Premature Mortality and Particulate Matter: A Critical Challenge in Urban Management

A Global Perspective on Effects, Placed in an Asian Context

Bob O'Keefe, Vice President
Health Effects Institute
Chair CAI-Asia

Sixth Regional EST Forum in Asia
New Delhi, India
9 November 2011

Sustainable Mobility and the Challenge of Particulate Matter

The evidence from Asia, in a global context

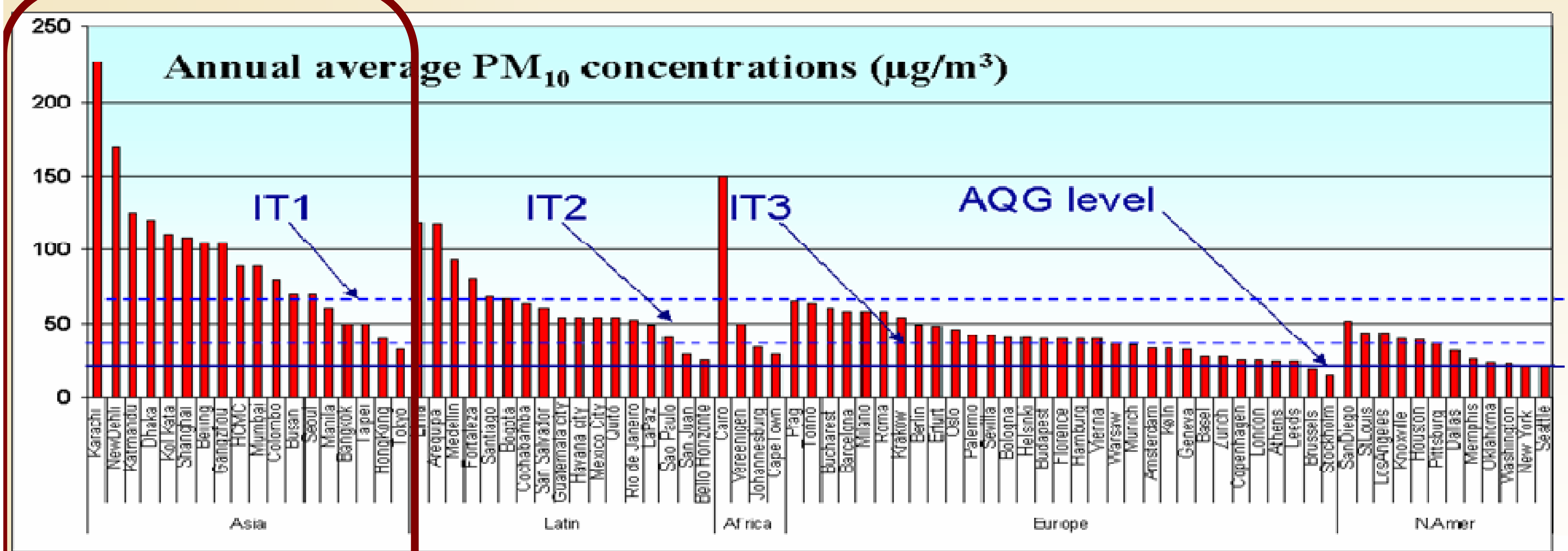
- The problem of Particulate Matter (PM)
  - PM levels in Asia
- What do we know about health effects?
  - PM, Nitrogen Oxides (NOx)
  - Effects of Traffic Exposure
  - Are effects similar in the developed and developing world?
- Who is most susceptible?
  - And how can transport policy exacerbate that?
- Hope for the future: the benefits of clean air

HEI

Air Pollution: A Problem Worldwide

Ambient Levels of Particulate Matter (PM) Exceed Current WHO Air Quality Guidelines

