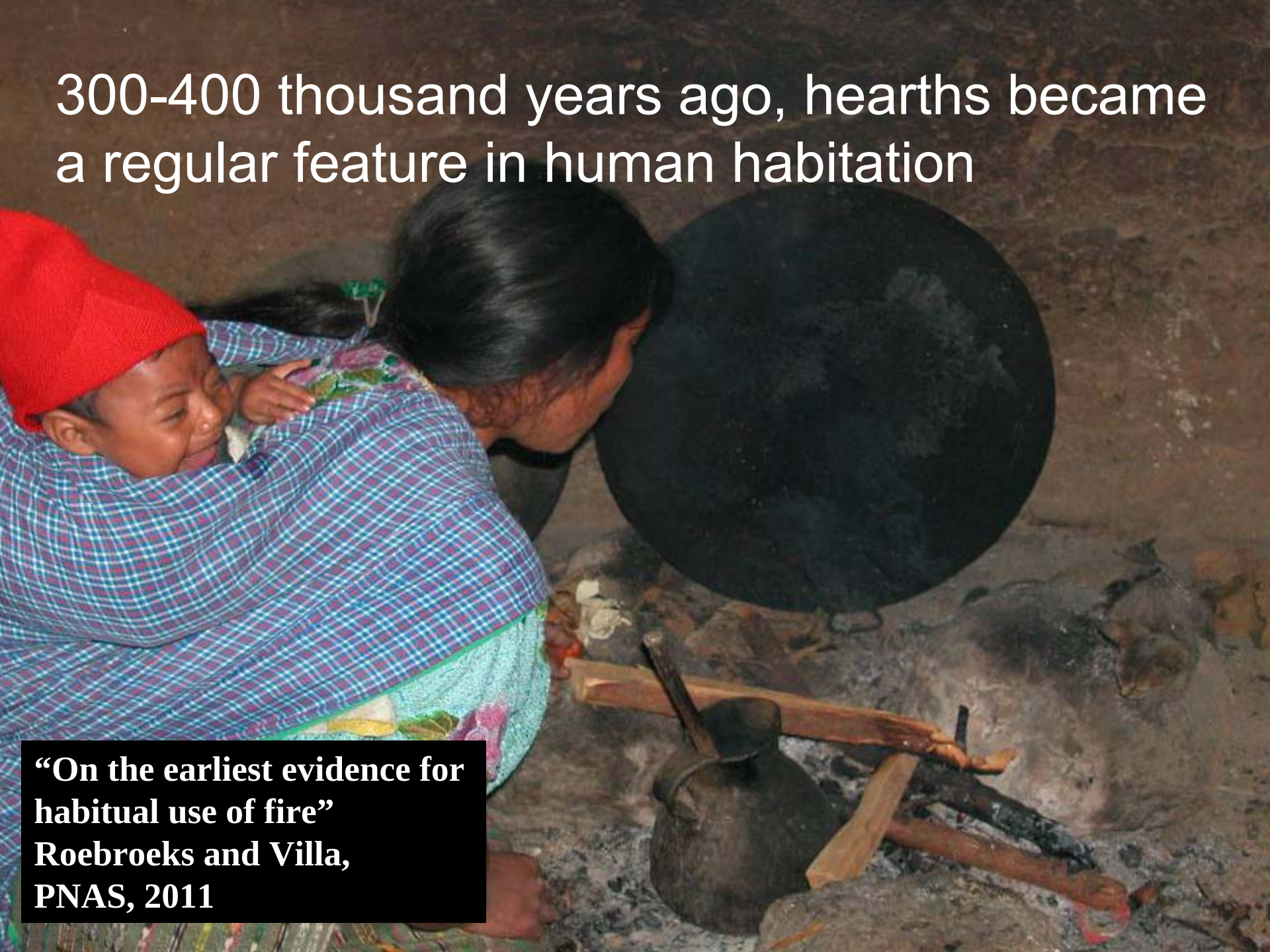
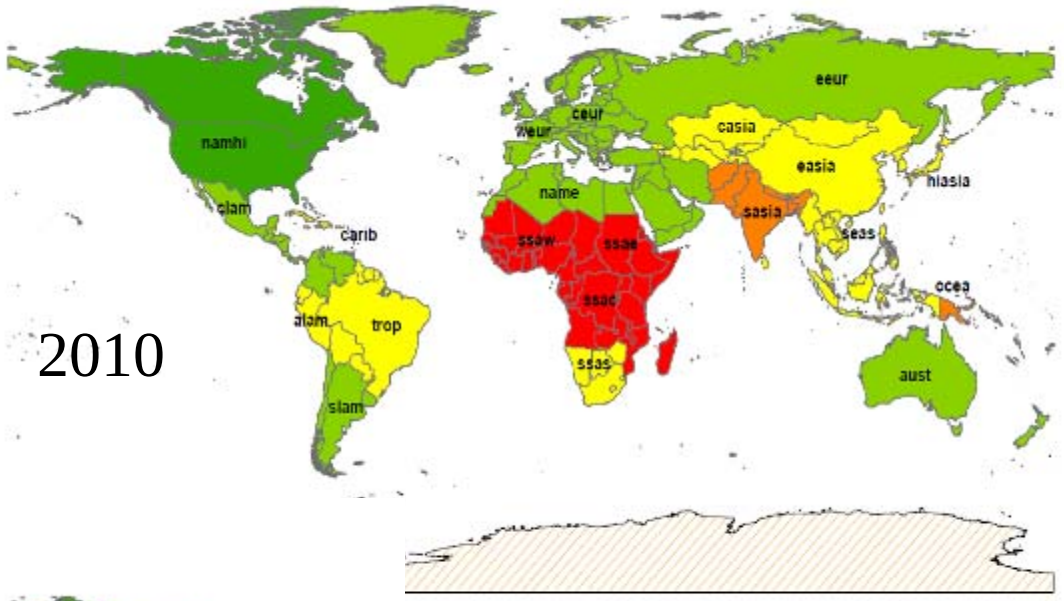
Smoke, health, and climate: the unfinished global agenda of incomplete combustion

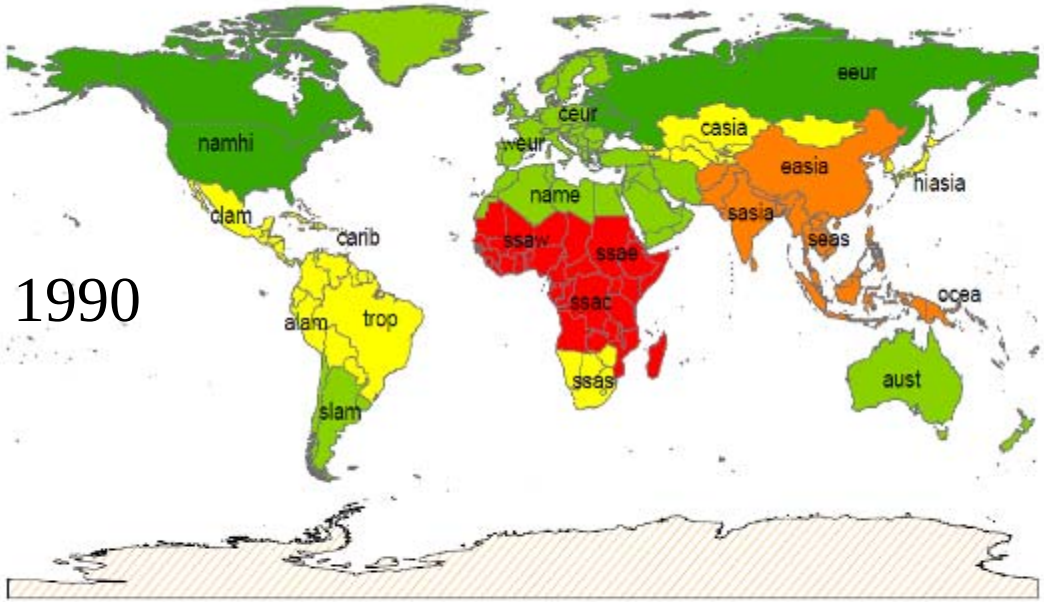
Kirk R. Smith
Professor of Global Environmental Health
University of California, Berkeley

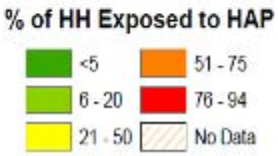
Global Health Sciences
UCSF, Oct 13, 2011


300-400 thousand years ago, hearths became a regular feature in human habitation
“On the earliest evidence for habitual use of fire”
Roebroeks and Villa,
PNAS, 2011

Households using biomass or coal to cook

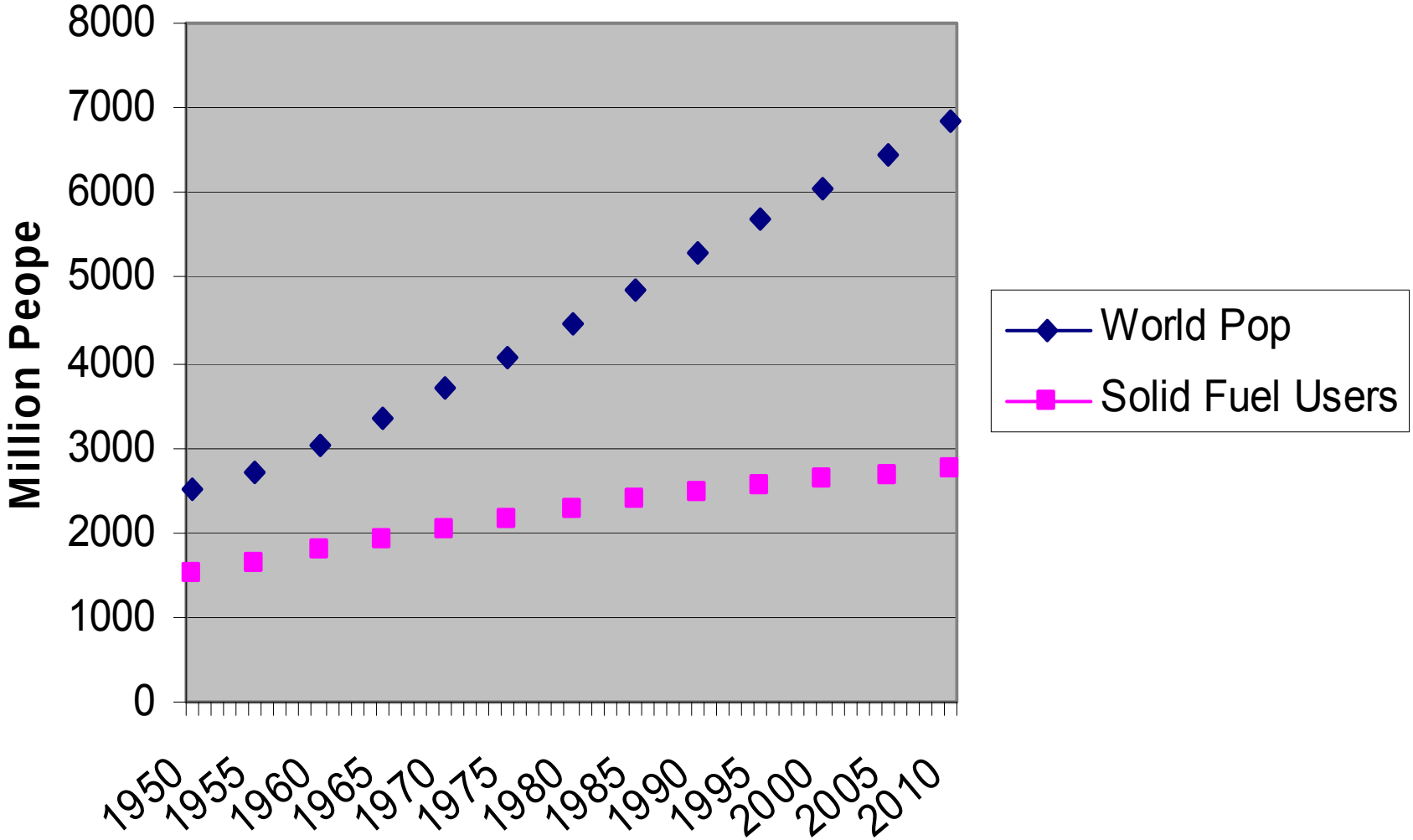






Comparative Risk Assessment (CRA) 2011- preliminary, Adair, et al.

World Population Using Solid Fuels



Biomass Cooking in History

- **Today, ~43% use solid fuels, about 3 billion people**
- **Although the percentage is dropping, the absolute number is still rising.**
- **Perhaps 20 million people a year are added to the total each year.**
- **Indeed, there are more people using solid fuels today for cooking than the total world population in 1950**
- **Or any year previously**


The three major solid fuels

Woodsmoke is natural – how can it hurt you?

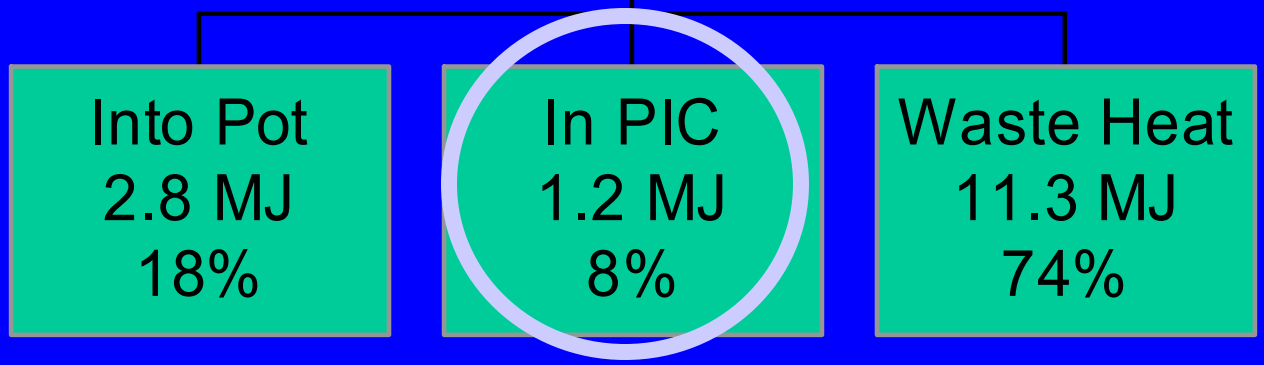
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Indian cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



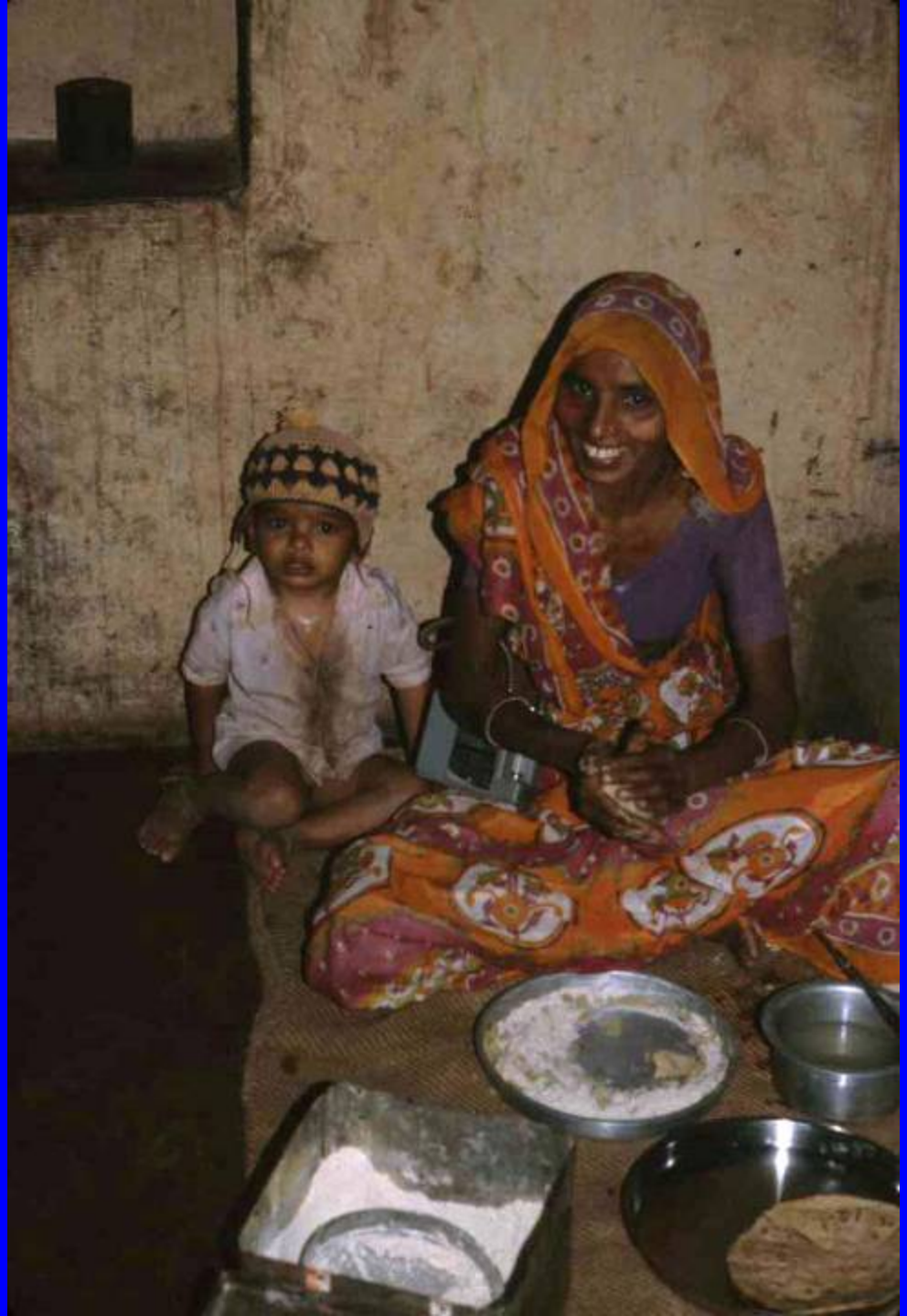
PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

