Air Pollution and Health: The India case

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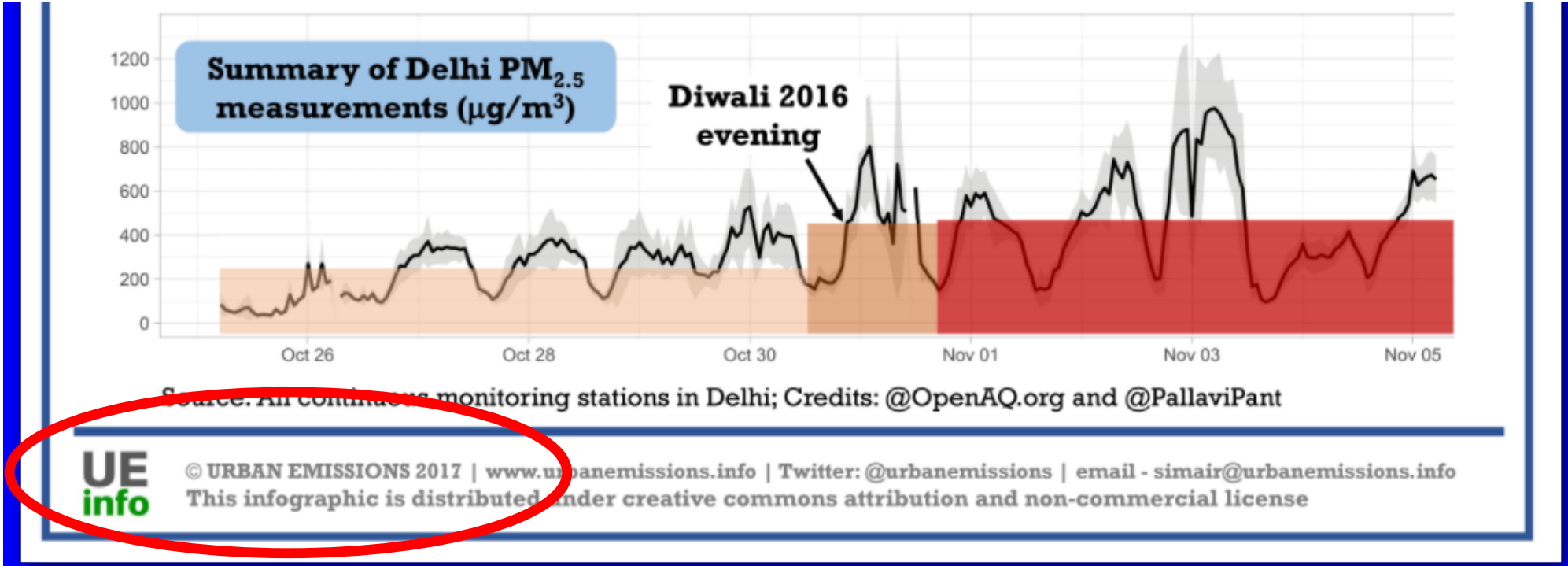
India Habitat Centre, New Delhi

First World NCD Congress

PGIMER, Chandigarh

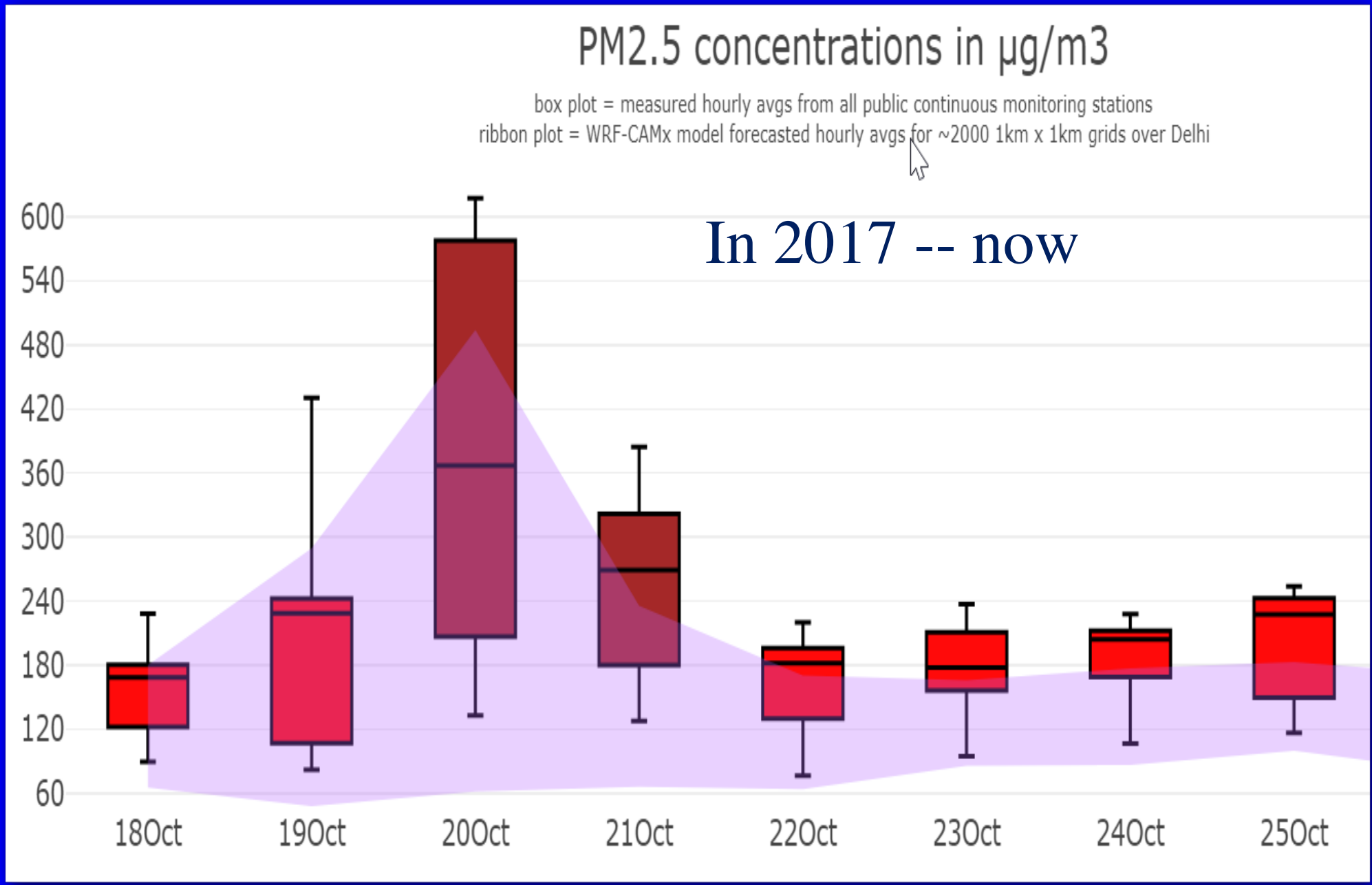
November 5, 2017



Delhi's pollution in 2016 – note effects of

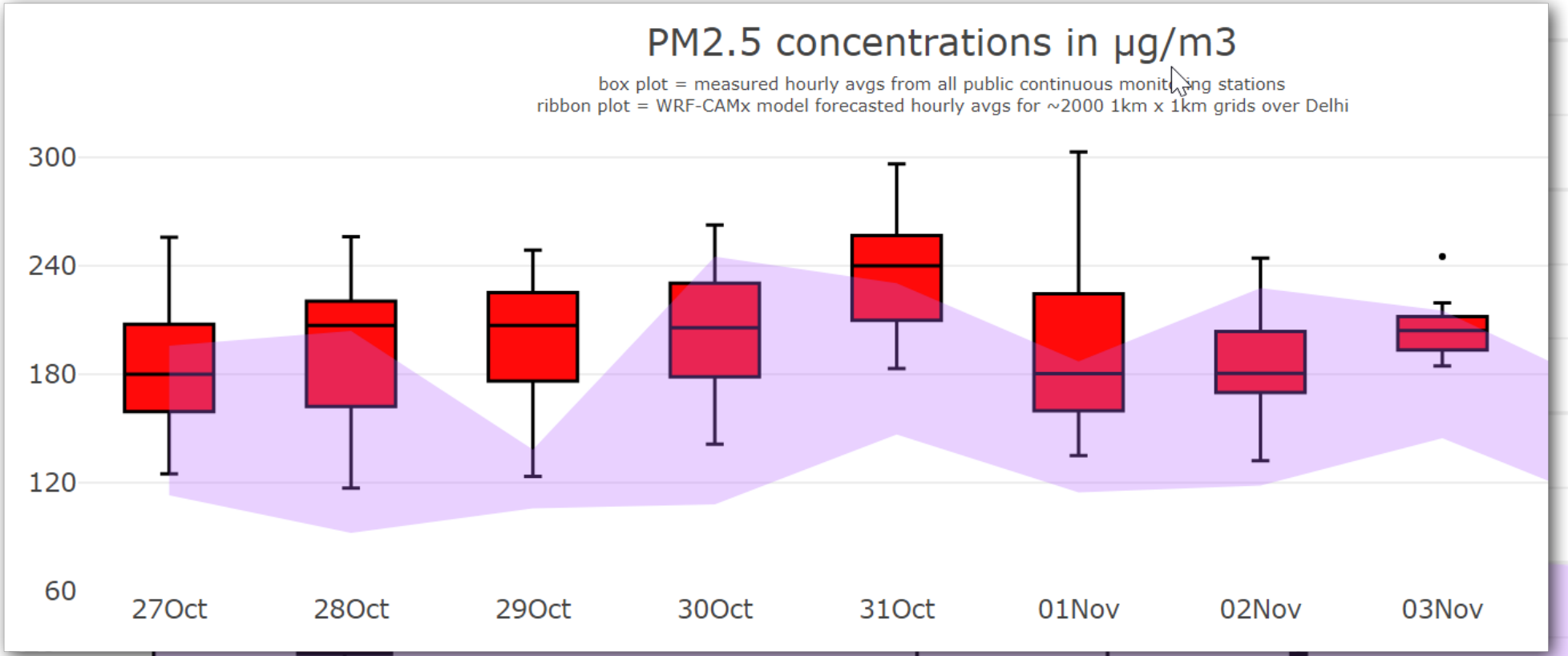
1) the holiday (Diwali) and

2) crop residue burning


PM2.5 concentrations in µg/m3
box plot = measured hourly avgs from all public continuous monitoring stations
ribbon plot = WRF-CAMx model forecasted hourly avgs for ~2000 1km x 1km grids over Delhi
In 2017 -- now
600
540
480
420
360
300
240
180
120
60
18Oct
19Oct
20Oct
21Oct
22Oct
23Oct
24Oct
25Oct

PM2.5 concentrations in µg/m3

box plot = measured hourly avgs from all public continuous monitoring stations
ribbon plot = WRF-CAMx model forecasted hourly avgs for ~2000 1km x 1km grids over Delhi



Particle deposition

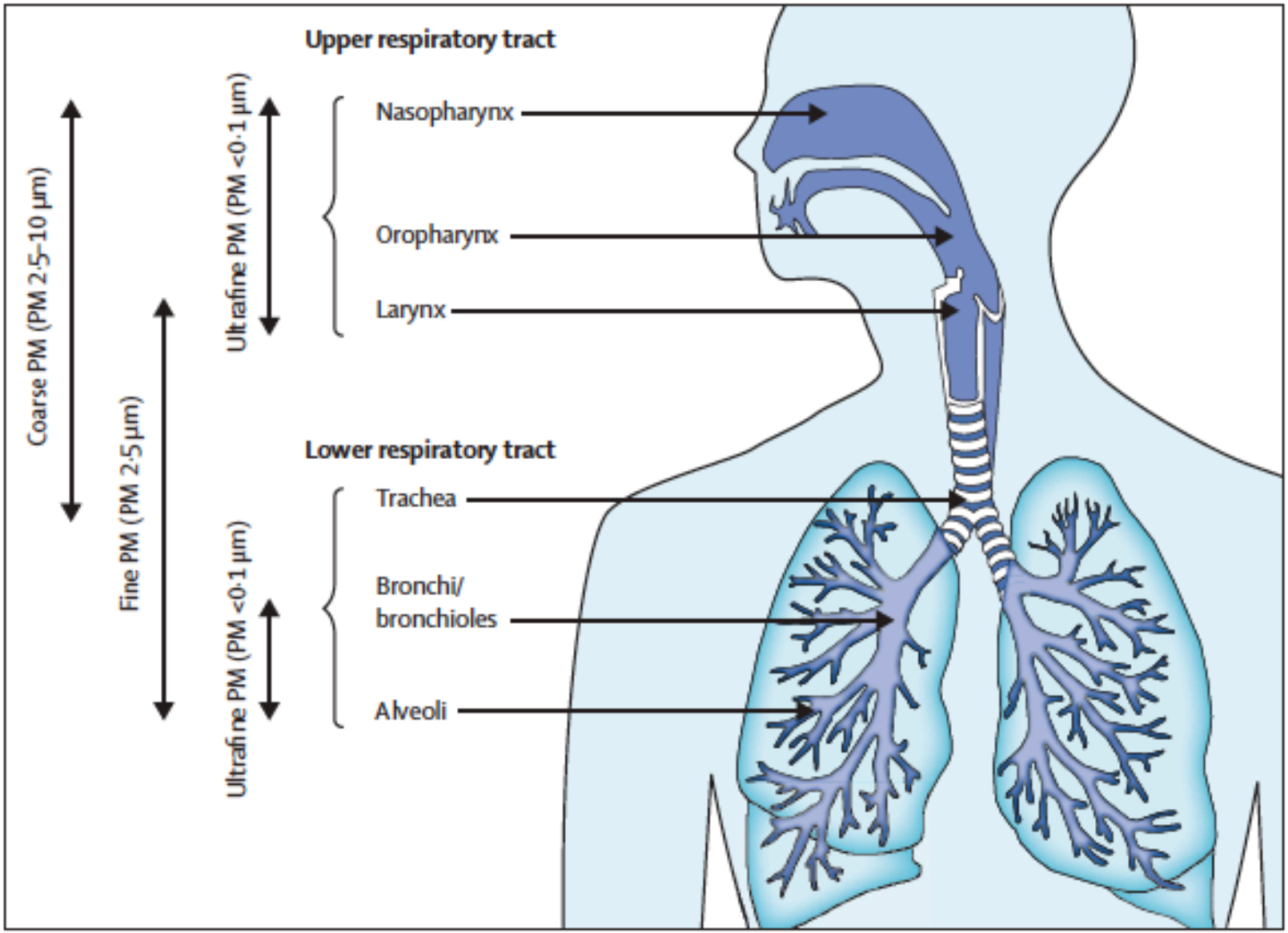
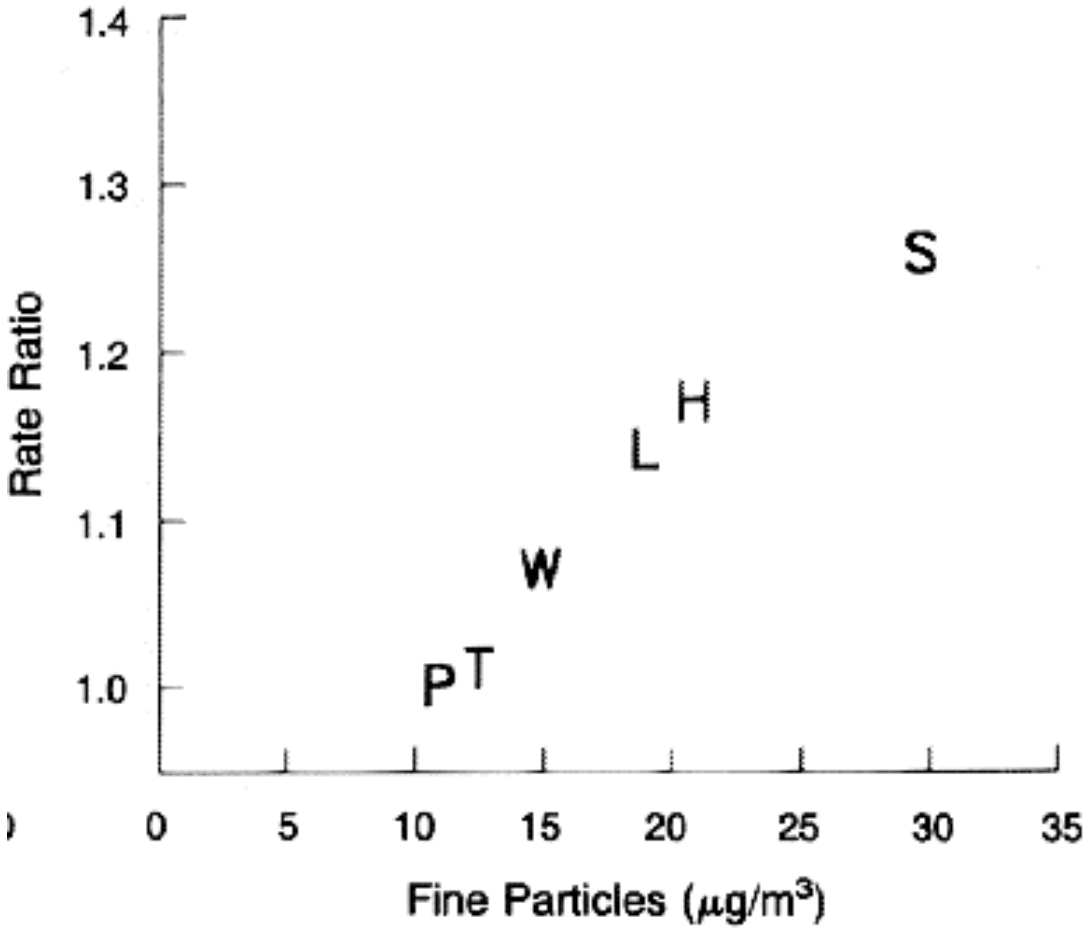