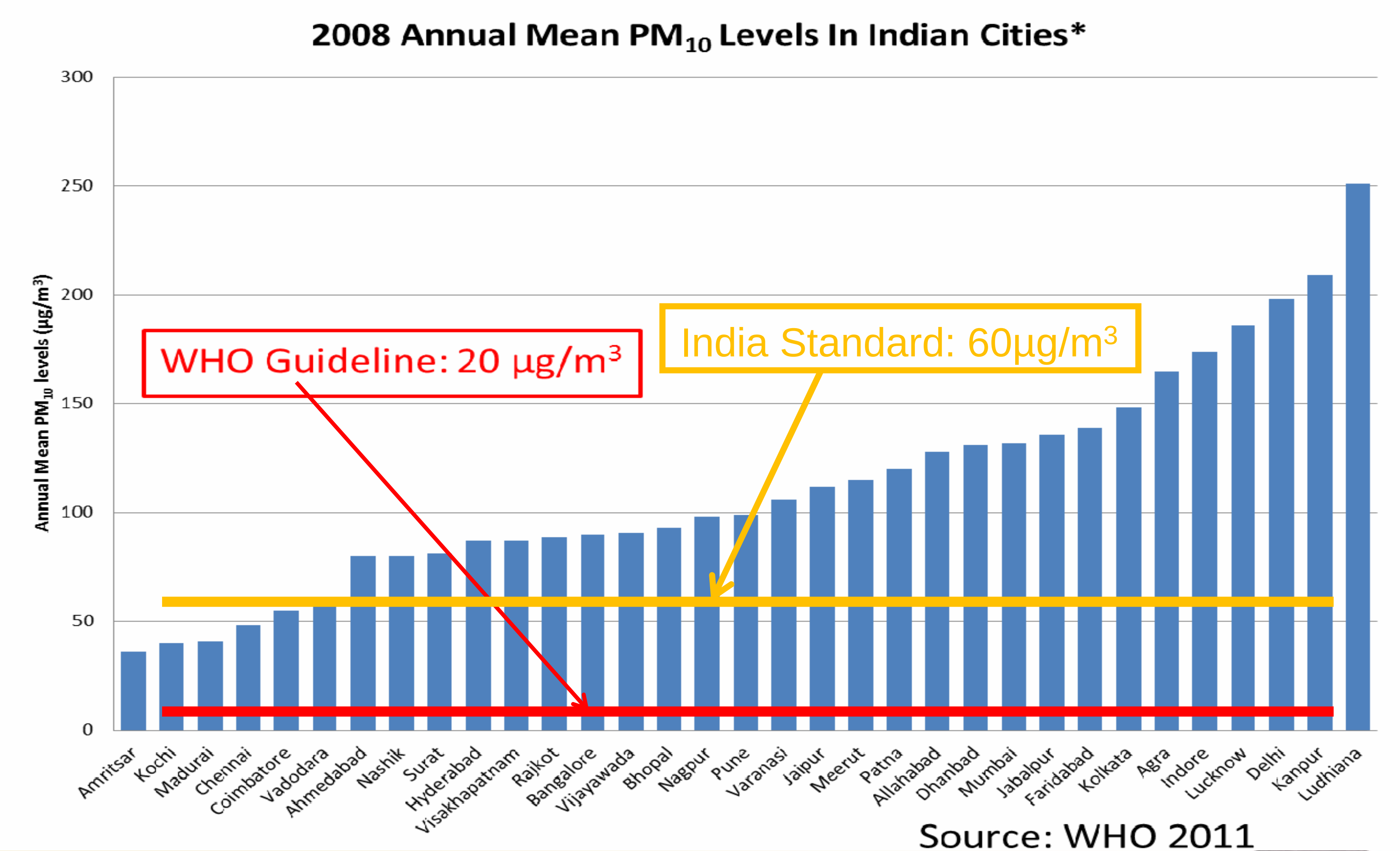
Especially in Some Asian Countries



ASIA

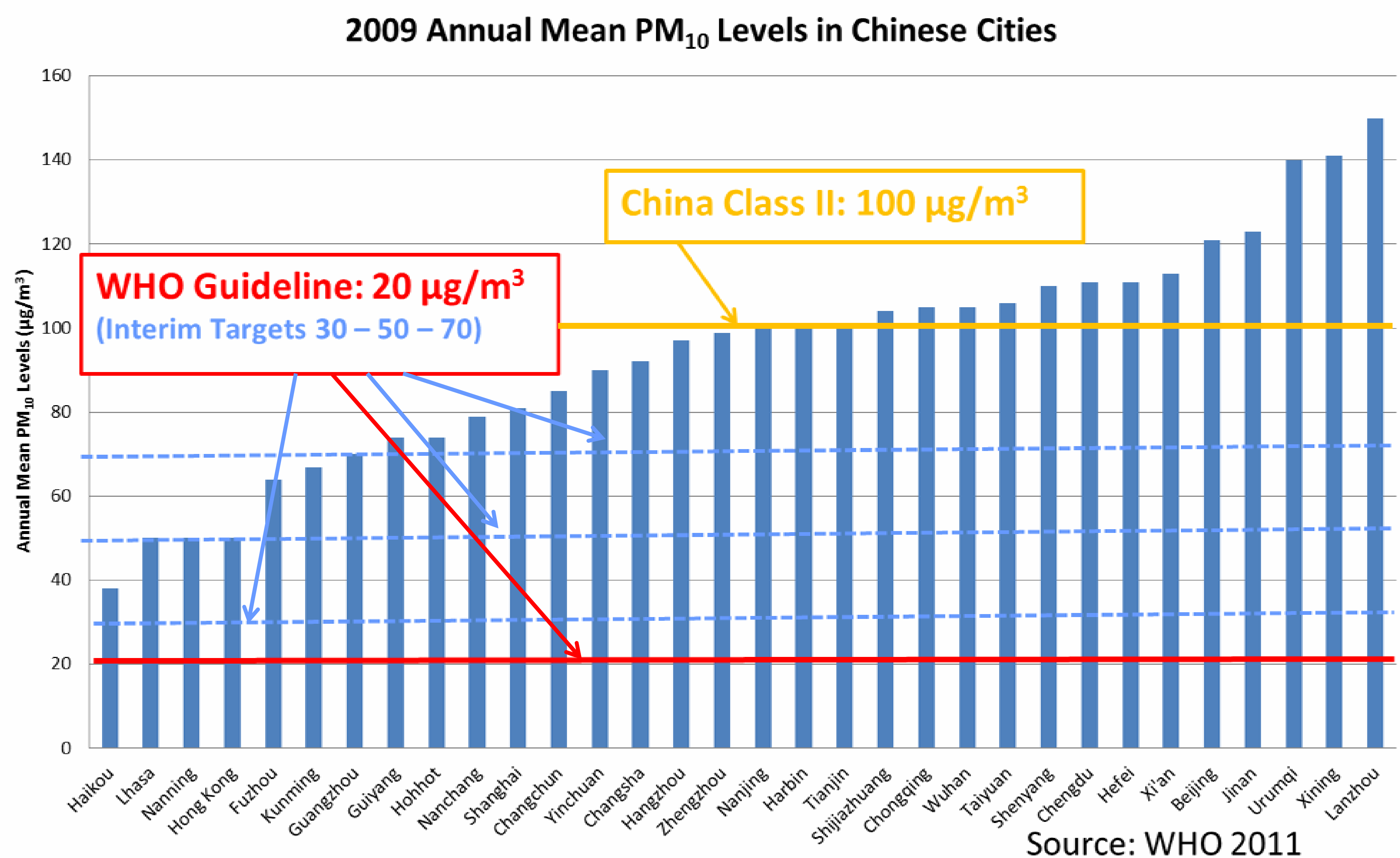
World Health Organization 2006

India: Many Cities Substantially Exceed WHO and Indian Air Quality Guidelines



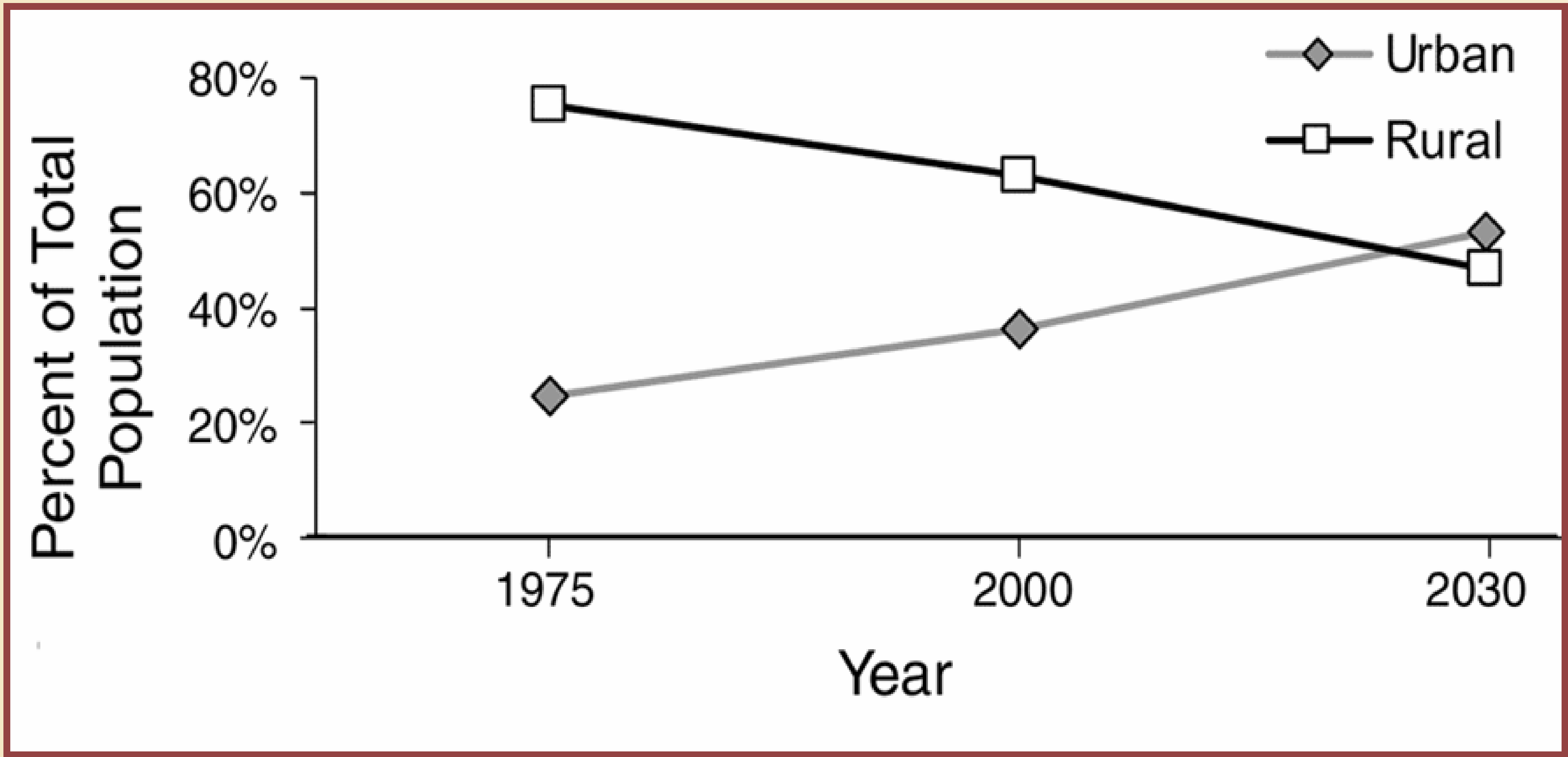
Source: WHO 2011

Most Chinese Cities Exceed WHO Air Quality Guidelines for PM_{10}



An Increasingly Urban Population

(data from UN/UN Centre for Human Settlements 1995-2002)



Sustainable Mobility and PM:

What Do We Know About Health Effects?

- PM
- Nitrogen Oxides (NOx)
- Traffic Health Effects

HEI Major Critical Review
(November 2010):

"Outdoor Air Pollution and Health in the Developing Countries of Asia"

-Asian Science in A Global Context

Summary of Current Global Epidemiologic Evidence on Health Effects of Air Pollution: Implications For Asia

Overview of all Asian health effects studies identified through 2007

Quantitative review (meta-analysis) of more than 80 time-series studies of daily mortality and hospital admissions

- ***Including 7 NEW PAPA Studies***

First-ever review of over 100 studies of the chronic effects of exposure to air pollution

HEI Special Report 18
www.healtheffects.org

*Public Health and Air Pollution in Asia – Science Access on the Net (PAPA-SAN)**

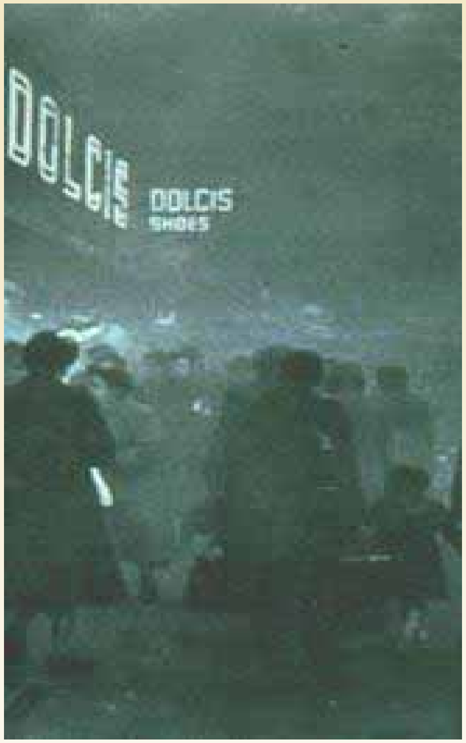
Studies of Air Pollution and Health in Asia, 1980–2007

- Web-based compendium of studies on health effects of air pollution in Asia
- Currently > 420 studies in 11 countries

*available at *http://www.healtheffects.org/Asia/papasan-home.htm*

PM

- High levels of PM (> 500 μ/m³) known to cause premature death
  - e.g. London 1952
- Studies in US, Europe, elsewhere have found association of PM with mortality at much lower levels (<50 μ/m³)
  - No evidence of a “threshold” (safe level)



London at Noon, December 1952

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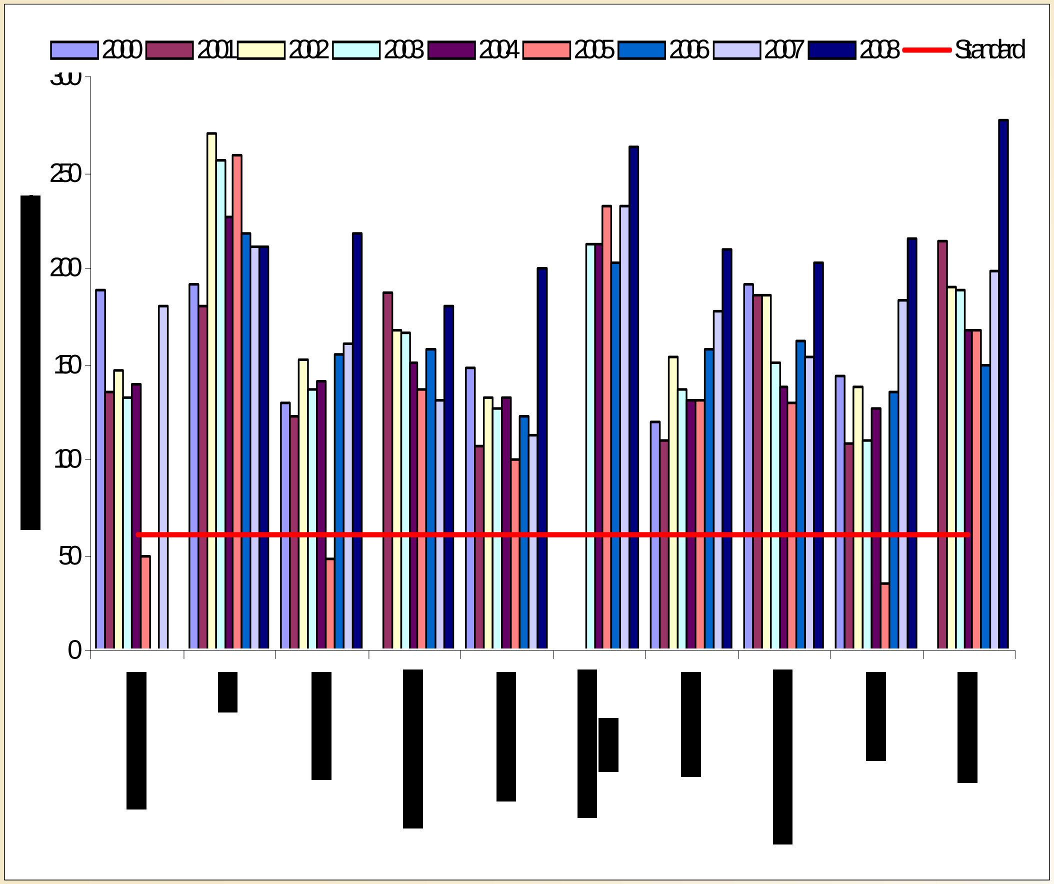
PM10 in Delhi:
Substantially Above Indian NAAQS of 60 µg/m^3

PM10: Annual average levels



hindustantimes

New Delhi, November 08, 2011

"Toxic Capital Air Killing Like Never Before"

Source: CSE analysis based on CPCB air quality data

HEI

India Ink The New York Times

Notes on the World's Largest Democracy

New Delhi India Gate November 21, 2011, 7:20 am
AQI 320,“ Hazardous“

Source: Ministry of Earth Sciences, Govt. of India

Effects of long-term $PM_{2.5}$ Exposure

Extended Follow-Up of the American Cancer Society Study of PM and Mortality; HEI Report #140, 2009

Tracking detailed effects in 600,000 people over 18 years

Large effects, especially for heart disease
(18% - 24% increase in risk per 10 μg/m^3 $PM_{2.5}$)

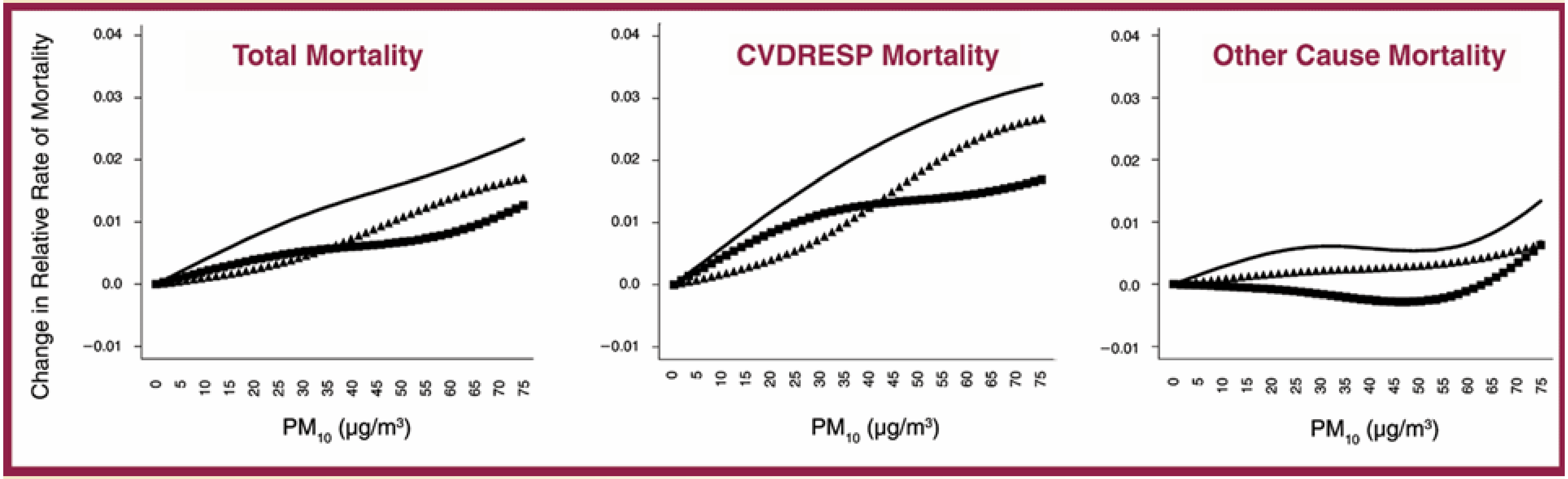
Commentary Table 3. Associations Between Various Causes of Death and Long-Term Exposure to $PM_{2.5}$ in Two Time Periods from the Nationwide Analysis[a]

Cause of Death	Standard Cox Model	Random Effects Cox Model[b]
HR per 10-μg/m^3 Change in $PM_{2.5}$ Exposure Level (Average for 1979–1983)		
All causes	1.03 (1.01–1.04)	1.04 (1.03–1.06)
Ischemic heart disease	1.12 (1.09–1.16)	1.18 (1.15–1.22)
Cardiopulmonary disease	1.06 (1.04–1.08)	1.09 (1.06–1.11)
Lung cancer	1.08 (1.03–1.14)	1.09 (1.03–1.15)
HR per 10-μg/m^3 Change in $PM_{2.5}$ Exposure Level (Average for 1999–2000)		
All causes	1.03 (1.01–1.05)	1.06 (1.04–1.08)
Ischemic heart disease	1.15 (1.11–1.20)	1.24 (1.19–1.29)
Cardiopulmonary disease	1.09 (1.06–1.12)	1.13 (1.10–1.16)
Lung cancer	1.11 (1.04–1.18)	1.14 (1.06–1.23)

Short Term (Daily) PM Effects

National Morbidity, Mortality and Air Pollution Study (NMMAPS)