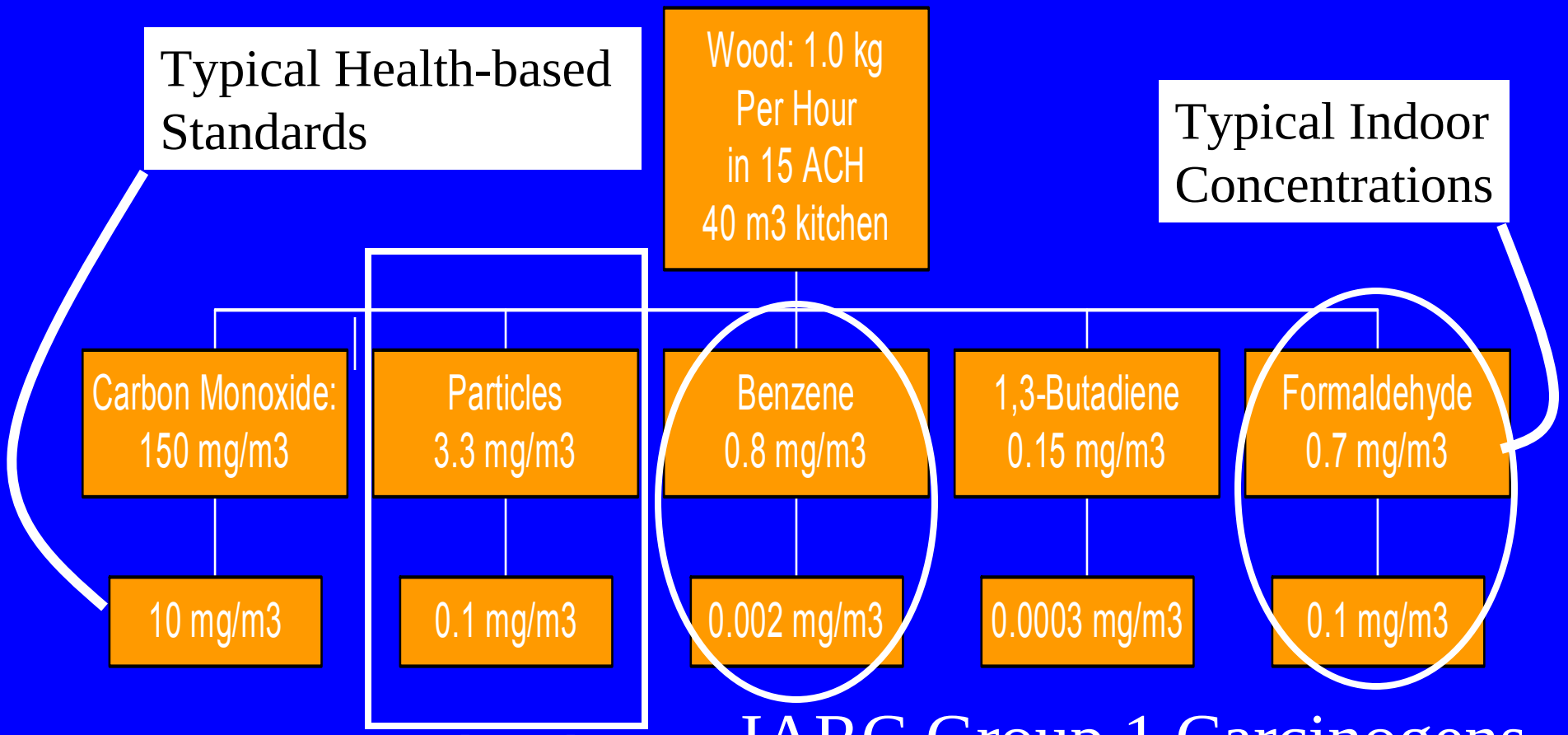
- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *formaldehyde* & *acrolein*
  - 25+ 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*

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



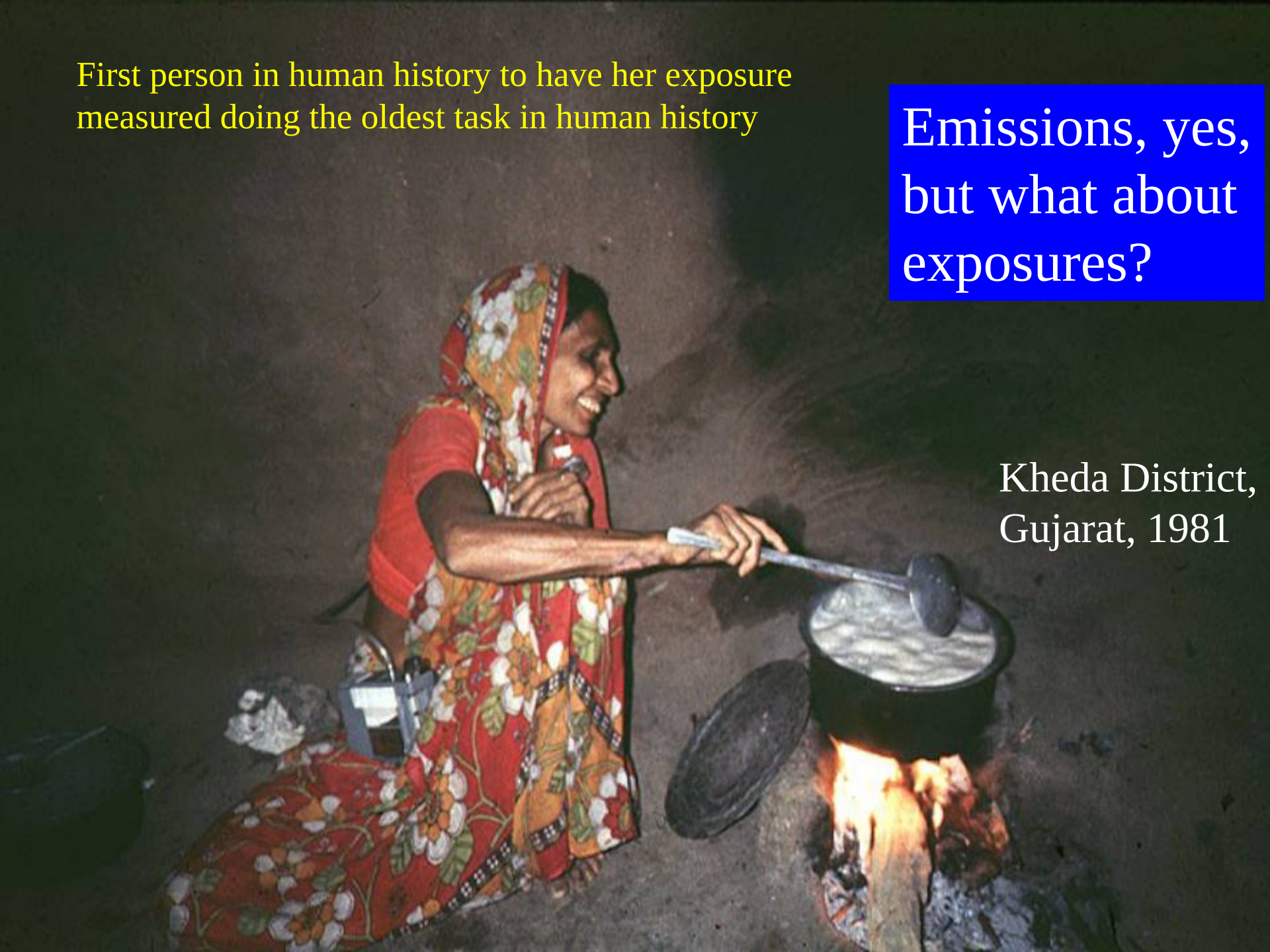
How much Ill-health?

Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



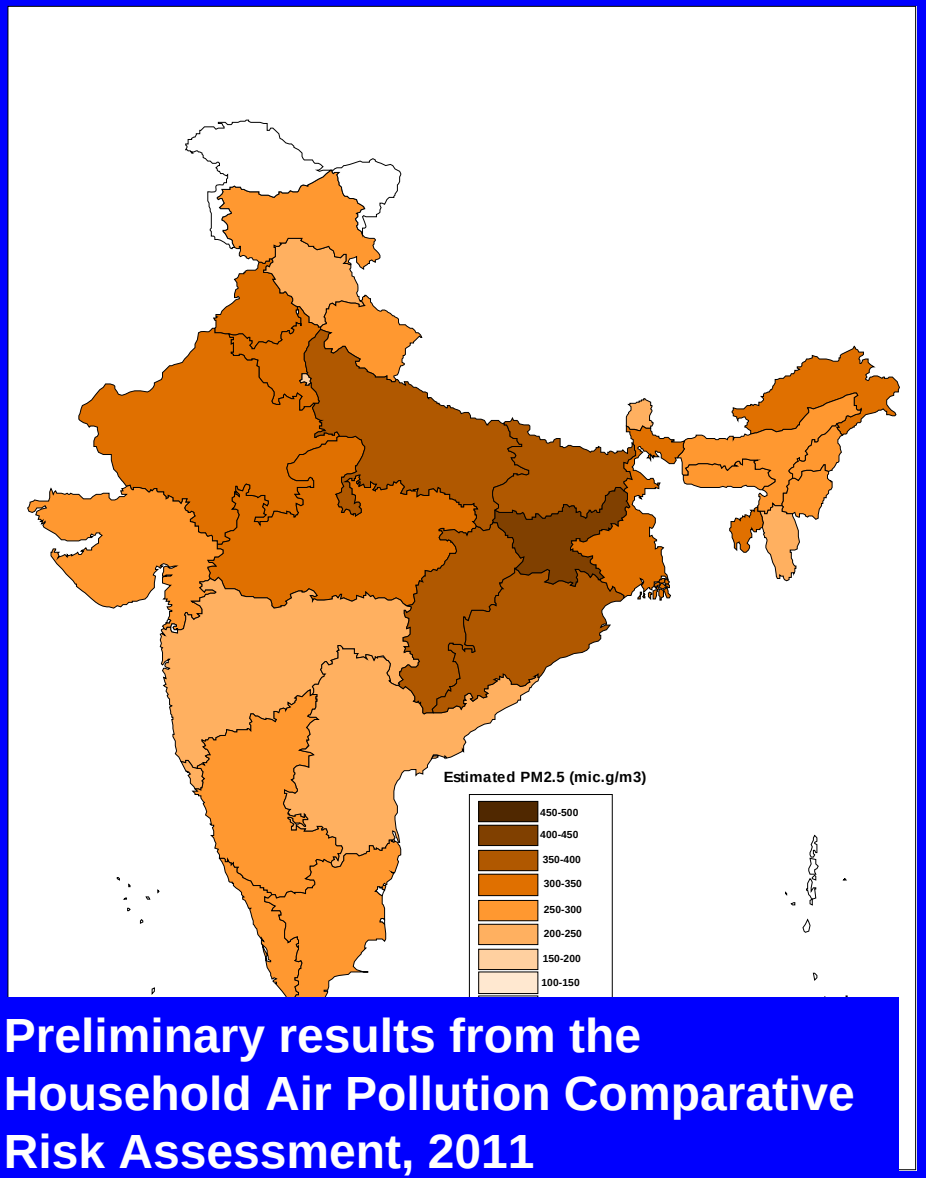
First person in human history to have her exposure measured doing the oldest task in human history

Emissions, yes, but what about exposures?



Kheda District, Gujarat, 1981

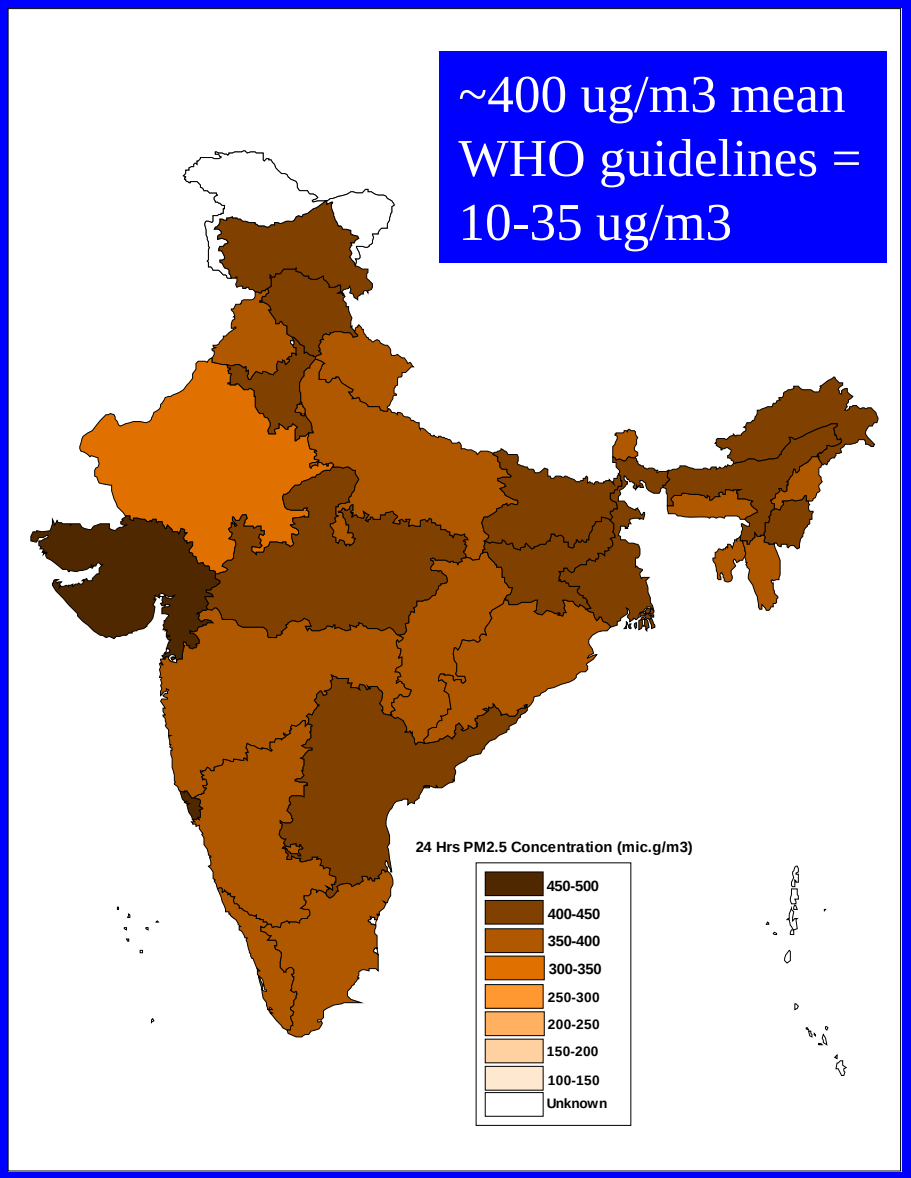
Estimated PM2.5 indoors for all households