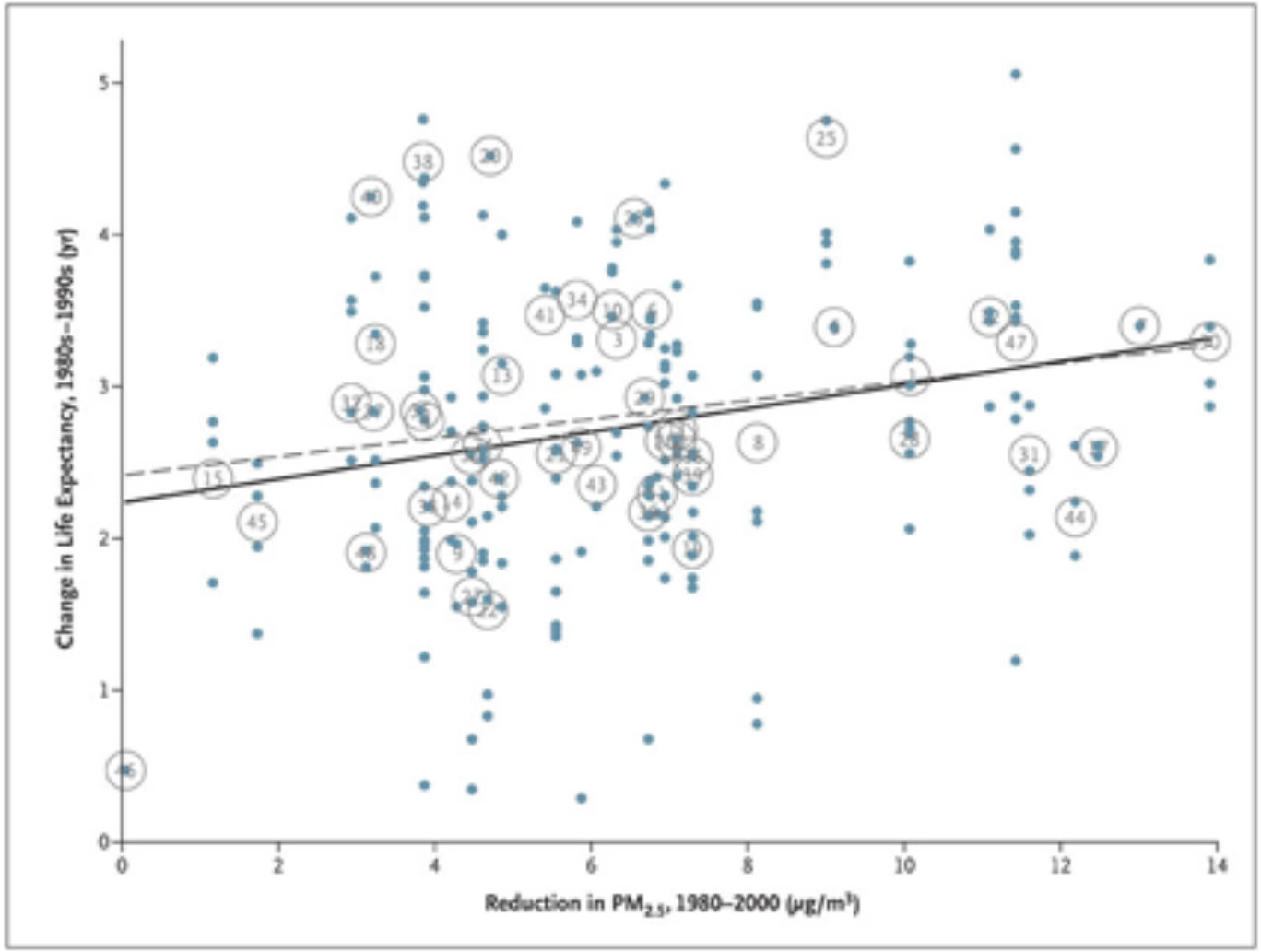
Figure 4: **Compartmental deposition of particulate matter**

An Association between Air Pollution and Mortality in Six U.S. Cities



Dockery et al. N Engl J Med 1993;329:1753-1759

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



Pope et al. N Engl J Med 2009;360:376-386.

Other Effects - examples

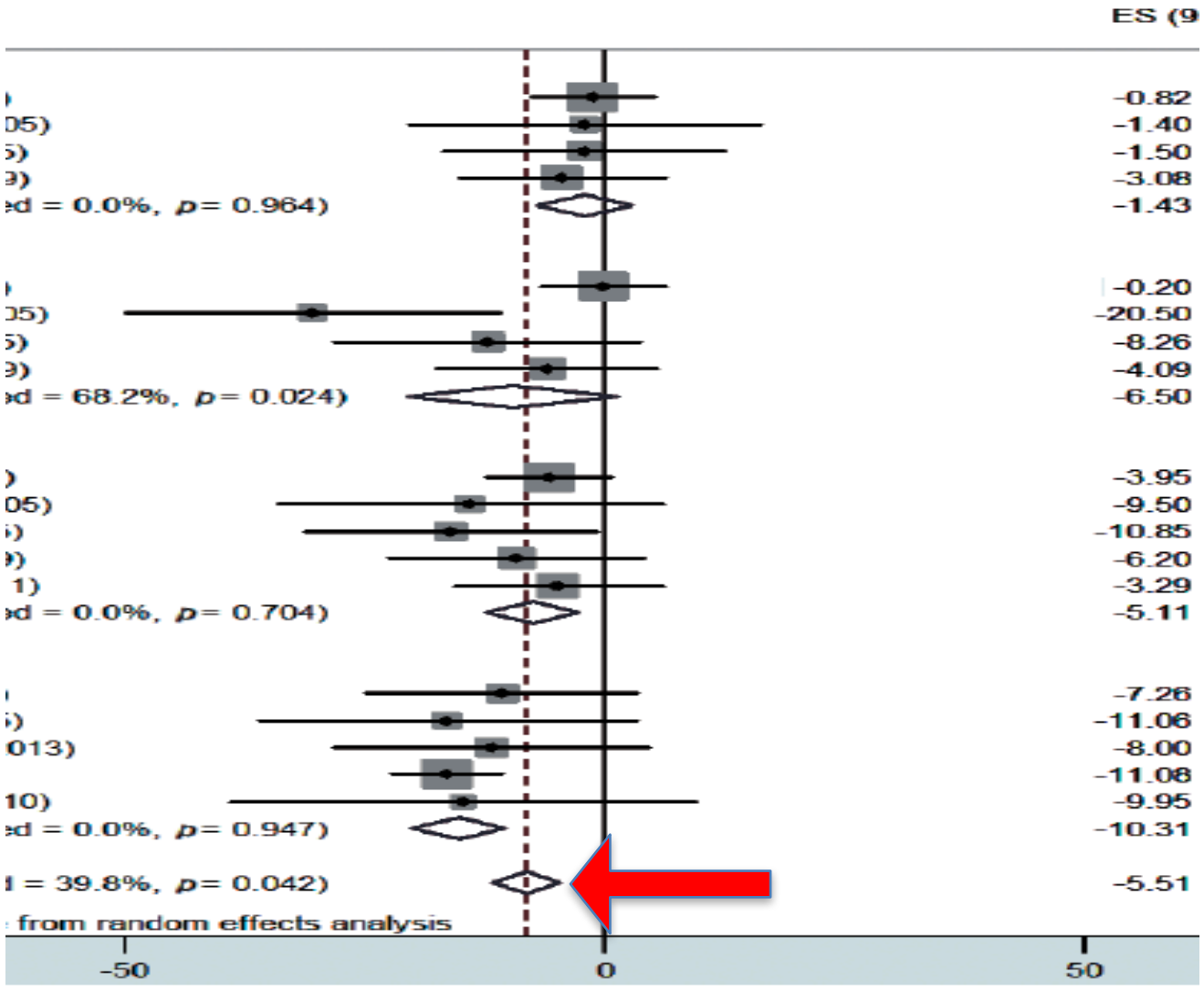
- Low birth weight
- Pre-term birth
- BMI
- Diabetes

A meta-analysis of exposure to particulate matter and adverse birth outcomes

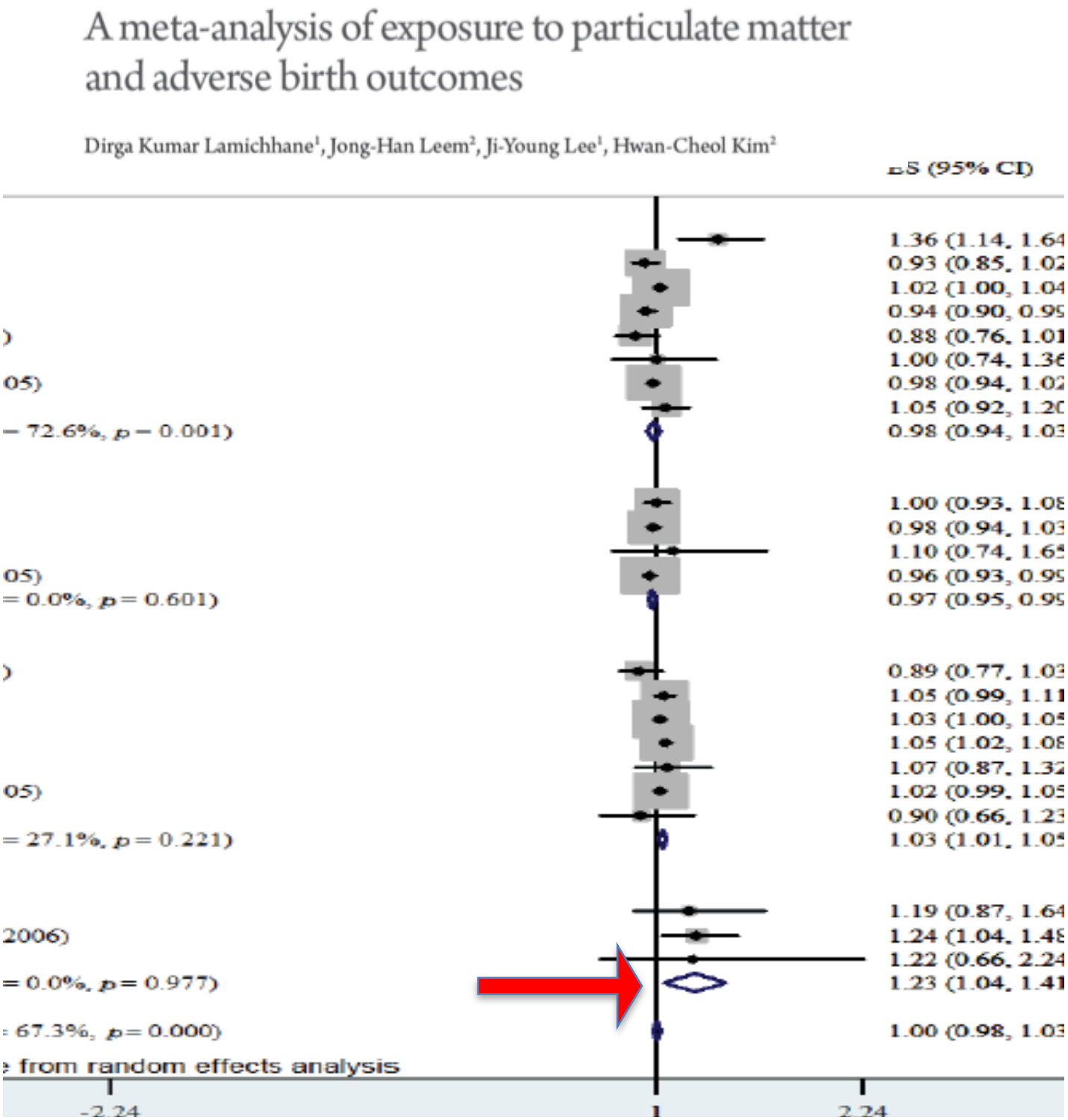
Dirga Kumar Lamichhane[1], Jong-Han Leem[2], Ji-Young Lee[1], Hwan-Cheol Kim[2]

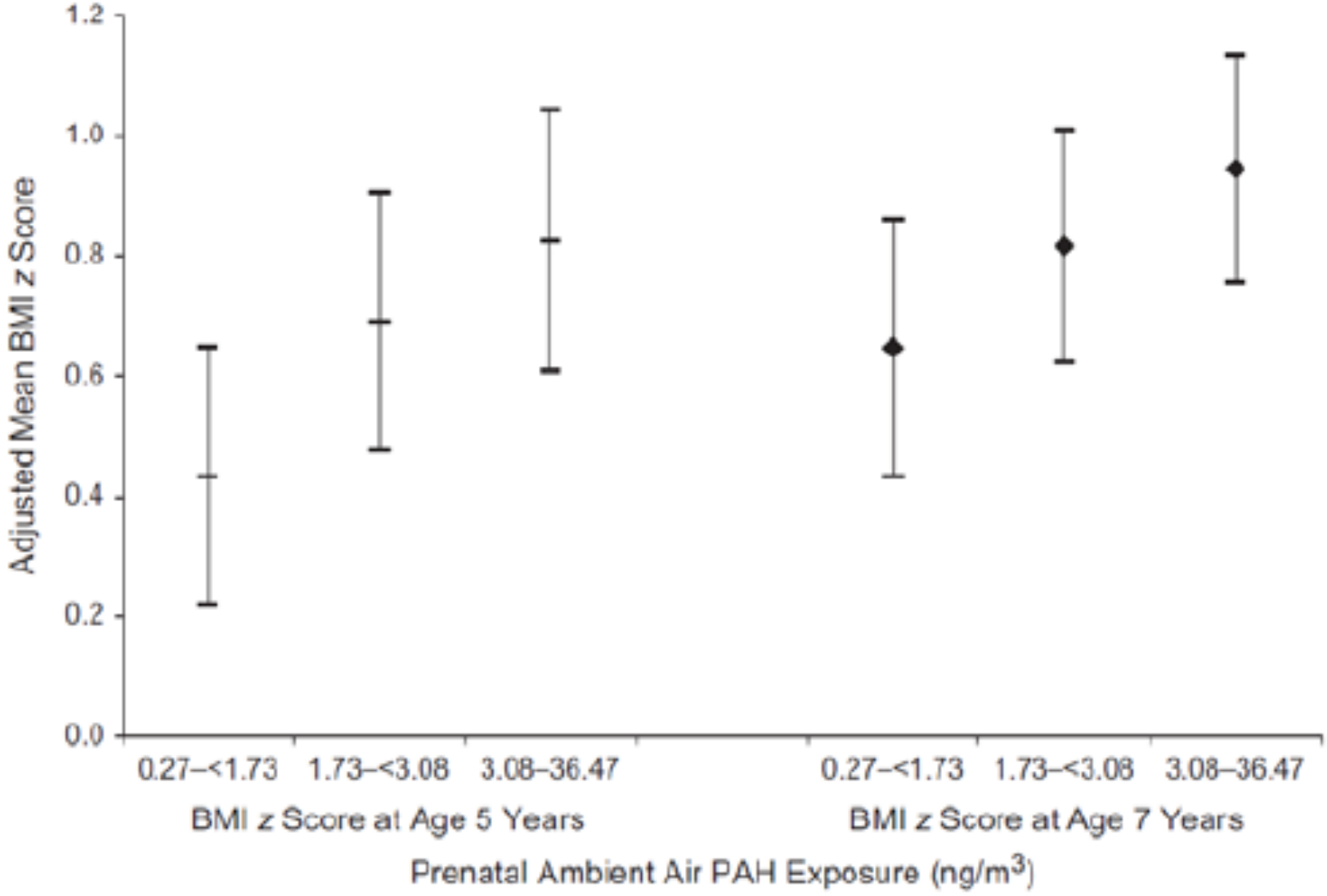
Environ Health Toxicol 2015;30:e2015011.