Approximately 0.2% increase in mortality per 10 µg/m³ PM10

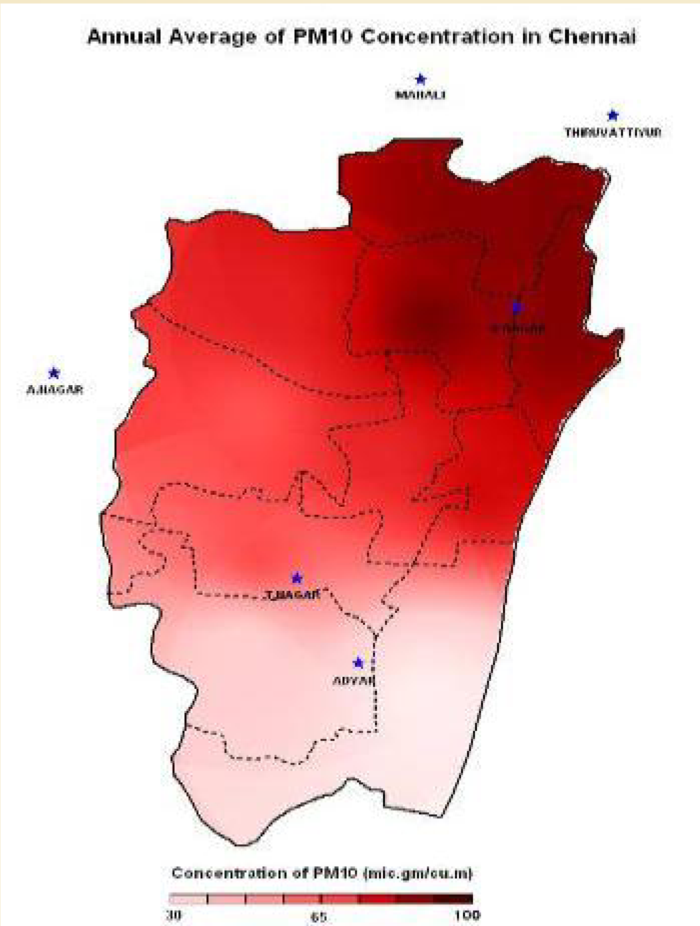


20 largest US cities
(Daniels et al HEI 2004)

New Indian Results:

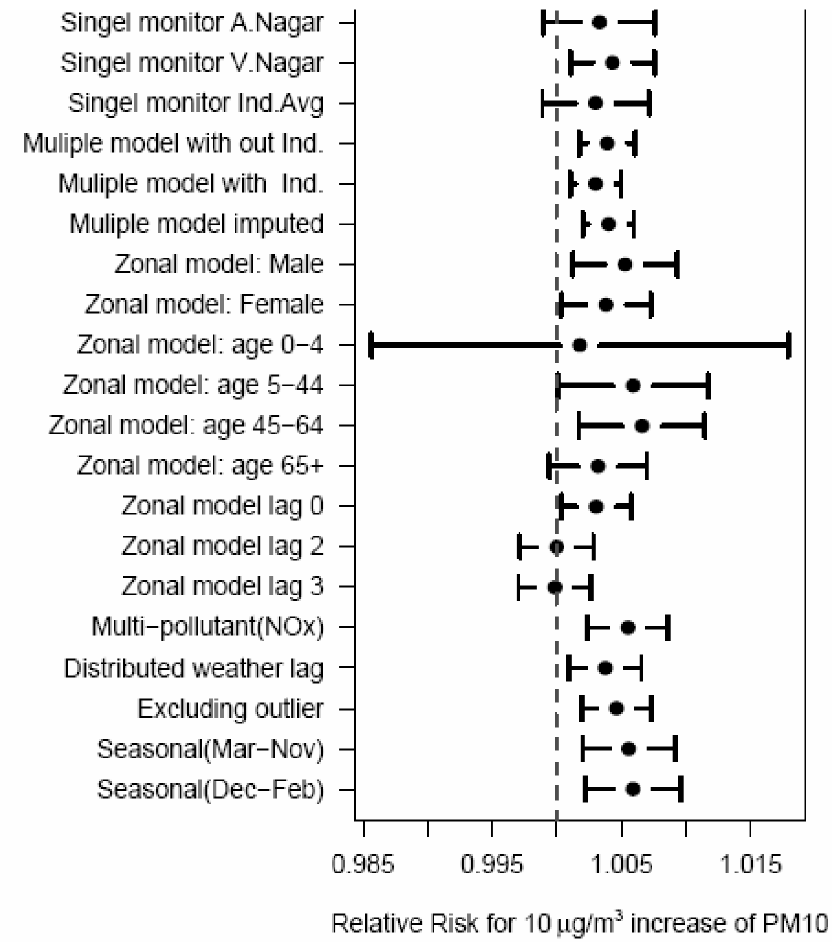
PM10 Evidence from Chennai PAPA study

Approximately 0.3% -0.6% increase in mortality per *10 µg/m³* PM10



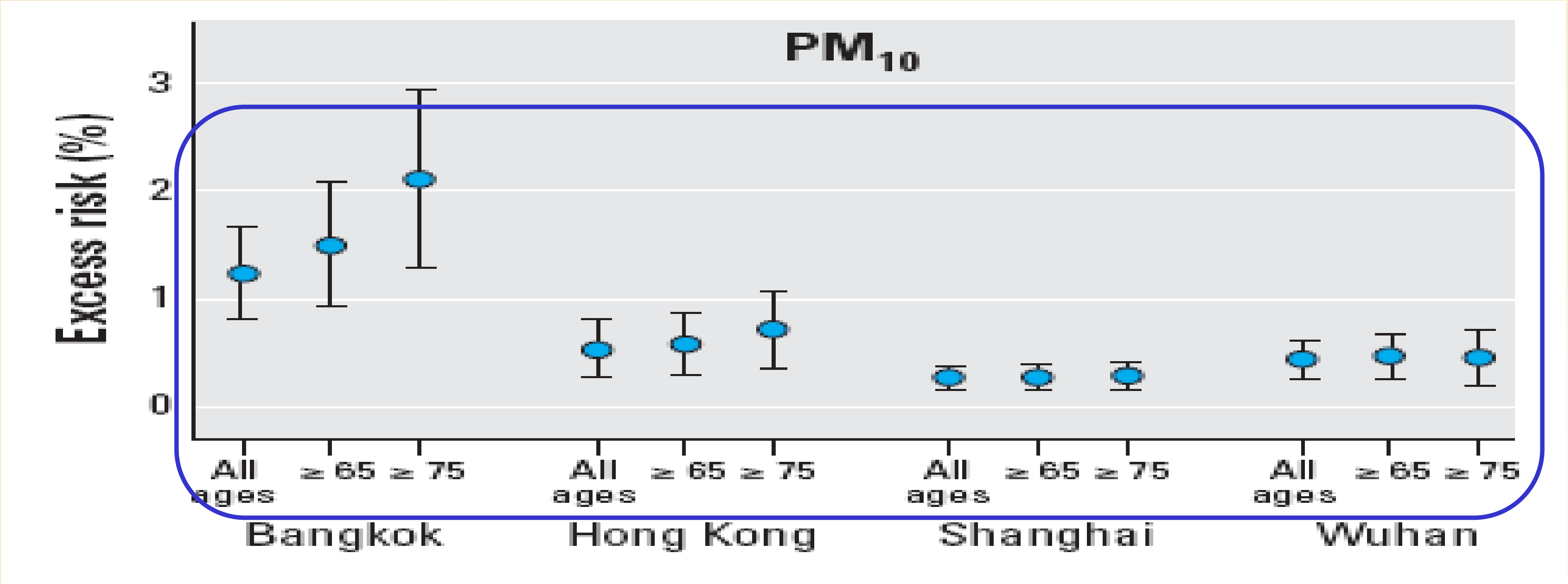
Dr. Kalpana Balakrishnan and colleagues HEI 2011

Fig. 23: A comparison of the estimated RR's for PM10 obtained from the core zonal model, alternative models and sensitivity analysis.



Chinese and Thailand Results
PM10 Evidence from the PAPA Multi-City, Coordinated Studies

Consistent small increase in premature mortality risk with daily increase in PM10



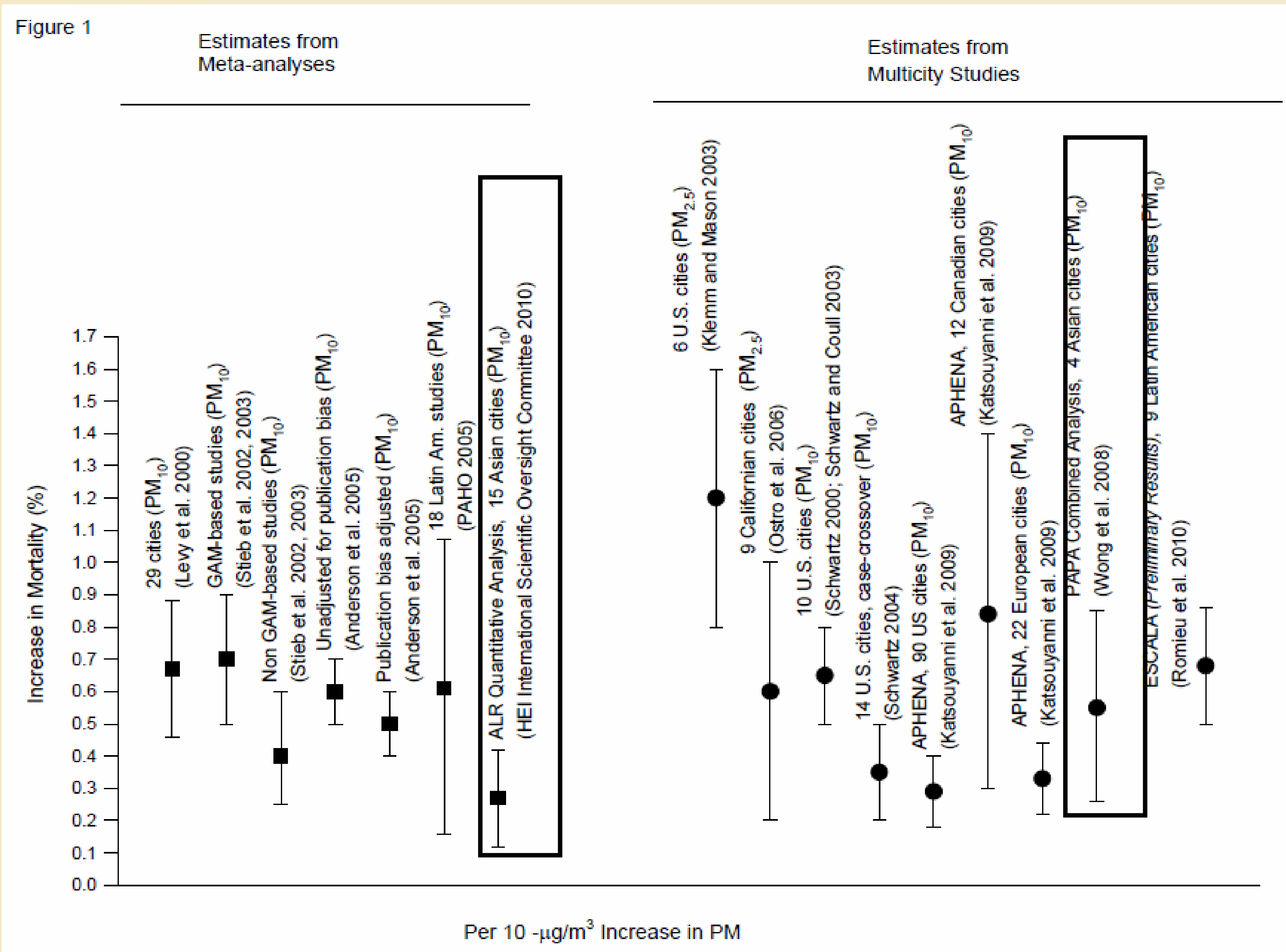
Excess risk (%) of mortality for a 10mg/m3 increase in average concentration of pollutants (lag 0-1 days)

HEI Research Report 154, November 2010

Asia in a Global Context

(Risk of Premature Mortality with Increased Exposure to PM10)

Effects of pollution on people around globe are more similar than different



New: WHO Global Burden of Disease Report September 2011

World Health Organization

Estimates impact of urban outdoor air pollution worldwide:

~795,000 premature deaths per year attributable to PM air pollution in Asian cities

Articles

Selected major risk factors and global and regional burden of disease

*Majid Ezzati, Alan D Lopez, Anthony Rodgers, Stephen Vander Hoorn, Christopher J L Murray, and the Comparative Risk Assessment Collaborating Group**

Summary

Background Reliable and comparable analysis of risks to health is key for preventing disease and injury. Causal attribution of morbidity and mortality to risk factors has traditionally been in the context of individual risk factors, often in a limited number of settings, restricting comparability. Our aim was to estimate the contributions of selected major risk factors to global and regional burden of disease in a unified framework.

