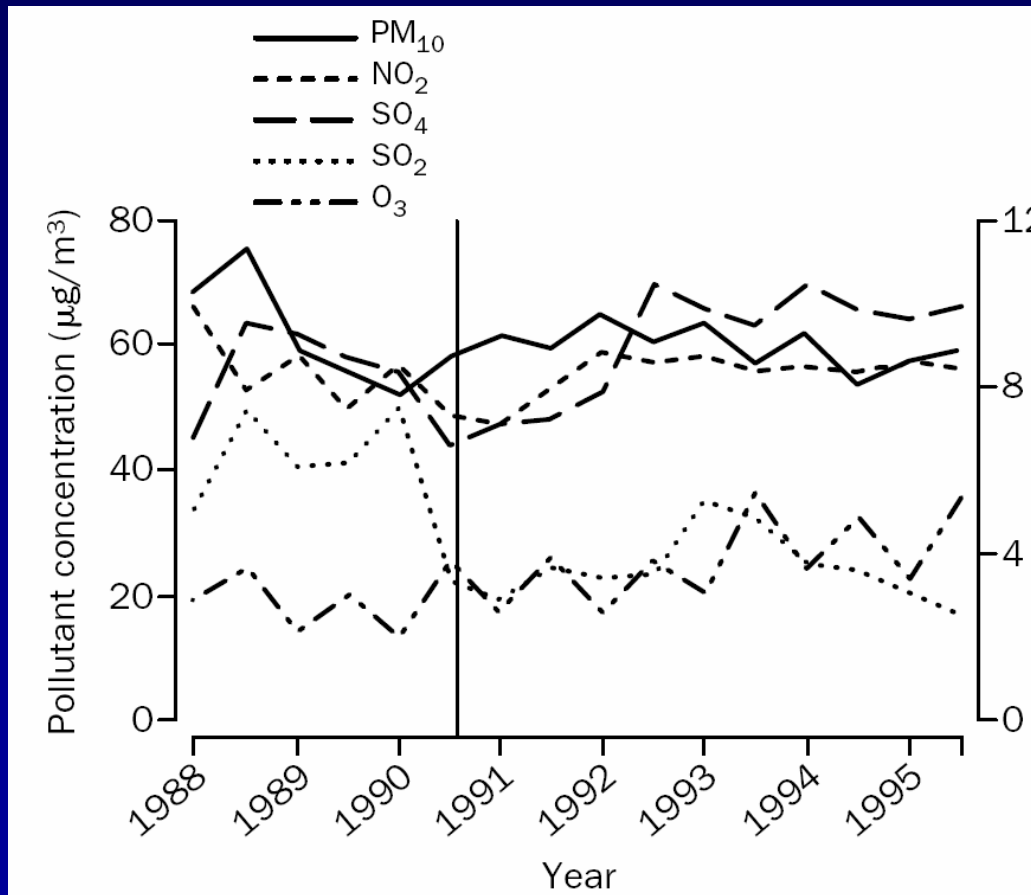
**500  $\mu\text{g}/\text{m}^3$  10-minute mean**