Birth Weight



Preterm Birth





Rundle et al., Am J Epidemiol 2012

Air Pollution and Diabetes

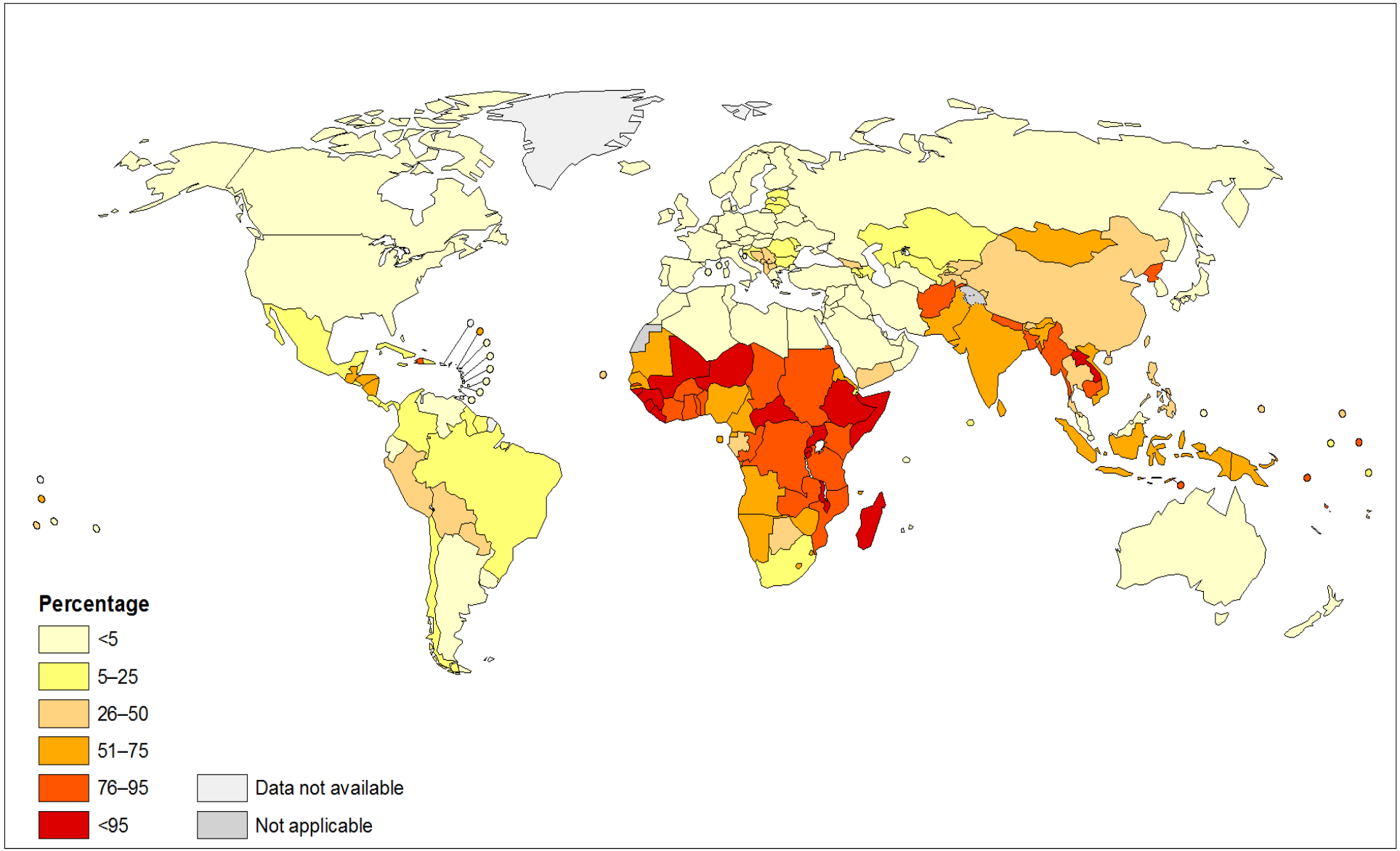
- Several studies have shown associations between diabetes in adults and exposure to traffic-related air pollution (TRAP)
- Evidence also building for children

Potential Mechanism

- Air pollution can induce oxidative stress and systemic inflammation
- $PM_{2.5}$ induced adipose tissue inflammation and insulin resistance in a mouse model of diet-induced obesity (Sun et al. Circulation 2009)
- Hypothesis:
  - Exposure to air pollution *in utero* and in early childhood increases risk of obesity and abnormal glucose metabolism later in childhood


The three major solid fuels

Population Cooking with Solid Fuels in 2010 (%)



Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization

Toxic Pollutants in Wood Smoke from Simple (poor) Combustion

- Small particles, CO, NO_2
- Hydrocarbons
  - [illegible] *adiene*
  - [illegible] *ne*
  - [illegible] *rene*
- Oxy
  - [illegible] *olein*
  - 254+ alcohols and acids such as *methanol*
  - 33+ phenols such as *catechol* & *cresol*
  - Many quinones such as *hydroquinone*
  - Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

Typical chulha releases 400 cigarettes per hour worth of smoke

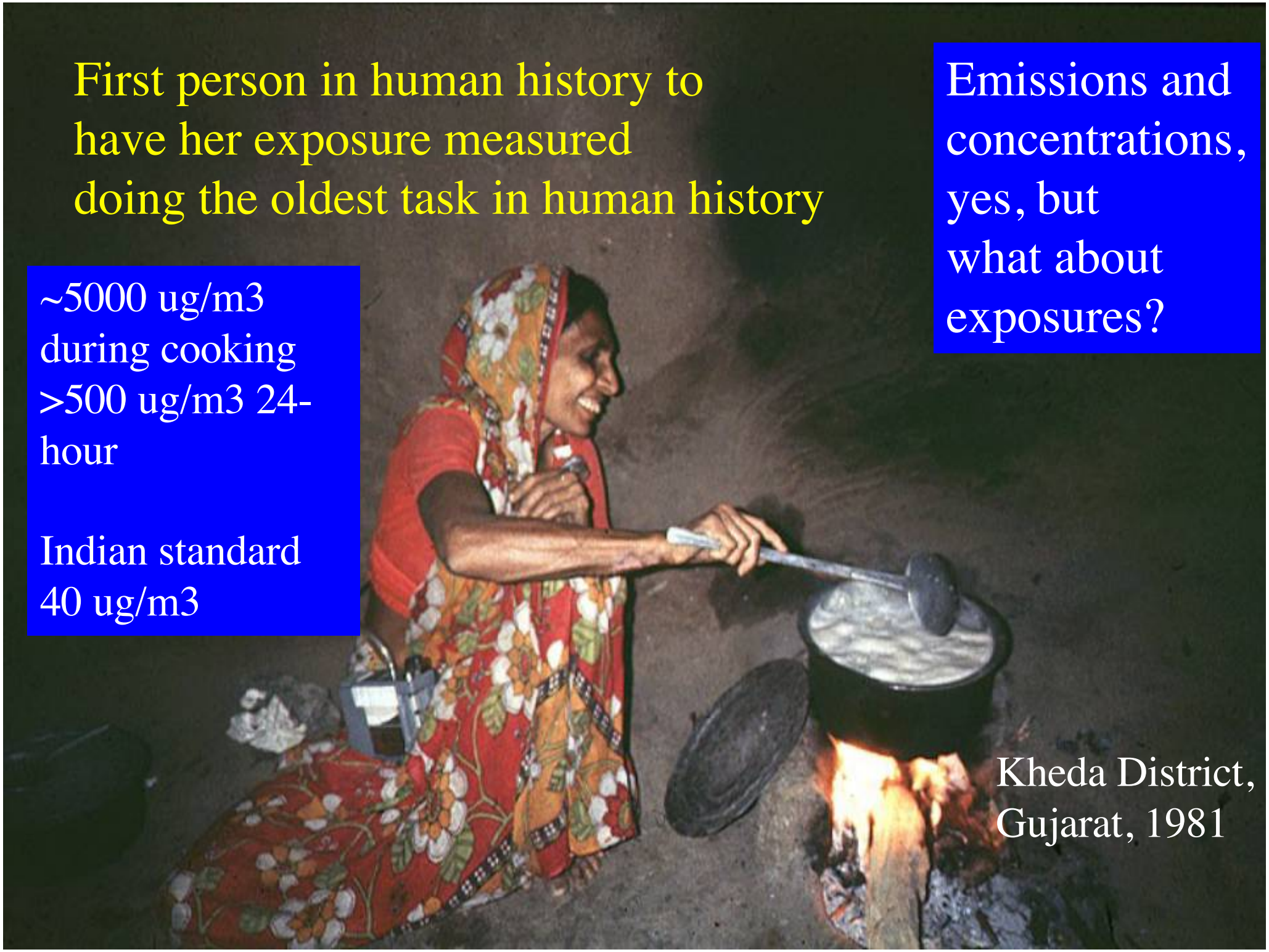
Source: Naeher et al, *J Inhal Tox*, 2007

First person in human history to have her exposure measured doing the oldest task in human history

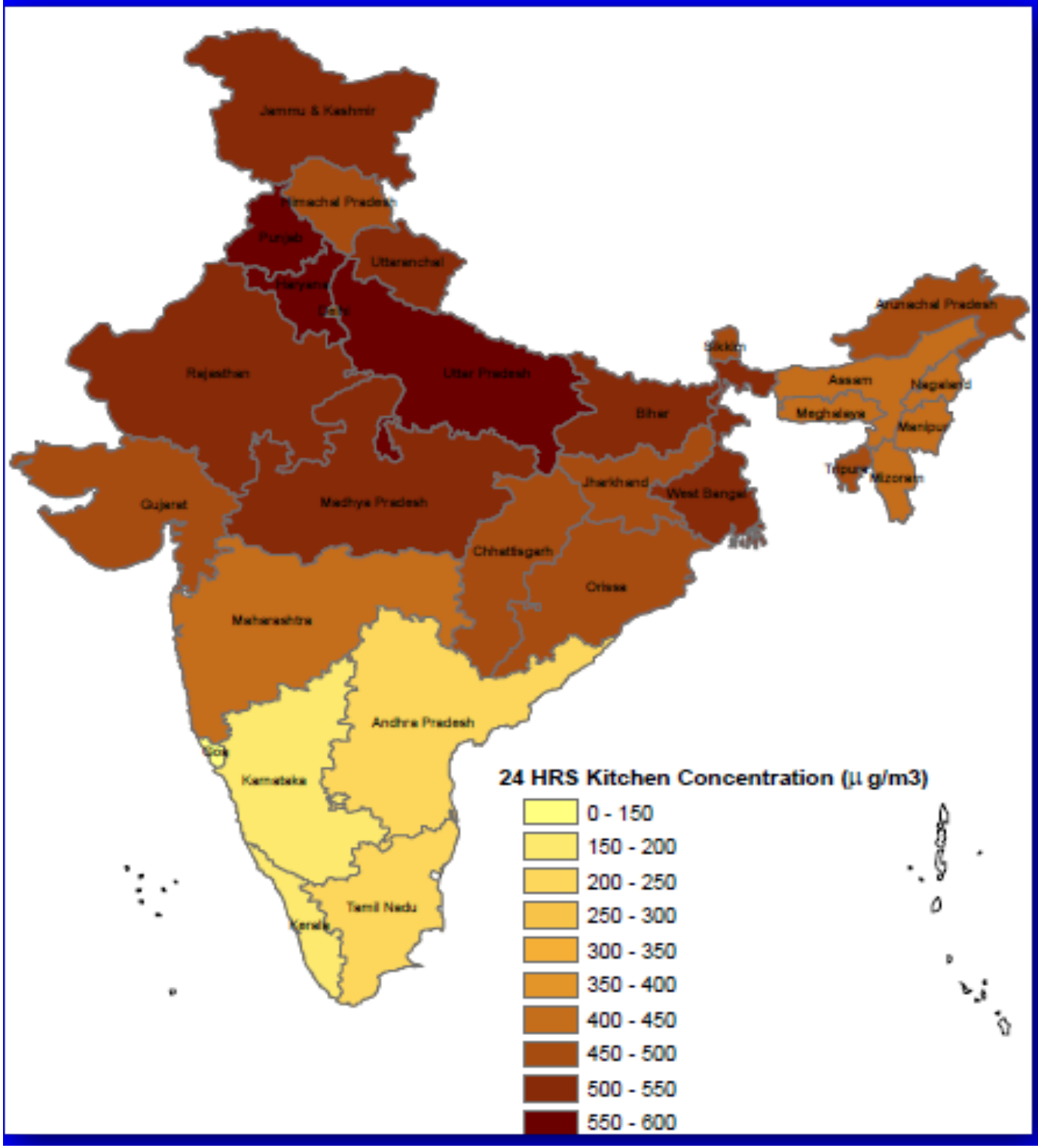
Emissions and concentrations, yes, but what about exposures?

~5000 ug/m3 during cooking
>500 ug/m3 24-hour

Indian standard
40 ug/m3



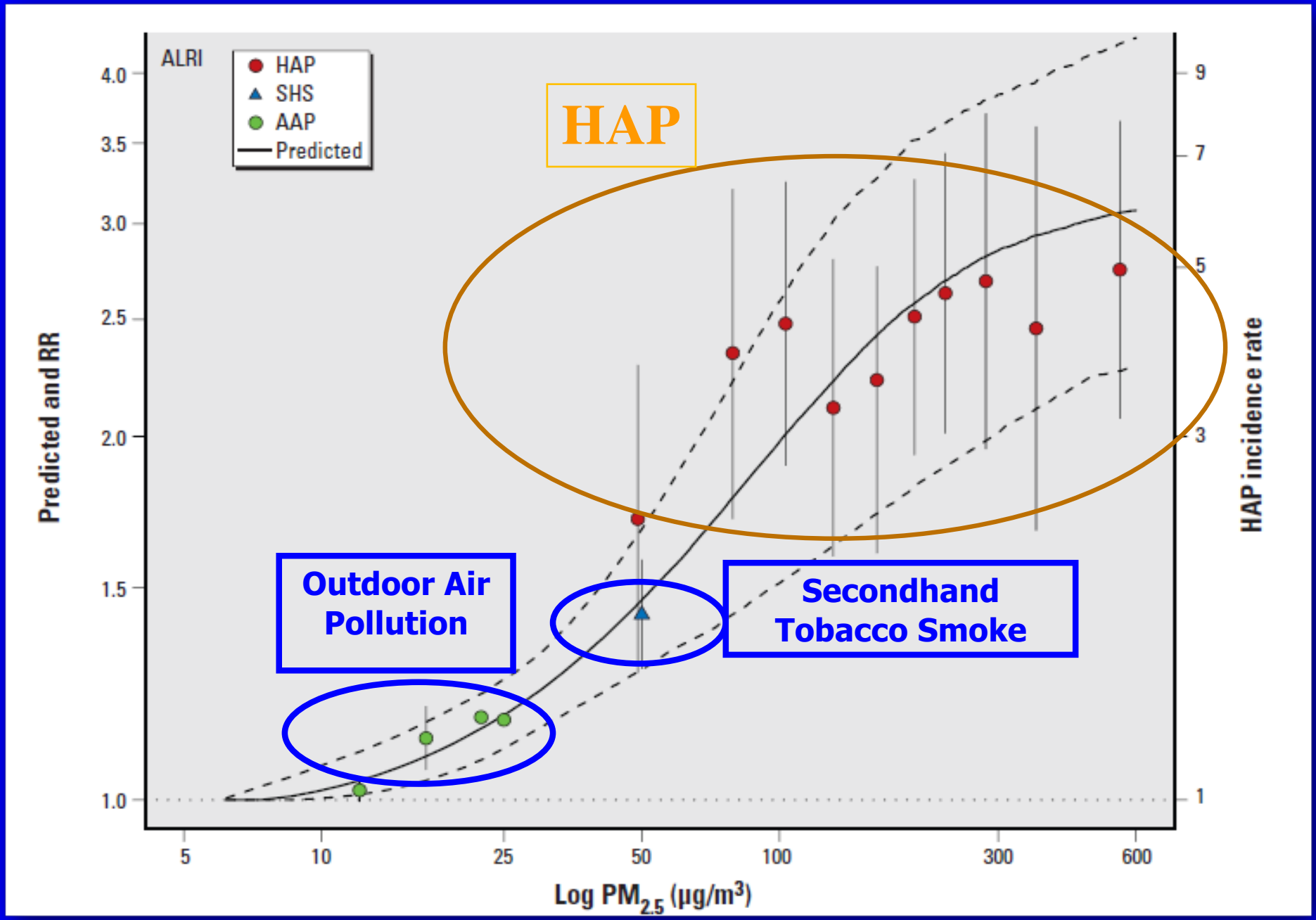
Kheda District, Gujarat, 1981



State-wise estimates of 24-h kitchen concentrations of PM2.5 in India

Solid-fuel using households

Balakrishnan et al. 2013 (SRU group)