Methods For 26 selected risk factors, expert working groups undertook a comprehensive review of published work and other sources—eg, government reports and international databases—to obtain data on the prevalence of risk factor exposure and hazard size for 14 epidemiological regions of the world. Population attributable fractions were estimated by applying the potential impact fraction relation, and applied to the mortality and burden of disease estimates from the global burden of disease (GBD) database.

Findings Childhood and maternal underweight (138 million disability adjusted life years [DALY], 9·5%), unsafe sex (92 million DALY, 6·3%), high blood pressure (64 million DALY, 4·4%), tobacco (59 million DALY, 4·1%), and alcohol (58 million DALY, 4·0%) were the leading causes of global burden of disease. In the poorest regions of the world, childhood and maternal underweight, unsafe sex, unsafe water, sanitation, and hygiene, indoor smoke from solid fuels, and various micronutrient deficiencies were major contributors to loss of healthy life. In both developing and developed regions, alcohol, tobacco, high blood pressure, and high cholesterol were major causes of disease burden.

Interpretation Substantial proportions of global disease burden are attributable to these major risks, to an extent greater than previously estimated. Developing countries suffer most or all of the burden due to many of the leading risks. Strategies that target these known risks can provide substantial and underestimated public-health gains.

Published online Oct 30, 2002
http://image.thelancet.com/extras/02art9066web.pdf
See Commentary

*Members listed at end of paper

Risk, Resources and Environmental Management Division, Resources for the Future, Washington, DC, USA (M Ezzati PhD); **Evidence and Information for Policy, WHO, Geneva, Switzerland** (Prof A D Lopez PhD, Prof C J L Murray MD); **and Clinical Trials Research Unit (CTRU), University of Auckland, New Zealand** (A Rodgers FRAFPHM, S Vander Hoorn MSc)

Correspondence to: Dr C J L Murray, Evidence and Information for Policy, WHO, CH-1211 Geneva, Switzerland
(e-mail: murrayc@who.int)

Introduction

Detailed descriptions of the magnitude and distribution of diseases and injuries, and their causes are important inputs to strategies for improving population health. Much work has focused on the quantification of mortality patterns and, more recently, on burden of disease.[1,2] Data on disease or injury outcomes alone, such as death or admission to hospital, tend to focus on the need for palliative or curative services. Reliable and comparable analysis of risks to health, however, is key for preventing disease and injury. Analysis of morbidity and mortality due to risk factors has frequently been done in the context of methodological traditions of individual risk factors and in a limited number of settings.[3–10] As a result, most such estimates have been made relative to an arbitrary, constant level of population exposure, without standardisation of the baseline exposure across risk factors. For example, the implicit baseline for much of the estimates of occupational disease and injuries has been "no work". Furthermore, the criteria for assessment of scientific evidence on prevalence, causality, and hazard size have varied greatly across risk factors, resulting in lack of comparability of estimated population health effects. Finally, the outcome of such estimates has been morbidity or mortality due to specific disease(s), making comparison among different risk factors difficult.

To assess risk factors in a unified framework, while acknowledging risk-factor specific characteristics, the Comparative Risk Assessment module of the global burden of disease (GBD) 2000 study has been set up as a systematic assessment of the changes in population health, which would result from modifying the population distribution of exposure to a risk factor or a group of risk factors.[11] This unified framework for describing population exposure to risk factors and their consequences for population health is an important step in linking the growing interest in the causal determinants of health across various public-health disciplines from natural, physical, and medical sciences to the social sciences and humanities.

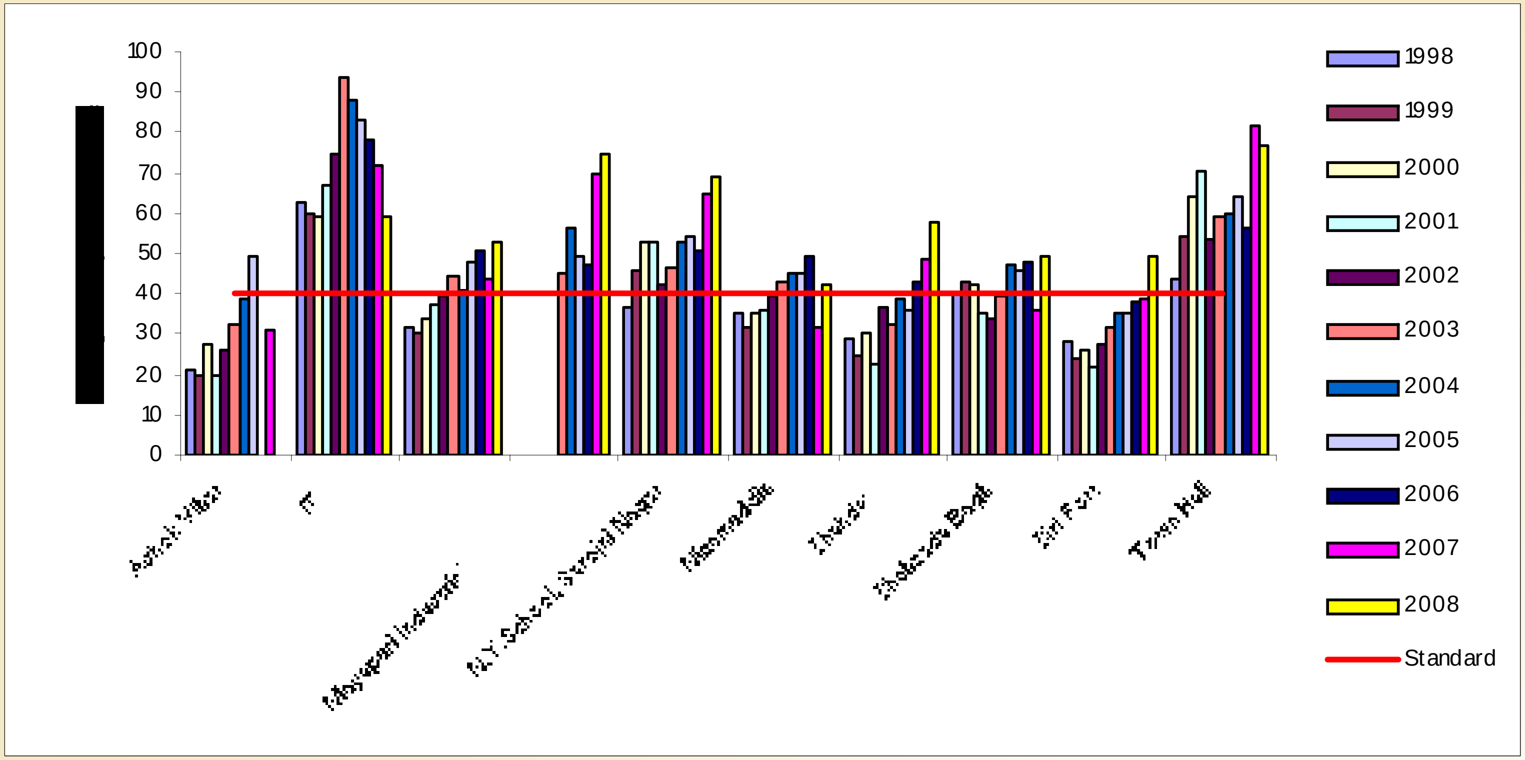
In addition to the above disciplinary obstacles and divisions, analysis of population health in a risk-based approach requires a framework for selection of risk factors among distal—eg, poverty or inequality—proximal and environmental—eg, air pollution or diet—and physiological—eg, blood pressure, HIV-1 as risk factor for tuberculosis—determinants of health.[12,13] Our aim was to develop such a framework by selecting risk factors in various levels of causality. Although gaps in epidemiological research on multiple layers of causality and risk-factor interactions would not allow inclusion of all inherently inter-related risk factors of interest, this selected group serves to emphasise the potential for disease prevention as a public-health tool.

The results of this work and additional background material are also presented in *World Health Report 2002:*

Nitrogen Dioxide (NO2)

- Known, like many “oxidants” to cause inflammation
- May cause serious problems at lower levels and short, high doses
- Also may be a “marker” for other pollutants (e.g. fine PM)

NOx Levels Rising in Delhi



Nitrogen oxide levels are rising in almost all locations in Delhi.

NOx also contributes to the problem of ozone pollution

Source: CSE analysis based on CPCB air quality data

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 SEPTEMBER 9, 2004 VOL. 351 NO. 11

The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age

W. James Gauderman, Ph.D., Edward Avol, M.S., Frank Gilliland, M.D., Ph.D., Hita Vora, M.S., Duncan Thomas, Ph.D., Kiros Berhane, Ph.D., Rob McConnell, M.D., Nino Kuenzli, M.D., Fred Lurmann, M.S., Edward Rappaport, M.S., Helene Margolis, Ph.D., David Bates, M.D., and John Peters, M.D.

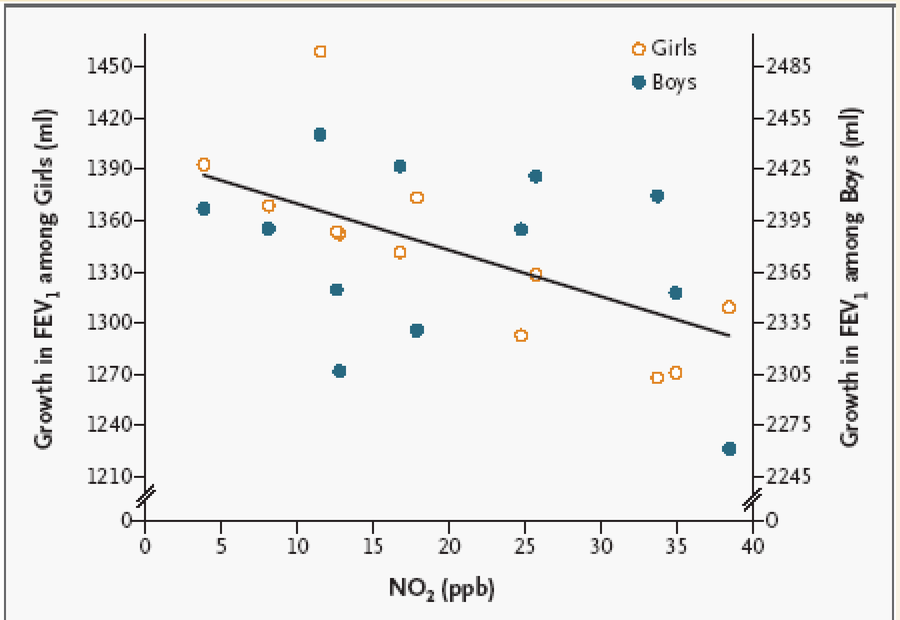


Figure 2. Community-Specific Average Growth in FEV_1 among Girls and Boys During the Eight-Year Period from 1993 to 2001 Plotted against Average Nitrogen Dioxide (NO_2) Levels from 1994 through 2000.