**WHO AQG 2000: 125  $\mu\text{g}/\text{m}^3$  24-hour mean**

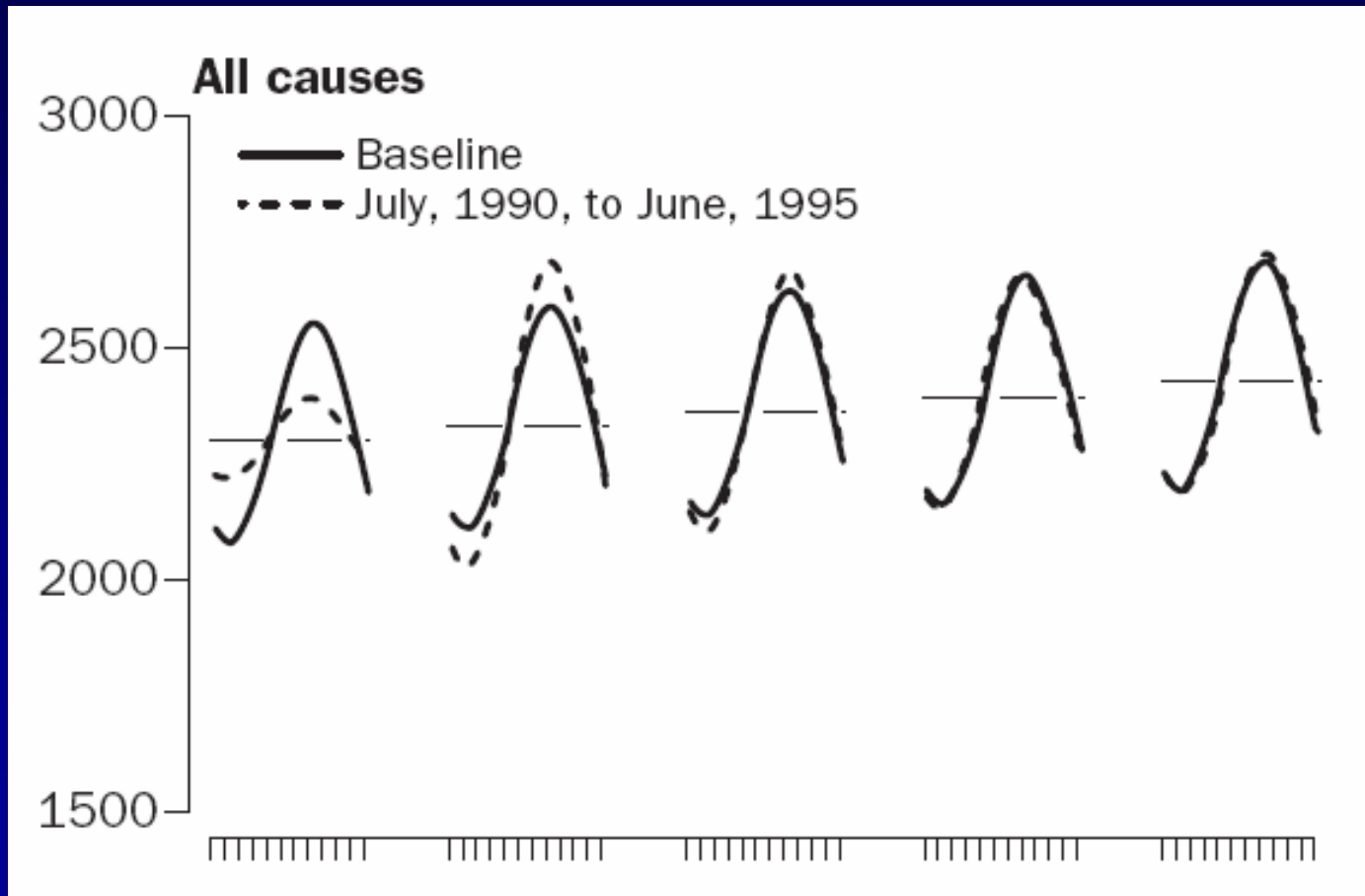
The latest evidence to emerge includes a study conducted in Hong Kong (Hedley et al., 2002) where a major reduction in the sulfur content of fuels has been achieved over a very short period of time. This has been linked to substantial reductions in health effects (e.g. childhood respiratory disease and all-age mortality). Recent time-series studies on hospital admissions for cardiac disease in Hong Kong and London, produced no evidence of a threshold for health effects at 24-hour  $\text{SO}_2$  concentrations in the range of 5–40  $\mu\text{g}/\text{m}^3$  (Wong et al., 2002). Twenty-four hour  $\text{SO}_2$  levels

# Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: an intervention study

Anthony Johnson Hedley, Chit-Ming Wong, Thuan Quoc Thach, Stefan Ma, Tai-Hing Lam, Hugh Ross Anderson



Lancet  
2002



## Cardiovascular Effects of Nickel in Ambient Air

*Morton Lippmann,<sup>1\*</sup> Kazuhiko Ito,<sup>1</sup> Jing-Shiang Hwang,<sup>2</sup> Polina Maciejczyk,<sup>1</sup> and Lung-Chi Chen<sup>1\*</sup>*

<sup>1</sup>New York University School of Medicine, Nelson Institute of Environmental Medicine, Tuxedo, New York, USA; <sup>2</sup>Institute of Statistical Science, Academia Sinica, Taipei, Taiwan

There has been one previous population study whose overall results can be interpreted as being consistent with an effect of Ni and/or V on daily mortality. Hedley et al. documented large reductions in the concentrations of Ni and V, but not in other metals, in Hong Kong after 1 July 1990 as a result of a mandated switch to fossil fuels with low S content (Hedley AJ, Chau PYK, Wong CM, unpublished data). This group (Hedley et al.

EHP 2006

**Table 4****WHO air quality guidelines and interim targets for SO<sub>2</sub>: 24-hour and 10-minute concentrations**

	<b>24-hour average (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>10-minute av- erage (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>Basis for selected level</b>
Interim target-1 (IT-1) <sup>a</sup>	125	–	
Interim target-2 (IT-2)	50	–	Intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value).
<b>Air quality guideline (AQG)</b>	<b>20</b>	<b>500</b>	

<sup>a</sup> Formerly the WHO Air Quality Guideline (WHO, 2000)

# Summary

- WHO AQGs have generally become lower
- Almost completely driven by new epidemiologic studies
- Thresholds increasingly difficult to find
- Single pollutants invariably occur in mixtures
- Evidence for single pollutant vs surrogate effect  $O_3 > PM > NO_2 > SO_2$
- [www.euro.who.int/air](http://www.euro.who.int/air)