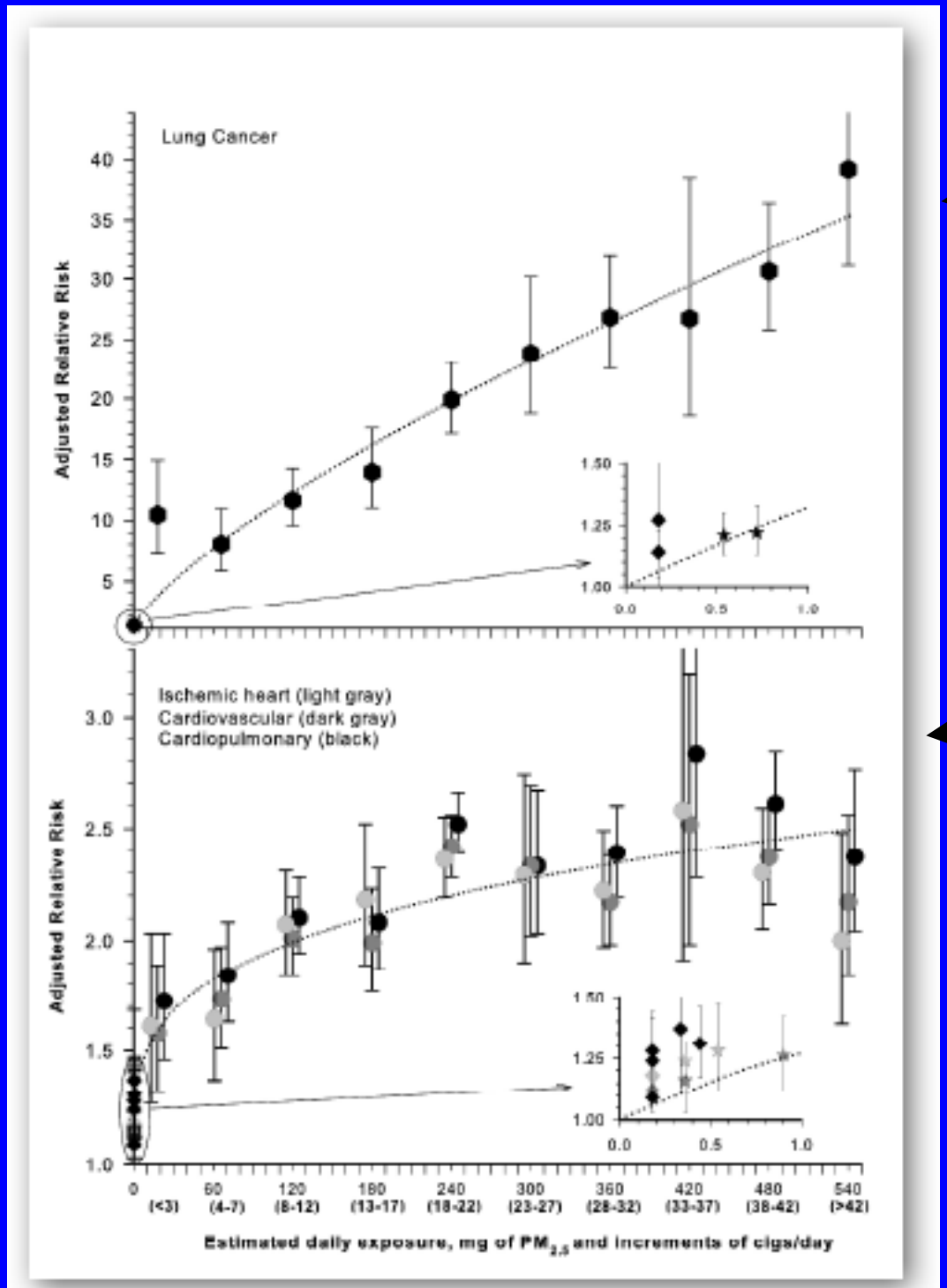


Burnett et al., EHP. 2014, Integrated Exposure-Response Functions

Table 2. Adjusted relative risk estimates[a] for various increments of exposure from cigarette smoking (versus never smokers), second hand cigarette smoke, and ambient air pollution from the present analysis and selected comparison studies.

Source of risk estimate	Increments of Exposure	Adjusted RR (95% CI)				Estimated Daily Dose $PM_{2.5}$ (mg)[b]
		Lung Cancer	IHD	CVD	CPD	
ACS- present analysis	≤3 (1.5) cigs/day	10.44 (7.30-14.94)	1.61 (1.27-2.03)	1.58 (1.32-1.89)	1.72 (1.46-2.03)	18
ACS- present analysis	4-7 (5.5) cigs/day	8.03 (5.89-10.96)	1.64 (1.37-1.96)	1.73 (1.51-1.97)	1.84 (1.63-2.08)	66
ACS- present analysis	8-12 (10) cigs/day	11.63 (9.51-14.24)	2.07 (1.84-2.31)	2.01 (1.84-2.19)	2.10 (1.94-2.28)	120
ACS- present analysis	13-17 (15) cigs/day	13.93 (11.04-17.58)	2.18 (1.89-2.52)	1.99 (1.77-2.23)	2.08 (1.87-2.32)	180
ACS- present analysis	18-22 (20) cigs/day	19.88 (17.14-23.06)	2.36 (2.19-2.55)	2.42 (2.28-2.56)	2.52 (2.39-2.66)	240
ACS- present analysis	23-27 (25) cigs/day	23.82 (18.80-30.18)	2.29 (1.91-2.75)	2.33 (2.02-2.69)	2.33 (2.03-2.67)	300
ACS- present analysis	28-32 (30) cigs/day	26.82 (22.54-31.91)	2.22 (1.97-2.49)	2.17 (1.98-2.38)	2.39 (2.19-2.60)	360
ACS- present analysis	33-37 (35) cigs/day	26.72 (18.58-38.44)	2.58 (1.91-3.47)	2.52 (1.98-3.19)	2.83 (2.28-3.52)	420
ACS- present analysis	38-42 (40) cigs/day	30.63 (25.79-36.38)	2.30 (2.05-2.59)	2.37 (2.16-2.59)	2.61 (2.40-2.84)	480
ACS- present analysis	43+ (45) cigs/day	39.16 (31.13-49.26)	2.00 (1.62-2.48)	2.17 (1.84-2.56)	2.37 (2.04-2.76)	540
ACS-air pol. original	24.5 $\mu g/m^3$ ambient $PM_{2.5}$	-----	-----	-----	1.31(1.17-1.46)	0.44
ACS-air pol. extend.	10 $\mu g/m^3$ ambient $PM_{2.5}$	1.14(1.04-1.23)	1.18(1.14-1.23)	1.12(1.08-1.15)	1.09(1.03-1.16)	0.18
HSC-air pol. original	18.6 $\mu g/m^3$ ambient $PM_{2.5}$	-----	-----	-----	1.37(1.11-1.68)	0.33
HSC-air pol. extend.	10 $\mu g/m^3$ ambient $PM_{2.5}$	1.21(0.92-1.69)	-----	1.28(1.13-1.44)	-----	0.18
WHI-air pol.	10 $\mu g/m^3$ ambient $PM_{2.5}$	-----	-----	1.24(1.09-1.41)[c]	-----	0.18
SGR-SHS	Low- moderate SHS exp.	-----	-----	1.16(1.03-1.32)	-----	0.36
SGR-SHS	Moderate-high SHS exp	-----	-----	1.26(1.12-1.42)	-----	0.90
SGR-SHS	Live with smoking spouse	1.21(1.13-1.30)	-----	-----	-----	0.54
SGR-SHS	Work with SHS exposure	1.22(1.13-1.33)	-----	-----	-----	0.72
INTERHEART	1-7 hrs/wk SHS exp.	-----	1.24(1.17-1.32)[d]	-----	-----	0.36
INTERHEART	Live with smoking spouse	-----	1.28(1.12-1.47)[d]	-----	-----	0.54

Pope et al.
Environmental Health Perspectives
2011, in press

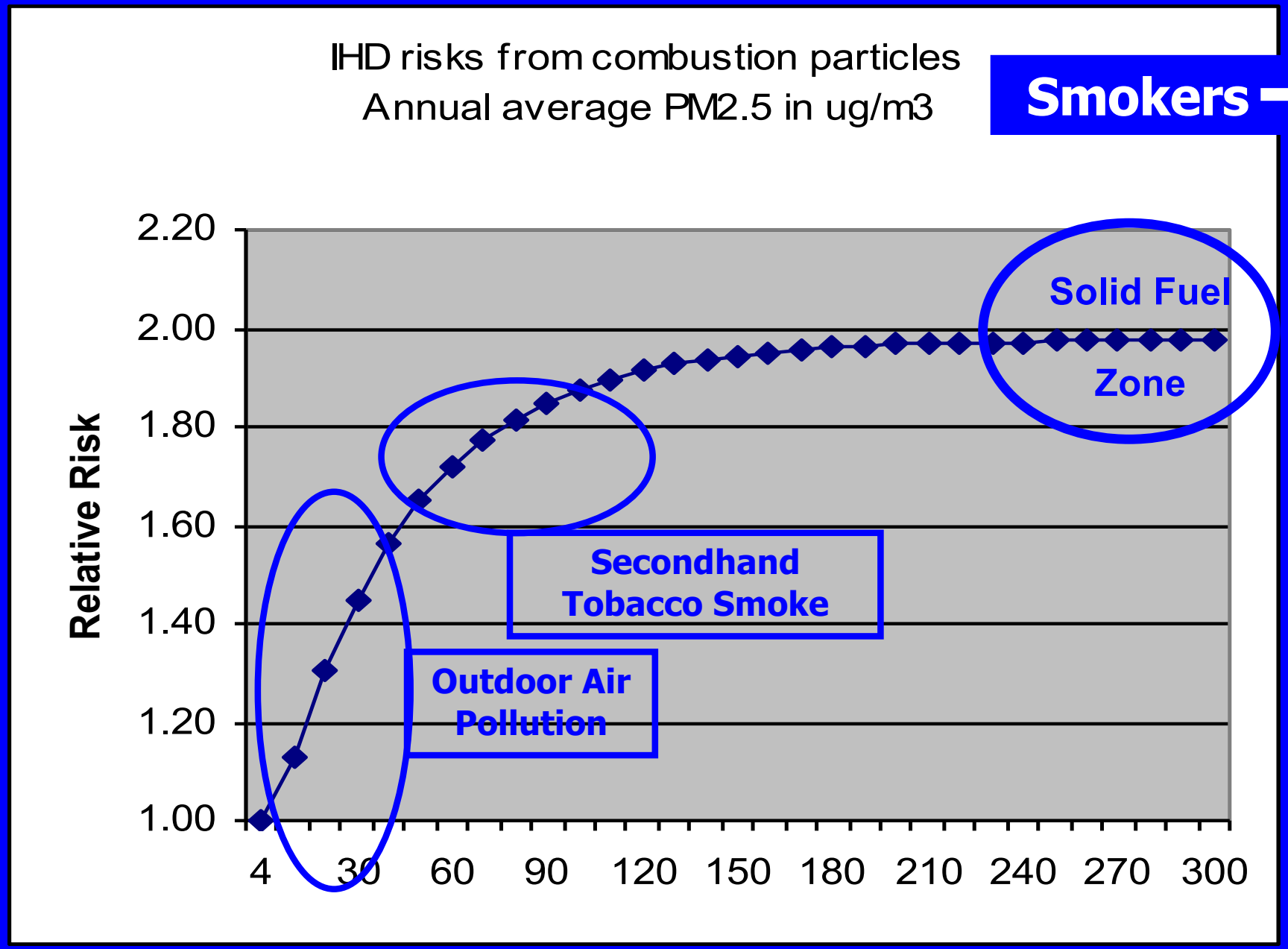


Lung Cancer

Heart Disease

Pope et al. Environmental Health Perspectives 2011, in press

Generalized Exposure-Response: Outdoor Air, SHS, and Smoking



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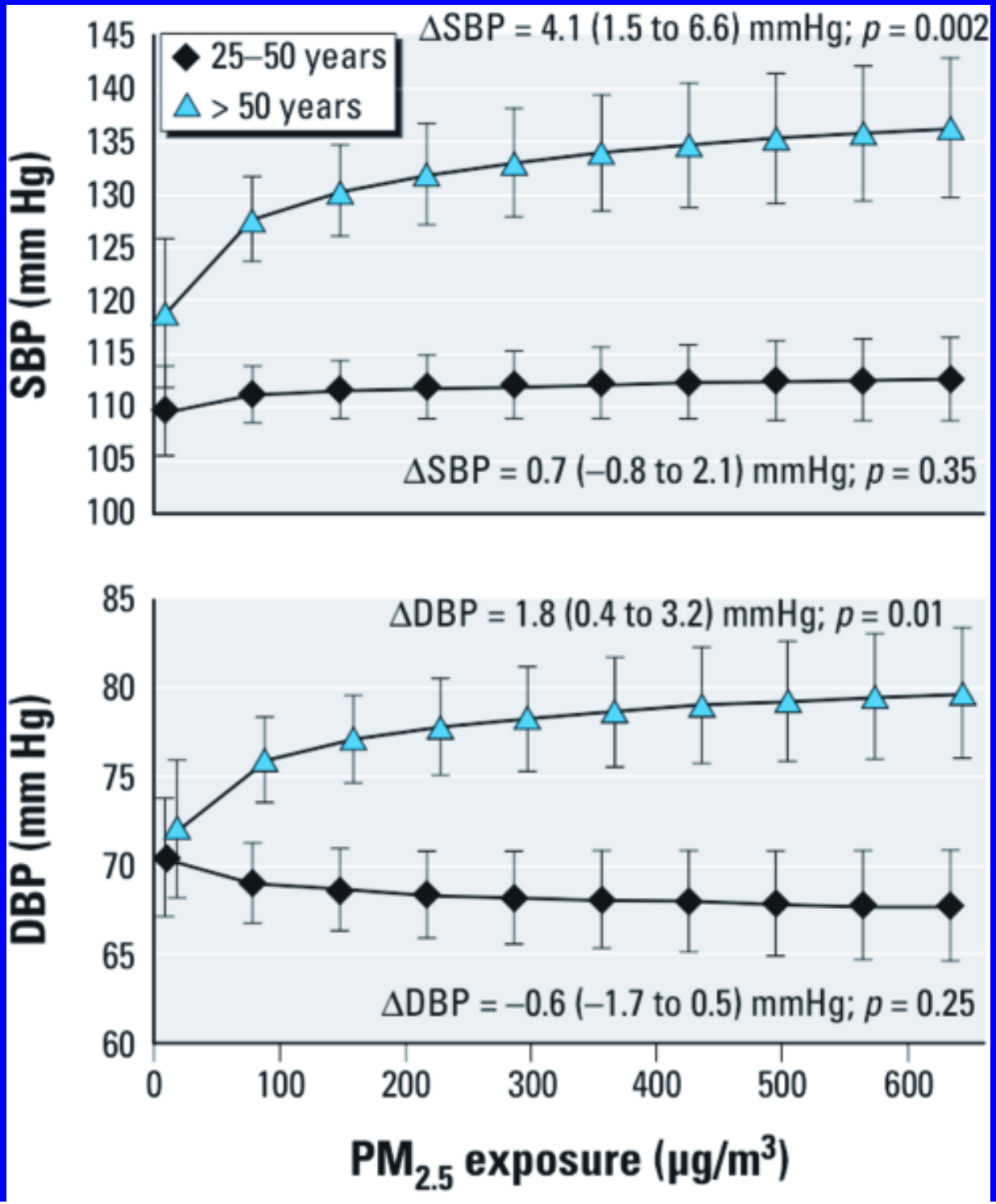


Household Air Pollution and Blood Pressure

In Yunnan

Baumgartner et al. Environmental Health Perspectives 2011, Oct

Intervention to Lower Household Wood Smoke Exposure in Guatemala Reduces ST-Segment Depression on Electrocardiograms

John McCracken,[1,2] Kirk R. Smith,[2] Peter Stone,[3] Anaité Díaz,[4] Byron Arana,[4] and Joel Schwartz[1]