Childhood lung function development reduced in those exposed to higher NO2

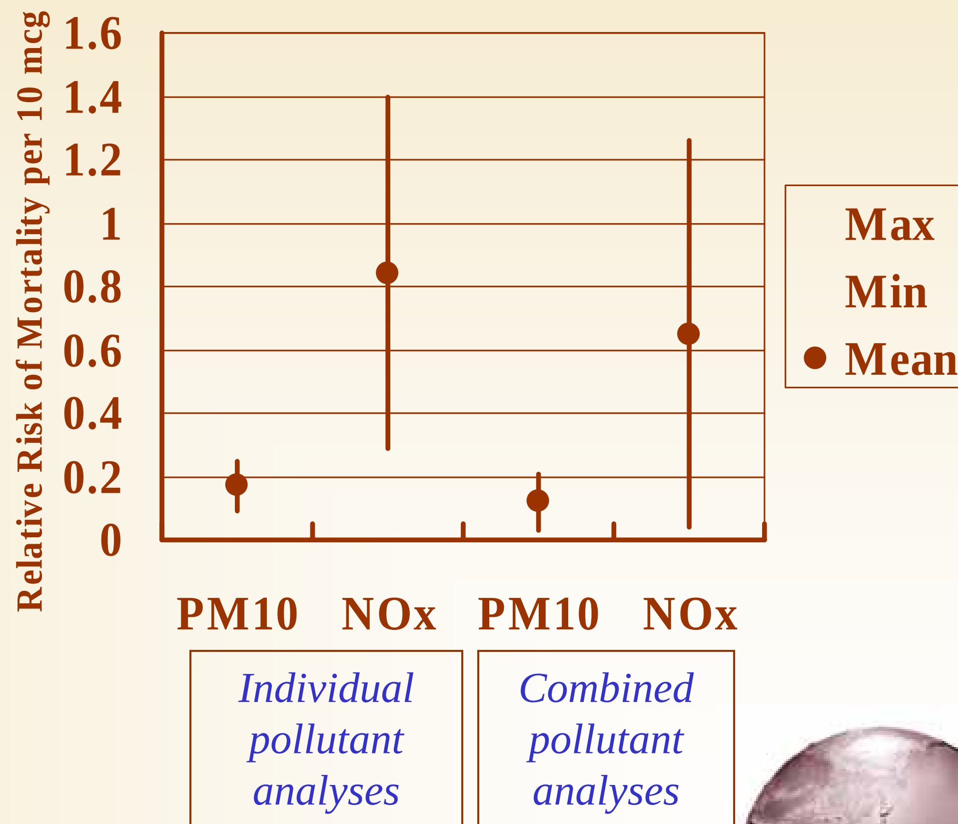
Community-specific average growth in FEV1 among Girls and Boys for the period 1993 to 2001 plotted against average nitrogen dioxide (NO2) levels from 1994 to 2000 (Gauderman 2004)

HEI

New NOx Results from India:

HEI Delhi (March 2011)

- Delhi study also tested Nitrogen Oxide and daily mortality associations
  - Independently and with PM10
- Found higher estimates of risk for NOx (0.65%/10 µg/m^3) than for PM10



The Role of Traffic Related Air Pollution

Traffic Related Air Pollution & Health: A Major Expert HEI Review 2010

Summarized & synthesized over 700 studies on health effects of traffic

- *Across a diverse and complex literature*

Found :

- *Highest exposures 300-500 meters from major roads*
- *Growing evidence of effects, especially asthma exacerbation in children*
- *Some questions still to be answered*

The New York Times

January 13, 2010

Report Links Vehicle Exhaust to Health Problems

A relationship was found between pollution from vehicles and impaired lung function and accelerated hardening of the arteries.

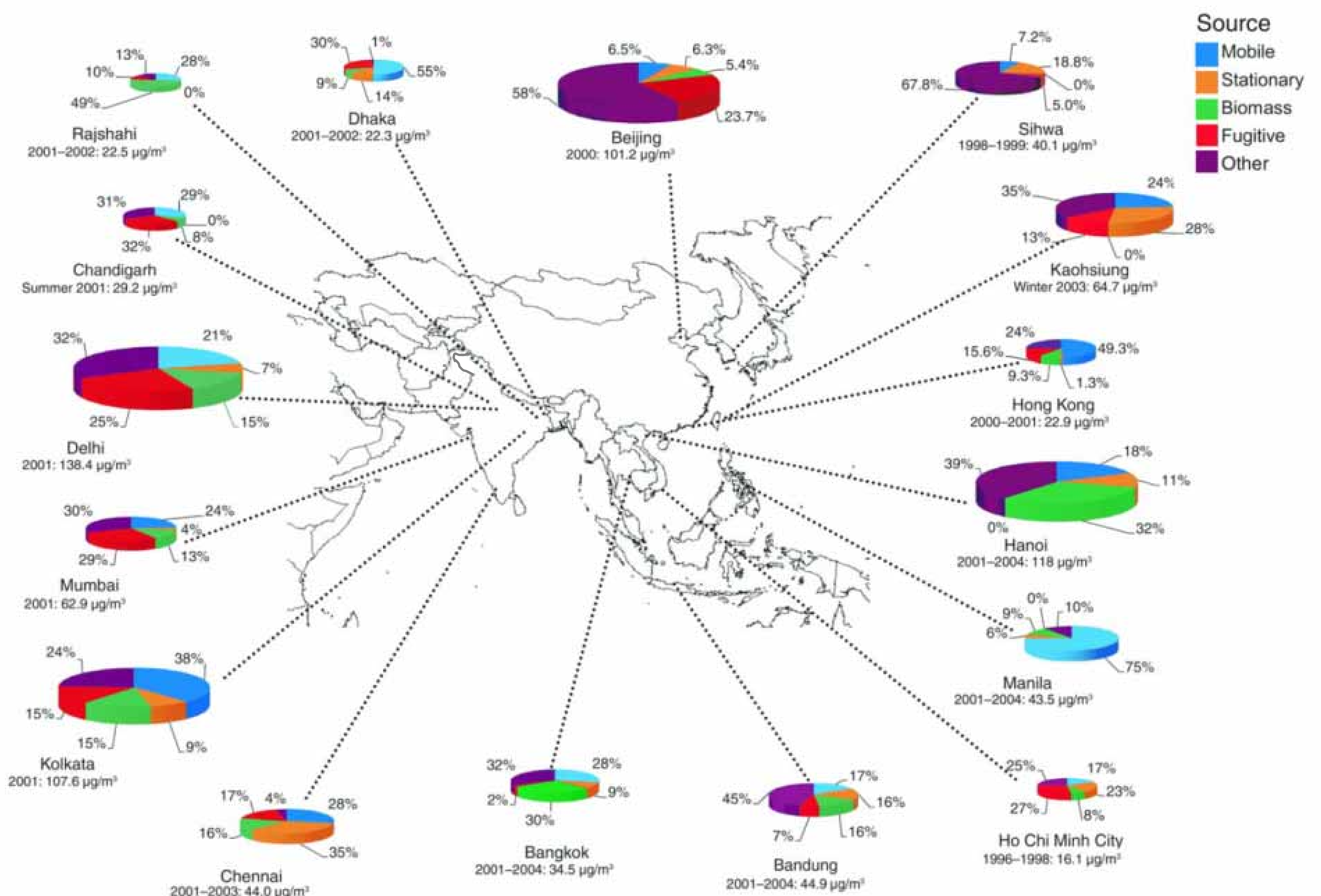
By MATTHEW L. WALD

Exhaust from cars and trucks exacerbates asthma in children and may cause new cases as well as other respiratory illnesses and heart problems resulting in deaths, an independent institute that focuses on vehicle-related air pollution has concluded.

The report, to be issued on Wednesday by the nonprofit Health Effects Institute, analyzed 700 peer-reviewed studies conducted around the world on varying aspects of motor vehicle emissions and health. It found "evidence of a causal relationship," but not proof of one, between pollution from vehicles and impaired lung function and accelerated hardening of the arteries.

It said there was "strong evidence" that exposure to traffic helped cause variations in heart rate and other heart ailments that result in deaths. But among the many studies that evaluated death from heart problems, some did not separate stress and noise from air pollution as a cause, it said.

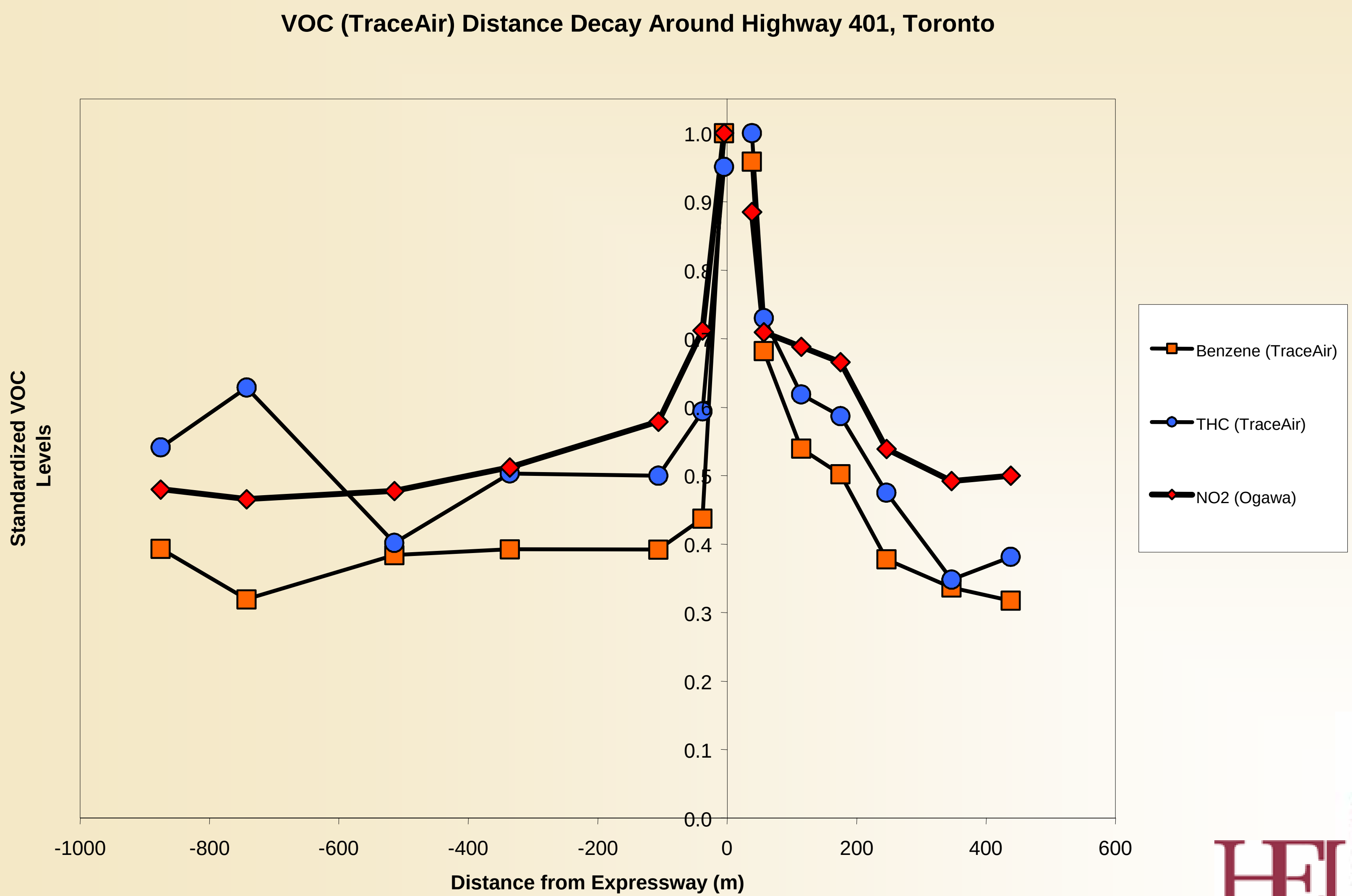
Asia PM 2.5 Source Apportionment: Vehicles ~20% - 35%



Source: Chowdhury, HEI 2010

Who is Likely to be Exposed?

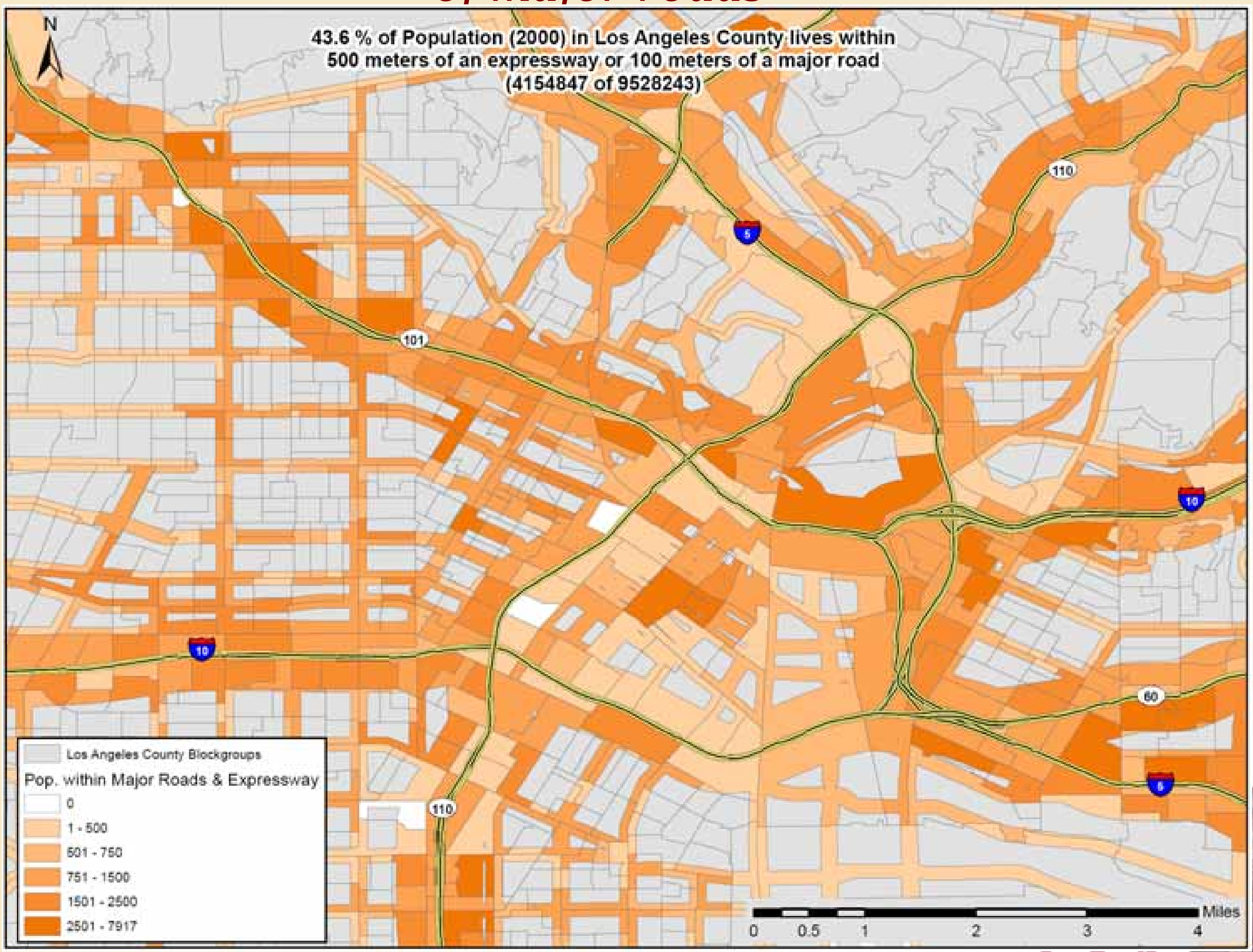
Highest levels within 300 – 500 meters of a major road