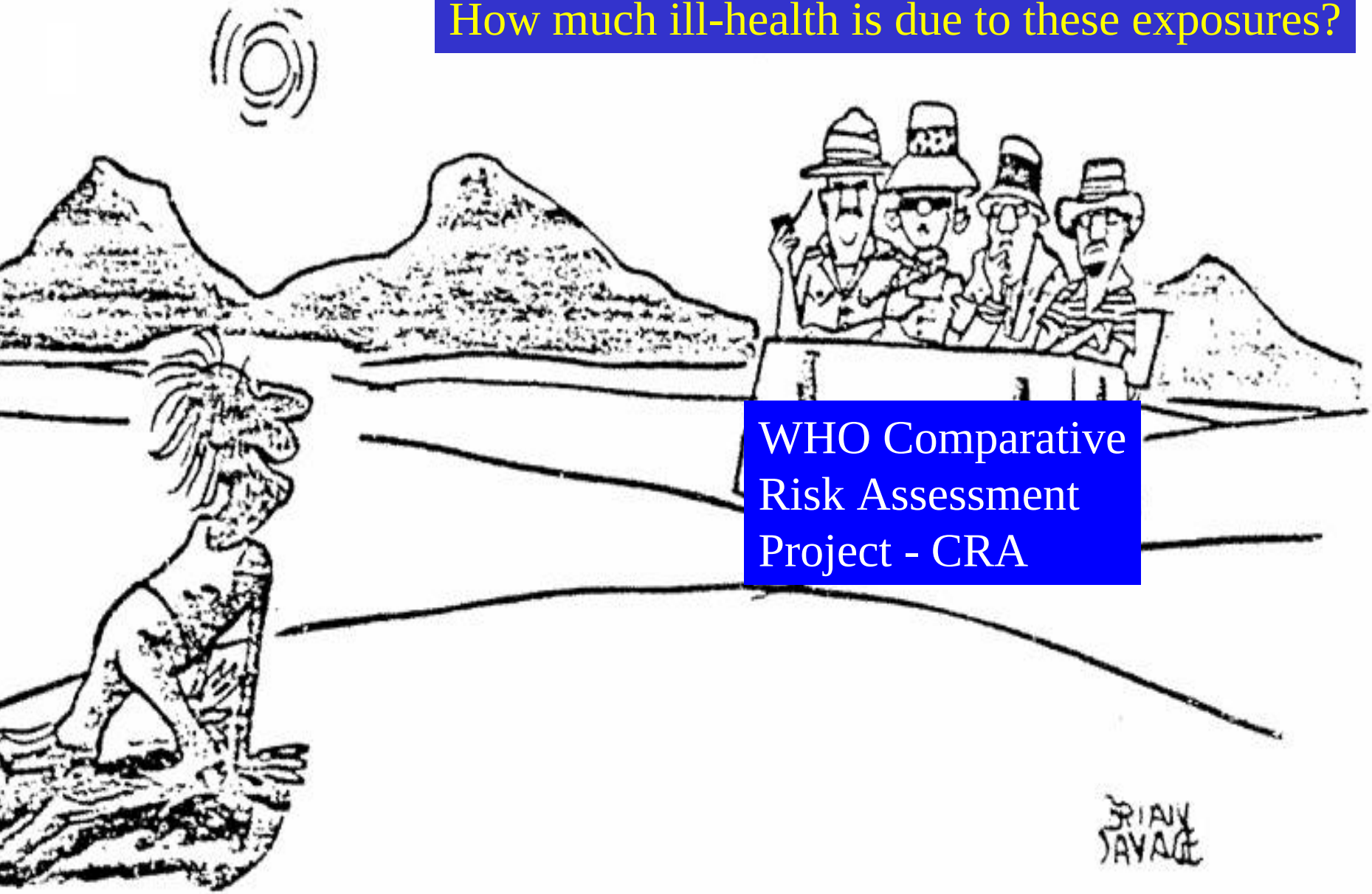
Preliminary results from the Household Air Pollution Comparative Risk Assessment, 2011

Estimated PM2.5 for only solid-fuel-using households

~400 ug/m3 mean
WHO guidelines = 10-35 ug/m3



How much ill-health is due to these exposures?



WHO Comparative Risk Assessment Project - CRA

"Thank God! A panel of experts!"

Courtesy of Ross Anderson

ALRI/
Pneumonia

Diseases for which we have epidemiological studies

COPD

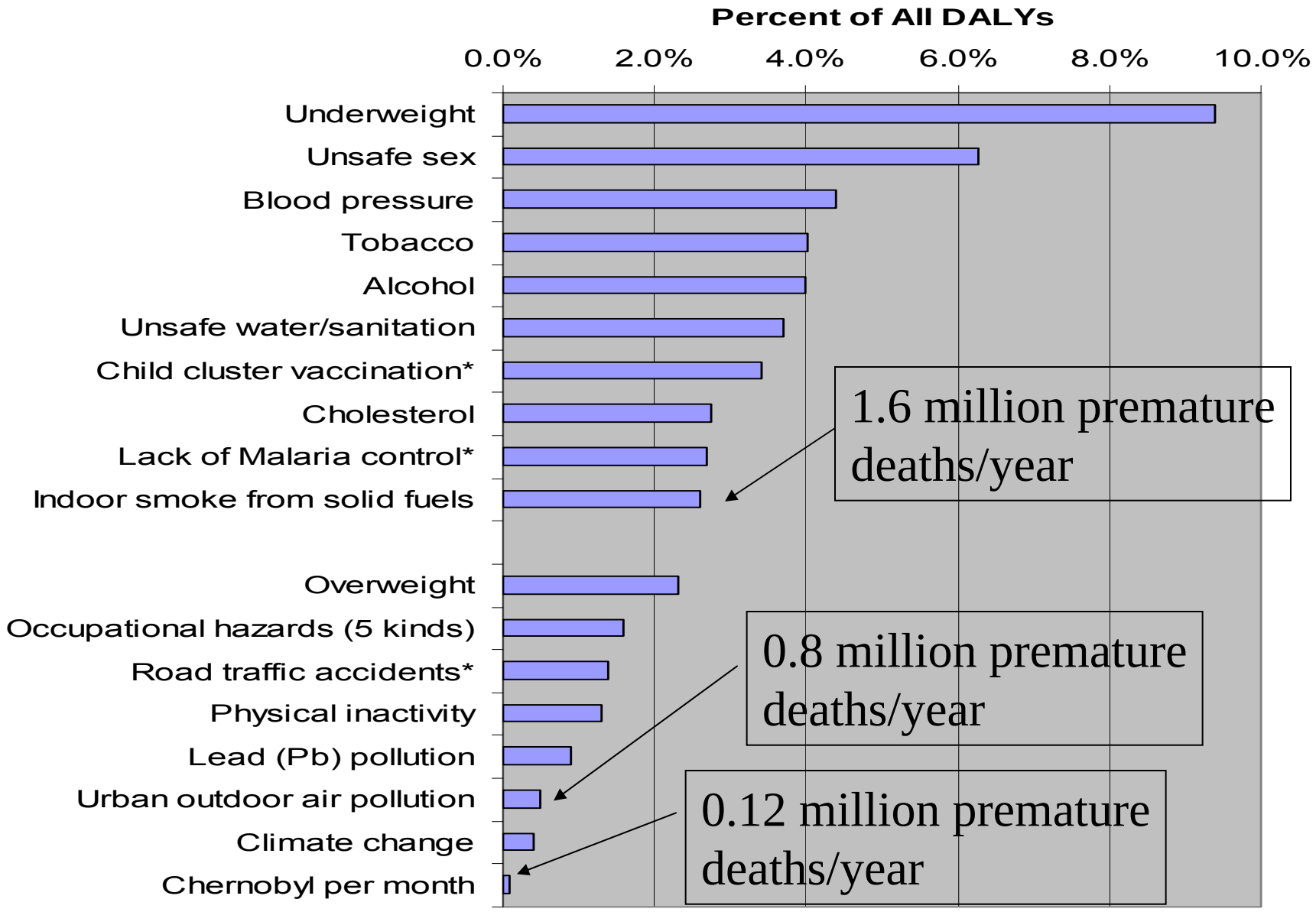
Lung cancer
(coal)

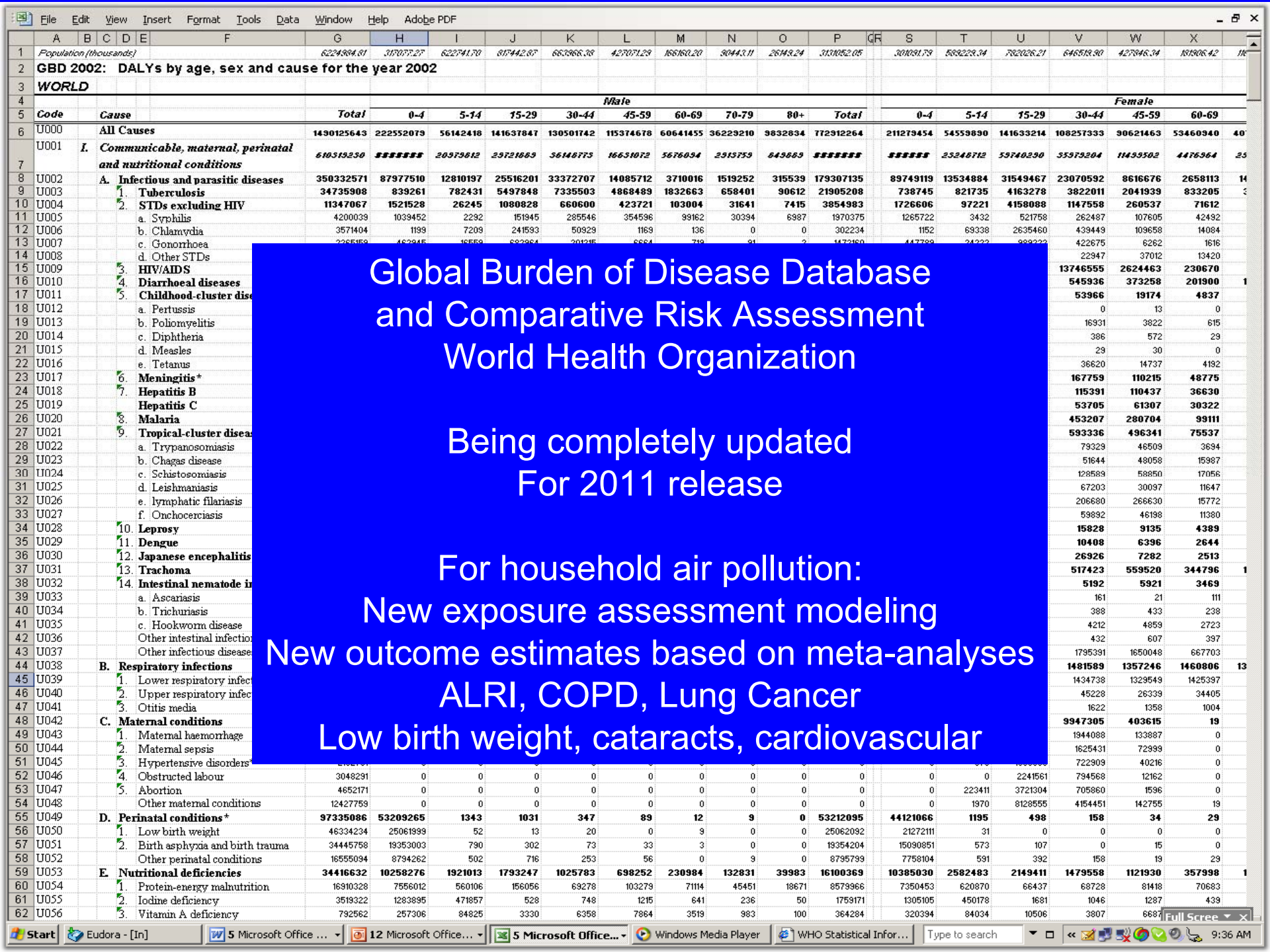
These three diseases were included in the 2004 Comparative Risk Assessment Managed and published by WHO

First ever comprehensive risk assessment with consistent rules of evidence and common databases

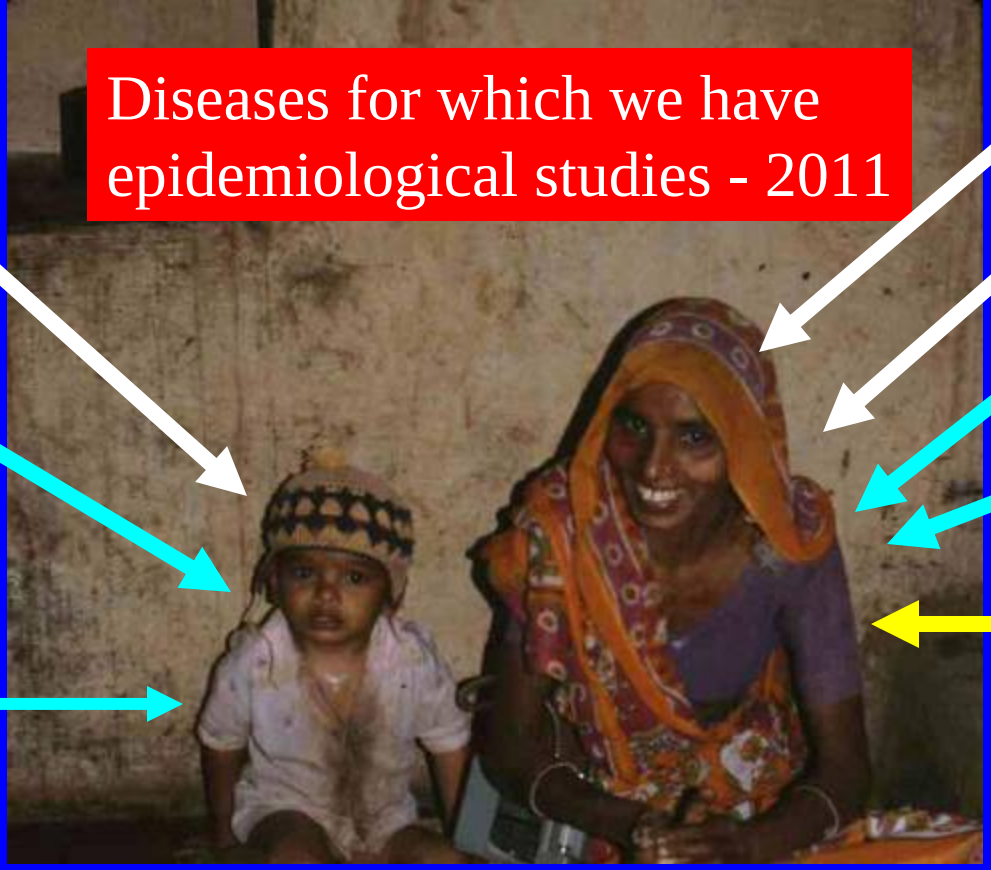
Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors




Global Burden of Disease Database
and Comparative Risk Assessment
World Health Organization
Being completely updated
For 2011 release
For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer
Low birth weight, cataracts, cardiovascular

Diseases for which we have epidemiological studies - 2011



ALRI/
Pneumonia

Low birth
weight

Stillbirth

COPD

Lung cancer
(coal)

Lung cancer
(biomass)

Blindness
(cataracts, opacity)

CV disease
Blood pressure
ST-segment

These additional diseases will be included in the 2011 Comparative Risk Assessment

In addition, using evidence from other exposure sources, CVD will be included

There is epi evidence for these other diseases, but considered insufficient to include in the 2011 Comparative Risk Assessment

Cognitive Impairment

Birth defects

Asthma?