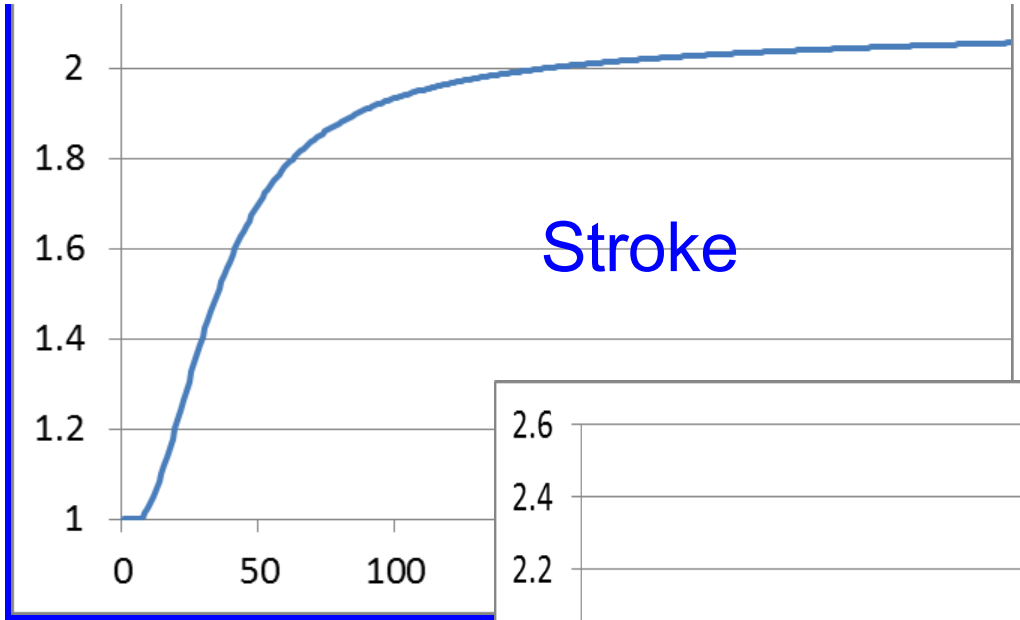
[1]Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA; [2]Environmental Sciences Division, University of California, Berkeley, California, USA; [3]Brigham and Women's Hospital, Boston, Massachusetts, USA; [4]Center for Health Studies, Universidad del Valle, Guatemala City, Guatemala

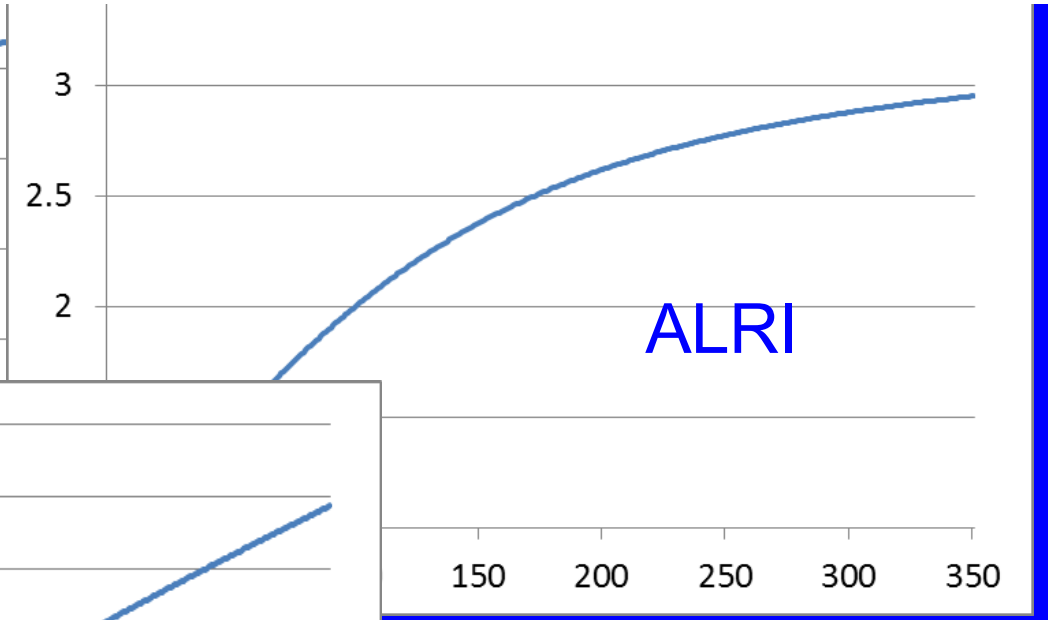
EHP Nov, 2011

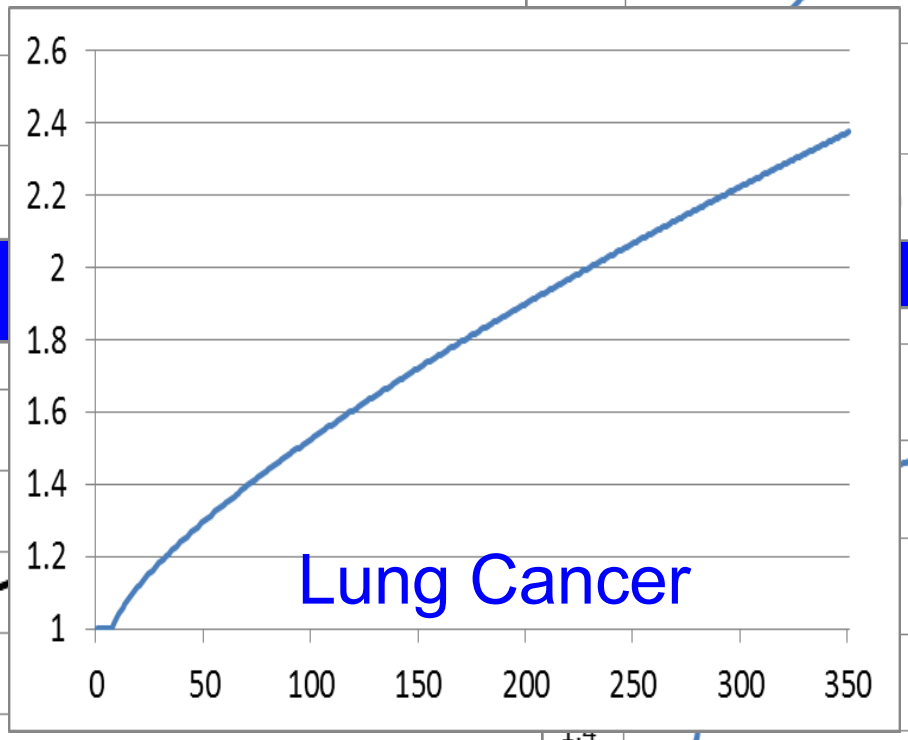
Table 3. Odds ratios (ORs) for nonspecific ST-segment depression (30-min average ≤ –1 mm, regardless of slope) associated with chimney-stove intervention compared with open fire from two study designs: between-groups and before-and-after analyses.

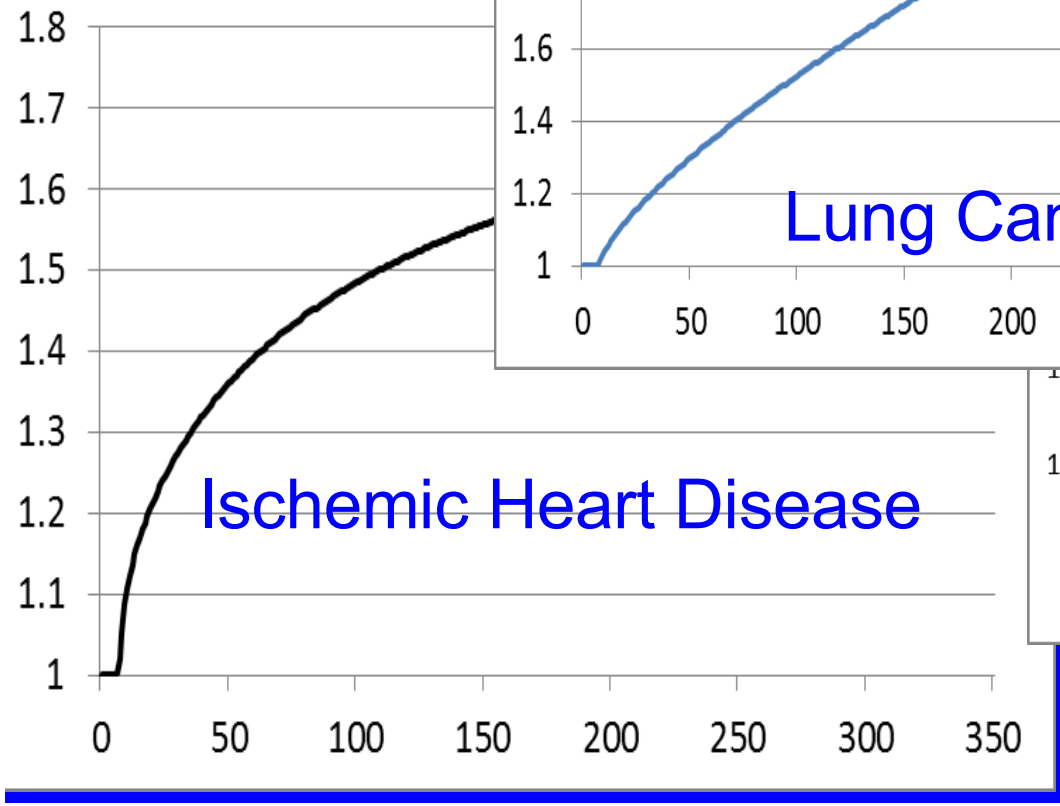
	Crude		Adjusted	
Comparison	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value
Between-groups	0.34 (0.15, 0.81)	0.015	0.26 (0.08, 0.90)[a]	0.033
Before-and-after (only control group)	0.41 (0.24, 0.70)	0.001	0.28 (0.12, 0.63)[b]	0.002

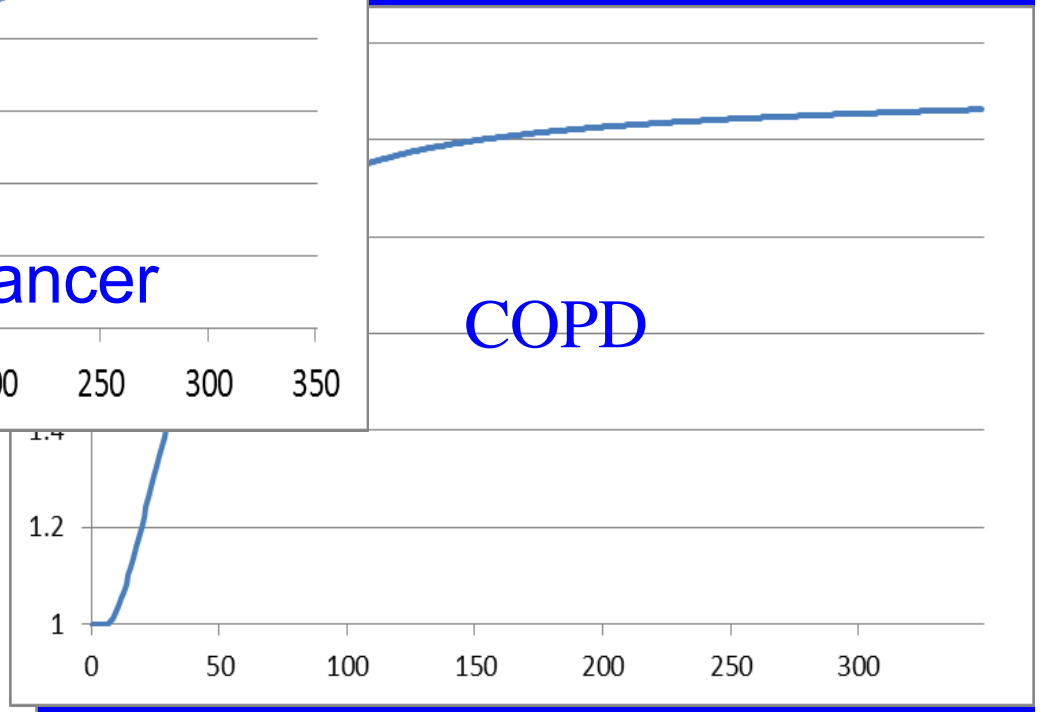
[a]Adjusted for age (quadratic), BMI (quadratic), asset index category, ever smoking, SHS, owning a wood-fired sauna, recent use of wood-fired sauna, and time of day (natural spline with 5 degrees of freedom). [b]Adjusted for age (quadratic), day of week, season (wet/dry), daily average temperature and relative humidity, daily rainfall, interactions of weather variables with season, recent use of wood-fired sauna, and time of day (natural spline with 5 degrees of freedom).