Toronto, Beckerman et al. (2008)

The HEI Traffic Review:

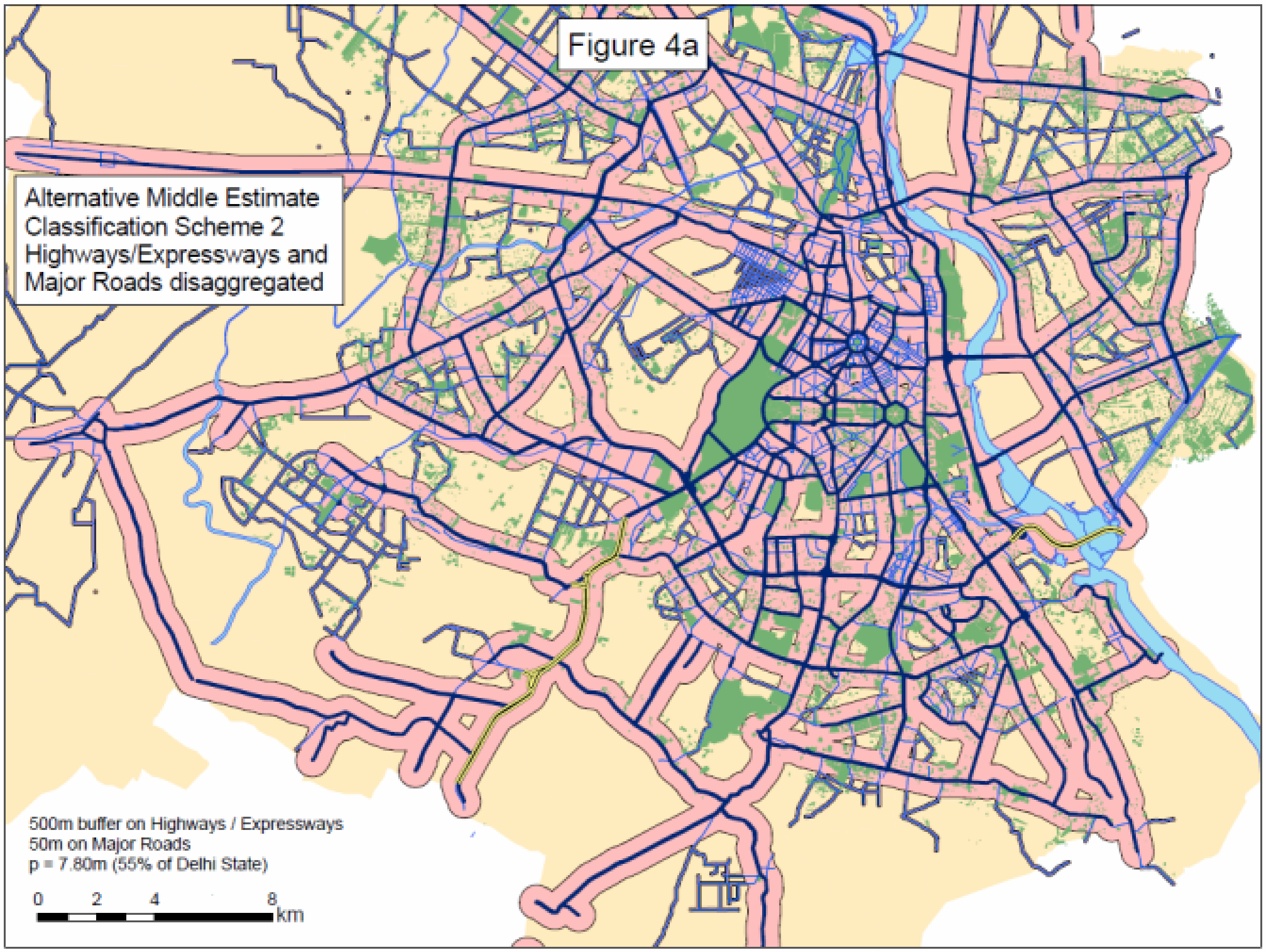
*In **Los Angeles**, **44% of population** live in the maximum zone of impact of major roads*



(within 500 meters of an expressway; 100 meters of a major road)

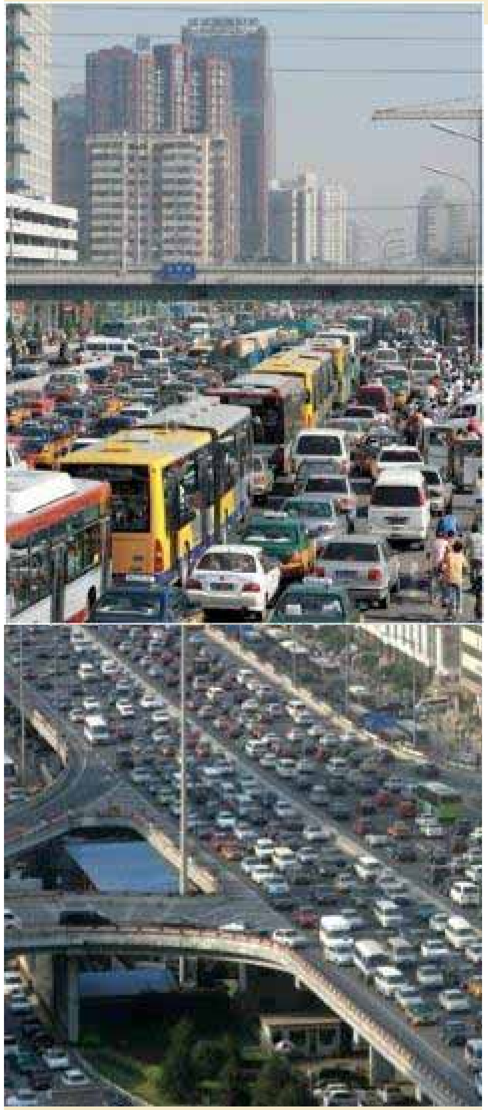
The Traffic Impact Area in Delhi:

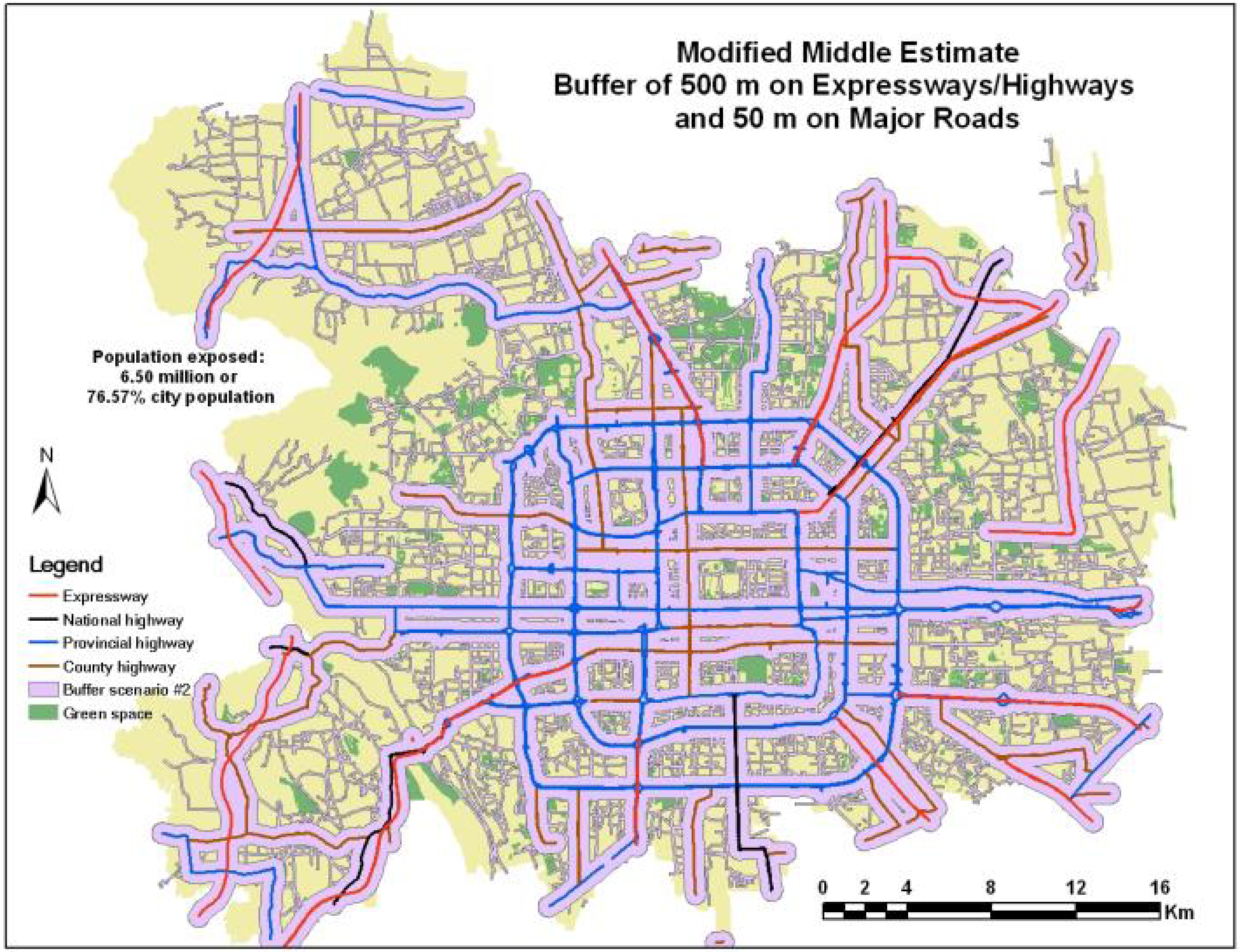
*New HEI Analysis: **55% of the Population** within 500 meters of a highway; 50 meters of a major road*



The Traffic Impact Area in Beijing:

New HEI Analysis: ***76% of the Population*** *within 500 meters of a highway; 50 meters of a major road*





Overall Traffic Conclusions

- While the data are often incomplete, the Panel found:
  - ***Sufficient*** evidence that exposure to traffic can cause exacerbation of asthma, especially in children
  - ***Suggestive*** evidence for other health effects (premature mortality, lung function, respiratory symptoms, and others)
  - But only ***limited evidence*** of effects for: Adult onset asthma; Health care utilization; COPD; Non-asthmatic allergy; Birth outcomes; Cancers
- "Given the large number of people living within 300- 500 meters of a major road, the Panel concluded that exposures to primary traffic generated pollutants are likely to be of public health concern and deserve attention"

HEI

New: WHO Global Burden of Disease Report September 2011

Estimates impact of urban outdoor air pollution worldwide:

~795,000 premature deaths per year attributable to PM air pollution in Asian cities

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Who is most at risk from premature mortality from PM Exposure?