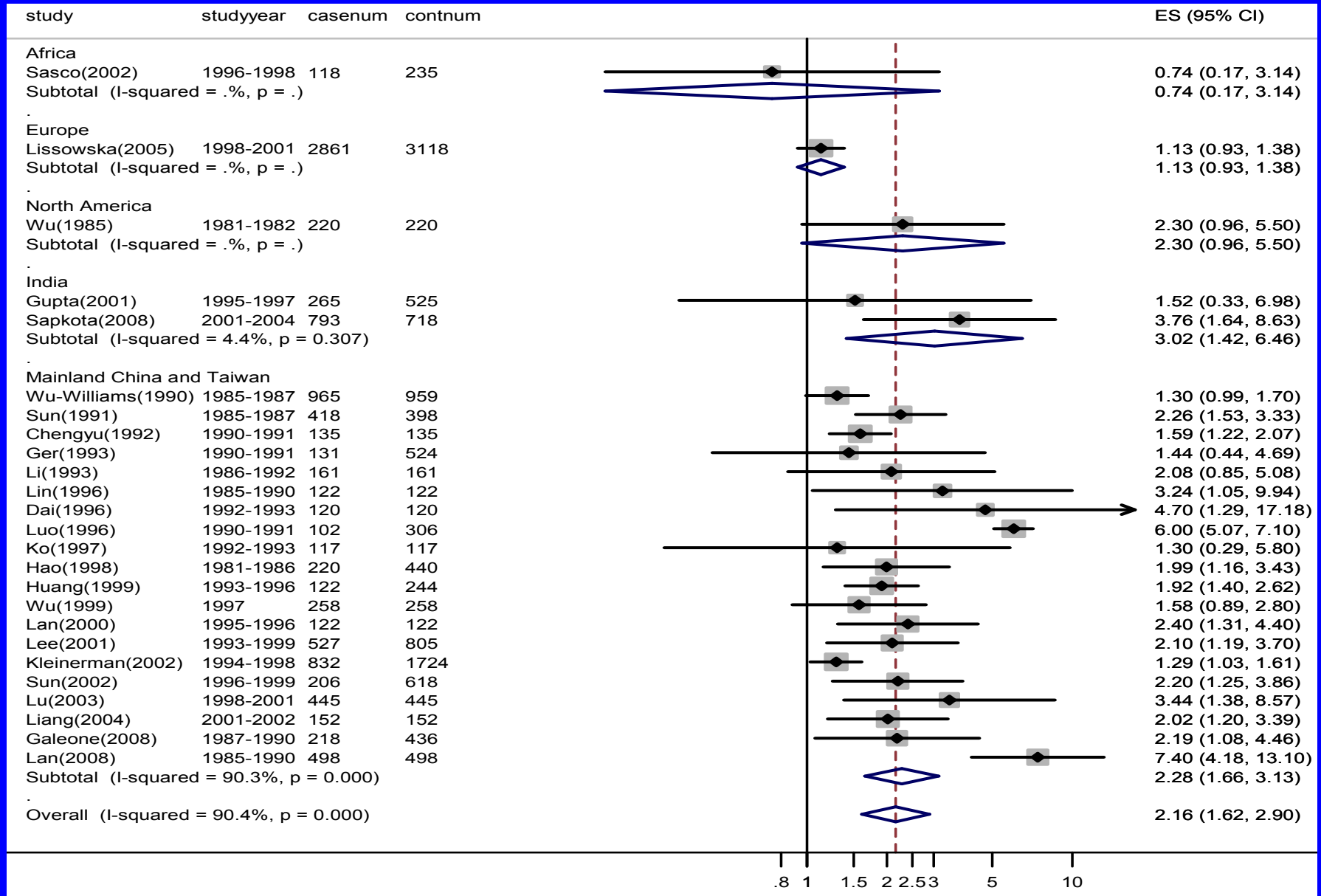
Tuberculosis

ALRI

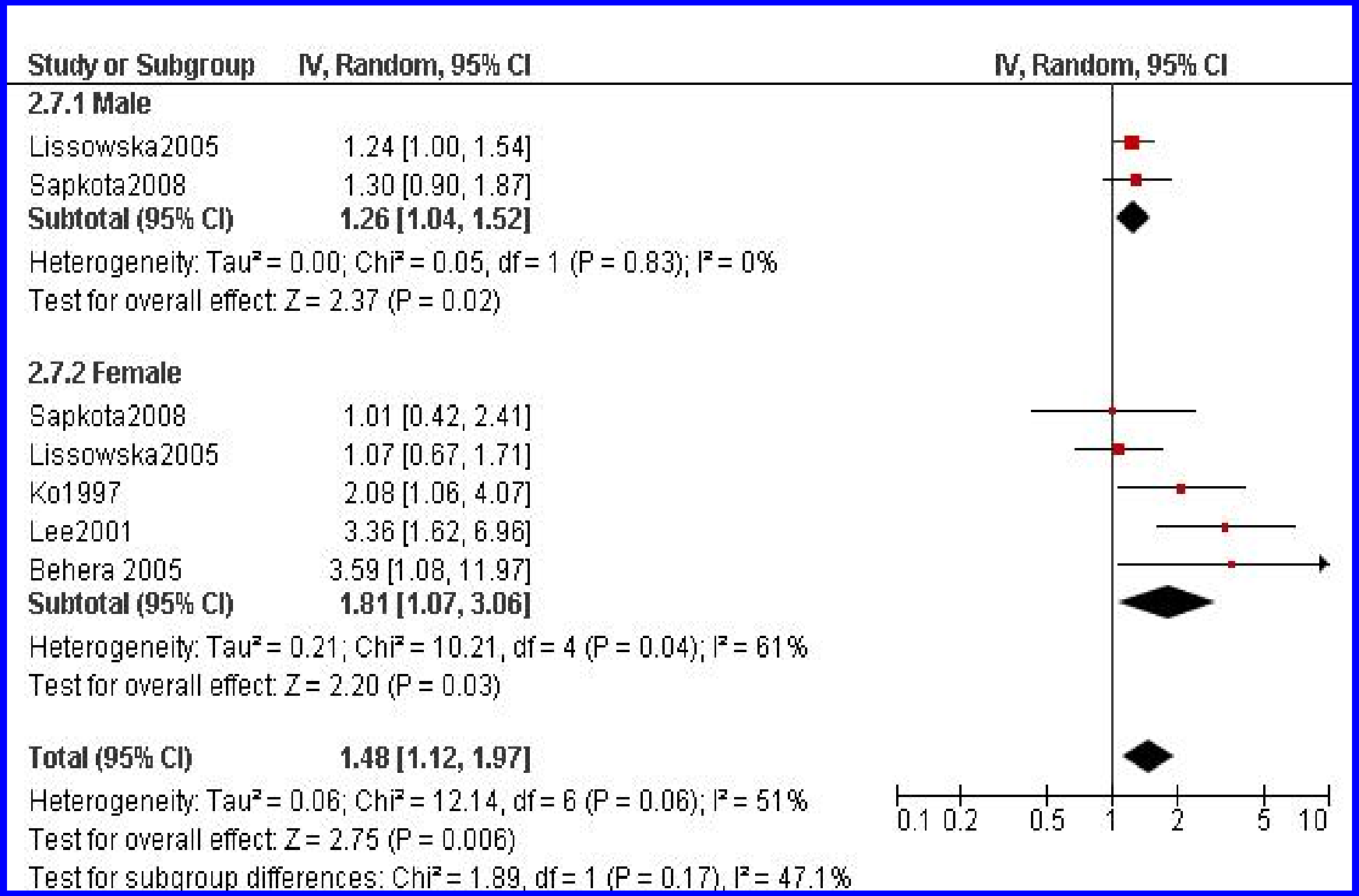
Other cancers (cervical, NP, upper airway)

Burns and the health/safety impacts of fuel gathering

Summary risk estimates of lung cancer associated with in-home coal use for heating and cooking by geographic region

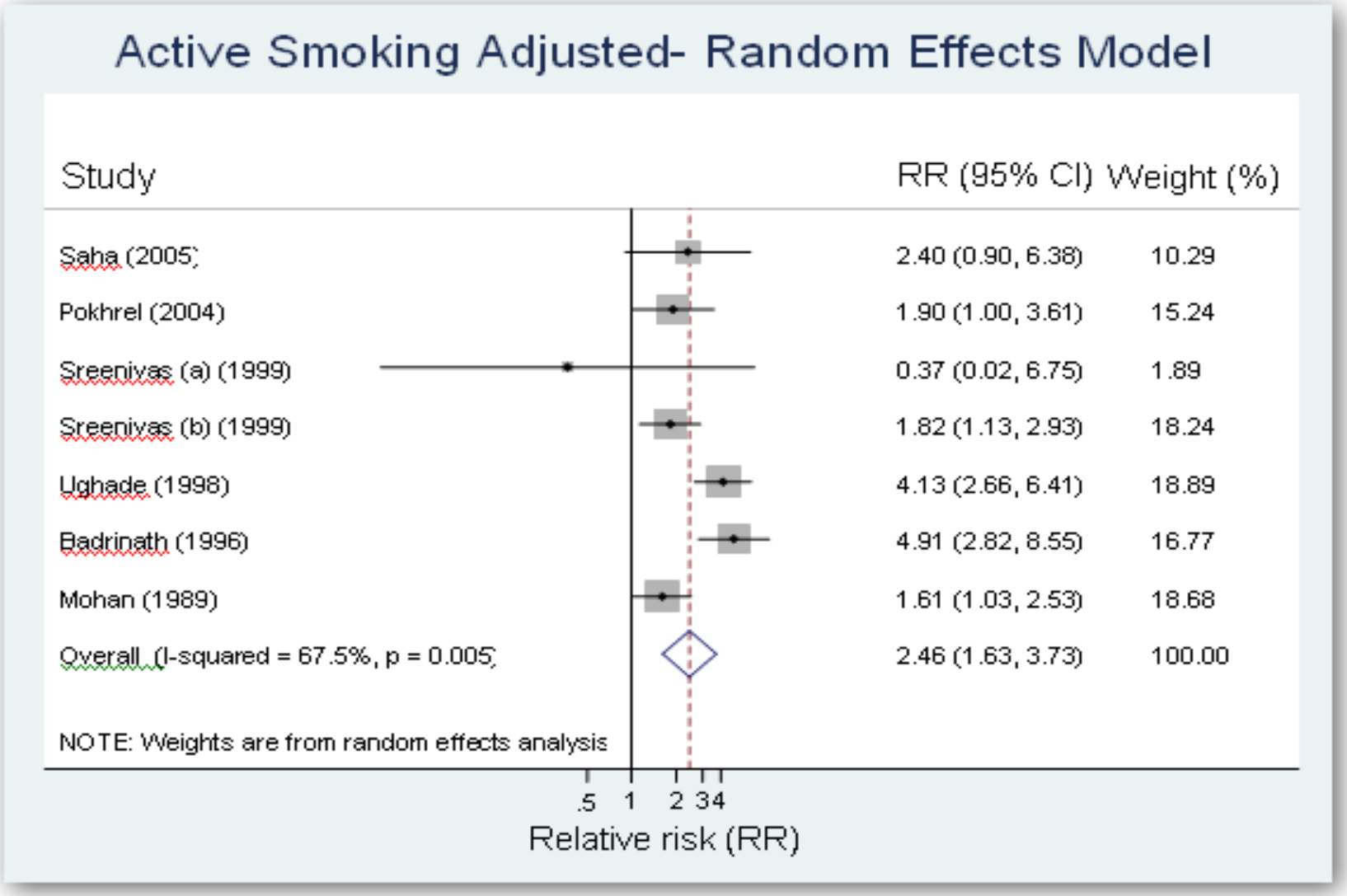


Lung Cancer: Biomass vs. clean fuel



CRA, Imran et al. preliminary

Cataracts and Biomass Cooking Smoke*



* Adjusted for UV

CRA Preliminary, Adair et al.

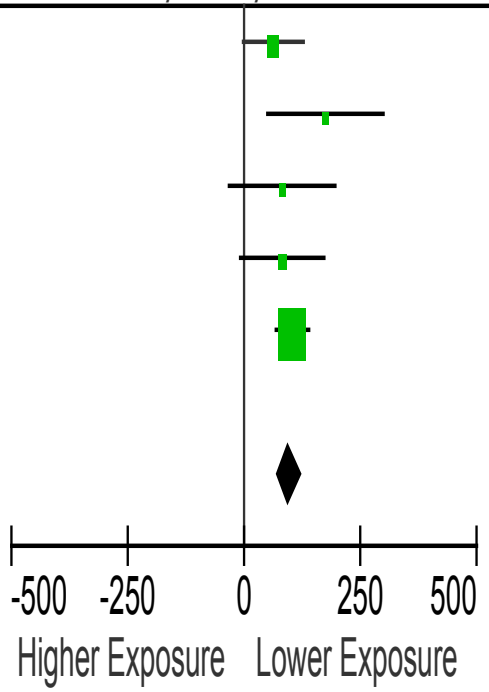
Pooled birth weight difference (low minus high exposure):

Adjusted estimates (Boy and Tielsch have GA)

Study or Subgroup	Lower Exposure Mean	SD	Total	Higher Exposure Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Boy 2002	2,835	533	357	2,772	525	871	18.5%	63.00 [-2.36, 128.36]
Mishra 2004	3,271	1,448	766	3,096	1,429	1535	5.0%	175.00 [50.00, 300.00]
Siddiqui 2008	2,812	404	80	2,730	385	108	6.0%	82.00 [-32.50, 196.50]
Thompson 2005	2,805	579	366	2,723	573	268	9.6%	82.00 [-8.69, 172.69]
Tielsch 2009	2,819	453	646	2,715	420	8958	60.9%	104.00 [68.00, 140.00]
Total (95% CI)			**2215**			**11740**	**100.0%**	**96.58 [68.49, 124.67]**

Heterogeneity: $Chi^2 = 2.85$, $df = 4$ ($P = 0.58$); $I^2 = 0\%$

Test for overall effect: $Z = 6.74$ ($P < 0.00001$)



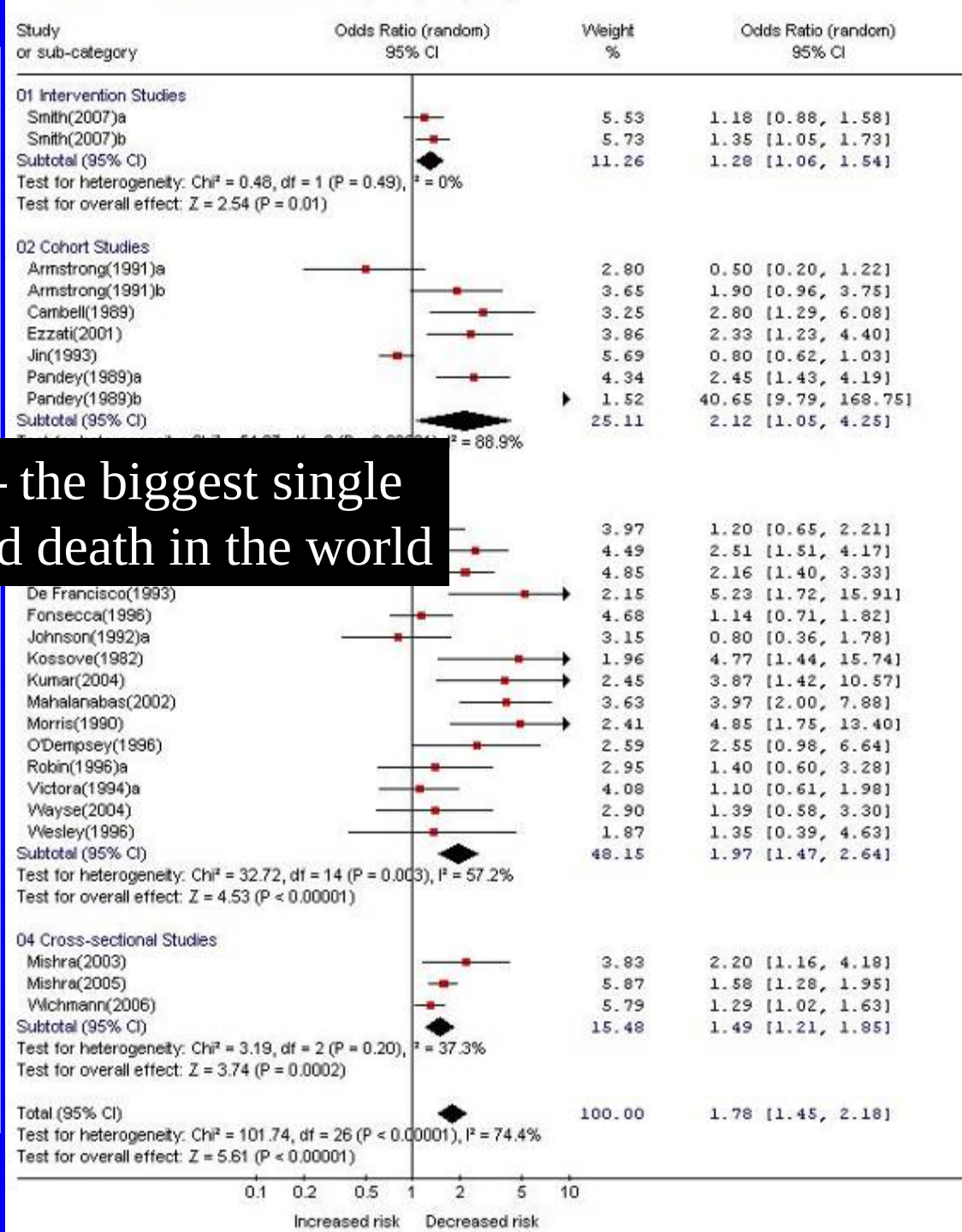
All estimates: +96.6g (68.5, 124.7)

Excluding self-reports +93.1g (64.6, 121.6)

CRA: Pope et al., 2010

Study design	N*	OR	95% CI
Intervention	2	1.28	1.06, 1.54
Cohort	7	2.12	1.06, 4.25
Case-control	15	1	
Cross-sectional	3	1.49	1.21, 1.85
All	26	1.78	1.45, 2.18

Dherani et al Bull WHO (2008)



Pneumonia – the biggest single cause of child death in the world

Outcome – 1a Binary exposures	Sex and Age	Estimates from SR/MAs	Estimates from 2004 CRA
ALRI*	M/F under 5 y	1.78 (1.45-2.18)	2.3 (1.9–2.7)
COPD	F >15 y	2.70 (1.95-3.75)	3.2 (2.3–4.8)
COPD	M >15	1.90 (1.15-3.13)	1.8 (1.0–3.2)
Lung Cancer-coal	F >15 y	1.98 (1.16, 3.36)	1.94 (1.09–3.47)
Lung Cancer -coal	M >15 y	1.31 (1.05, 1.76)	[1.51 (0.97–2.46)]
Lung Cancer - biomass	F >15 y	1.81 (1.07-3.06)	--
Lung Cancer - biomass	M >15y	1.26 (1.04-1.52)	--
Cataracts	F >15 y**	2.47 (2.04-3.15)	--
Low Birth Weight***	M/F	1.52 (1.28, 1.80)	--
---Deficit Birth Weight	M/F	93.1g (64.6, 121.6)	--