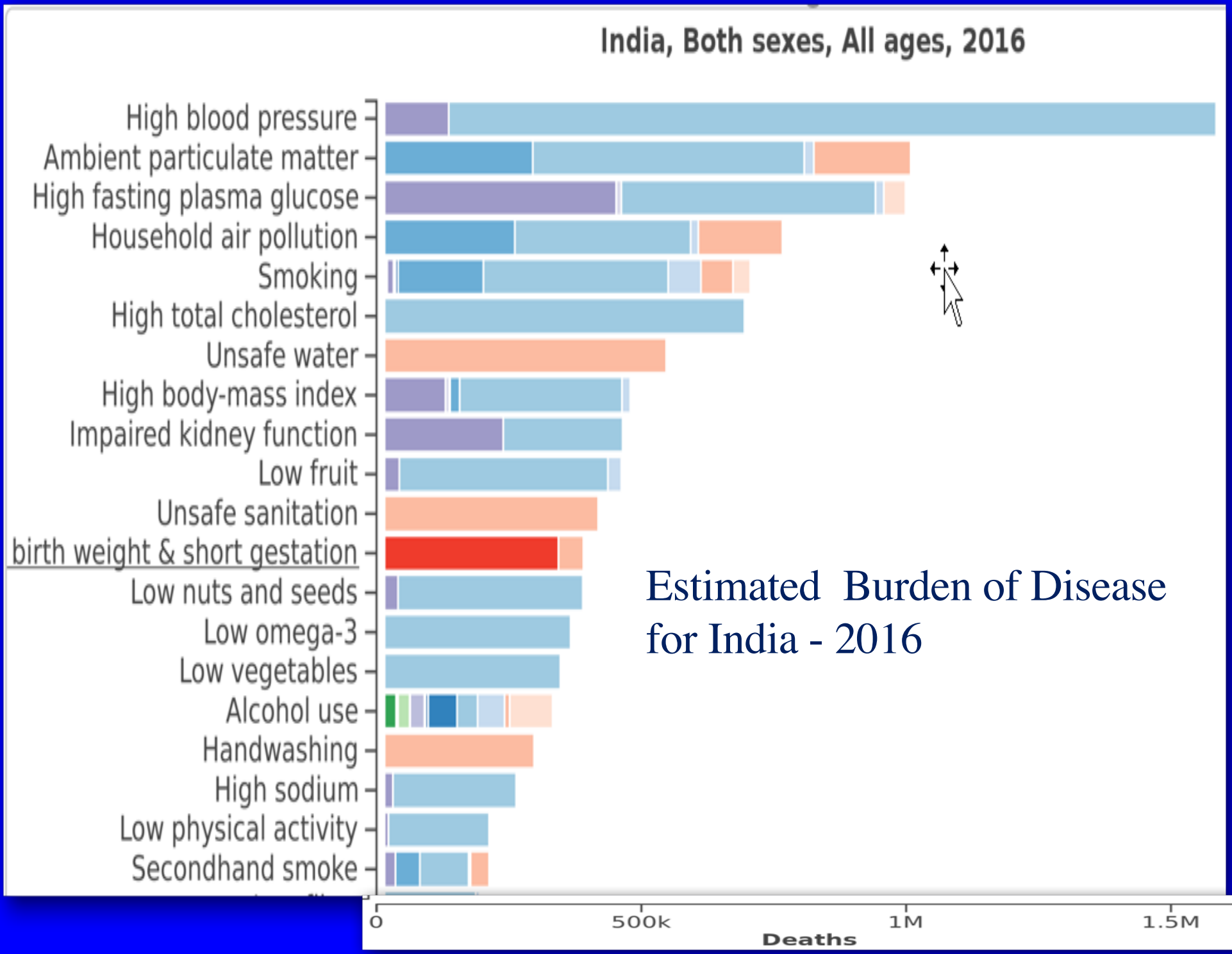




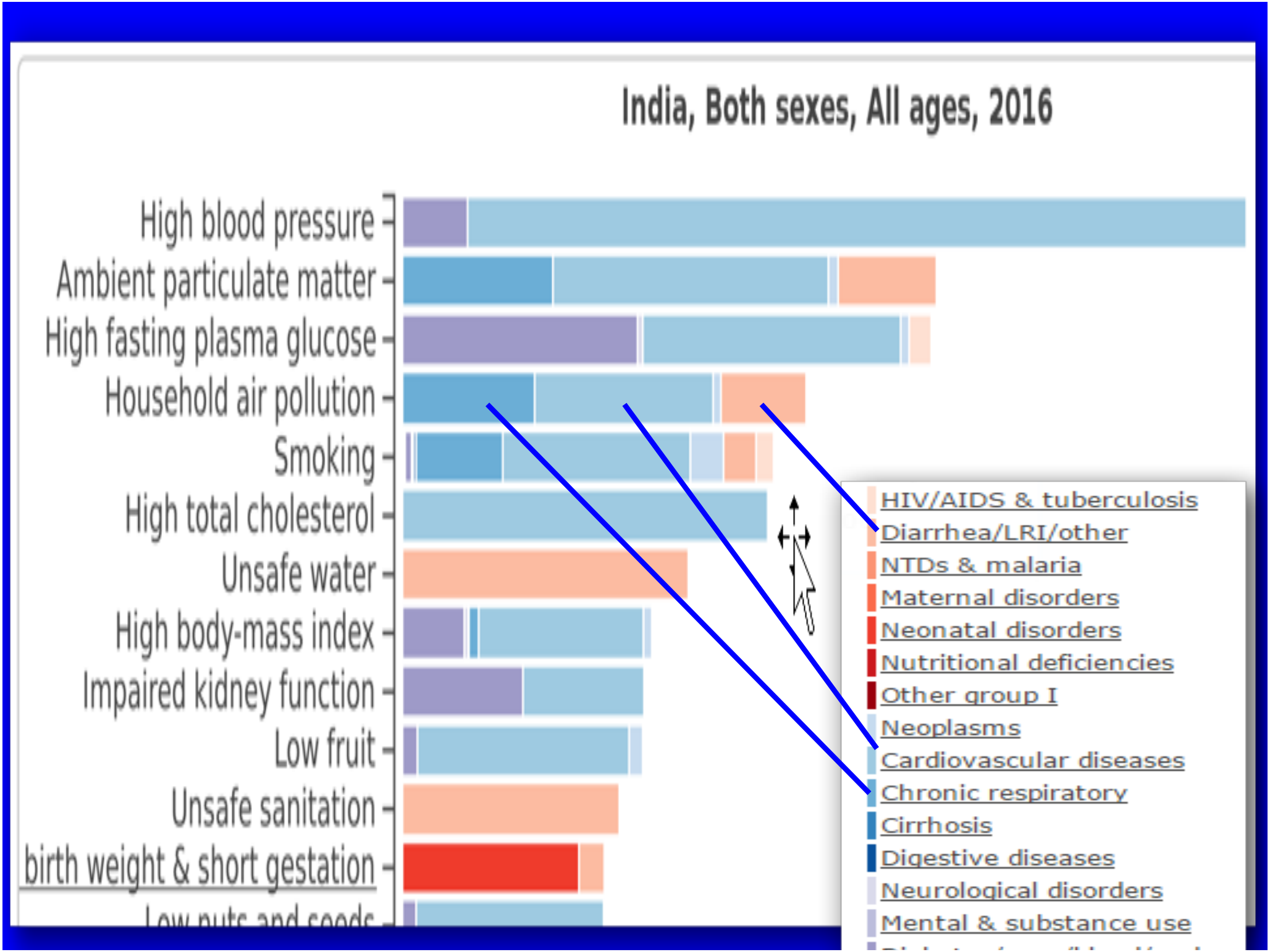


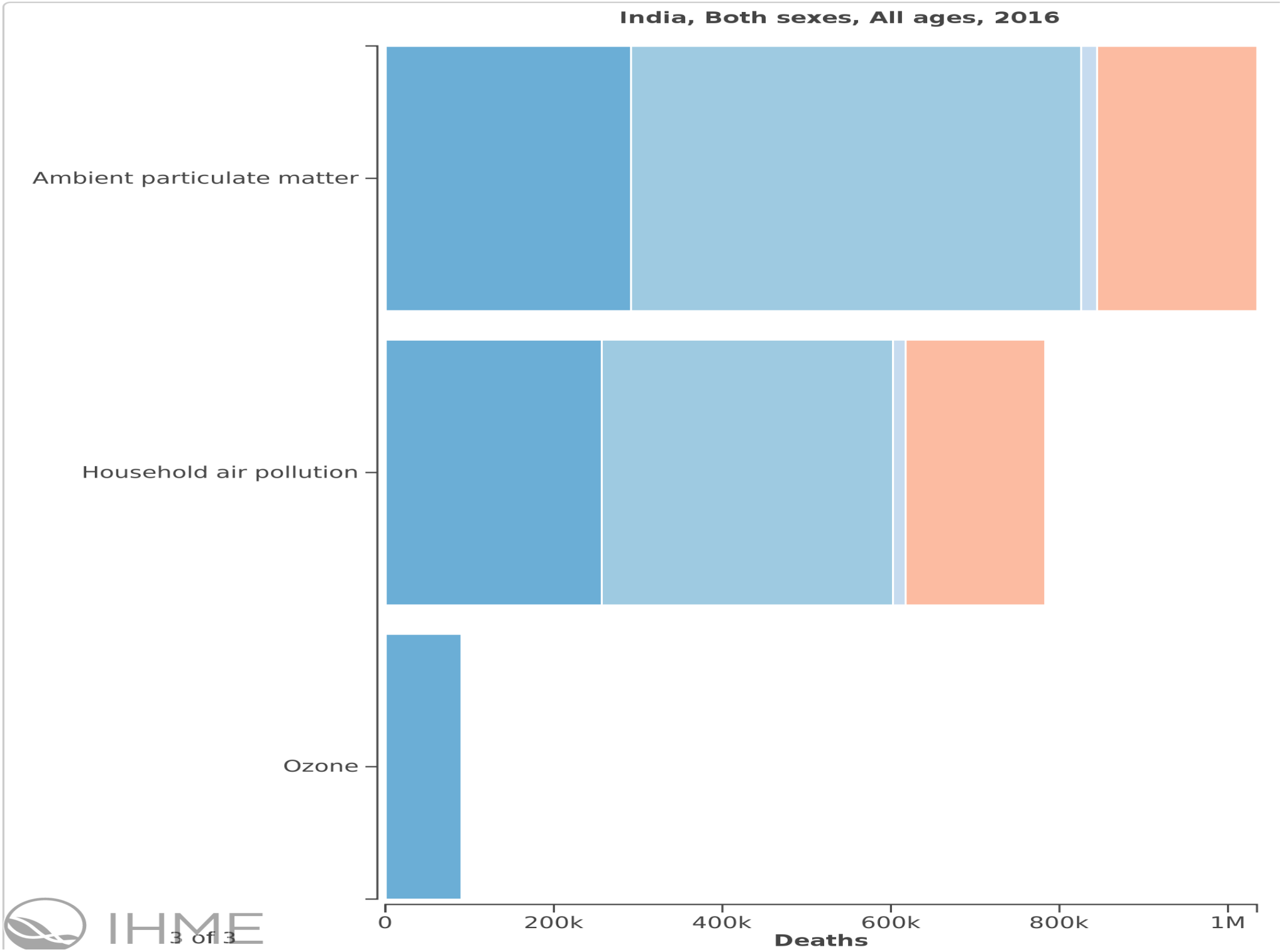


ug/m3 annual average $PM_{2.5}$

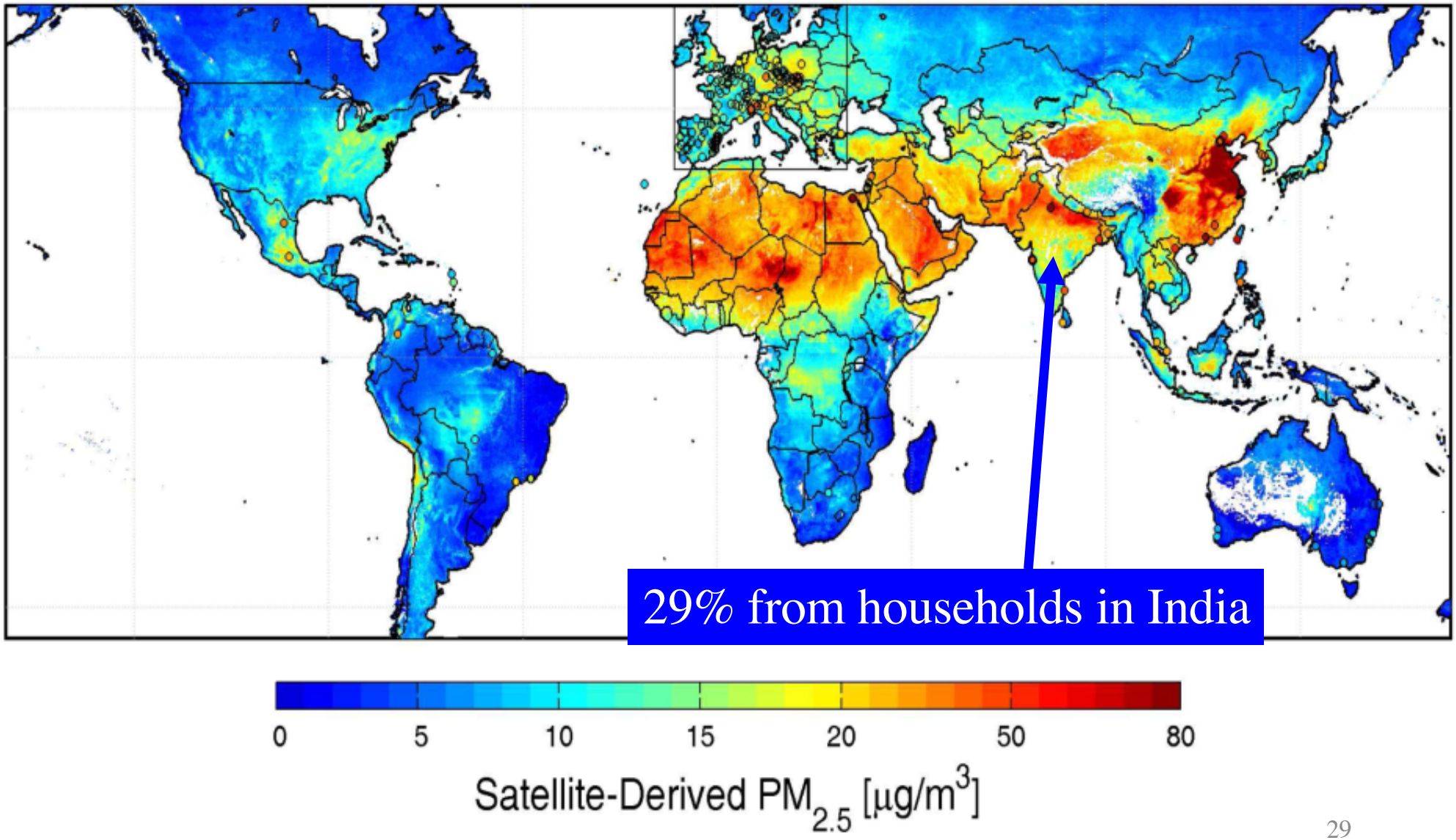


Estimated Burden of Disease for India - 2016

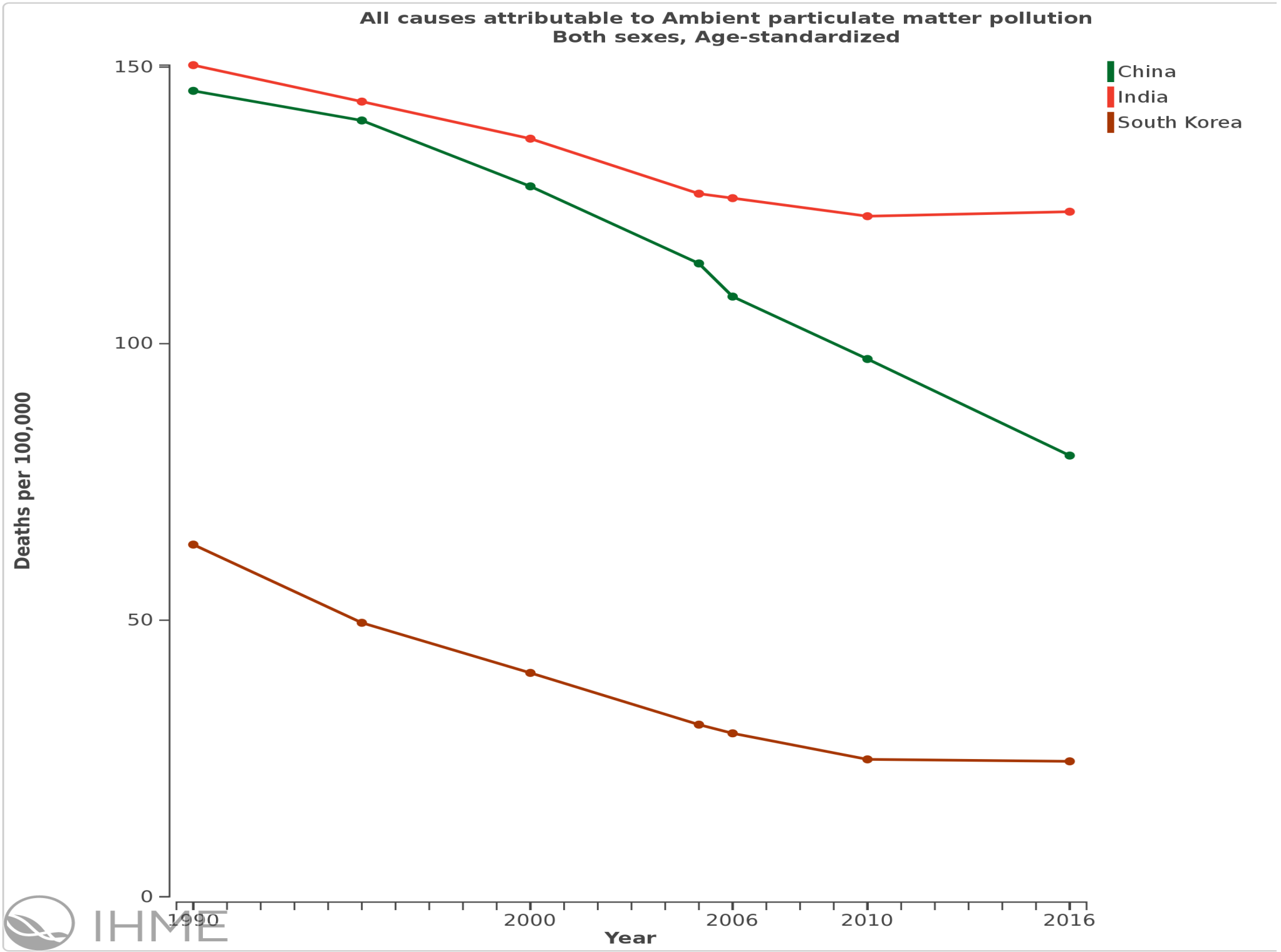

India, Both sexes, All ages, 2016
High blood pressure
Ambient particulate matter
High fasting plasma glucose
Household air pollution
Smoking
High total cholesterol
Unsafe water
High body-mass index
Impaired kidney function
Low fruit
Unsafe sanitation
birth weight & short gestation
HIV/AIDS & tuberculosis
Diarrhea/LRI/other
NTDs & malaria
Maternal disorders
Neonatal disorders
Nutritional deficiencies
Other group I
Neoplasms
Cardiovascular diseases
Chronic respiratory
Cirrhosis
Digestive diseases
Neurological disorders
Mental & substance use