- Highest effects generally seen among:
- Older, frail members of society
- Those with preexisting heart or lung disease

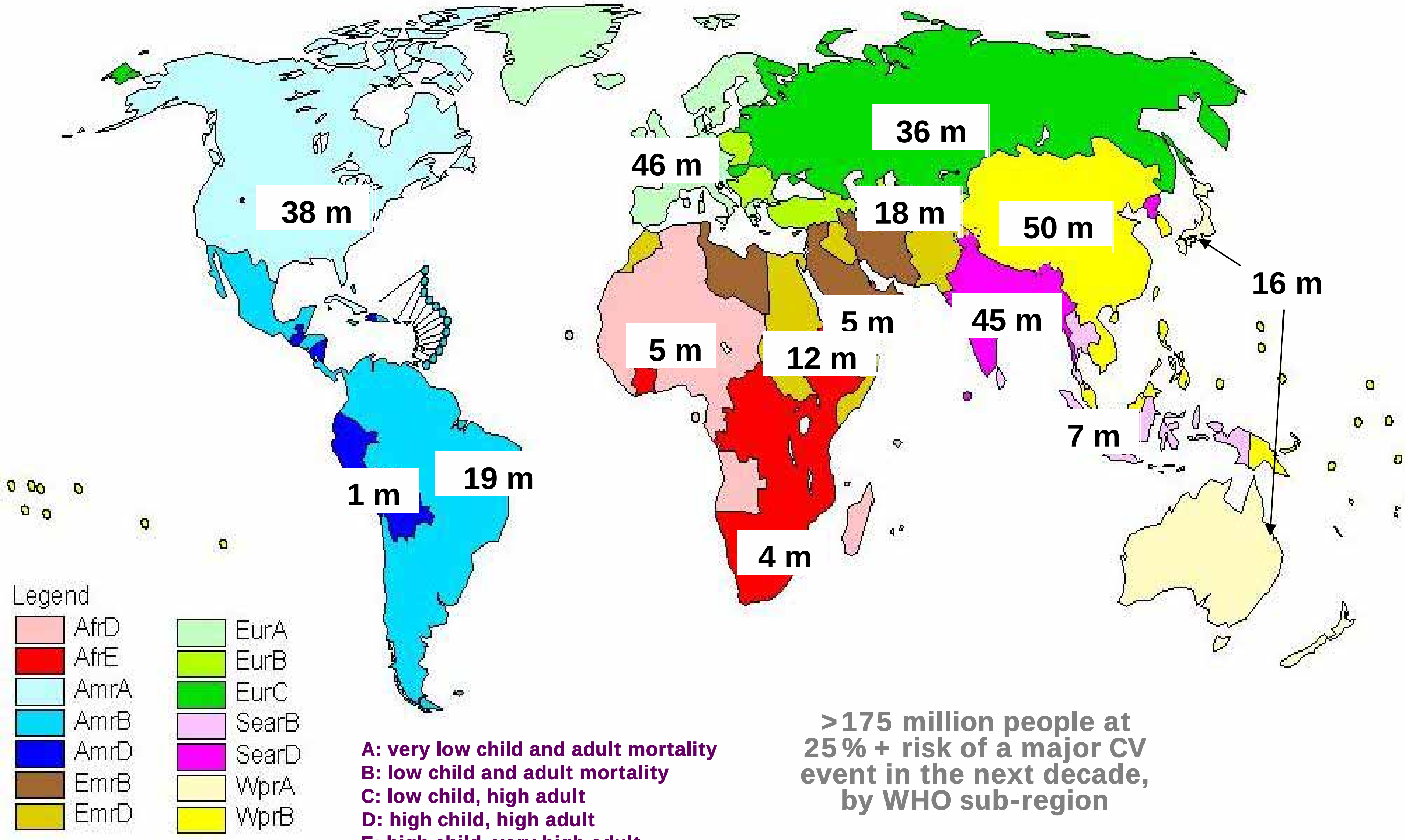
  Highest PM effects for Heart disease

  (18% - 24% increase in risk per 10 µg/m3PM2.5)

  Diseases that increase as populations age

  Diseases that increase with obesity, sedentary lifestyle

Number of people at high CV risk globally in 2000
(A Rogers 2005)



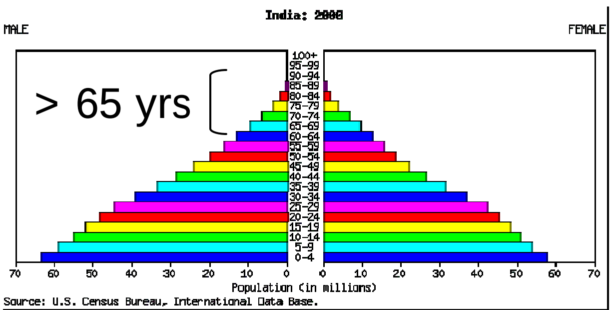
A: very low child and adult mortality
B: low child and adult mortality
C: low child, high adult
D: high child, high adult
E: high child, very high adult

>175 million people at 25% + risk of a major CV event in the next decade, by WHO sub-region

The demographic transition:

As Asia ages – and economies grow - susceptibility to heart disease increases

India 2000



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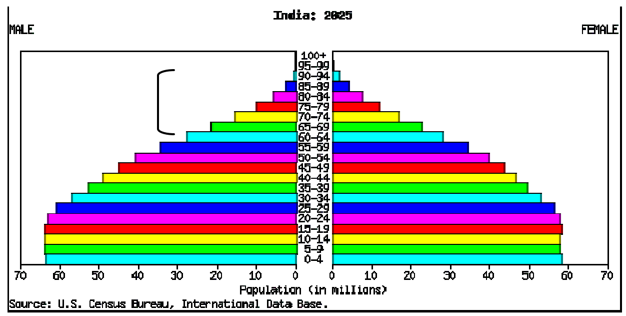
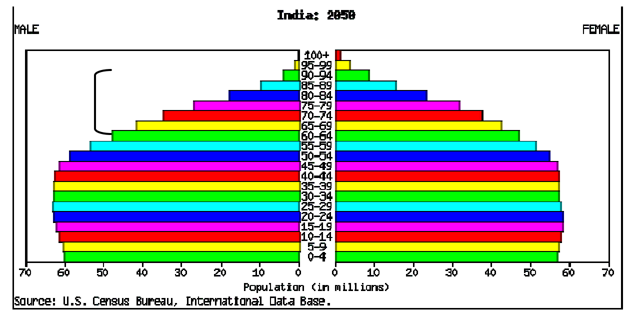
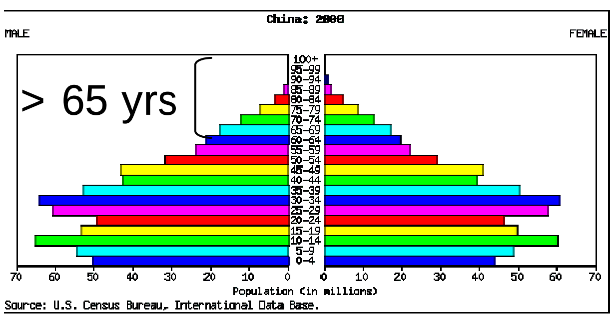


2050



China 2000



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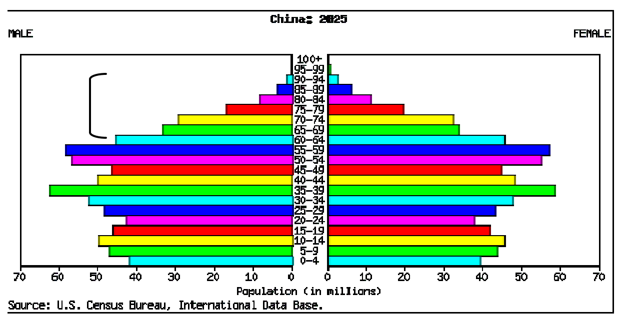

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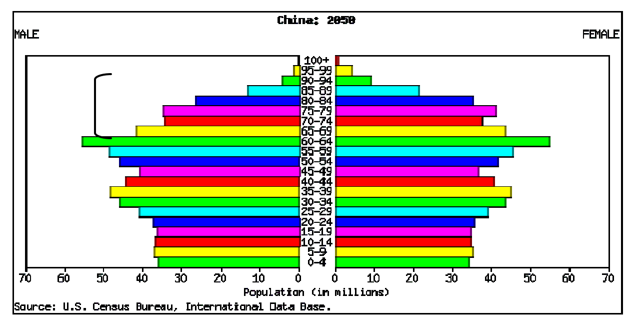

And how can transport policy exacerbate these trends?

As Asia ages, and economies grow, barriers to cardiovascular fitness are also increasing

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29S-6328

Physical Activity

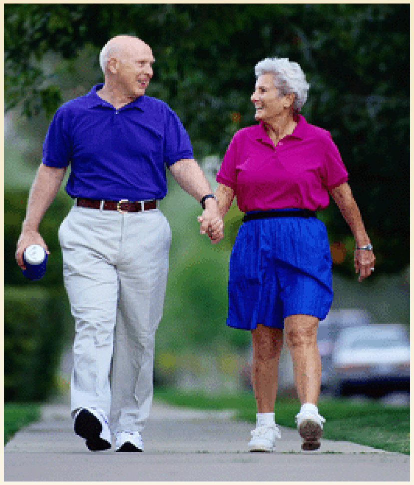
Non-walkable environment

Sedentary lifestyle

Overweight

Increase in Cardiovascular disease

Increasing susceptibility to air pollution



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Can We Look To the U. S. for Solutions to a motorized society?

The "No Sidewalk" Approach

The obstructed sidewalk

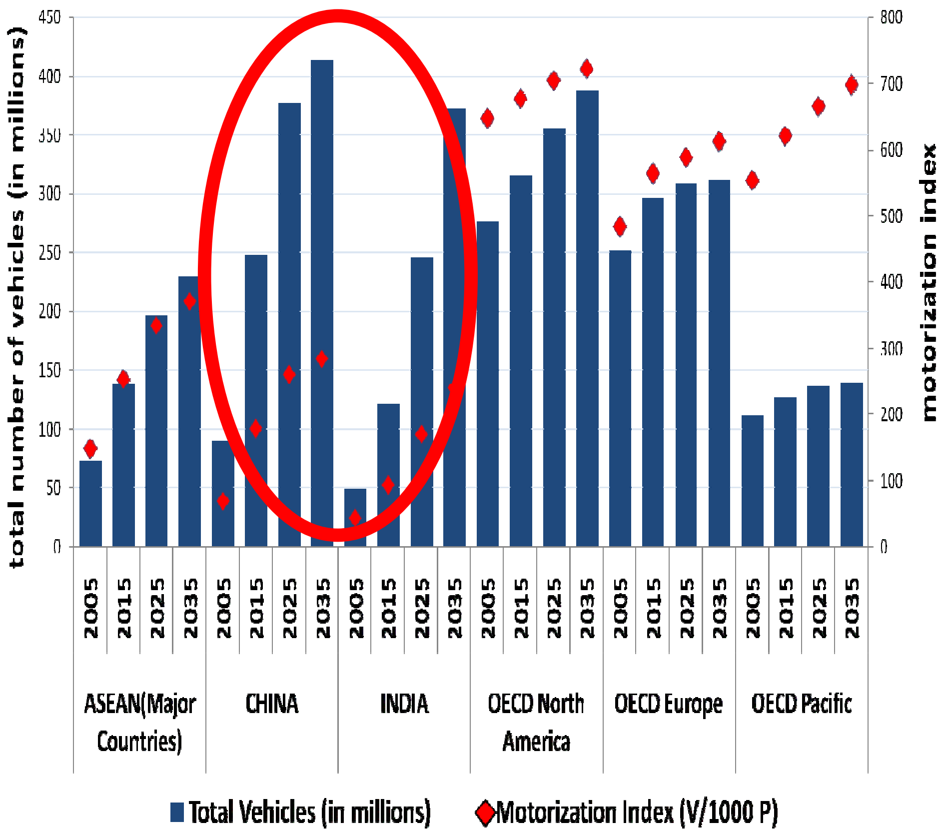
The Mixed Message

Perhaps,

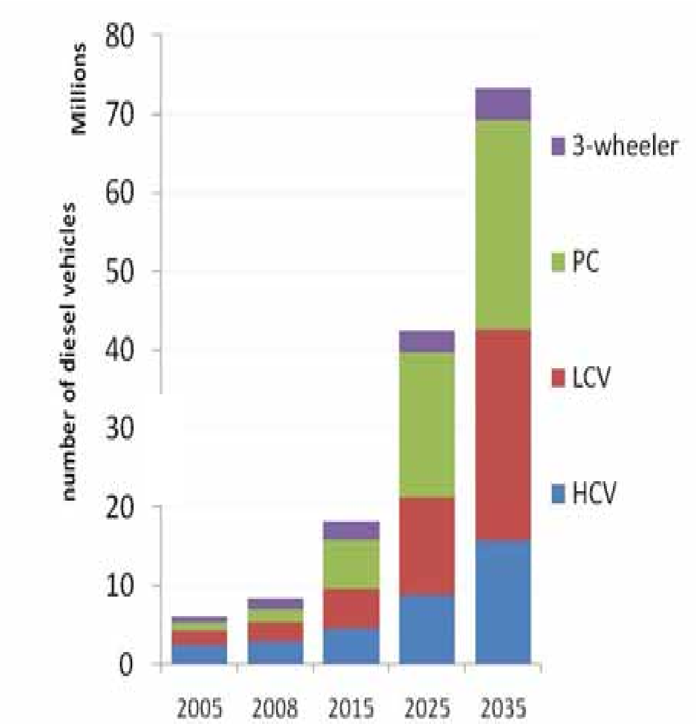
but only sometimes…

Increasing Motorization Across Asia

Vehicles



Diesel Vehicles



Source: 2009. ADB, CAI-Asia, Segment Y Ltd., and IEA

And what can come with car-based economies?