Risk Estimates for New CRA: Household Air Pollution

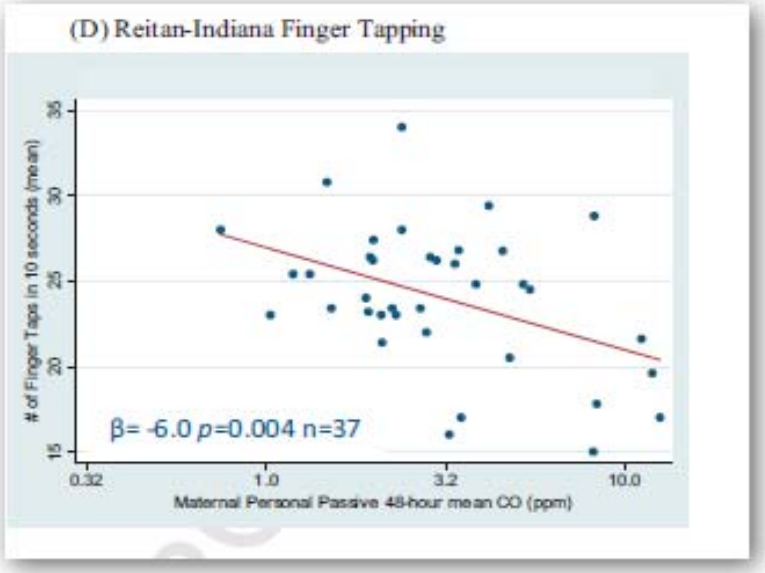
Contents lists available at SciVerse ScienceDirect

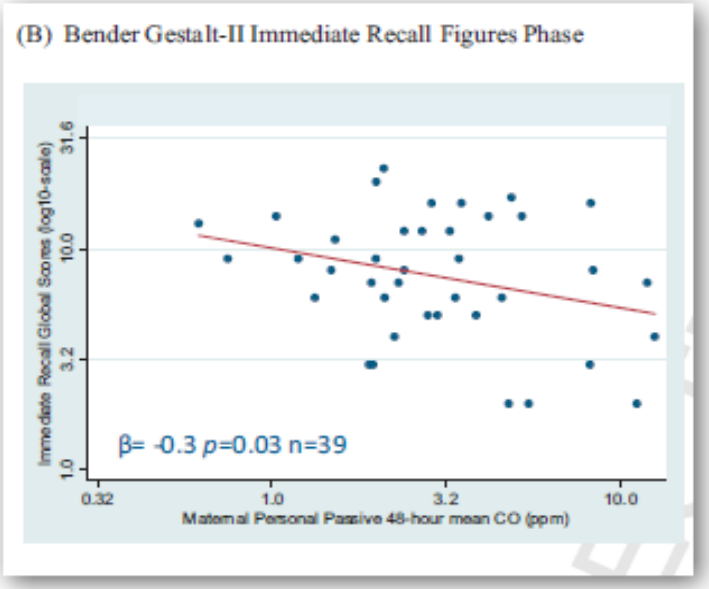
NeuroToxicology

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





Story of Two Conferences

- Air pollution conference
  - High exposures to large vulnerable population
  - No more health effects work needed
- International health conference
  - Need to know exact benefit to be expected
  - Still some doubt about causality
- Where are your randomized controlled trials?

History of an RCT

- ~1980: Case reports of health effects in South Asia
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
  - Chose randomized controlled trial (RCT) of ALRI
- 1986-89: Unfunded proposals to do RCT in Nepal
- 1990: WHO establishes committee to find best sites
- 1990-1992: Criteria established and site visits made
- 1992: Highland Guatemala chosen
- 1991-1999: Pilot studies to establish data needed for proposal – does stove work and do people use it?
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2006: Fieldwork completed
- 2011: Main results published
- 25+ years from deciding to conduct RCT to results!

THELANCET-D-09-06268R3

S0140-6736(11)60921-5

Embargo: [add date when known]

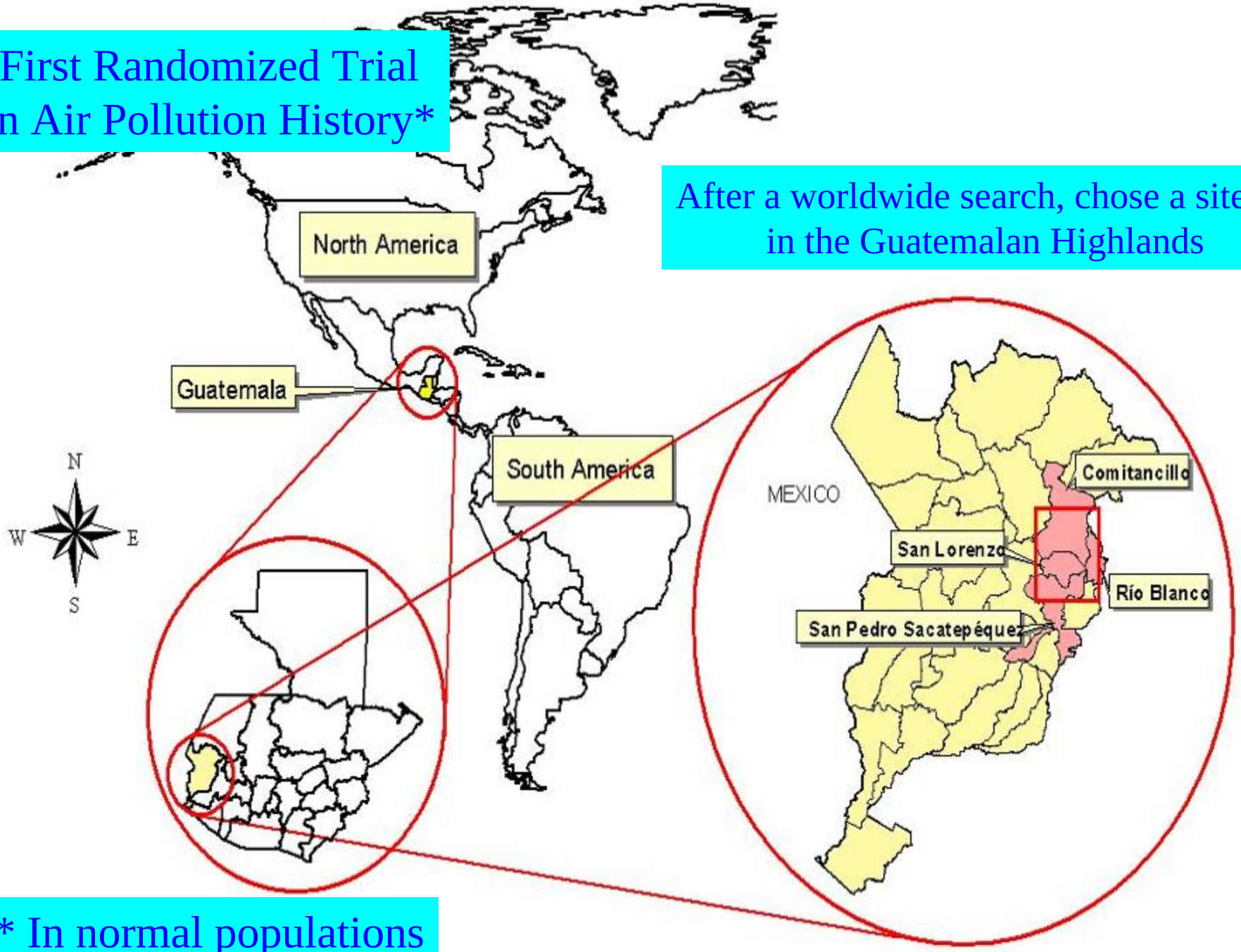
Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial

Kirk R Smith, John P McCracken, Martin W Weber, Alan Hubbard, Alisa Jenny, Lisa M Thompson, John Balmes, Anaite Diaz, Byron Arana, Nigel Bruce

In press, Oct 2011

First Randomized Trial In Air Pollution History*

After a worldwide search, chose a site in in the Guatemalan Highlands



* In normal populations

RESPIRE – Randomized trial (n=518)

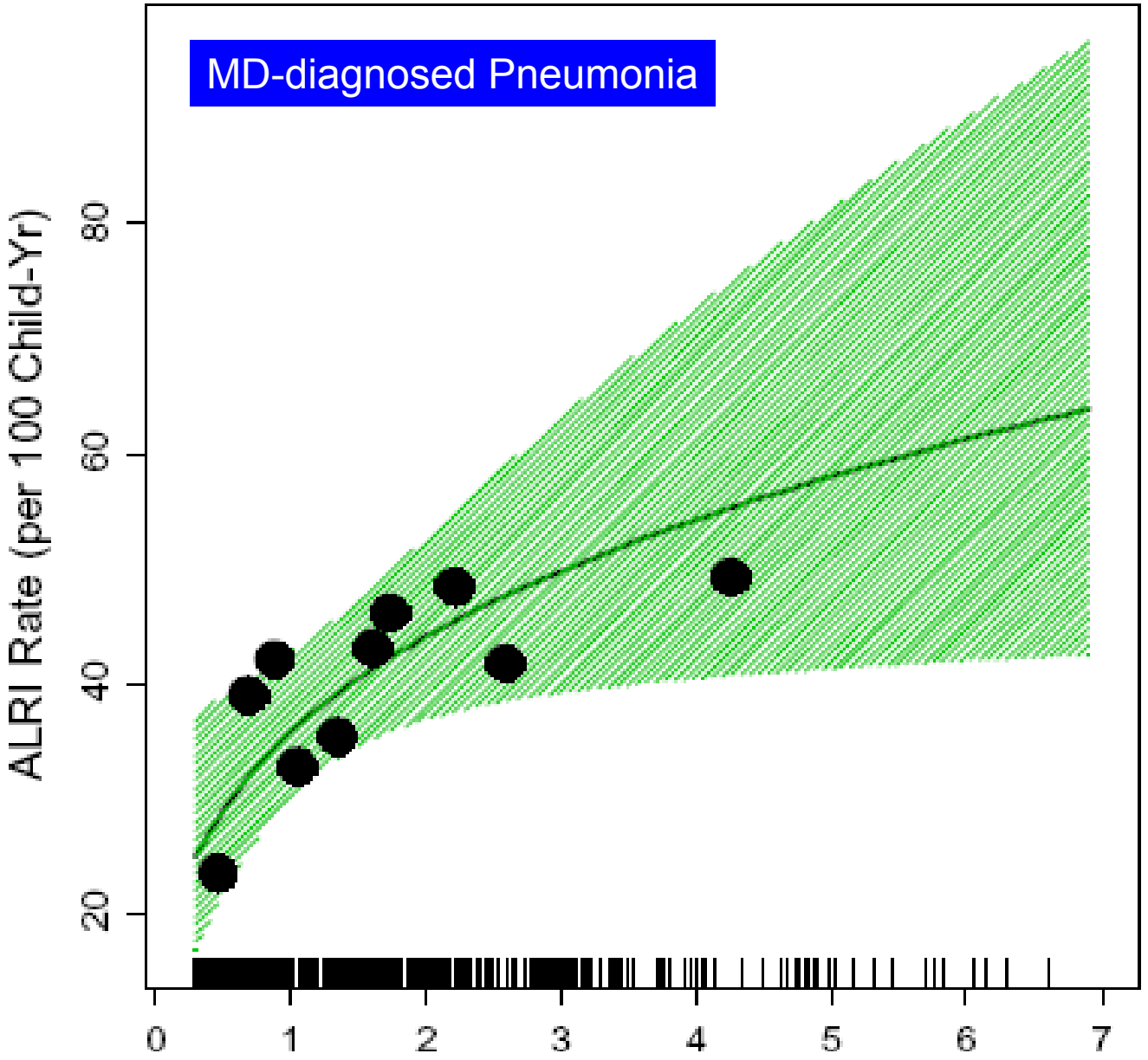
Impact on pneumonia up to 18 months of age

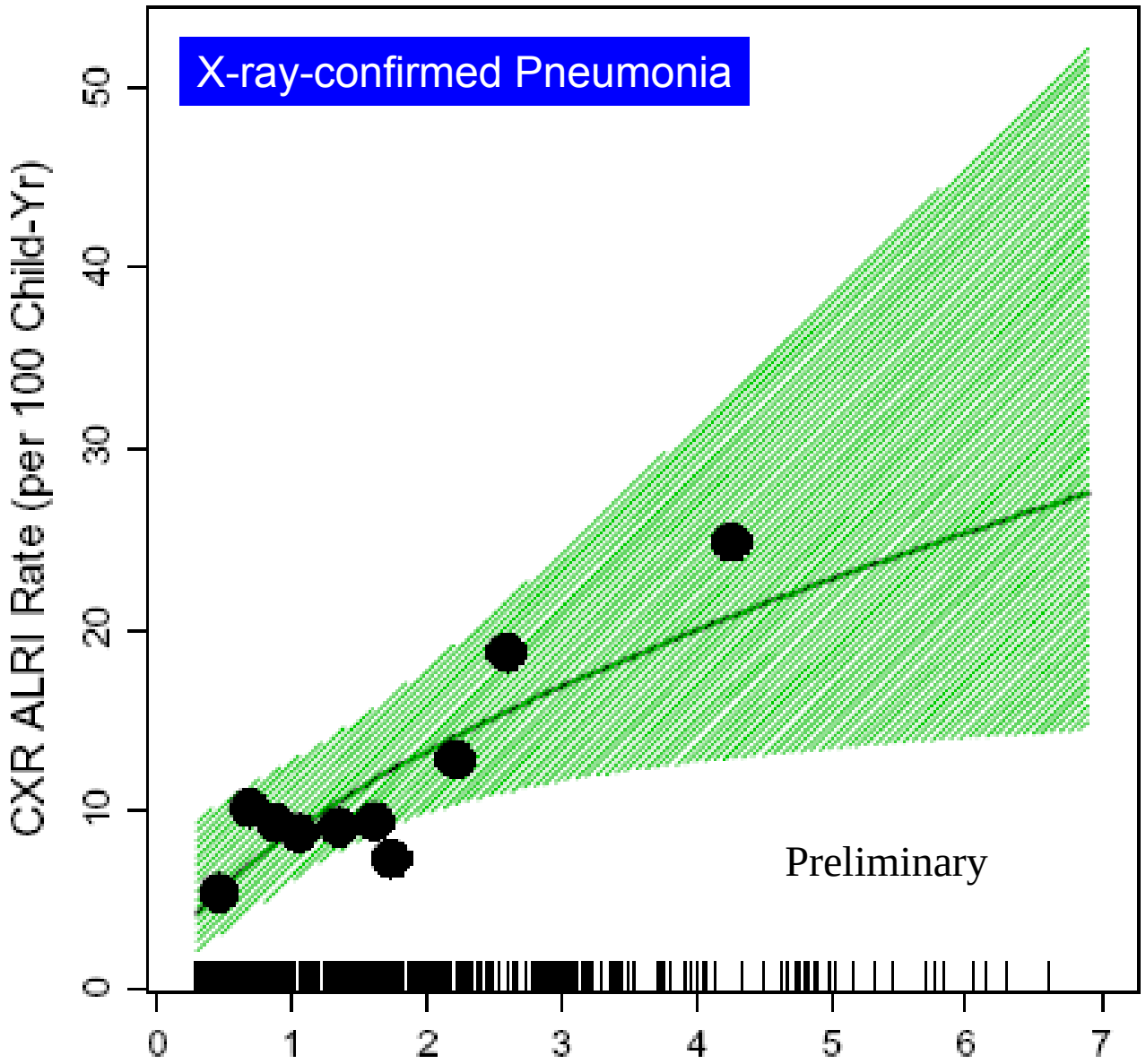
Traditional open 3-stone fire: kitchen 48-hour $PM_{2.5}$ levels of 600 - 1200 $\mu g/m^3$