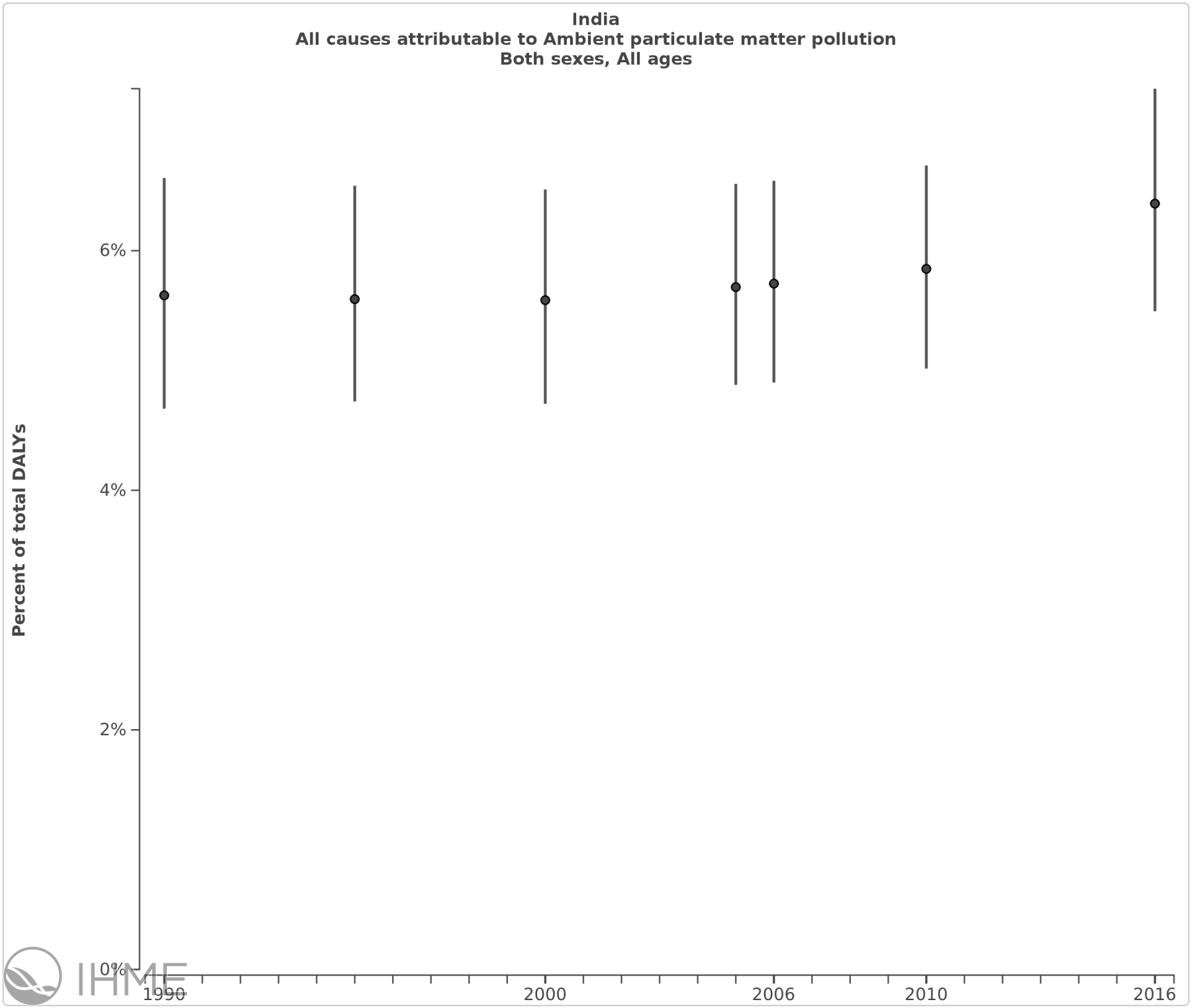

India, Both sexes, All ages, 2016
Ambient particulate matter
Household air pollution
Ozone
0
200k
400k
600k
800k
1M
Deaths

Satellite-based ambient $PM_{2.5}$



van Donkelaar et al, EHP 2010


All causes attributable to Ambient particulate matter pollution
Both sexes, Age-standardized
China
India
South Korea
150
100
50
0
Deaths per 100,000
1990
2000
2006
2010
2016
Year
IHME


India
All causes attributable to Ambient particulate matter pollution
Both sexes, All ages
Percent of total DALYs
6%
4%
2%
0%
1990
2000
2006
2010
2016
IHME

Remember

- GBD numbers are highly uncertain – these are central estimates
- And change with new models and databases
- Some health outcomes not included
  - Low birth weight/prematurity
  - TB/asthma
  - Other cancers: cervical, etc.
  - Diabetes, arthritis, low IQ, BMI

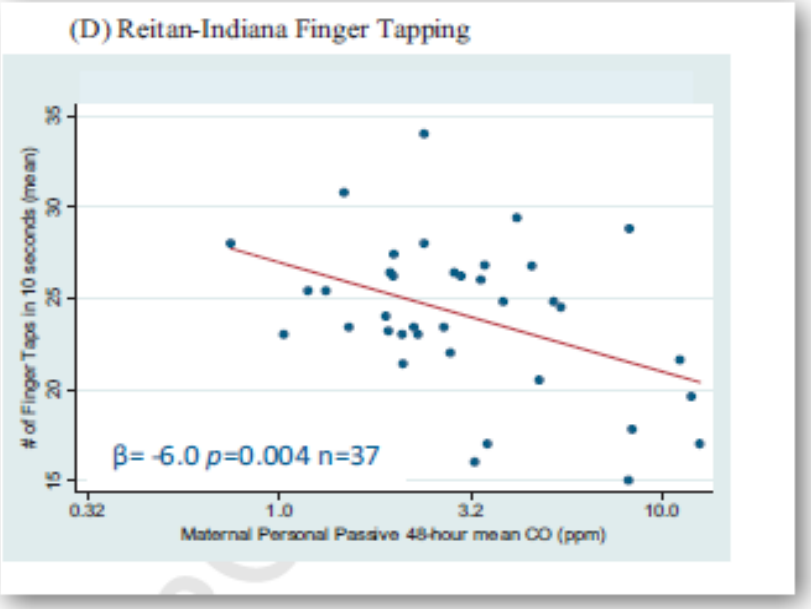
Contents lists available at SciVerse ScienceDirect

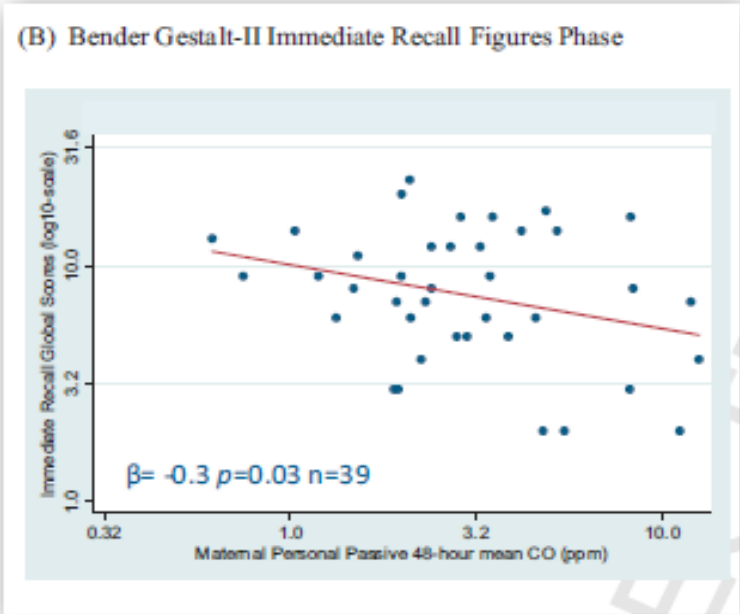
NeuroToxicology

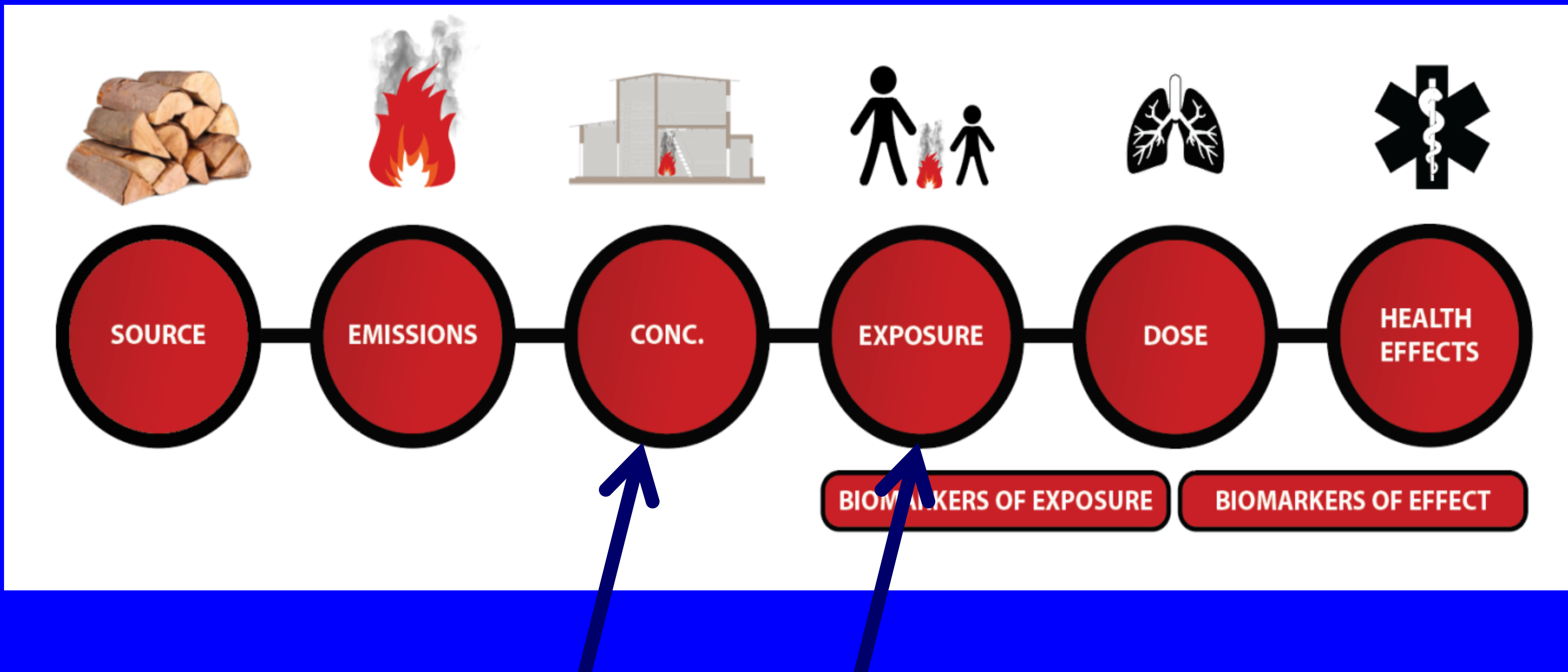
Neurodevelopmental performance among school age children in rural Guatemala is associated with prenatal and postnatal exposure to carbon monoxide, a marker for exposure to woodsmoke

Linda Dix-Cooper[a], Brenda Eskenazi[b], Carolina Romero[c], John Balmes[a,d], Kirk R. Smith[a,*]

[a] Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, CA 94720-7360, USA
[b] Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley, CA, USA
[c] Centro de Estudios en Salud Universidad Del Valle, Guatemala
[d] Division of Occupational and Environmental Medicine, Department of Medicine, University of California, San Francisco, CA, USA



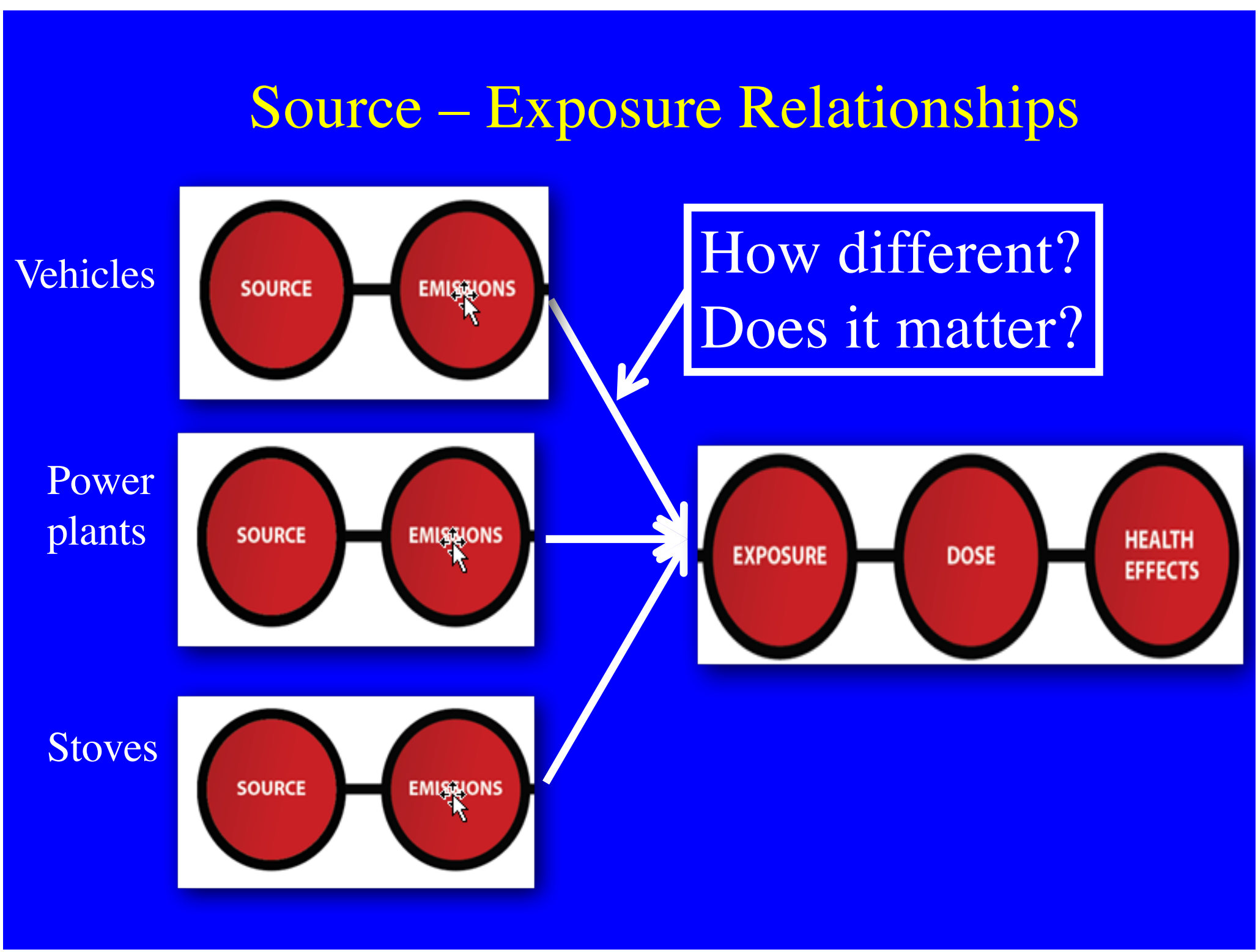




Classic air pollution monitoring focuses on concentrations in fixed locations

Exposure is a much better metric for understanding and controlling health risk

Source – Exposure Relationships

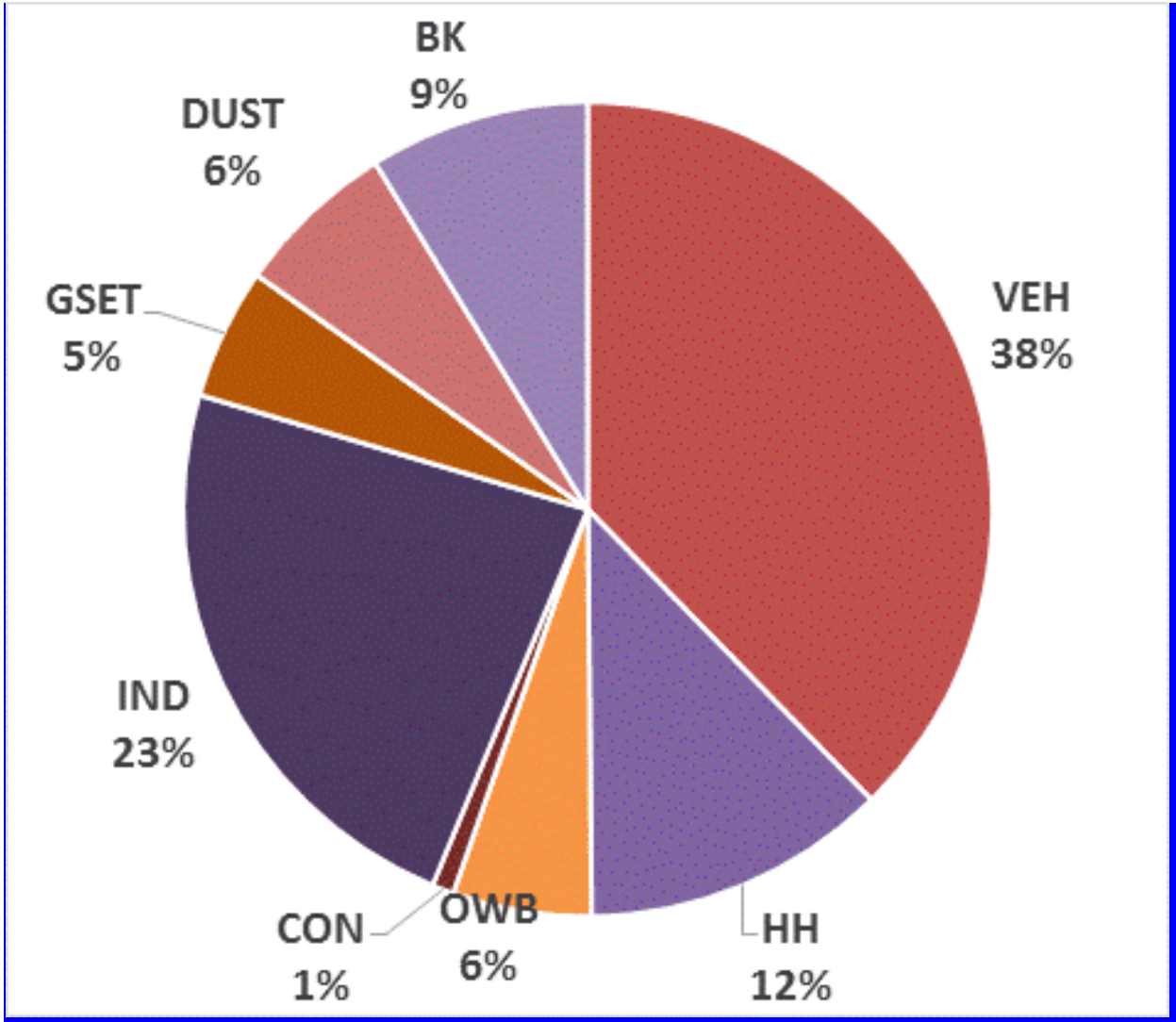


Ministry of Health and Family Welfare Air Pollution Task Force - 2015

- First Ministry of Health in world to treat AP as one of its major priorities and consider along with other risk factors in its mission
- First government agency in the world not to address AP by location, but by total exposure – a true health focus
- Thus, not indoor/household, not outdoor, but by what will give the most health benefit