No need to walk to the mail box!

Drive-Thru Wedding Chapel

Las Vegas, NV

So much for the "walk down the aisle"

You can avoid exercise <u>and</u> *eat pastry at the same time*

An especially good idea,
purchase alcohol while driving

Drive-Thru Funerals

Gardner Memorial Chapel

Junior Funeral Home

Adams Funeral Parlor

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Global Concern for Road Safety

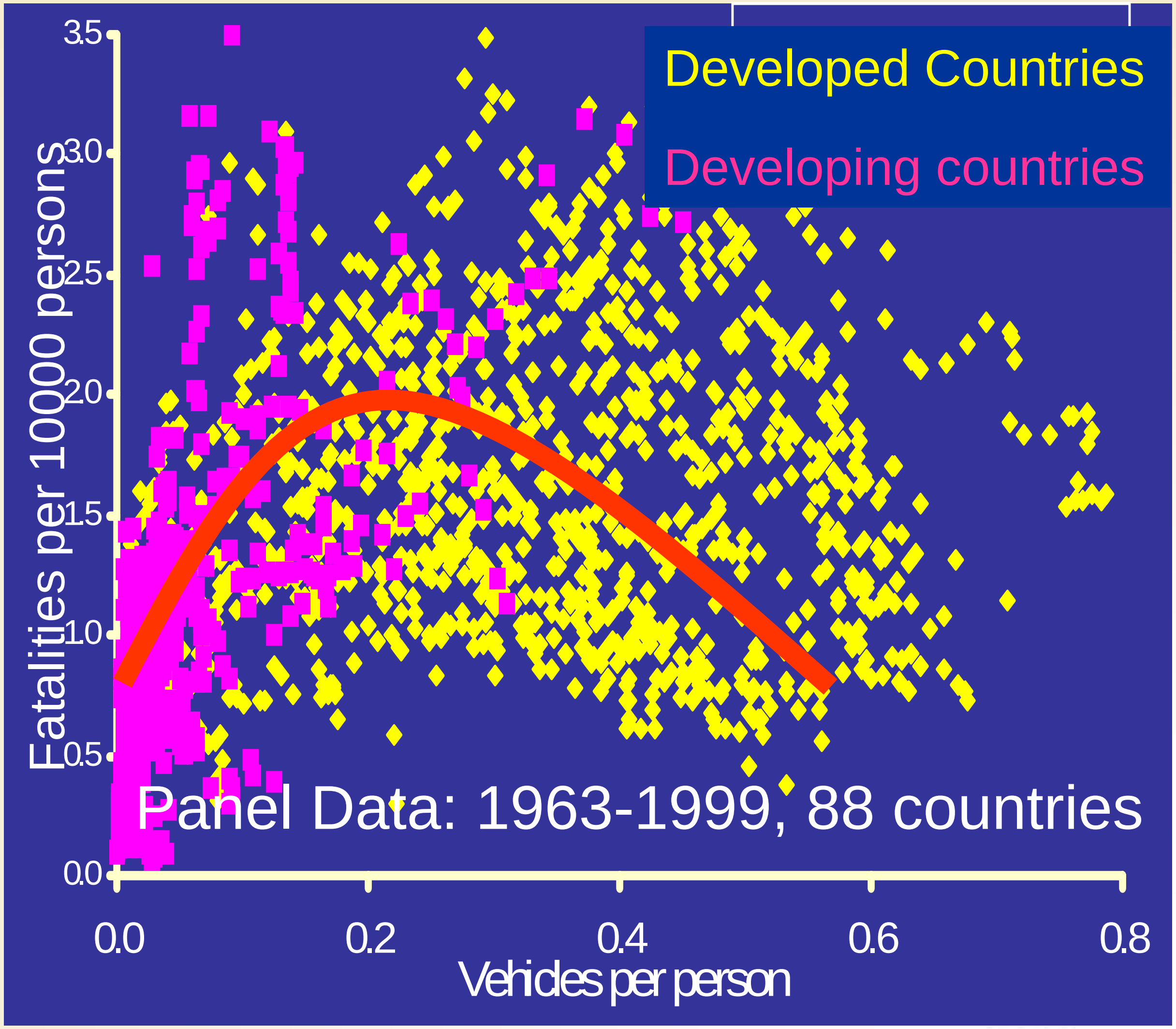
WHO 2002:

-1.2 million fatalities worldwide

-50 million injuries

-Estimated as 11th leading cause of death in the world

Increasing Vehicles vs. Rates of Mortality (Bhalla 2009)



Toward a Sustainable Future:

Many ways forward

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Toward a sustainable future

Many ways forward

- Cleaner fuels and vehicles
- Green Freight
- Improved Urban Planning
- Public transit
- Improved walkability
- Bicycle paths

- Many, many others……

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The NEW ENGLAND JOURNAL of MEDICINE

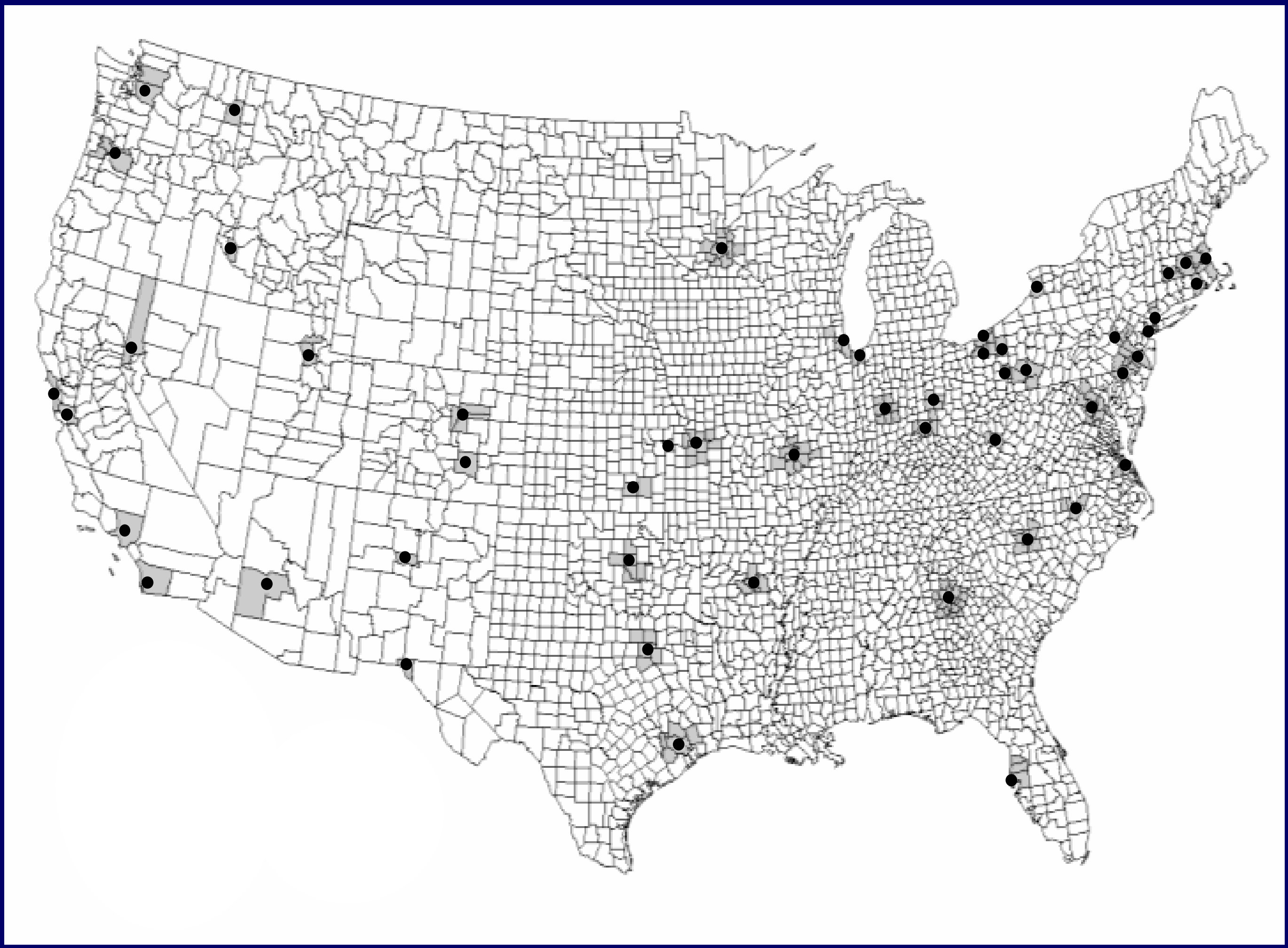
Fine-Particulate Air Pollution and Life Expectancy in the United States

C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.

January 22, 2009


Majid Ezzati


Doug Dockery



Evaluated changes in Life Expectancy with changes in PM2.5 for the 2-decade period of approximately 1980-2000

Matching $PM_{2.5}$ data for 1979-1983 and 1999-2000 in 51 Metro Areas

Life Expectancy data for 1978-1982 and 1997-2001 in 211 counties in 51 Metro areas

A 10 $\mu g/m^3$ decrease in $PM_{2.5}$ was associated with a <u>7.3 month</u> increase in life expectancy

Table 2. Results of Selected Regression Models, Including Estimates of the Increase in Life Expectancy Associated with a Reduction in $PM_{2.5}$ of 10 μg per Cubic Meter, Adjusted for Socioeconomic, Demographic, and Proxy Indicators for Prevalence of Smoking.*

Variable	Model 1	Model 2	Model 3	Model 4	Model 5†	Model 6‡	Model 7‡
				years			
Intercept	2.25±0.21§	0.80±0.19§	1.78±0.27§	1.75±0.27§	2.02±0.34§	1.71±0.51§	2.09±0.36§
Reduction in $PM_{2.5}$ (10 $\mu g/m^3$)	0.72±0.29¶	0.83±0.20§	0.60±0.20§	0.61±0.20§	0.55±0.24¶	1.01±0.25§	0.95±0.23§
Change in income (in thousands of $)	—	0.17±0.02§	0.13±0.02§	0.13±0.01§	0.11±0.02§	0.15±0.04§	0.11±0.02§
Change in population (in hundreds of thousands)	—	0.08±0.02§	0.05±0.02§	0.06±0.02§	0.05±0.02§	0.04±0.02	0.05±0.02¶
Change in 5-yr in-migration (proportion of population)‖**	—	0.19±0.79	1.28±0.80	—	—	−0.02±1.83	—
Change in high-school graduates (proportion of population)‖	—	0.17±0.56	−0.11±0.53	—	—	−0.90±0.86	—
Change in urban residence (proportion of population)‖	—	−0.76±0.32¶	−0.40±0.25	—	—	0.03±1.88	—
Change in black population (proportion of population)‖††	—	−1.94±0.58§	−2.74±0.58§	−2.70±0.64§	−2.95±0.78§	−5.06±2.12§	−5.98±1.99§
Change in Hispanic population (proportion of population)‖††	—	1.46±1.23	1.33±1.10	—	—	2.44±2.22	—
Change in lung-cancer mortality rate (no./10,000 population)	—	—	−0.07±0.02§	−0.06±0.02§	−0.07±0.03¶	0.01±0.03	0.02±0.03
Change in COPD mortality rate (no./10,000 population)	—	—	−0.07±0.02§	−0.08±0.02§	−0.09±0.03§	−0.15±0.06§	−0.19±0.05§
No. of county units	211	211	211	211	127	51	51
R^2‡‡	0.05	0.47	0.55	0.53	0.60	0.76	0.74

This increase in life expectancy persisted even after controlling for socio-economic, demographic, or smoking variables (± 2.4) months

The Bottom Line:

Whether in the developed or the developing world, the evidence is clear:

Reducing Air Pollution Extends Lives

…***and sound transport policy can help reduce susceptibility as well***…

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Special Thanks

- Howard Frumkin M.D., Dean University of Washington School of Public Health

- Clean Air Initiative For Asian Cities (CAI-Asia

Thank You

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