Chimney wood stove, locally made and popular with households


CO monitor
CO monitor

Preliminary



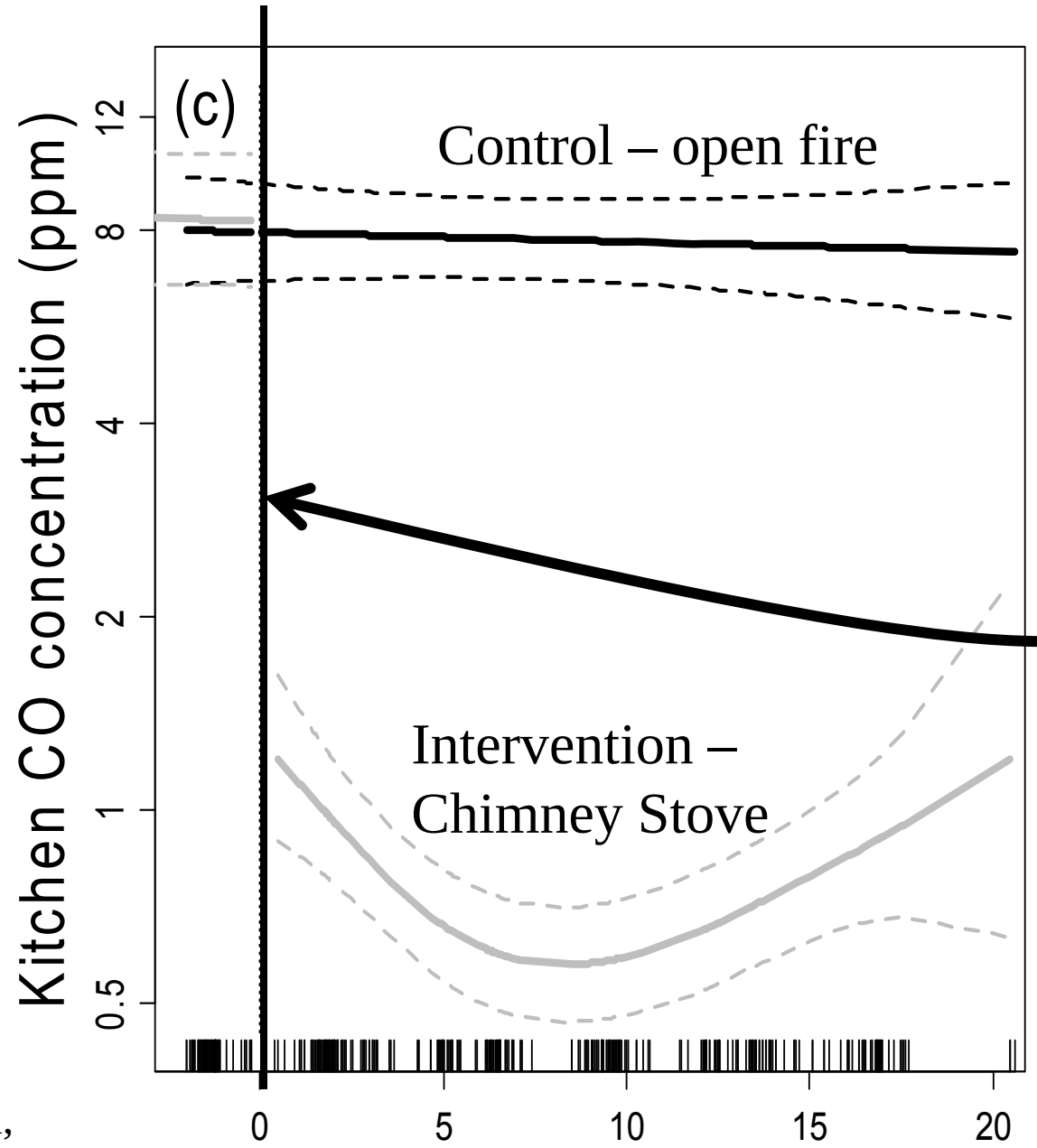


Approximate Mean PM2.5 exposure in 100s of ug/m3

RESPIRE: Pneumonia Reductions with Exposure Reduction Preliminary Results

Exposure reduction	Overall MD-pneumonia	Severe (hypoxic) MD-pneumonia	CXR pneumonia	Severe (hypoxic) CXR pneumonia
25%	0.92 (0.86, 0.99)	0.88 (0.80, 0.97)	0.84 (0.74, 0.96)	0.79 (0.69, 0.95)
50%	0.82 (0.70, 0.98)	0.73 (0.59, 0.92)	0.66 (0.49, 0.91)	0.56 (0.40, 0.88)
75%	0.67 (0.50, 0.96)	0.53 (0.35, 0.84)	0.44 (0.24, 0.83)	0.31 (0.16, 0.78)
90%	0.51 (0.31, 0.93)	0.35 (0.17, 0.76)	0.26 (0.09, 0.74)	0.15 (0.05, 0.67)

Guatemala RCT: Kitchen Concentrations



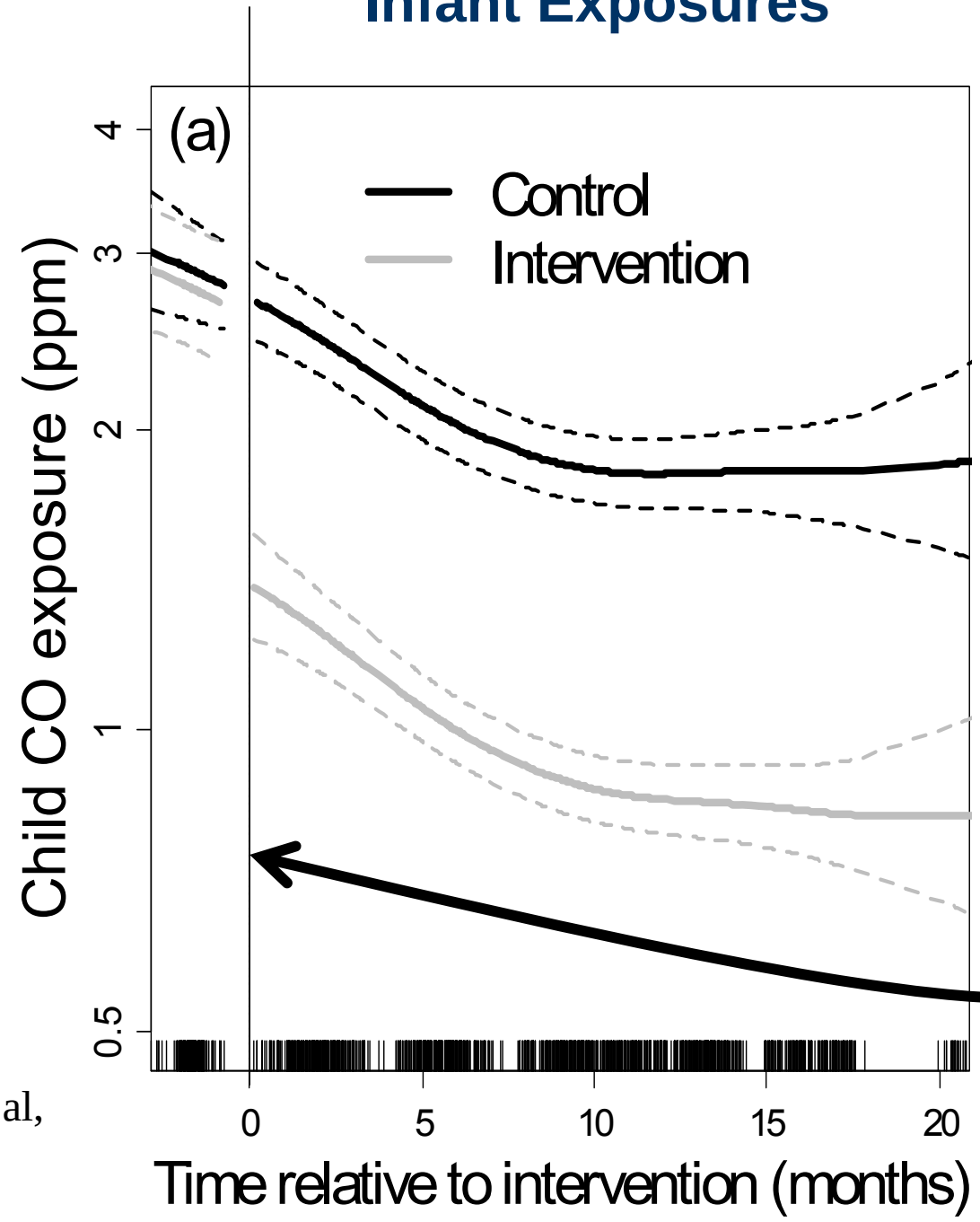
Effect of Chimney Stove On Kitchen CO Levels

Factor of ~10 less

285 48-h measurements

Smith, et al, 2010

Infant Exposures



1888 48-h measurements

Effect of Chimney Stove On Infant Exposures - 2x less

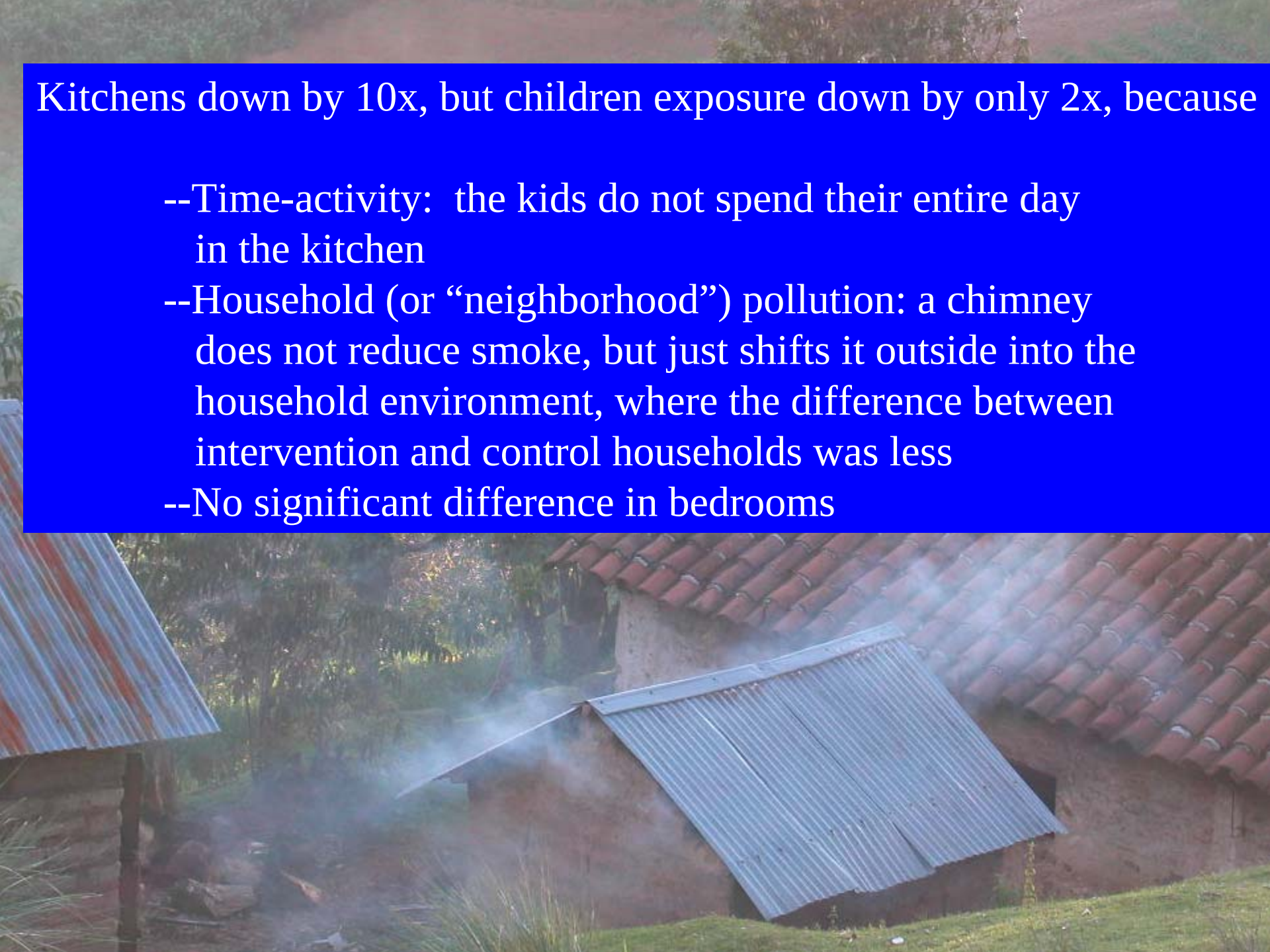
Smith, et al, 2010

Kitchens down by 10x, but children exposure down by only 2x, because

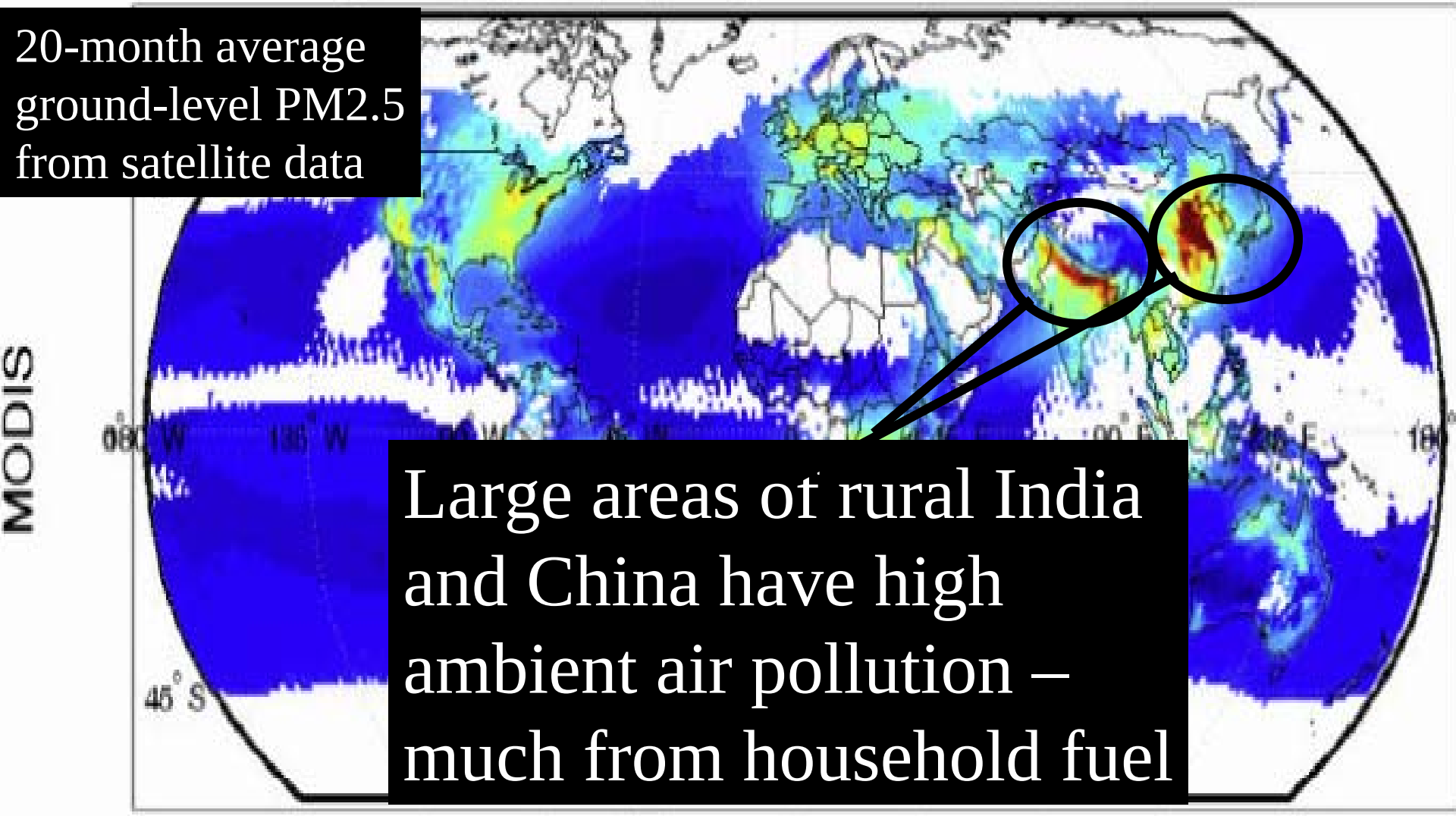
--Time-activity: the kids do not spend their entire day in the kitchen

--Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less

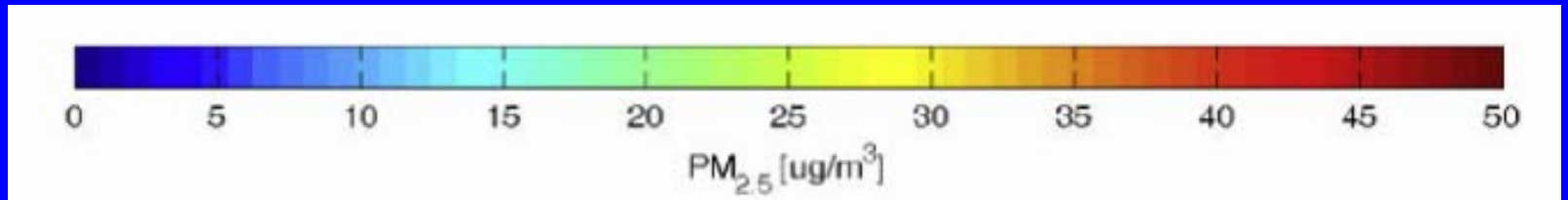
--No significant difference in bedrooms



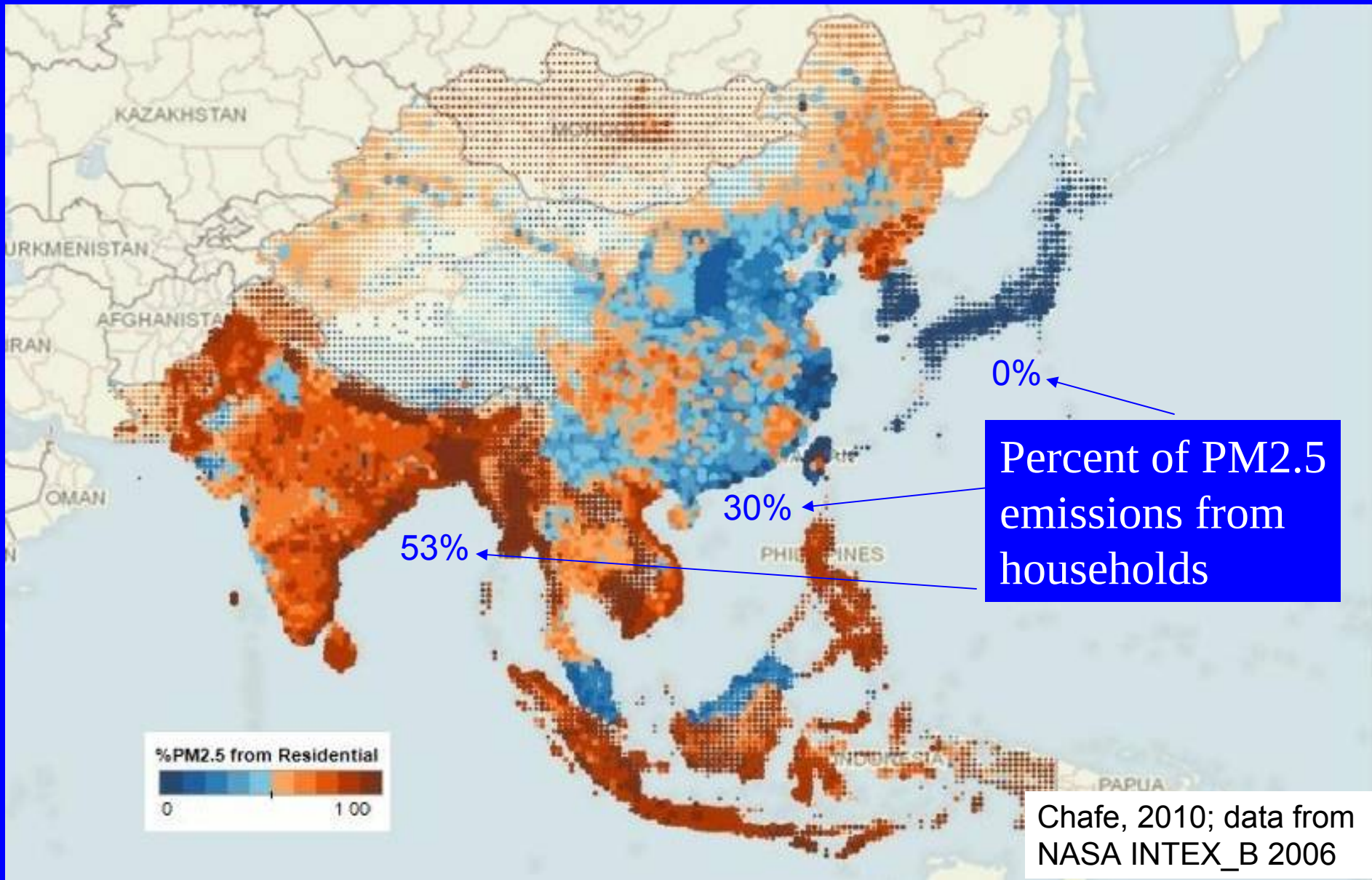
20-month average ground-level PM2.5 from satellite data



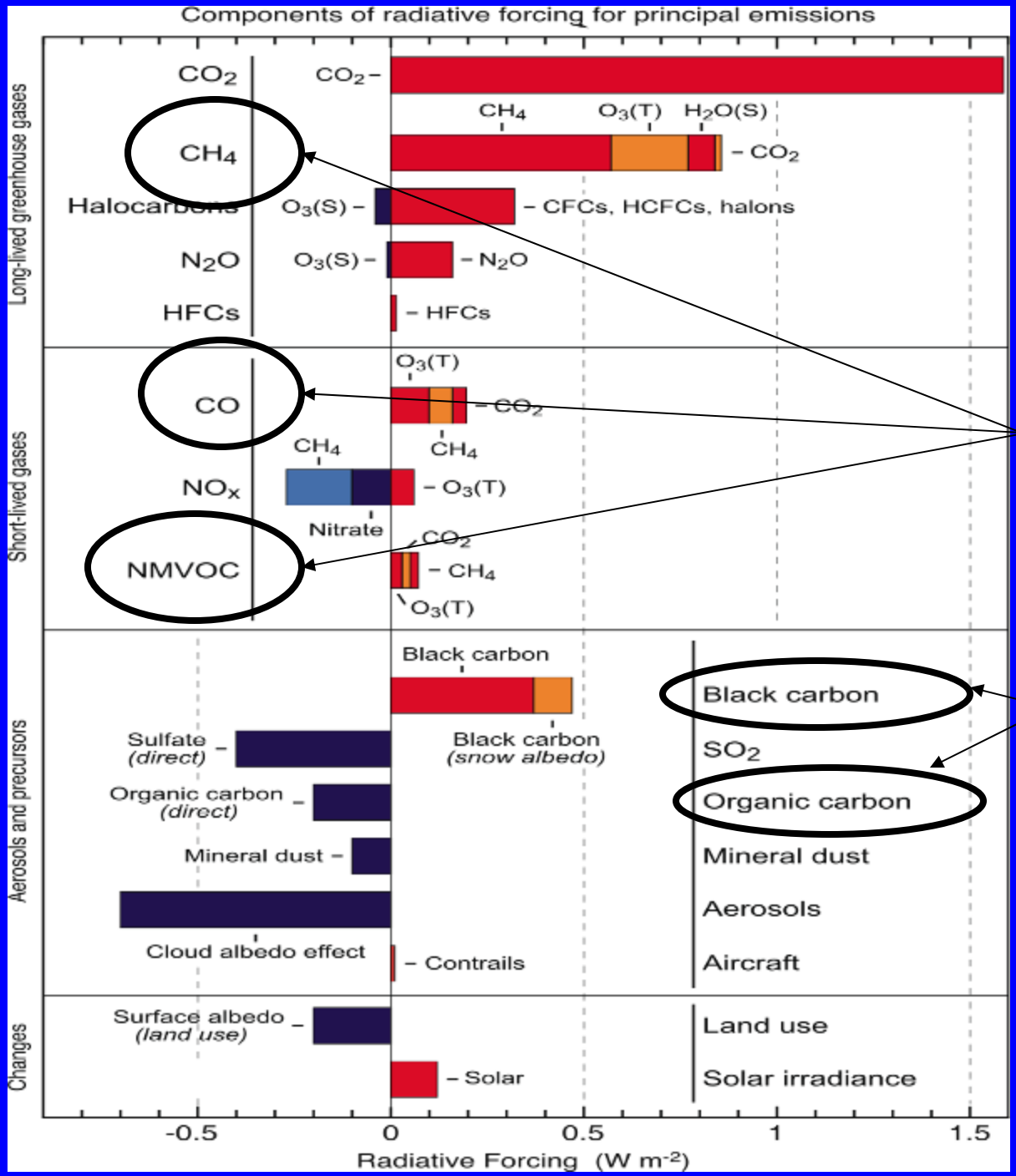
Large areas of rural India and China have high ambient air pollution – much from household fuel



NASA INTEX_B Database
Percent $PM_{2.5}$ emissions from households



Chafe, 2010; data from NASA INTEX_B 2006

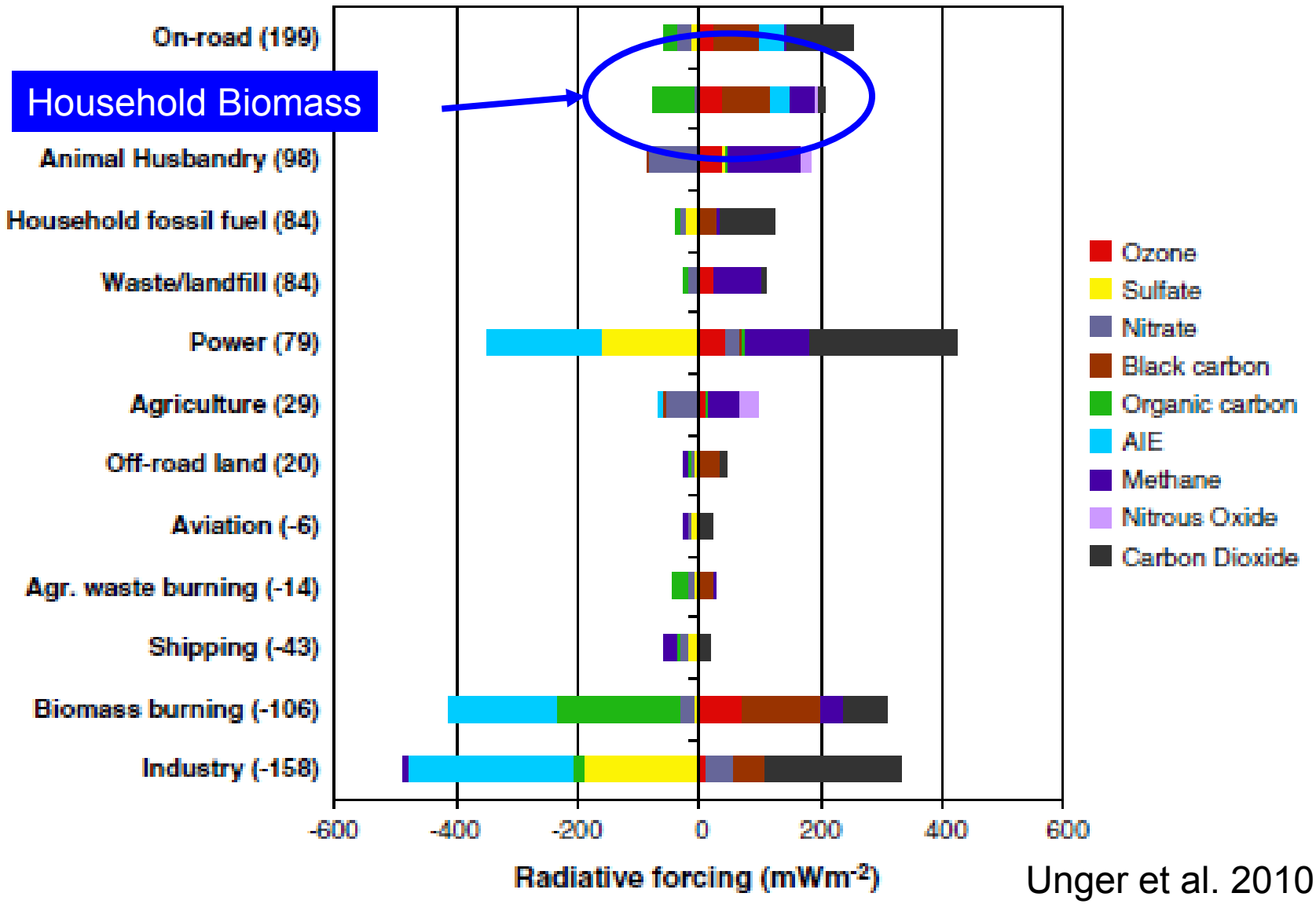


Warming in 2005 from emissions since 1750

A large part from PIC: products of incomplete combustion

IPCC, 2007

Climate Warming in 2020 Under Present Trends



Unger et al. 2010

Combustion Particles

The Generalized Exposure Response (GER)

Heart Disease and Combustion Particle Doses

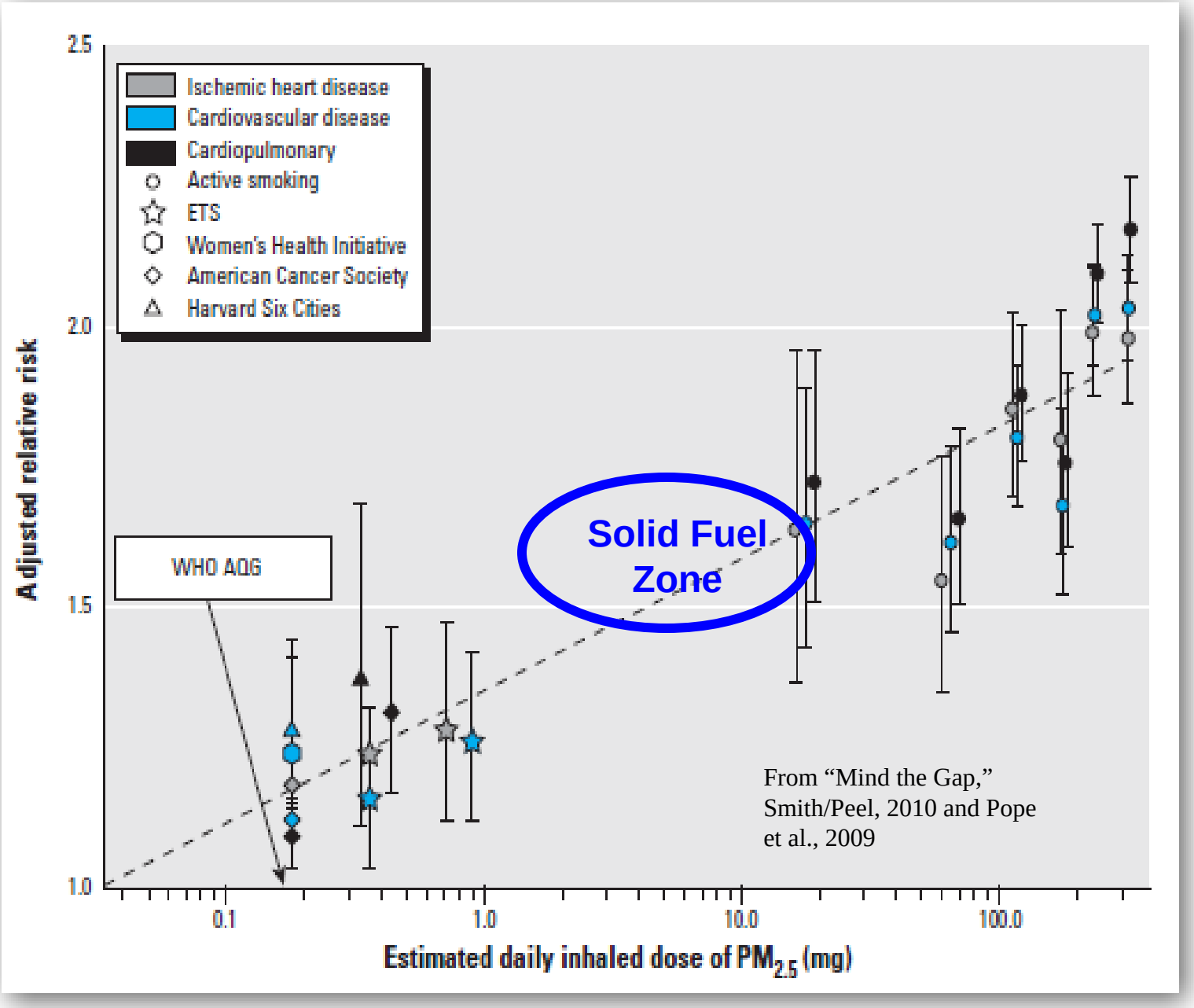
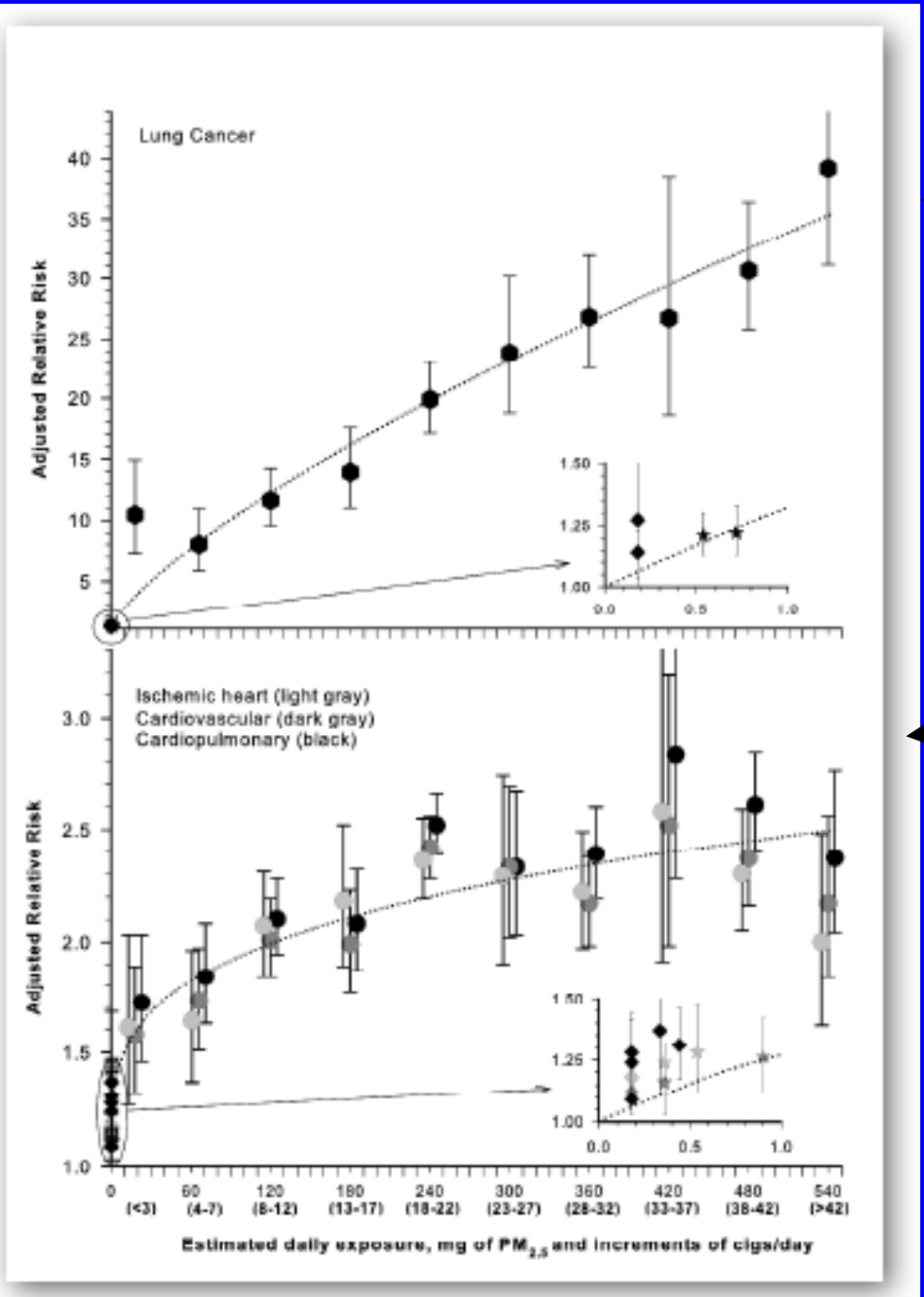


Table 2. Adjusted relative risk estimates[a] for various increments of exposure from cigarette smoking (versus never smokers), second hand cigarette smoke, and ambient air pollution from the present analysis and selected comparison studies.