MoHFW AP Task Force

- Total exposure approach requires utilizing estimates of relation between emissions of each source category and exposure.
- Emissions weighted essentially by proximity to population
- Goal is to change source apportionment to exposure apportionment
- Several analytic approaches now available – new research agenda to make viable for policy



Hyderabad-2012

Emissions – $PM_{2.5}$

MOHFW Report, 2015
estimates by Guttikunda

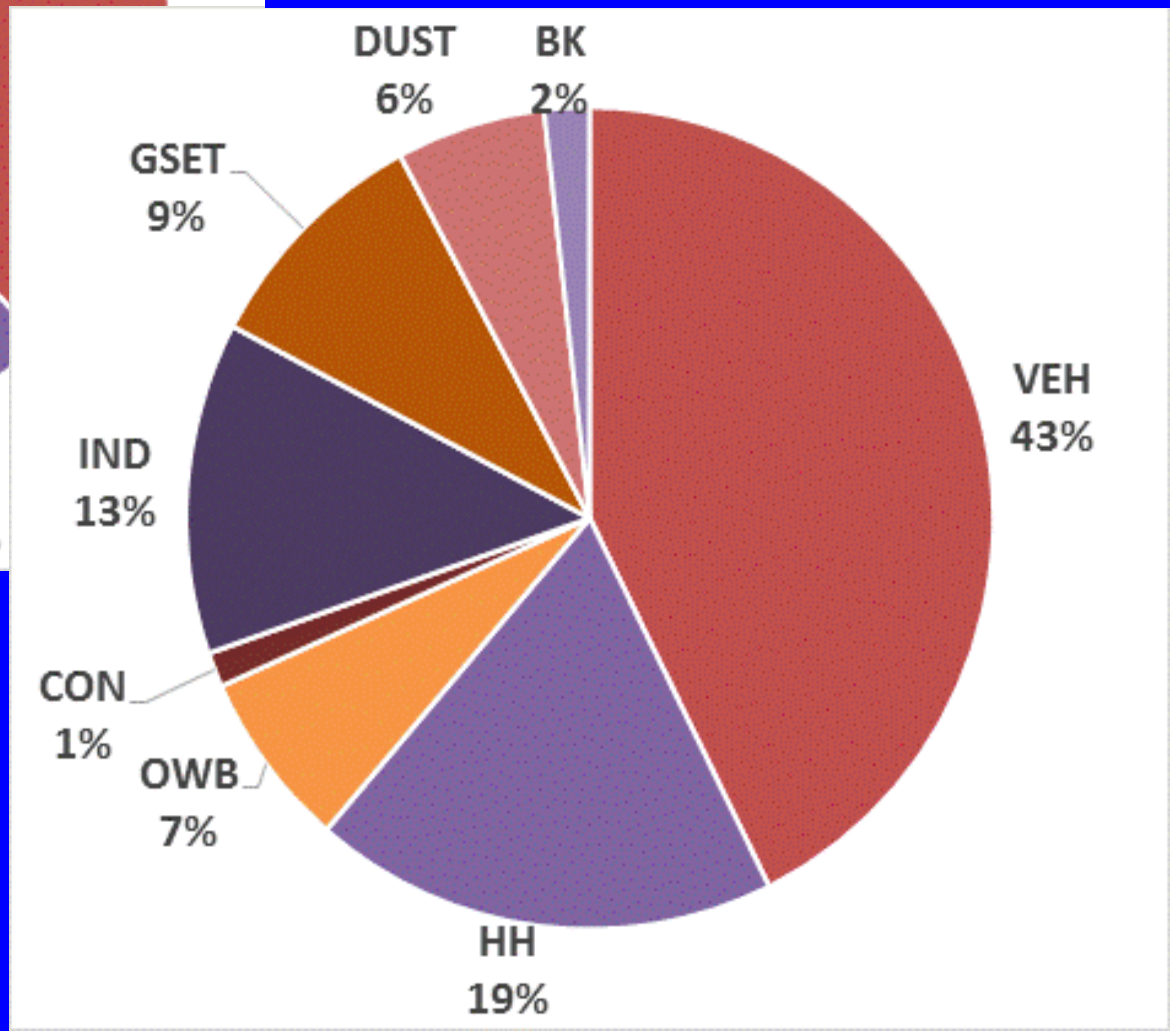
Ambient Intake Fractions in Hyderabad

ppm – grams inhaled per tonne emitted

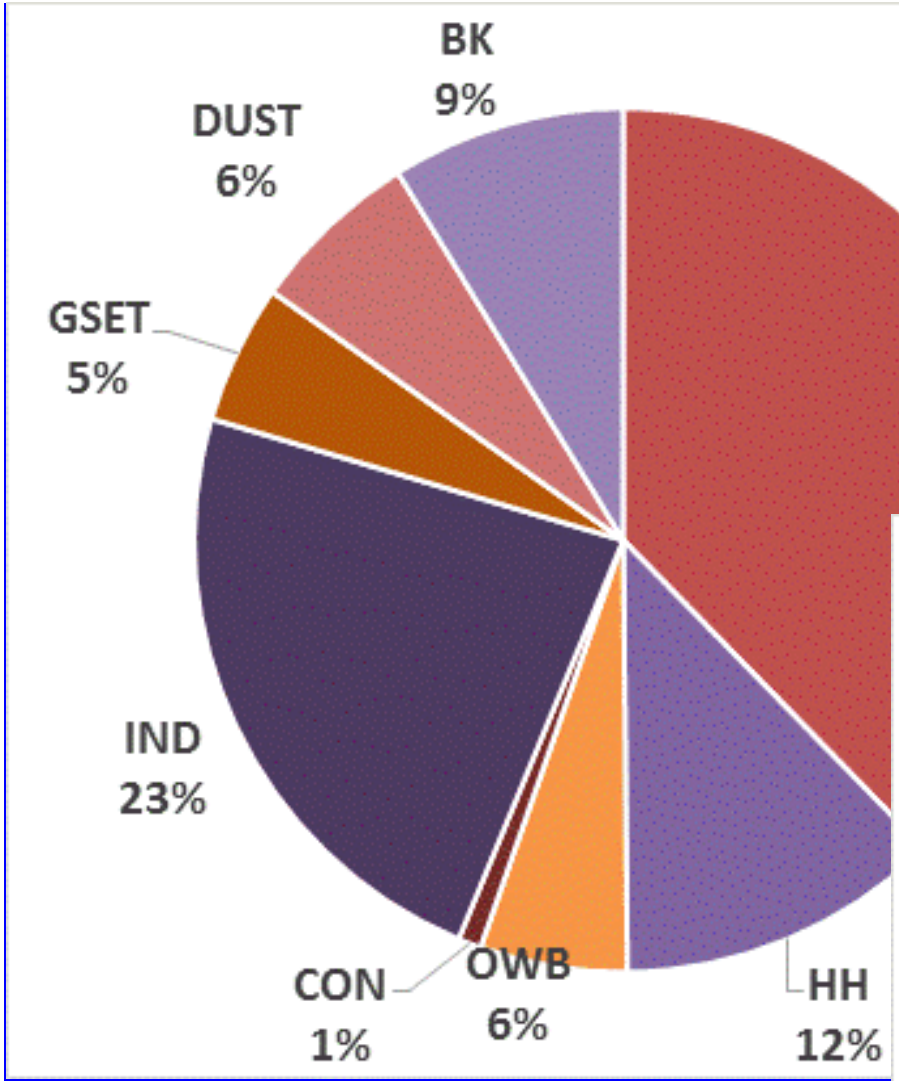
	Average	SD
Households	175	97
Construction	175	93
Waste.burn	140	74
Veh.exhaust	130	64
Gen.sets	123	53
Industries	65	17
Dust	18	4
Power plants	7.4	7.0
Brick.kilns	6.8	1.9

Hyderabad-2012

Ambient Exposures– $PM_{2.5}$



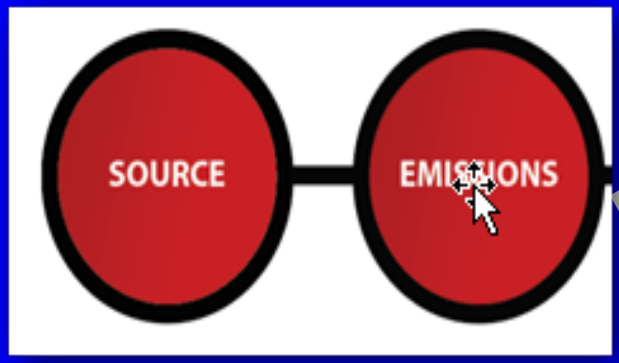
Emissions – $PM_{2.5}$



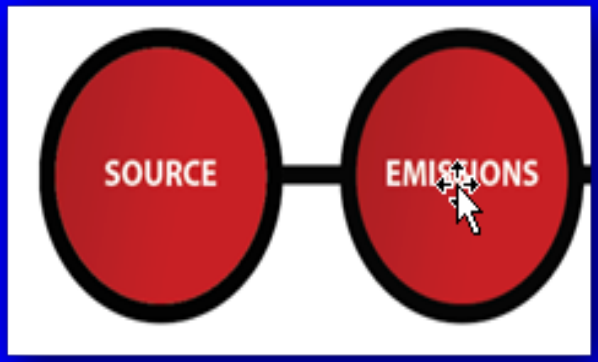
Draft MOHFW Report
estimates by Guttikunda

Source – Exposure Relationships

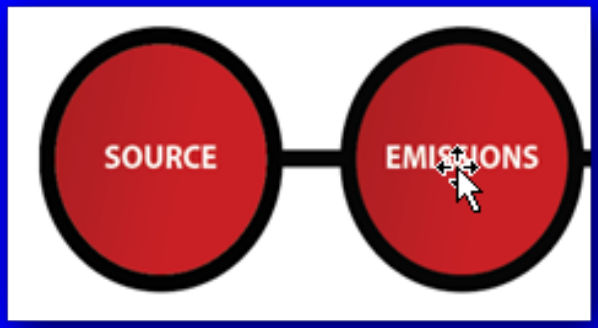
Vehicles



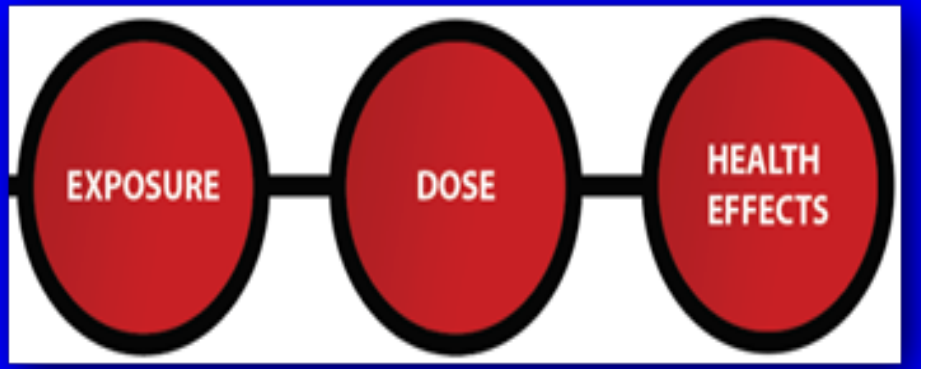
Power plants



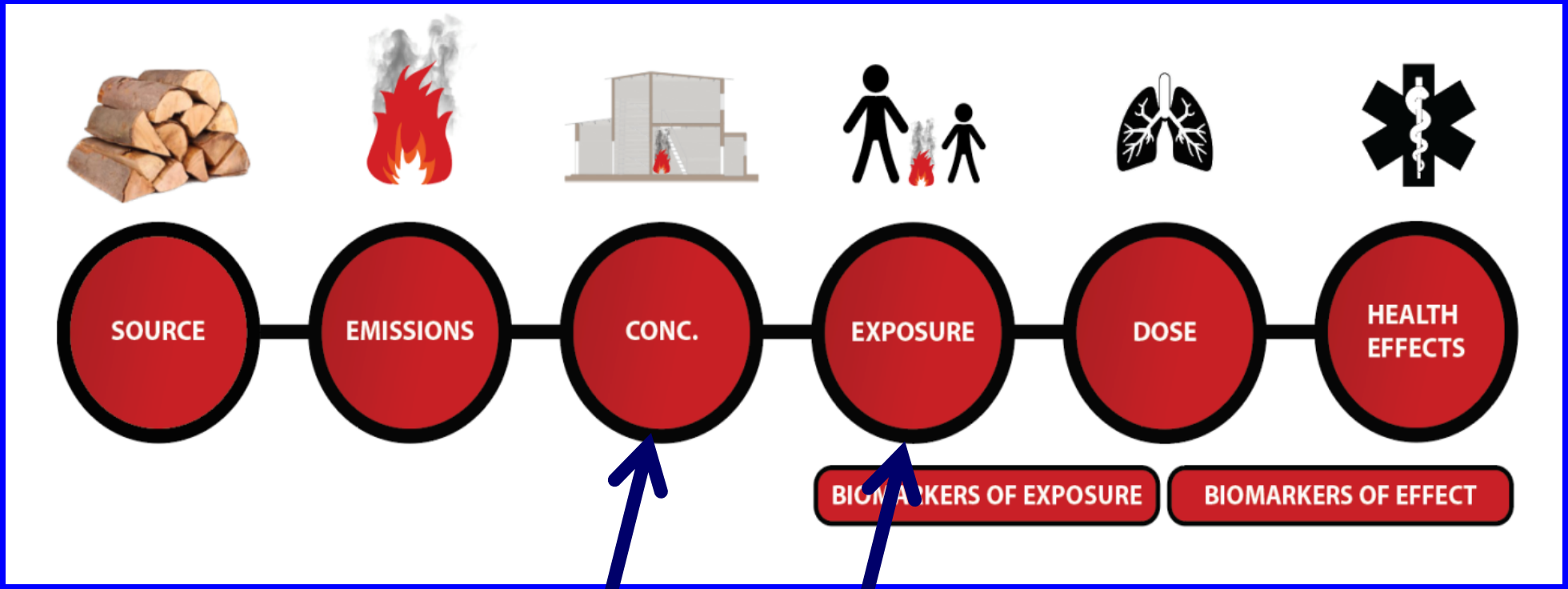
Stoves



How different?
Does it matter?



Yes, a factor of 100 different!



Classic air pollution control focuses on concentrations in fixed locations

Integrated exposure allows more nuanced and efficient air pollution control that weights sources by their impact on exposure and health rather than environmental quality

Summary

- Eventually, we wish to control all sources of air pollution, all the time, everywhere.
- But we cannot afford to do so immediately
- What metric gives the optimal pathway such that the most health protection is occurring at each stage of investment?
- Metrics of exposure are the way to do so

India

- Still with ~two-thirds of households using solid cookfuels
- Most polluted cities in the world, but also major amounts of ambient pollution in rural areas
- Highest burden of disease from air pollution in the world
- Highest total air pollution burden/capita of all middle-income countries – 2x China


COLLABORATIVE
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URBAN emissions .info

Mission

- **The CCAPC**
  - **evaluates, and compares policy options for dealing with India's health-damaging air pollution of all types,**
  - **provides a platform for institutions to work together to solve problems and recommend policy, and**
  - **works to develop capacity to address the policy implications of air pollution in the country.**

NIMBY versus MIMBY

- Not in my backyard (NIMBY) is a well known issue in environmental health
- But MIMBY (Must be in my backyard) is a more fundamental problem
- Local data are obviously valuable
- But we cannot repeat every study in every part of the world
- When do we have enough information for policy?
- In particular for HAP risk for CVD outcomes; these now come from ambient and other data only?

Risk Modifiers

- Age
- Sex
- Race/ethnicity
- Socioeconomic status
- Neighborhood
- Stress
- Diet
- Obesity
- Diabetes
- Other exposures (e.g., tobacco smoke, biomass smoke, occupational vapors, dusts, fumes)

Many thanks

For publications
& presentations:
Just “Google”
Kirk R. Smith

For the new Centre
http://www.ccapc.org.in/