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

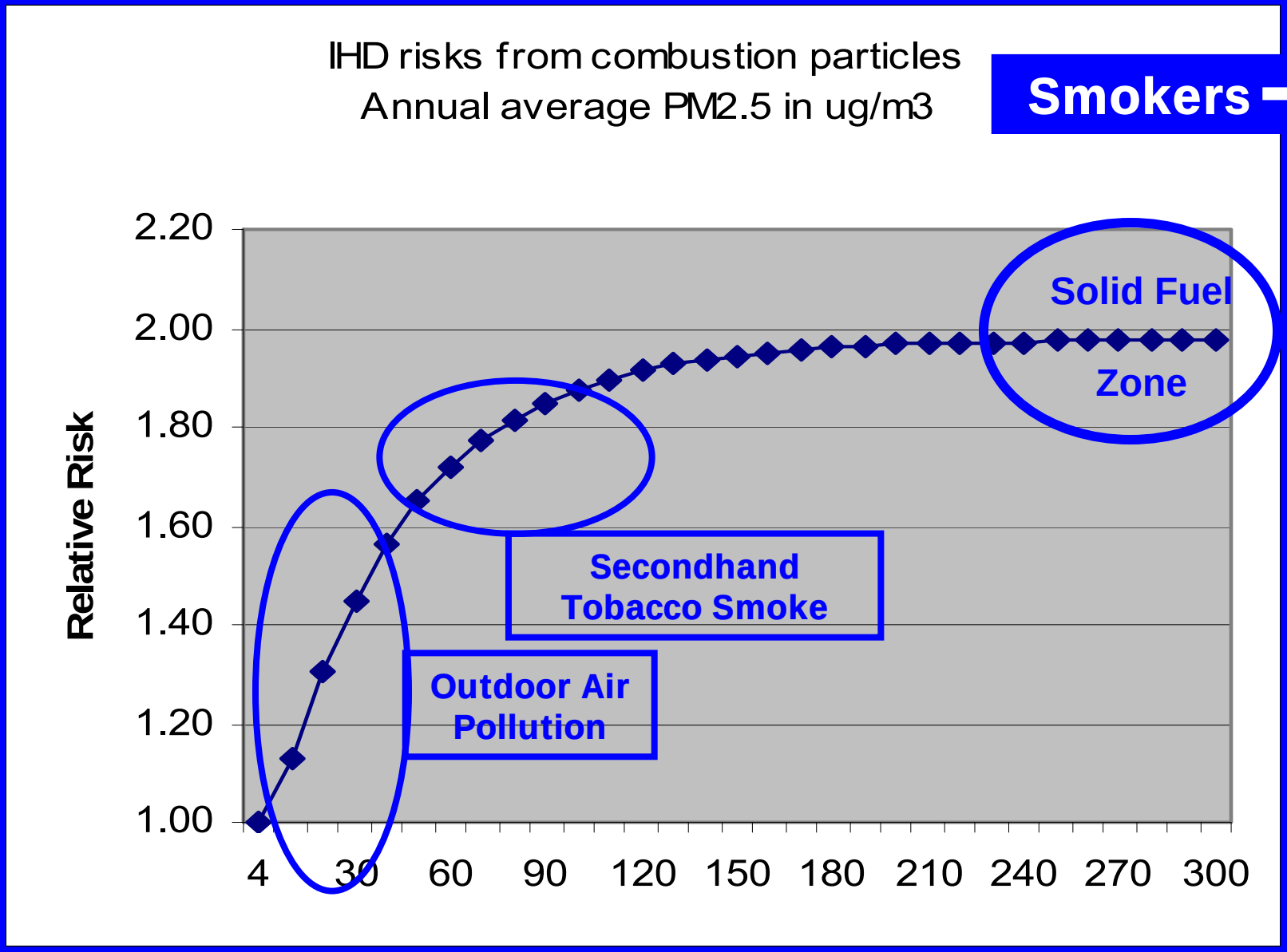


Lung Cancer

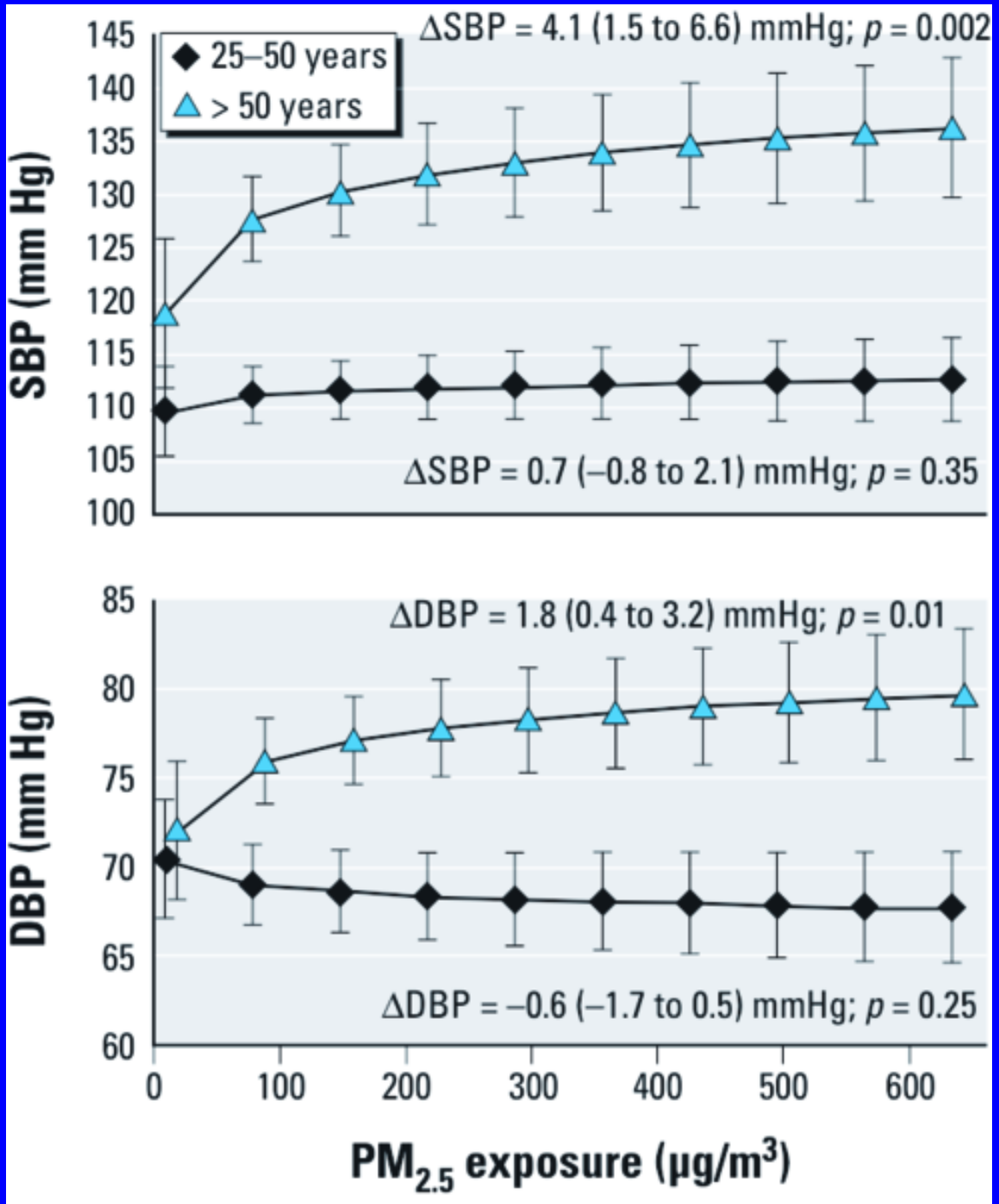
Heart Disease

Pope et al. Environmental Health Perspectives 2011, in press

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



CRA, 2011

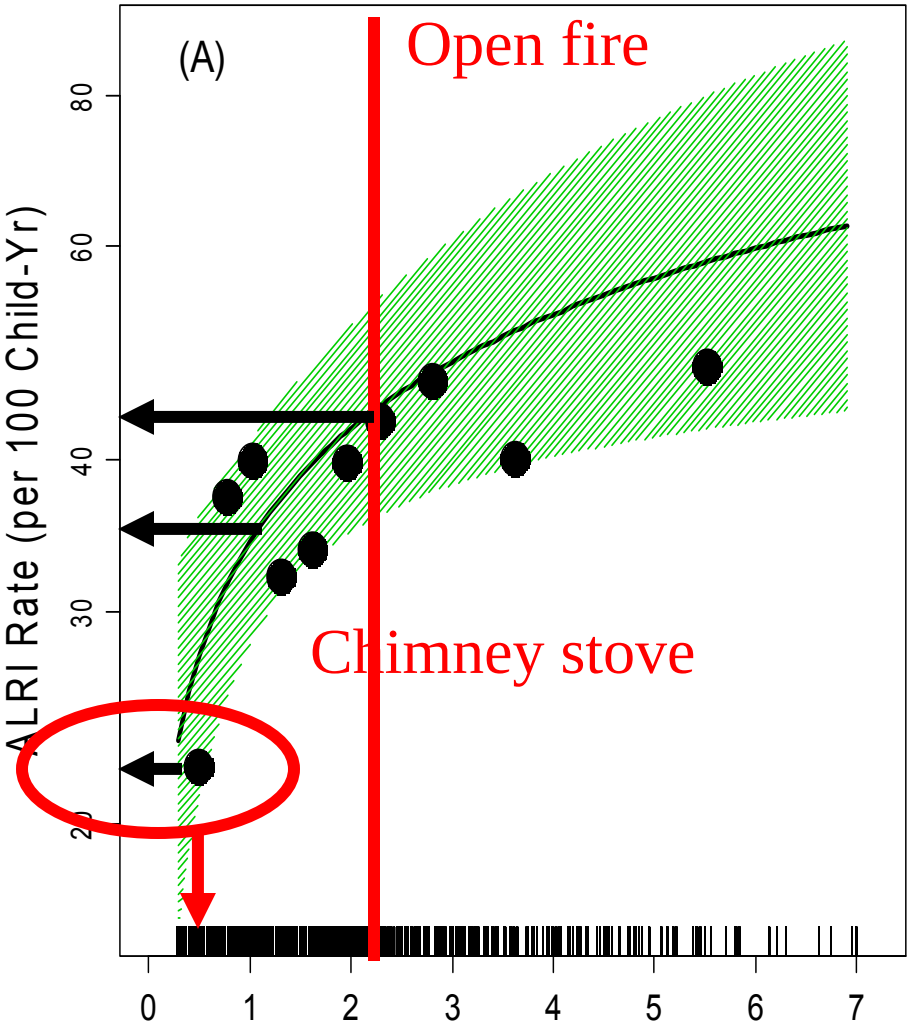


Household Air Pollution and Blood Pressure

In Yunnan

Baumgartner et al. Environmental Health Perspectives 2011, Oct

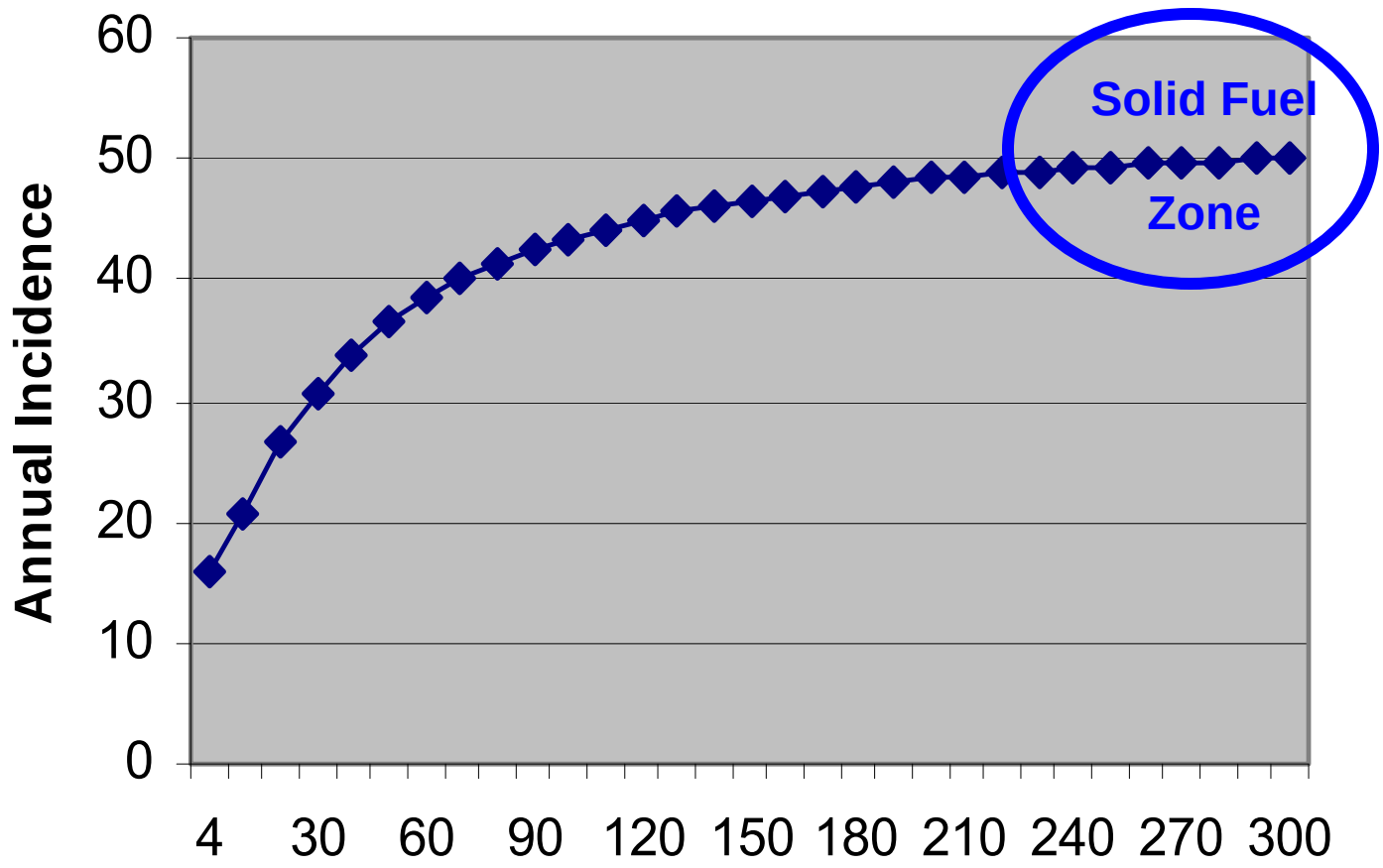
MD-diagnosed Acute Lower Respiratory Infection



Where we Want to Be!

RESPIRE-Guatemala

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



CRA, 2011

Outcome – 1b Generalized Exposure-Response (GER)	Sex and Age	Exposure -- ug/m3 PM2.5, annual average* (China)	Estimates from GER**
GER from OAP, SHS & HAP			
ALRI	M/F under 5 y	286 (143)	3.10 (2.54)
Interpolate GER from OAP, SHS, & ATS			
IHD	F >15 y	335 (167)	1.98 (1.96)
IHD	M >15	205 (102)	1.97 (1.88)

Summary

- Worst thing to do is stick burning stuff in your mouth – 5+ million premature deaths
- Next worse is burning in your house – 2 million deaths
- Next worse is having someone else nearby sticking in their mouth – 400k deaths
- Even bad to have on your planet – 2+ million deaths
- Chimneys do not help – need to stop producing the pollution at all.

Many thanks

Publications and presentations on website – easiest to just "google" Kirk R. Smith